Fire safety requirements on textile membranes in temporary building structures

Per Blomqvist, Anna Bergstrand, Nick Neumann, Ida Larsson and Per Thureson (SP)

Staffan Bengtson (Brandskyddslaget)

Brandforskprojekt 305-111

SP Technical research Institute of Sweden

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Per Blomqvist, Anna Bergstrand, Nick Neumann,
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Staffan Bengtson (Brandskyddslaget)

Abstract

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Textile membranes are increasingly used in various types of building structures, both in permanent and in particular in temporary buildings. The traditional use of textile membranes for larger structures has been for tents, however, applications for textile membranes have become wider and has come to include new application areas such as event buildings erected for sport contests or other major events. The use of textile membranes for weather protection during the construction or renovation of multi-storey buildings for flats and offices is another new growing application. Unfortunately, the current Swedish regulations regarding fire safety are unclear and possibly inadequate for these types of applications.

The safety requirements for temporary tents were under revision in Sweden at the time of this work. It was therefore important to investigate the effect of regulatory alternatives to ensure that the fire safety for textile membranes in temporary buildings was maintained.

This project has investigated the existing fire protection requirements in Sweden for tents and other temporary textile structures and the application of these requirements in practice; has investigated the situation regarding standards and the actual applications of these standards in Europe; and has studied the fire behaviour of some typical textile membranes in selected relevant fire tests used for classification. The fire testing further included experiments on a larger scale in order to obtain a baseline for the new fields of application.

Recommendations are given that could be used for a revised national regulatory system in Sweden to ensure a safer and more consistent assessment of textile membranes in tents and other temporary textile building structures. The test methods proposed as a basis for the fire safety requirements for textile membranes in temporary buildings are those defined in EN 13501-1. Requirements proposed for various applications are given in the report. Only single-layer applications of textile membranes are dealt with in the report.

Key words: tents, textile membranes, fire safety requirements

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Contents

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Sammanfattning (in Swedish)

Textila vävar används idag i allt större omfattning i olika typer av byggnadskonstruktioner, både i permanenta och speciellt i temporära byggnader. Den traditionella användningen av textila vävar för större strukturer har varit för samlingstält. Under senare år har användningen av textila vävar kommit att innefatta nya användningsområden som t ex evenemangsbyggnader som uppförs för en tävling eller annat större arrangemang. Dessa byggnader kan bestå av flera våningar och vara konstruerade med väggar och tak av textil väv. Ett annat exempel på ett nytt och ökande användningsområde för textila vävar är väderskydd vid nybyggnation och renovering av flervåningshus. Man klär här in byggnaden som är under arbete med textila vävar på utsidan av byggnadsställningarna vilket ger en permanent byggnad inuti en temporär tältstruktur.

Det är i nuläget oklart vilka regler som skall tillämpas i ovan nämnda nya applikationer då brandskyddskraven på en textil byggnadsstruktur kan falla mellan olika myndigheters regelverk och i vissa fall har man ett gränsdragningsproblem. Det är därför sannolikt att man i dag inte har en tillräckligt hög brandsäkerhet i vissa fall. Frågan om brandsäkerhetskrav för textila vävar i temporära byggnader är dessutom aktuell genom att MSB (Myndigheten för Samhällsskydd och Beredskap) genomför en revidering av sina Allmänna råd gällande säkerhetskrav för samlingstält. Det är därför viktigt att ta ett grepp om problematiken för att säkerställa att brandsäkerheten för temporära textila byggnader bibehålls, eller ännu hellre höjs, i samband med införandet av de reviderade reglerna.

Med bakgrund av frågetecknen vad gäller säkerheten för nya applikationer av textila vävar i temporära byggnader och osäkerheten av tillämpningen av befintliga regler, har arbetet i detta projekt innefattat en översyn av befintliga regler och krav vad gäller brandsäkerhet för samlingstält och andra temporära textila byggnadsstrukturer. Ett mål för projektet har varit att säkerställa brandsäkerheten för traditionella samlingstält i samband med den pågående revideringen av MSB. I projektet har även ingått att kartlägga och definiera brandsäkerhetskrav för nya typer av textila byggnadsstrukturer av temporär karaktär.

Arbetet i projektet har innefattat en undersökning av befintliga brandskyddskrav i Sverige för samlingstält och andra textila byggnadsstrukturer samt tillämpningen av befintliga brandskyddskrav i praktiken. Man har också inventerat befintliga Europeiska standarder och undersökt de faktiska krav som tillämpas i Europa. Arbetet har vidare innefattat att ta fram brandbeteende för ett antal typiska textila vävar för några utvalda applikationer som en bas för ett förslag på reviderade krav.

Sverige har ett regelverk gällande brandsäkerhet för samlingstält som styrs av ordningslagen och regleras av MSB:s krav och allmänna råd[i]. Dessa regler är framtagna specifikt för samlingstält och kraven baseras på ett småskaligt test med en mindre flamma[ii] eller alternativt ett storskaligt test[iii]. Reglerna ger också utrymme för att godkänna vävar där man kan visa att de brandtekniska egenskaperna motsvarar de ovan nämnda.

Under projektets gång har man sett att detta system ofta fungerar för traditionella samlingstält, som t ex cirkustält, där det ställs krav på besiktning och typgodkänd tältväv. När det gäller nya typer av temporära tältbyggnader ser det ut som om kraven vilka i praktiken ställs från tillsynsmyndigheten kan vara otydliga. Det är förvånande att polisen inte i samtliga fall ställer krav på att tältbyggnaden skall vara besiktigad, vilket är

[i] SRVS 1995:1 och 1995:1 ”Besiktning av samlingstält – Allmänna råd”.
[ii] SIS 650082 (vävar < 3.5 mm) eller NT Fire 002 (vävar > 3.5 mm).
[iii] SP Metod 2205.

huvudkravet i ordningslagen (förordning 1993:1633). Huvudanledningen till att det ställs otydliga krav är troligen att de nuvarande allmänna råden från MSB ger utrymme till olika sätt att visa att tältväven är ett ”svårantändligt material”.

Det har med BBR 19 (2012) skett en förändring av kraven för enkellagers textila vävar i permanenta byggnader. Här har kravet ändrats från ”svårantändligt material” vid provning enligt den Svenska testmetoden SIS 650082, med kriterier från Boverket[iv], till ett lägsta krav på Euroklass E, vilket innebär testmetoden EN ISO 11925-2 med 15 sekunders flamapplikation. I nuläget är alltså kraven och testmetoderna olika för en textil väv beroende på om den skall användas i en temporär eller en permanent byggnad.

När det gäller textila vävar för väderskydd kan man konstatera att det inte finns några förordningar som reglerar de brandtekniska egenskaperna. I vissa fall förekommer det krav från den lokala räddningstjänsten eller från byggherren och då har kraven ofta varit godkännande enligt EN 13501-1, men kraven som ställs på Euroklass varierar säkert. Det är uppenbart att Arbetsmiljöverket som har ansvaret inom detta område bör sätta upp tydliga krav för att öka säkerheten.

Inom Europa har man till stor del gått ifrån nationella standarder när det gäller brandteknisk provning av textila vävar och tillämpar nu istället EN 13501-1, d v s den Europeiska klassificeringsstandarden för ytskiktsmaterial i byggnader. Kraven på specifik Euroklass för olika tillämpningar varierar mellan länderna. Information om tillämpningen av provningsstandarder i olika Europeiska länder ges i Tabell 1 i rapporten. Man kan notera att de nordiska länderna Norge, Finland och Danmark alla har satt krav baserat på Euroklasser, utom Danmark som i nuläget har SIS 650082 som krav för temporära textila byggnader (tält). Danmarks regler för temporära textila byggnader är dock under revision för närvarande.

Inom projektet utfördes olika typer av klassificeringsprovningar med ett urval textila vävar. Ett större antal PVC/Polyester vävar av olika tjocklek och fabrikat provades. Detta var i första hand vävar som används till traditionella samlingstält och till eventbyggnader. En av PVC/Polyester vävarna var för väderskydd vid byggnation. Även en textil väv (polyetenväv) för användning som väderskydd för byggnadsställning provades.

Samtliga vävar provades enligt SIS 650082 samt EN ISO 11925-2. Slutsatserna från dessa tester var att man med EN ISO 11925-2 kunde sortera ut samma produkter som underkändes i SIS 650082. EN ISO 11925-2 test med 15 sekunders kantantändning bedömdes ställa motsvarande eller något högre krav jämfört med den nuvarande applikationen av SIS 650082. Detta provningsförfarande med EN ISO 11925-2 motsvarar Euroklass E.

Några PVC/Polyester vävar samt polyetenväven valdes ut för provning enligt EN 13823 vilket är en mer storskalig provningsmetod där man mäter utvecklad brandeffekt, flamspridning och rök. För att uppnå en högre Euroklass än E krävs tester enligt EN 13823 samt EN ISO 11925-2 test med 30 sekunders flamapplikation.

Resultaten från EN 13823 testerna visade att monteringen av den textila väven är viktig för resultatet av provningen. Med ett metallstag för montering av provkroppens hörn får man en mer rättvisande provning. Generellt ger denna provmontering en lägre Euroklass men med ett mer repeterbart resultat. En annan observation var att resultatet från ett EN ISO 11925-2 test med 30 sekunders flamapplikation mot provkroppens yta ger en bättre korrelation med provningsresultaten från EN 13823 än ett EN ISO 11925-2 test med flamapplikation mot provkroppens kant.

[iv] Boverkets Allmänna råd 1993:2.

Storskaliga referensförsök utfördes med två PVC/Polyester vävar med olika tjocklekar samt med polyetenväven. Olika testscenarier byggdes upp som försökte efterlikna ett eventtält med och utan avdelande våning för PVC/Polyestervävarna, och i fallet med polyetenväven efterliknades en väderskyddsapplikation. En propanbrännare användes som tändkälla.

De viktigaste resultaten från försöken med PVC/Polyester vävarna var att de visade på bra brandegenskaper med liten brandspridning. Dom var i princip självslocknande när branden spridit sig bort från antändningskällans lågor. De problem man kunde se med vävarna var rökproduktion och nedfallande brinnande material. Det sistnämnda var mindre allvarligt då brandspridningen var mycket begränsad men rökproduktionen kan ge problem vid en utrymningssituation. Man har tidigare antagit att bildad rök vädras ut genom att det snabbt bildas ett hål vid brand i en tältduk, men försöken visade att det vid en hög takhöjd inte bildas något hål i taket och att ett hål i sidan av byggnaden inte vädrar ut tillräckligt med rök.

Försöken med polyetenväven visade på stor brandspridning och nedfallande brinnande droppar/material. Brandspridningen i väven var mindre allvarlig då den var långsam, men det nedfallande materialet bildade poolbränder på marken vilket måste betraktas som allvarligt. Sådana poolbränder kan bidra till brandspridning till närliggande material och byggnader.

Baserat på de brandförsök som utförts inom projektet och undersökningen av brandtekniska krav på textila vävar i andra Europeiska länder ger rapporten ett förslag på reviderade provningskrav för textila vävar i temporära byggnader. Förslaget är att sätta kraven genom klassificeringsstandarden EN 13501-1 och sätta Euroklass E (med kantantändning) som ett minimikrav.

Motiveringen till förslaget är att detta ger krav enligt samma klassificeringsstandard som nu tillämpas för textila vävar i permanenta byggnader i Sverige samt som tillämpas i de flesta andra europeiska länder. Förslaget innefattar också att man differentierar kravet beroende på typen och användningen av den temporära byggnaden. Kravet föreslås vara högre i det fall byggnaden har mer än en våning eller då det finns en upphöjd läktare eller liknande som är högre än halva maximala takhöjden i en envåningsbyggnad. Dessa högre kravs ställs för att reducera risken för att rök från brand i den textila väven försvårar utrymning. Förslaget på reviderade provningskrav ges i Tabell 20 i rapporten.

För textila vävar som används som väderskydd föreslås ett minimikrav på Euroklass E (med kantantändning).

1 Introduction

Textile membranes are increasingly used in various types of building structures, both in permanent and in particular in temporary buildings. The traditional use of textile membranes for larger structures has been for tents, which typically have been circus tents. In recent years, however, applications for textile membranes have become wider and current regulations and testing requirements have not kept pace with technical developments. It is currently, in some cases, unclear what rules apply to a given textile building structure as the fire safety requirements of such a structure may fall under different regulatory authorities. In cases where there is a problem of inter-agency boundaries and responsibilities this leads to potentially dangerous building situations. It is therefore likely that today one does not have a high enough fire safety in such cases. At the very least, one does not have a sufficiently well-defined level of safety which can be tested against real world scenarios to validate the level of fire safety.

The issue of fire safety requirements for textile membranes in temporary buildings is particularly relevant in Sweden at the moment, as MSB[v] is conducting a review of current safety requirements for tents. It is, therefore, important to investigate this issue to ensure that the fire safety for textile membranes in temporary buildings is maintained, or where appropriate raised in the revised rules.

In recent years the use of textile membranes has come to include new application areas such as event buildings erected for a sport contests or other major events. These temporary buildings may consist of several floors and are designed with walls and roof made of textile membranes. Such buildings were erected, *e.g.*, during the golf tournament Scandinavian Masters (Bro Hof) in 2013, as Beer tents at Zinkensdam, Stockholm, during 2013 and at the regatta Volvo Ocean Race (Marstrand) in 2009. In all cases, these were events with a large number of people visiting these temporary buildings. Unfortunately, the current regulations regarding fire safety is unclear and possibly inadequate for these types of temporary buildings.

Another new and growing use of textile membranes is the use of weather protection during the construction or renovation of multi-storey buildings for flats and offices. In this application you dress the scaffolding erected against the building with textile membranes which results in a permanent building (under construction or refurbishing) inside a temporary tent structure. Again, current regulations are inadequate for this application.

The applications discussed above raise questions about which regulations applies in these cases, and also if the test methods that are used for classification testing provide relevant information. The use of temporary event buildings in the form of a "multi-storey tent" provides a demarcation problem in which the rules applicable to tents are used today, in most cases, but where the rules for permanent buildings might be more appropriate. In cases where the building can be considered as permanent, the regulations from Boverket[vi, vii] relating to fire protection of buildings apply. This regulation refers to the European classes for testing and classification of surface materials inside a building (EN 13501-1) and Swedish national rules regarding ignition and fire spread to the building's exterior. Where the building is classified as temporary the regulatory framework from MSB for tents applies.

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[v] MSB is the Swedish Civil Contingency Agency which is the agency responsible for safety and security in Sweden.
[vi] Boverket is the Swedish National Board of Housing, Building and Planning.
[vii] Boverkets byggregler, BBR kap. 5, Brandskydd.

The classification criteria that are actually applied in practice for such textile building structures are not known, and probably vary from case to case. It is a problem if the correct rules are not applied and especially if this results in a decreased level of safety. Especially in the case of event buildings there are additional aspects of fire safety, such as the requirements on the building structure in case of a fire and the possibility for evacuation. Further could the increasing use of these temporary textile buildings lead to the emergence of new businesses tailored to this market, some with a lack of internal quality control, Without an adequate legal framework governing the fire safety, the emergence of fraudulent businesses would entail substantial risks.

Against the backdrop of these question marks concerning the safety of new applications of textile membranes in temporary buildings, and the uncertainty of the application of existing rules, it is necessary to review the rules and requirements regarding fire safety of tents and other temporary textile building structures. Such a review should include an examination of the implications of an alternative system in terms of the final fire safety of the structures in question.

The goal of this project is to safeguard the fire safety for traditional tents in connection with the on-going review being made by MSB. The project also includes identifying and defining relevant fire safety requirements for new types of temporary textile building structures. The project goal will be achieved by developing a proposal for appropriate requirements in the revised national framework, where the proposed testing requirements have been validated and compared against existing requirements in Sweden.

The goals will be achieved by investigating the existing fire protection requirements in Sweden for tents and other temporary textile structures and the application of these requirements in practice; investigating the situation regarding standards and the actual applications of these standards in Europe; and studying the fire behaviour of some typical textile membranes in selected relevant fire tests used for classification. The fire testing will further include experiments on a larger scale in order to obtain a baseline for the new fields of application. As the current requirements for tents of traditional circus tent type rest against a previously performed validation trail, the reference tests conducted in this project will focus on textile membrane applications for events buildings (*i.e.* "multi-storey tents") and the cladding of scaffolding in construction.

The work in this project has focused on the requirements and reaction-to-fire behaviour of textile membranes. The issues regarding fire resistance of the load carrying structure and evacuation from a textile building structure during a fire are not handled in this project but are both very important and it is recommended that these are revisited in a separate project.

The project will provide recommendations that could be used for a revised national regulatory system in Sweden to ensure a safer and more consistent assessment of textile membranes in tents and other temporary textile building structures.

2 Fire safety requirements in Sweden

2.1 Textile building structures

The fire safety requirements for a building structure made from textile membranes are basically governed by the length of time the building is intended to be present at a certain location. The criteria for classification of a building[viii] as temporary or permanent is thus fundamental when establishing which requirements are applicable. The fire safety requirements are presently different for these two types of building definitions (temporary compared to permanent) which in certain cases gives problems in applying these requirements.

The practical criteria for classifying a building as permanent have been found to be 4-5 weeks. However, also the annual erection of a textile building structure at the same location but for a shorter period could result in the classification of the building as permanent.

The authority responsible for giving the permission for erecting a textile building structure is the local police in the case of a temporary building and the local building committee for permanent buildings. Surprisingly, during the work in this project it was identified that outside areas with a detailed local development plan there seems to be no regulations whatsoever that applies for erecting large temporary textile building structures.

Information is given below concerning the present requirements in Sweden for textile building structures and the application of textile membranes for weather protection of buildings during construction or renovation. The project group has also collected examples of the fire safety requirements applied in some actual building projects for these areas of application.

2.1.1 Temporary structures

2.1.1.1 Background to present requirements

The Swedish fire safety regulations for public tent buildings are governed by the Public Order Act[ix] and are regulated by requirements and guidelines from MSB[x]. These rules are designed specifically for larger tents (> 150 persons) and the fire safety requirements are based on tests with a small flame[xi] where the required level of performance is based on past information from large-scale fire tests. A large-scale test[xii] can indeed be conducted as an alternative to the small-flame test.

The regulations are withheld by the requirement of inspection in SFS 1993:1633. An inspection certificate is valid for five years when the textile membrane has a test certificate that proofs that it has passed the Swedish test requirements. SP has conducted these inspections and issued inspection certificates.

[viii] Included in the definition of a building in the Swedish Planning and Building Act (PBL) is that building structure is permanent.
[ix] Ordningslagen SFS 1993:1617, SFS 1993:1633.
[x] SRVS 1995:1 och 1995:1 ”Besiktning av samlingstält – Allmänna råd”. (Eng. translation: Inspection of public tents – General Guidelines.)
[xi] SIS 650082 (membranes < 3.5 mm) or NT Fire 002 (membranes > 3.5 mm).
[xii] SP Metod 2205.

Inspection certificates have been assigned also based on German (class B1) and French (class M2) tests certificate on the fire technical properties of the textile membrane. This has been possible based on the guidelines from MSB. However, in these cases the time period before renewing the certificate is three years instead of five. After this first time period the test method applied for renewing the certificate has always been the Swedish test SIS 650082.

Textile membranes for larger tents are usually of the type PVC-coated polyester. This type of membrane is mechanically strong and can have good fire performance with the addition of a flame retardant (usually antimony). Another type of textile membrane sometimes used is made of heavy duty cotton fibre, but this type of product is less common in Sweden.

The relevance of the regulatory framework for tents for the two aforementioned new types of temporary textile building structures (events buildings and weather protection of buildings) is unknown. Further, a recent problem concerns cases where multi-layer membranes are used with an insulating layer in-between, as the fire risk will likely be significantly higher in such applications. It is clear that these applications are not properly handled by today's requirements for temporary structures made of textile membranes but it is unclear what requirements should be imposed.

As mentioned previously, MSB is presently in the process of revising the current requirements and recommendations for tents. It is highly likely that EN standards (European standards) will be suggested to replace or supplement the current Swedish requirements. It is unknown whether the suggested EN standards[xiii,xiv,xv] would maintain the present safety level for tents in Sweden, and it is also unknown how applicable these standards are for new application areas such as event buildings and weather protection.

Note that these EN standards have already been adopted as Swedish standards (SS-EN). This is an automatic process whereby a European standard is adopted as a Swedish standard. There are, however, no legal requirements in the EU that a Member State must apply an EN standard as the basis for national requirements, i.e. they become a national standard but may or may not actually be used as part of national regulations. In cases where there is a harmonized product standard that refers to an EN standard for product requirements this becomes mandatory. However, there is no harmonized product standard for tent or textile membranes for tents presently.

It is also important to recall that the above mentioned EN standards have been developed by standardization groups at European level where expertise and experience in terms of fire safety is unclear. EN 13782:2005 was developed by CEN/TC152 / WG2 - "Fairground and amusement park machinery and structures - Safety /Tents". EN 15619:2008 and EN 14115:2001 was developed by CEN / TC 248 - "Textile products".

2.1.1.2 Examples of applications

Different examples of applications of the present regulations for temporary building structures constructed from textile membranes have been collected and are summarized below.

[xiii] SS-EN 13782:2005 ”Tillfälliga anläggningar – Tält – Säkerhet”.
[xiv] SS-EN 15619:2008 ”Gummi- eller plastbelagda tyger – Provisoriska byggen (tält) säkerhet – Specifikation för belagda tyger för tält och liknande byggnader.
[xv] SS-EN 14115 ”Textil – Brandbeteende hos material till stora tält och liknande produkter – Antändlighet.

Example A)

Yearly there is a Christmas Market on *Sergels Torg* in the centre of Stockholm (see Figure 1 and Figure 2). The market takes place in a tent with an area of 400 m^2 which is erected for a period of five weeks. In connection with this event there are many questions regarding fire safety, i.e.:

I) Fire protection inside the tent.

II) Contingency plan in case of a fire on the bridge structure above the tent.

III) The potential of a fire in the tent to delay the evacuation from nearby shops and theatre.

Figure 1 Tent building at the Christmas market on Sergels Torg in the center of Stockholm.

Figure 2 Typical use of the tent building.

Regarding I), as mentioned previously, the requirements depend on whether the tent structure is considered temporary or permanent. There is no exact limit for this in PBL[xvi] (plan- och bygglagen) but often 4-5 week is the practical limit. For a temporary building the public order act SFS 1993:1617, and the regulation SFS 1993:1633, are applicable. The requirements for a permanent structure are regulated in PBL. In this case the public order act was applied. In this regulatory framework it is stated that the tent is allowed to be used only if sufficient: stability, material fire properties, and escape possibilities are certain.

Regarding the Sergels Torg tent the police authorities asked the local rescue services in Stockholm for advice on fire requirements. The rescue services gave the following advice:

- The tent fabric shall be of the type approved as ”difficult to ignite” (but the rescue services did not refer to any test standard).
- There shall be evacuation signs.
- There shall be free walking area through the exits.
- One side of the tent should be open.

Figure 3 shows a photo of the label for the tent fabric. There is no connection to Swedish requirements.

[xvi] PBL is an abbreviation of the Swedish Planning and Building Act.

Figure 3 Label on the tent fabric.

Regarding II and III (see above) the rescue services has stated that evacuation from nearby shops should not be delayed and that there should not be any combustible material below the bridge structure.

All this gives very little measurable guidance for the police authorities to inspect against. In Stockholm it is not the fire brigade's but the police's responsibility to inspect this kind of event. This creates a problem as the police have only limited knowledge of fire protection.

Example B)

At the horse race *Elitloppet* (in 2012), at *Solvalla horse racing track*, a two storey tent structure was raised 2-3 m from an existing office building. The tent structure was erected for a period of one week and is shown as a photo (Figure 4) and drawings (Figure 5 and Figure 6).

Figure 4 The two-floor textile building erected at Solvalla horse racing track.

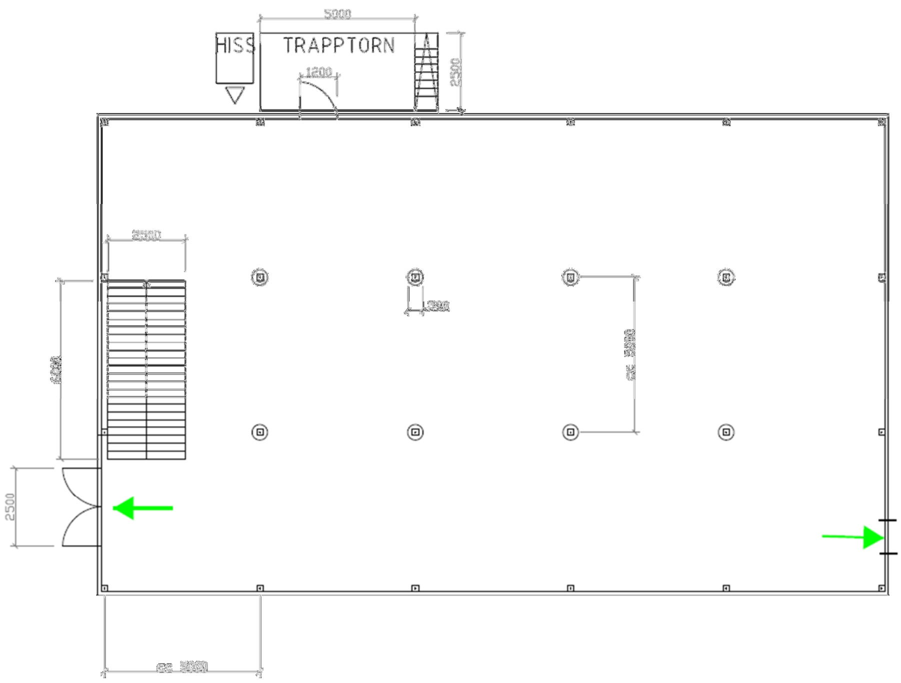


Figure 5 Drawing – Ground floor.

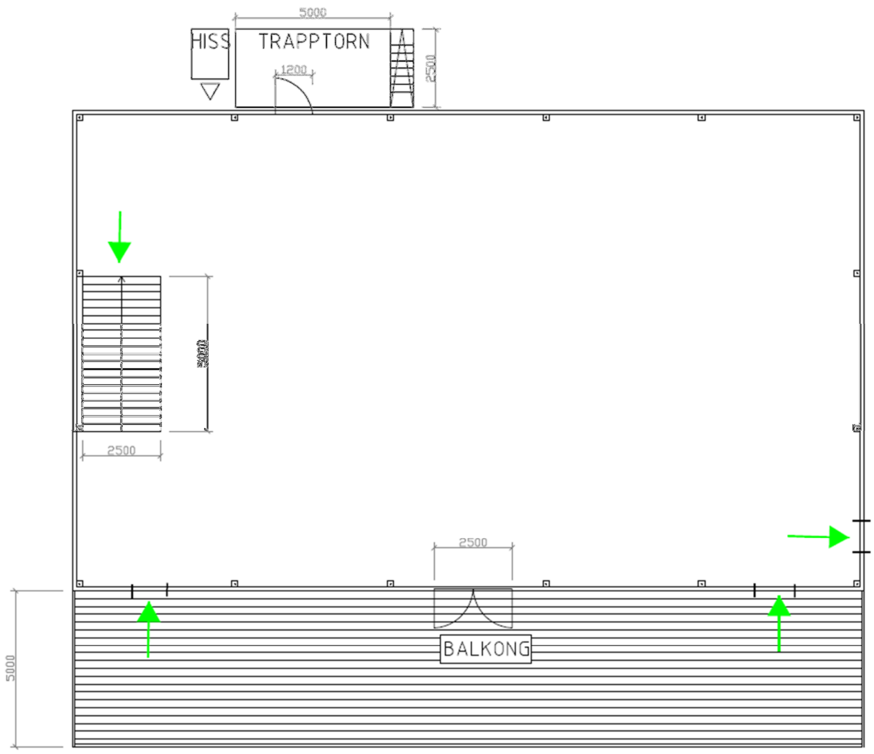


Figure 6 Drawing – Upper floor.

The upper floor is designed for 250 people and the bottom floor for 220 people. The tent was used for spectators. With the same background as in Example A) the Stockholm rescue services have given their views in a statement to the police.

Among other things the following was required:

- Evacuation from the event area is not allowed to be blocked or diminished by the tent structure.
- The tent fabric should be approved as “difficult to ignite”.
- Load carrying structures and loose fittings should not affect the safety negatively.

Basically the same requirements as for Sergels Torg were given. This gives the police very little (if any) help in setting measurable requirements as part of their inspections. The problem of potential fire spread to the existing building is not considered at all.

Example C)

The big Golf tournament *Scandinavian Masters* is held yearly at Bro Hof outside of Stockholm. During this event, a two storey tent structure was erected for the duration of one week. The connections between the two floors are open steel stairs. The load carrying structures consist of steel beams. The floors on the upper floor consist of plywood.

In first chapter, first § and second §, of SFS 1993:1617 it is stated that the law is effective for public places in detail planned areas. However, it is also stated that the municipality may consider other places outside of detail planned areas as public places for setting requirements. Regarding Bro Hof no police permission is applied for. Instead, the organizer trusts that the tent provider can guarantee a sufficiently high level of safety. In this case De Boer (the tent provider) states that they follow TÜV (Technischer Überwachungsverein) regarding the reaction-to-fire performance of the tent fabric and the stability of the load carrying structures. It is, however, uncertain whether the requirements from TUV are sufficient to ensure a relevant level of safety and whether these requirements should be accepted by Swedish regulations.

Example D)

On *Vaksala square* in Uppsala, there is a yearly October festival. The location of the tent buildings are shown in the drawings presented in Figure 7.

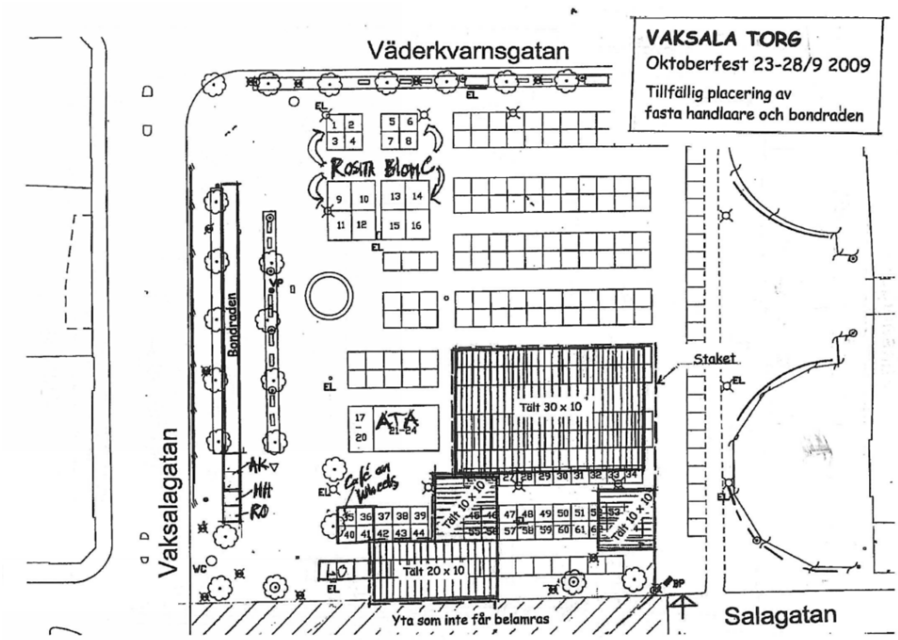


Figure 7 Drawings of tents at the October festival at Vaksala square in Uppsala.

As can be seen there are four separate tent structures erected adjacent to each other. These structures were erected for a period of one week. Uppsala rescue service stipulated that SRVFS 1995:1 should be followed. The requirement level in their report was, however, not well defined, and only states that the tent fabric shall consist of fire approved material. No test method or appropriate level of performance is given.

Uppsala rescue service also requires a label providing the fire properties of the tent fabric and inspects the tent before it can be put into service.

As seen from the examples above there is a need for clarification regarding requirements and test methods. Further, a harmonised approach from the different authorities: Boverket, MSB and Rikspolisstyrelsen[xvii], is desirable.

The reason for the unclear requirements on test methods for the fire technical performance of the textile material is that authorities seems often to require “material difficult to ignite” instead of referring to a specific test or regulation. This must be a result of the text in the guidelines from MSB (1995:1) where the wording “material difficult to ignite” is given as the requirement, but where different test methods can be used to fulfil these requirements.

[xvii] Rikspolisstyrelsen is the National Swedish Police Board.

2.1.2 Permanent structures

2.1.2.1 Background to present requirements

Regulations concerning the fire safety in permanent buildings are given in the Building Regulations BBR19 (2012) from Boverket. Requirements for permanent tent buildings are given in Chapter 5:5 (Protection against the development and spread of fire and smoke in buildings) which under Section 5:521 (Walls, ceilings, floors and fixtures) states that *"In tent buildings with a single layer of textile membrane ceiling- and wall materials should have a surface layer with a minimum of fire technical class E.*[xviii]*"*

This represents a change from BBR 18 (2008) where the requirements for tent buildings were given in Chapter 5:5 (Protection against the spread of fire within the fire compartment) under Section 5:511(General - General Advices) it stated that *"textile membranes for tent buildings meet the requirements of the regulation's second paragraph, if made by a single layer of fire resistant membrane. (BFS 2008:6)"*. This was practically interpreted as a requirement that the membrane should pass the test SIS 650082.

The new requirement in BBR 19 (2012) shall be interpreted as a minimum level and the required level should be regulated by the use of the tent building. The intention from Boverket is that the required fire technical class (Euroclass) should be higher than class E if the tent building is not used exclusively as a warehouse or similar use[xix].

2.1.2.2 Examples of applications

Different examples of applications of the regulations for permanent building structures constructed from textile membranes have been collected and are summarized below.

In permanent tent structures PBL, PBF (plan- och byggförordningen)[xx] and BBR should be used instead of the Public Order Act and the requirements and guidelines from MSB. For buildings with a single layer of textile membranes the requirement from BBR is class E. In a textile building structure intended as an assembly hall for more than 150 persons, or other special locations, the requirements would instead be B-s1, d0 if following the intentions of BBR.

Example A)

Brommapojkarna is one of the largest soccer clubs for young boys and girls in the Stockholm area. In order to be able to play indoors the whole year, three large textile buildings were erected in Bromma in the year 2003 (see Figure 8 and Figure 9).

[xviii] Class E of reaction-to-fire performance according to EN 13501-1 (see Appendix 2).
[xix] Personal communication with Anders Johansson, Boverket.
[xx] PBL is an abbreviation of the Swedish Planning and Building Regulation.

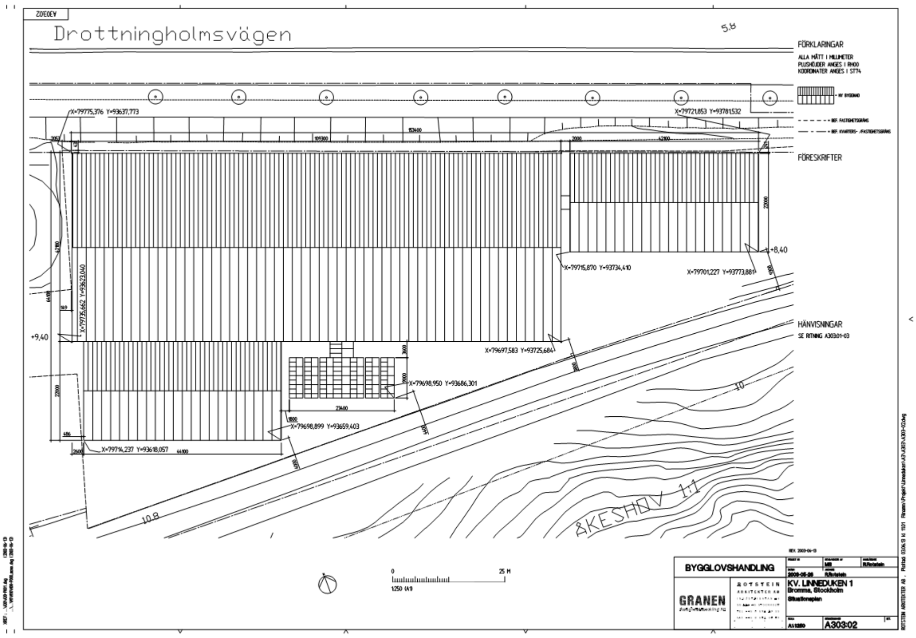


Figure 8 Plan of textile building for indoor soccer training.

Figure 9 Photo of the textile building for indoor soccer training.

Discussion arose regarding the reaction-to-fire quality of the tent fabric, in this case a fabric in two layers. At that time, permanent tent textile structures were classified as a place of assembly and therefore required to fulfil SIS 650082.

In this case SIS 650082 was not considered to be relevant due to the two layer construction. Instead, tests principally according to SP Method 2205 were conducted. In the full scale test tent, a wood crib was placed within a box of hard wood fibre (size 2×1×1 m^3) inside the tent structure as a fire source (see Figure 10 and Figure 11).

Figure 10 The fire source placed in a corner of the tent building (just ignited).

Figure 11 The wood crib fully on fire.

The test run showed that the requirements in the method regarding fire spread, burning droplets and pieces, and opening area were fulfilled (see Figure 12).

Figure 12 Damages to the test building as documented after the test.

Note that a joining cord started burning and the fire progressed far away from the ignition source.

Example B)

There is a plan in the *Gävle city* area to build ice hockey arenas with steel walls and the roof with double layer tent fabric. These are permanent structures and BBR should therefore be used.

According to BBR the tent membrane should be classified according to B-s1, d0 in this case. It is, however, not quite certain whether this is a proper classification for this type of structure. Another question in this case is how it fulfils EKS regarding the load carrying structure. In this case there are no load carrying components because air pressure keeps the roof up which implies that a fire that opens up a hole in the roof structure could result in a collapse of the roof. One needs to include this scenario in a proper fire technical assessment of such a building.

2.2 Textile membranes for weather protection

2.2.1 Background to present requirements

The cladding of scaffolding for renovation or new construction of multi-story buildings mainly uses technically simpler types of textile membranes, often made of polyethylene to provide a high light transmission and an economical product.

With regard to fire safety requirements for these textile membranes, there appears to be no clear regulation. Arbetsmiljöverket[xxi] has the overall responsibility in this case and the requirements for the safety at the working place are given in AFS 2009:2 [1]. The requirements regarding fire protection are very general here but there is some guidance in

[xxi] Arbetsmiljöverket is the Swedish Work Environment Authority.

a memo from Arbetsmiljöverket [2]. In this memo it is stated in *Chapter 4 - Responsibilities*, that "*The use of weather protection can be dangerous in the event of fire or smoke, as it quickly can be filled with smoke.*" It provides, however, no fire technical requirements for textile membranes and no reference to any test method.

It seems that the use of textile membranes for this application is almost entirely unregulated. In some cases, there are requirements from the local rescue service or from the builder for test approval according to EN 13501-1 (the European classification standard for surface lining materials in buildings). In other cases, there are probably no fire requirements requested whatsoever.

2.2.2 Examples of applications

Different examples of applications of regulations and actual requirements for the cladding of scaffolding with textile membranes have been collected and are summarized below.

It is, as discussed above, unclear which requirements that should be used in these cases. Sometimes there are only construction workers in the building which could be under refurbishing or new construction. However, in other cases, the building could be filled with people, as in the case of the renovation of an apartment block or an office building. As described above the regulations in AFS 2009:2 are very vague on these issues.

Example A)

When the tower and the facade of the *Klara Church* in Stockholm were refurbished the whole building was covered with textile weather protection. The small flame test according to SIS 650082 was considered in this case. However, the owner of the church found this small fire test insufficient. In order to assess the fire protection of the fabric it was tested in a similar way as a drapery (SP Fire 043) by SP. In this method a quite large flame (flame height ~50 cm) is in contact with the freely hanging fabric. The fire shall not destroy the fabric outside of the area of the flame. The fabric used in this specific application fulfilled this requirement.

Example B)

At *Stora Mossen* in Stockholm there are a large number of three storey apartment buildings where the façade was insulated with polystyrene plastic in such a way that it started to become mouldy. When refurbishing these apartment houses the whole building was covered with a weather protection while the residents still lived in the building. The “façade” was now combustible, which is against the regulations for facades. It would have been difficult to rescue people by ladders in case of a fire. There were no requests for any special requirements to regulate the safety of these buildings during the period of refurbishment. In fact, the fire safety of the temporary façade was probably not considered at all.

3 Standards and requirements in Europe

3.1 European standards

There are EN-standards available where the reaction-to-fire behaviour of textile membranes in building structures is referred to with different degrees of detail. There are standards available for applications in both temporary and permanent buildings. All standards with some relevance which were found by the authors are listed in Appendix A and the most relevant are discussed below.

For tents there is a standard available regarding the general safety of larger tent structures, **EN 13782:2005 "Temporary structures – Tents – safety"**. This standard specifies safety requirements which need to be observed at design, calculation, manufacturing, installation, maintenance, operation, examination and testing of mobile, temporary installed tents of more than 50 m^2 ground areas. The field of application for the standard covers all kinds of temporary covered structures. Regarding fire safety the standard states that the burning behaviour of the fabric is one parameter to be tested and that EN standards shall be used for testing if existing. Annex A (informative) says that "Walls, fabrics used for textile decorations and other materials should have permanent flame retardance". Annex A further lists European and identified national standards regarding burning behaviour of textile fabrics relevant for covering of temporary structures. The Swedish regulations and the SIS 650082 test are not included in this list.

There is also a standard available with requirements specifically for textile fabrics with polymer coatings intended for tents. This standard is denoted **EN 15619:2008+A1:2010, "Rubber or plastic coated fabrics – Safety of temporary structures (tents) – Specification for coated fabrics intended for tents and related structures"**. The purpose of this standard is to specify the characteristics, the requirements and the test methods for coated fabrics intended for temporary structures and tents. The standard proposes different level of performance (A, B, C) for each characteristic – or T1, T2, T3, T4 for the reaction-to-fire behaviour. The standard refers to EN 14115:2001 (see below) for test of reaction-to-fire behaviour. Tests according to EN ISO 11925-2 with 60 s flame application are additionally required for the highest class (T1) for materials that open up from the pilot flame in the EN 14115 test (introduced with A1:2010). Note that this is not a Product standard and it is therefore not mandatory to implement it into regulations in the Member countries.

EN 15619 is currently under revision and the reaction-to-fire classification from EN 13501-1 has been proposed to be included as an alternative to the classes (T1-T4) based on testing according to EN 14115. The results of the voting on the revised standard was, however, not available at the time of writing this report.

EN 14115:2001, "Textiles – Burning behaviour of materials for marquees, large tents and related products – Ease of ignition" specifies a test method for the burning behaviour of industrial and technical textiles used for tarpaulins, large tents, marquees, related structures, airducts, etc. A test apparatus consisting of an electrical heater and a small flame is used. The test specimen is mounted at an angle of 30 degrees relative the horizontal plane and the electrical heater is placed under the sample. The sample has the dimensions 600 mm × 180 mm. The test is originally a French test method.

EN 13501-1:2007, "Fire classification of construction products and building elements –Part 1: Classification using data from reaction to fire tests" is used for the classification of textile membranes in permanent buildings, although the tests methods referred to in the classification standard originally were developed for testing of solid surface lining products. It has been found during the course of this project that EN 13501-1 is used quite commonly for textile membranes intended for use in temporary buildings and for membranes used for weather protection.

For weather protection, requirements are given in **prEN 16508, "Temporary works equipment - Encapsulation constructions - Performance requirements and general design"**. This standard contains, however, no specific requirements concerning fire safety.

3.2 Applications of standards

Our impression is that the fire performance requirements for textile membranes generally referred to in Europe today for permanent buildings, temporary buildings and weather protection, is EN 13501-1. Although EN 15619 and EN 14115 exist for testing and classification of tent buildings, EN 13501-1 is more often required. The proposal to include EN 13501-1 classification in EN 15619 for tents is probably a reaction to this.

Another trend in test requirements for textile membranes seen in Europe is that some countries that have substituted national tests for EN 13501-1 are starting to require complementary testing using the old national tests. This could be a reaction to the fact that the tests referred to in EN 13501-1 were not originally developed for textile membranes and that both the tests and the classification system are not perfectly suited to this group of products.

The classification criteria used in the European countries differs from each other where some countries using EN 13501-1 have higher requirement regarding smoke production while others have higher requirement regarding ignition and burning rate. The application of standards and the required performance level in some European countries are summarized in Table 1. Note that this information is based on information from the reference group to this project and has not been confirmed with authorities in respective each country.

Table 1 Summary of requirements on single layer textile membranes for temporary- and permanent building structures*.

Country	Tests and requirements for **temporary** textile buildings	Tests and requirements for **permanent** textile buildings
Sweden	SIS 650082 or SP Method 2205	EN 13501-1, E (minimum requirement); B-s1,d0 for assembly halls (>150 persons) and other special locations
Norway	EN 13501-1, B-s3, d0	EN 13501-1, B-s3, d0
Denmark	SIS 650082 (these requirements are currently under revision)	EN 13501-1, B-s1, d0 or D-s2,d2 or B_{roof} (t2), according to use and type of building
Finland	EN 13501-1, no fixed requirements - decided by local authorities	EN 13501-1, requirements as for any other building material
Germany	DIN 4102-1, B1 or EN 13501-1, C-s3, d0	DIN 4102-1, B1 or EN 13501-1, C-s3, d0
France	NF P 92-500, M2	Office buildings: EN 13501-1, A2-s2, d0 Industrial buildings: NF P 92-500, M0 Warehouses: NF P 92-500, M0

* Note: The information in the table is based on available information from the reference group and has not been confirmed with authorities in each respective country.

4 Fire tests with textile membranes

An investigation of the fire behaviour of typical textile membranes for some selected applications has been within the scope of this project. A range of products were provided by the companies that were part of the Reference Group. The products investigated included a range of PVC coated polyester fabrics (PVC/PES), textile membranes that are used for large tents and event buildings, the application depending on the surface weight. One of these PVC/PES products was for use as weather protection. Additionally a polyethylene membrane for weather protection applications on scaffoldings was included in the test programme. These products are described in Section 4.1 below.

All products were tested with the current Swedish classification tests, SIS 650082, and EN ISO 11925-2, which is one of the required tests in EN 13501-1. Both tests are "small flame" tests for the determination of ignition performance, flame spread and dripping behaviour.

A number of these products were further tested with EN 13823, the SBI-method for EN 13501-1 classification. For class E, EN ISO 11925-2 is required only, but from class D and higher, the SBI-test is additionally required. The EN 13501-1 classification system is described in Appendix B.

Large-scale demonstration tests were made with a few selected products (Product B, J and N). These tests were conducted to obtain information on the fire spread, burning behaviour and smoke production in a large application. The applications chosen to be replicated were: an event building with a large ceiling height, a two storey event building and weather protected scaffoldings.

4.1 Textile membrane products

The textile membrane products that were studied are described in Table 2. The current reaction-to-fire classifications of the products in Table 2 have kindly been provided by the producers, and are given in Appendix C.

Table 2 Textile membrane products tested in the project.

Product	Type	Thickness (mm)*	Surface weight (g/m^2)	Typical application**
A	PVC/PES	0.7	850	Tents
B	-"-	0.5	590	Tents
C	-"-	0.6	750	Tents
D	-"-	0.5	490	Tents
E	-"-	0.5	630	Tents
F	-"-	0.5 – 0.6	650	Tents
G	-"-	0.7	850	Tents
H	-"-	0.8	900	Larger textile buildings
I	-"-	0.7	800	Tents
J	-"-	0.7	900	Larger textile buildings
K	-"-	0.9	1100	Larger textile buildings
L	-"-	0.7	900	Larger textile buildings
M	-"-	0.9 – 1.0	1100	Larger textile buildings
N	Polyethylene	0.7 – 1.1	280	For use on scaffolding for weather protection
O	PVC/PES	0.5 – 0.6	650	Temporary roof during renovation of buildings

* Measurements made by SP Fire Technology.

** General description based on that PVC/PES membranes with a surface weight <900 g/m^2 often is used for small to medium sized tents, and that membranes with a surface weight >900 g/m^2 often is used for larger textile building such as event buildings and sports arena.

4.2 Classification tests

4.2.1 Small-flame tests - SIS 650082 and EN ISO 11925-2

Description of tests

The classification test required for large tents in Sweden is SIS 650082 which is an ignition test method using a small gas flame. EN ISO 11925-2 is a similar type of test but with a smaller flame. One important part of the assessment of the classification testing made here, was to investigate whether SIS 650082 could be replaced by EN ISO 11925-2 and if this would influence the actual required performance levels for reaction-to-fire.

In order to make an assessment of the results from these two tests it is necessary to be familiar with the test procedures which are given below.

The ***Swedish standard SIS 650082***[xxii] uses a small gas flame, 38 mm high, as ignition source. The ignition source is placed under the edge of the test specimen (size 50 mm × 300 mm) for 12 seconds and is then removed.

According to the guidelines for type approval ”Boverkets riktlinjer för typgodkännande, Brandskydd, Allmänna råd 1993:2, utgåva 2”, section 1.1.2, a material, thinner than or equal to 3.5 mm, is considered difficult to ignite if the material during the test according to SIS 65 00 82 fulfils the following requirements for five out of six tests:

- The after-flame time shall not exceed 2 seconds in average and not 3 seconds in any test.
- Burnt, melted or in any other way destroyed length shall not exceed 90 mm in average and not 115 mm in any test.

However, if the tested cloth is a PVC-cloth intended for use in a temporary tent building there is an alternative requirement which is supported by full scale fire tests[xxiii] on equal qualities of cloth.

In this case the criteria for not passing the test are:

- When all six test specimens are completely consumed during the test and the time of consumption is less than 120 seconds in average and/or less than 80 seconds in any test.
- Burning droplets or parts are produced.

The standard ***EN ISO 11925-2*** uses a small gas flame, equal to a match flame, 20 mm high, as ignition source. This test method is integrated into the European classification standard for building products, EN 13501-1.

The gas flame is applied on the edge and surface of the specimen (size 90 mm × 250 mm). When testing textile membranes for tent buildings, if the two sides differ, both sides should be tested for surface ignition. The criteria for E-classification according to EN 13501-1 are as follows:

- Flame tip must not reach 150 mm vertically from the point of application of the test flame, within 20 s from the time of application. 15 s exposure time.
- Observation of flaming droplets/particles, ignition of the paper.
- If the flame spread criteria is fulfilled but burning droplets ignite the paper, the classification is E-d2.

The criteria for receiving a higher classification than E according to EN 13501-1 are as follows:

- Flame tip must not reach 150 mm vertically from the point of application of the test flame, within 60 s from the time of application. 30 s exposure time.
- Observation of flaming droplets/particles, ignition of the paper.

Complete tests were conducted with all products, i.e. EN ISO 11925-2 tests were made with both edge and surface application of the flame, and both surfaces were tested. Tests with 30 s application time were made first and in cases where the product did not pass this test, tests with 15 s application time were made. In all tests detailed notes of ignition

[xxii] SIS 650082 is currently withdrawn as a Swedish standard.
[xxiii] SP Metod 2205.

and burning behaviour were taken. Photos were taken of sample specimen before and after the tests.

Test results

The test results for both SIS 650082 and EN ISO 11925-2 are summarized in Table 3. Complete tests results with notes and photos are provided in Appendix D and Appendix E.

It was clearly seen from the SIS 650082 tests that membranes with a high surface weight passed the test, but membranes with a lower weight often failed. However, product B has a relatively low surface weight and passed the test, although the test was passed with the smallest margin regarding damaged length. Product E, which has a marginally higher surface weight, failed due to the time of "after flame". Note that the products D and E that failed the SIS 650082 test still would have been accepted for use in temporary tent buildings (see explanation of test criteria above). Product O, however, failed both in the SIS 650082 test and the EN ISO 11925-2 test for class E.

For the EN ISO 11925-2 tests, a similar trend was seen. Membranes with high surface weight often passed the test with 30 s application time (class > E) or passed with 15 s application time (class E). Two products failed the test (class F). These were product O, which has been used as a temporary roof during renovation of buildings, and product N, a polyethylene membrane used for weather protection. Neither of these two products is used for tent buildings.

Table 3 Results from SIS 650082 and EN ISO 11925-2 (small flame tests).

Product	Surface weight (g/m²)	SIS 650082	EN ISO 11925-2
		Result	Result
N	280	Fail	**F**
D	490	Fail*	E
B	590	Pass	E
E	630	Fail*	E
O	650	Fail*	**F**
F	650	Pass	E
C	750	Pass	E
I	800	Pass	>E
A	850	Pass	>E
G	850	Pass	E
H	900	Pass	E
J	900	Pass	E
L	900	Pass	>E
K	1100	Pass	>E
M	1100	Pass	>E

* Supported by full scale fire tests on equal qualities of cloth, the tested cloth is deemed to meet the criteria for use in a temporary tent building.

The results of the tests made by SP in the project are compared in Table 4 with the results from the tests which are the basis for the existing classification of the products. This information was provided by the producers of the membrane products.

Table 4 Comparison of test results in this project and the test results used for the current classification of the product.

Product	Surface weight (g/m^2)	SIS 650082		EN ISO 11925-2	
		Test	Current classification of product	Result	Current classification of product
N	280	Fail	-	**F**	-
D	490	Fail	-	E	>E
B	590	Pass	-	E	-
E	630	Fail*	Pass	E	>E
O	650	Fail	-	**F**	-
F	650	Pass	Pass	E	>E
C	750	Pass	Pass	E	-
I	800	Pass	-	>E	>E
A	850	Pass	Pass	>E	-
G	850	Pass	Pass	E	>E
H	900	Pass	Pass	E	-
J	900	Pass	Pass	E	>E
L	900	Pass	Pass	>E	>E
K	1100	Pass	-	>E	-
M	1100	Pass	-	>E	>E

* Clearly passed in earlier tests.

From the evaluation of the test results, discussions have arisen regarding the test routine when testing according to EN ISO 11925-2. Depending on the end use application of the membrane, edge ignition might sometimes be excluded. Instead, only the method for surface ignition is performed and only on one side of the product regardless of the surface structure.

What can be seen from tests according to EN ISO 11925-2 is that edge ignition is in most cases the most difficult test to pass, which could mean that a product passing 30 s ignition time for surface ignition, might not manage more than 15 s ignition time for edge ignition. Examples are the G and J membranes which would obtain a higher classification if tested only with surface ignition. Another example is the E membrane which could obtain a higher class if tested only with surface ignition on the rough side. See also Appendix E for a table including all the differences in test results depending on the application method during tests according to EN ISO 11925-2.

Table 5 Differences in test results depending on the application method during tests according to EN ISO 11925-2.

Product	Surface weight (g/m^2)	EN ISO 11925-2	Edge ignition		Surface ignition Smooth side		Surface ignition rough side	
		Final result	Result		Result		Result	
			15 s	30 s	15 s	30 s	15 s	30 s
N	280	**F**	Fail	-	Fail	-	Fail	-
D	490	E	Pass*	Fail	Pass	-	Pass	Pass
B	590	E	Pass	Fail	Pass	-	Pass*	Fail
O	650	**F**	Fail	-	Fail	-	Fail	-
E	630	E	Pass	Fail	Pass	Fail	-	Pass
F	650	E	Pass	Fail	Pass	-	Pass	Fail
C	750	E	Pass	Fail	Pass	-	Pass	Fail

I	800	>E	-	Pass	-	Pass	-	Pass
A	850	>E	-	Pass	-	Pass	-	Pass**
G	850	E	Pass	Fail	-	Pass	-	Pass
H	900	E	Pass	Fail	Pass	-	Pass	Pass
J	900	E	Pass	Fail	-	-	-	Pass
L	900	>E	-	Pass**	-	Pass	-	Pass
K	1100	>E	-	Pass	-	Pass	-	Pass
M	1100	>E	-	Pass	-	Pass	-	Pass

* Flame tip reached 150 mm marking within 20 s in one test; three extra specimens were hence tested to confirm the classification.

** Flame tip reached 150 mm marking within 60 s in one test; three extra specimens were hence tested to confirm the classification.

4.2.2 Intermediate scale tests - EN 13823 (SBI)

Description of tests

The standard EN 13823 (SBI, Single Burning Item test) is a medium scale test method for determination of heat release rate, smoke production and burning behaviour of construction products such as surface layers for walls and ceilings. The test method is part of the European classification standard for building products EN 13501-1.

The test specimen consists of two wings with the dimensions 1500 mm × 1000 mm and 1500 mm × 500 mm. The wings are mounted vertically and perpendicular to each other. The ignition source is a gas burner with a nominal effect of 30 kW. The burner is placed in the corner formed by the perpendicular wings of the product. The test apparatus is shown schematically in Figure 13.

During testing measurements are conducted of the following parameters: FIGRA (FIre Growth Rate index), SMOGRA (SMoke Growth Rate index), THR (Total Heat Release), TSP (Total Smoke Production), HRR (Heat Release Rate) and SPR (Smoke Production Rate). The test method also includes visual observations of LFS (Lateral Flame Spread) and burning droplets or particles.

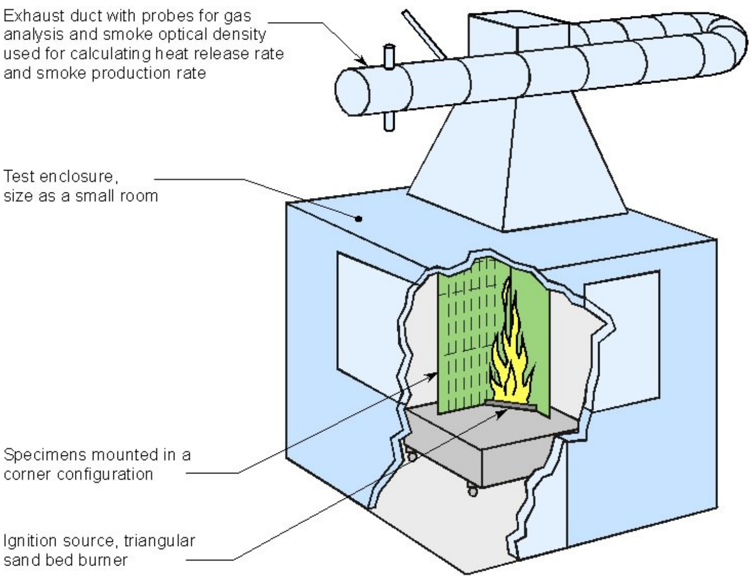


Figure 13 Schematic drawing of the SBI-test apparatus.

The SBI-test is used to achieve classes A2-D. To achieve classes B-D an additional test according to EN ISO 11925-2 is performed (see Appendix B).

A limited number of the textile membrane products included in the project were selected for SBI-tests. The selection was made in an effort to include a variety of products with different surface weight, intended for different applications. The selection considered the results of the small-flame tests.

The mounting of the sample specimen in the SBI is described in EN 13823. The mounting can be done according to two principles: 1) mounting as in the end use application, or 2) standard mounting. When products are tested using the first principle, the test results are valid only for that application. When products are tested using the standard mounting, the test results are valid for that specific end use application and can be valid for a wider range of end-use applications. For the standard mounting there are specifications given in the standard; however, the standard mounting is specifically designed for board materials.

There is, however, one product standard available for a specific application of textile membrane materials. This is the product standard for stretched ceilings, EN 14716:2004. In this product standard there is a detailed description of the mounting requirements for the SBI test, including a description of a test frame. This test frame was used in all tests reported here. A single piece of membrane was fitted in the corner position and mechanically fixed in the upper and lower edges of the test frame. Backing boards were positioned behind the sample with an air-gap of 80 mm (mounting specification given in EN 14716:2004 and also for standard mounting with an air gap in EN 13823).

It has been reported previously by SP [3], and it was also acknowledged by members of the Reference Group, that the mounting method described above can give non-repetitive results for some membrane materials. The reason is that the corner of the sample specimen moves away from the flame during the test.

A modification of the mounting method was investigated by fitting a metal support in the corner position to fix the corner of the sample specimen. The metal support used was an L-profile in steel with the dimensions 20 mm×20 mm. This method of mounting has been investigated earlier [3].

The two methods for mounting the samples in the SBI were investigated and triplicate tests were run with both methods. The samples were, as a rule, mounted with the rough surface exposed to the incident heat flux, since the rough side would be likely to be faced inwards in a building.

A sample specimen mounted without support is shown in Figure 14 (a), and the same membrane material mounted with a metal profile as a corner support is shown in Figure 14 (b).

(a) (b)

Figure 14 Mounting of the textile membrane in the SBI-test. (a) Normal standard mounting. (b) Mounting with a corner support.

Test results

All tests were video recorded and photographs were taken before, during, and after the test. Results of the tests are summarised in Table 6. Photos of selected test specimens and graphs with HRR and SPR results are given in Appendix F.

For the tests with the standard mounting of the sample species three out of four of the PVC/PES membranes gave a low FIGRA and received a B class from the SBI-test. Only Product L burned more substantially which resulted in a higher FIGRA and a C-class. The polyethylene membrane tested gave flame spread to the edges of the test specimen and showed extensive dripping, which resulted in a low class (class D) from the SBI-test.

The tests with the addition of a corner support gave a higher FIGRA for the PVC/PES products tested (Product L was not tested), which resulted in a lower class for products E and J. Product B, however, maintained the same class as from the tests with standard mounting.

The polyethylene membrane, Product N, was not affected significantly by the mounting method. This product showed approximately the same fire behaviour in the tests with the addition of a corner support.

Table 6 Results from EN 13823 (SBI) tests conducted with selected products using two types of mounting of the sample species.

Product	Surface weight (g/m²)	Results from tests: *Standard mounting of textile membrane (EN 14716:2004)*		Results from tests: *Addition of corner support*	
		Class from SBI	FIGRA*	Class from SBI	FIGRA*
N	280	D-s2,d2**	74	D-s1,d2**	94
B	590	B-s2,d0	0	B-s2,d0	52
E	630	B-s2,d0	78	C-s2,d0	206
J	900	B-s3,d0	36	D-s3,d2	366
L	900	C-s3,d2	230	-	Not tested

* Average of $FIGRA_{0.2\ MJ}$ for three tests
** LFS to the edge of specimen

The mounting method with a corner support has the advantage that it more closely resembles the mounting in a real textile building where a corner normally is supported by a metal beam or some part of the framework of the building. This mounting procedure also gives less ambiguous classification results. It has been reported previously that tests without a corner support can give non-repetitive results [3]. In the tests conducted here there was no product that showed very non-repetitive results in the tests with normal mounting, however, Product E had a FIGRA of 105 W/s in one of the three tests which was close to the limiting value of 120 W/s for class B.

Results and classification from previous SBI tests with the products, that forms the basis of the existing classifications of the products, are given in Table 7. If comparing with the results from the tests made in this project with a standard mounting, in Table 6, it is seen that the results are comparable for product E and product L. There is, however, a difference for product J, which can be due to the fact that the mounting procedure is important for the results of the SBI-test and that the standard mounting procedure can produce non-repetitive results.

Table 7 EN 13823 (SBI) tests data for the existing classification of the product.

Product	Surface weight (g/m²)	SBI results from current classification of product	
		Class from SBI	FIGRA*
N	280	-	-
B	590	-	-
E	630	B-s2,d0	10
J	900	C-s3,d2	146
L	900	C-s3,d0	307

4.2.3 Conclusions from classification tests

The major objectives of the classification tests conducted were to investigate whether alternatives to the current test in Sweden, SIS 650082, could be found among European tests; and, to find an acceptance level that would not decrease the safety level for tent buildings in Sweden if implemented.

It was found that the EN ISO 11925-2 small flame tests could replace SIS 650082. It had previously been assumed that the EN ISO 11925-2 was an easier test to pass due to the somewhat smaller size of flame, but that was not substantiated. It was seen that the selectivity of the EN ISO 11925-2 test depended on the test procedure used. A comparison of the test results from SIS 650082 with the results from EN ISO 11925-2 with different test produces used is given in Table 8. The comparison is based on the results presented in Table 3 and Table 5.

Table 8 Comparison of test results from SIS 650082 with the results from EN ISO 11925-2 with different test procedures used.

	Comparison of EN ISO 11925-2 with SIS 650082 test results			
Results from SIS 650082 tests	*EN ISO 11925-2 30 s flame application Edge ignition*	*EN ISO 11925-2 15 s flame application Edge ignition*	*EN ISO 11925-2 30 s flame application Surface ignition*	*EN ISO 11925-2 15 s flame application Surface ignition*
11 products passed	5 of the 11 products passed	All 11 products passed	8 of the 11 products passed	All 11 products passed
3 products failed in test but accepted for tent building	None of these products passed	2 of these products passed	1 of these products passed	2 of these products passed
1 product failed in test and was not accepted for tent building	The product did not pass	The product did not pass	The product did not pass	The product did not pass

The comparison shows that the EN ISO 11925-2 test with 30 s flame application and edge ignition is clearly more severe compared to the SIS 650082 test. Only five products out of eleven passed these criteria.

The results of the comparison of 15 s flame application with the EN ISO 11925-2 test was that the results were very similar to those from the SIS 650082 tests. Eleven products out of eleven passed both tests. Of the three products that failed the SIS-tests but were accepted in tent application, two of these products passed the EN ISO 11925-2 test. The polyethylene product that failed SIS 650082 also failed EN ISO 11925-2.

One could further see from the results of the EN ISO 11925-2 test that it is very important that the test procedure regarding edge or surface ignition is specified and that it is decisive for the test results which side of the membrane product that is tested. It was agreed within the Reference Group that the rough side of the product should be oriented towards the flame if there was a difference in the surface appearance of the two sides. The reason for testing the rough side is that this side normally is located towards the interior of a textile building.

The test results for the products that were subjected to complete EN 13501-1 testing for Euro classification are summarized in Table 9. These results show that the only membrane used for weather protection (product N) included in the test series, received a low classification in all tests it was subjected to. Regarding Euroclasses this product obtains an F class due to failing the small flame test according to EN ISO 11925-2. The classification procedure is that the product obtains the lower of the classes from the individual testing methods used.

Table 9 Summary of results of the different classification tests conducted.

Product	Surface weight (g/m^2)	SIS 650082	EN ISO 11925-2 Edge application	EN ISO 11925-2 Surface application	EN 13823 (SBI) *Standard mounting*	EN 13823 (SBI) *Mounting with corner support*
N (polyethylene)	280	Fail	F	F	D-s2,d2	D-s1,d2
B	590	Pass	E	E	B-s2,d0	B-s2,d0
E	630	Fail*	E	>E	B-s2,d0	C-s2,d0
J	900	Pass	E	>E	B-s3,d0	D-s3,d2
L	900	Pass	>E	>E	C-s3,d2	-

* Supported by full scale fire tests on equal qualities of cloth, the tested cloth is deemed to meet the criteria for use in a temporary tent building.

The results for the PVC/PES products tested are more complex to interpret. First, it is clear that the EN ISO 11925-2 test with 30 s flame application is difficult to pass for textile membrane products when edge application is applied. Here only Product L passed that criterion. For surface application, all products except Product B passed. It has been observed previously that thin membranes often fail in this test [3]. The reason is that the flame quickly burns a hole and the material is then exposed to the flame from both sides. All PVC/PES products did pass the criteria for 15 s flame application, both for surface and edge application of the flame.

Comparing the results of EN ISO 11925-2 and EN 13823 tests, the general impression is that the results for surface application in EN ISO 11925-2 corresponds to the behaviour in the EN 13823, better than edge application. That is, however, not true for product B. This product behaves very well in the EN 13823 test, irrespectively of the mounting procedure, and the result of the EN ISO 11925-2 test does not represent the behaviour of the product when subjected to a larger ignition source (as in the SBI-test) at all.

4.3 Large-scale reference tests

The large-scale reference tests are presented in the following chapters. The tests were conducted to study the ignition and burning behaviour in a large scale application of some typical textile membrane products, selected from the products characterised with classification tests in this project.

The products selected were the polyethylene membrane for weather protection of scaffoldings (product N), a PVC/PES membrane with a lower surface weight (product B) and a PVC/PES membrane with a higher surface weight (product J).

The polyethylene membrane for weather protection was investigated in a test scenario that was very close to a real application on scaffolding. The PVC/PES membranes were investigated using two scenarios, both with relevance for event building applications. In one of these scenarios the test building was an open room with a large ceiling height. In the other scenario, a combustible dividing floor was included in the test building. In both of these scenarios the depth of the building was less than that of a real building. This implies that heat and smoke are accumulation in the volume of the building much faster than in a real building. These two test scenarios were therefore more severe compared to a real event building application.

In addition to the main tests, where the ignition source was a sand burner having a heat release which corresponds to a burning wastebasket placed in one corner of the test building, practical ignition tests were also conducted using a small lighter. The reason for conducting the practical ignition tests was to investigate the validity of the ISO EN 11925-2 test classification in a close-to-real application.

4.3.1 Scenarios

The test scenarios are described below:

Scenario 1 – Weather protection of scaffolding

Scaffolding, having a total height of 4.086 m, a length of 5.892 m and a depth of 1.655 m was erected. The scaffolding had two levels where the inserted floor was mounted at a height of 2.115 m (See Figure 15). The inserted floor was made of perforated metal.

The textile membrane covered the ceiling, front side, the short side exposed to the flames (right side) and the upper part of the left short side (see Figure 16 and Figure 17). To simulate the void between scaffolding and a building under construction, the back side was left open and the scaffolding was erected at a distance of 90 cm from the wall behind.

Figure 15 Inserted floor made of perforated steel separates the first from the second floor.

Figure 16 Front side and the short side exposed to the ignition source.

Figure 17 Front-side and the unexposed side of the test setup.

Scenario 2 – Textile building structure without an inserted floor

A temporary textile building was simulated with a total height of 4.086 m, a length of 5.892 m and a depth of 1.655 m. No inserted floor was introduced.

The textile membrane covered the ceiling, front side, short side exposed to the flames (right side) and the upper part of the left side (see Figure 18 and Figure 19). To create an enclosed room, the upper half of the rear side was covered with a non-combustible fabric and the lower half was covered with non-combustible boards (see Figure 20).

Figure 18 Front-side and the unexposed side of the test setup.

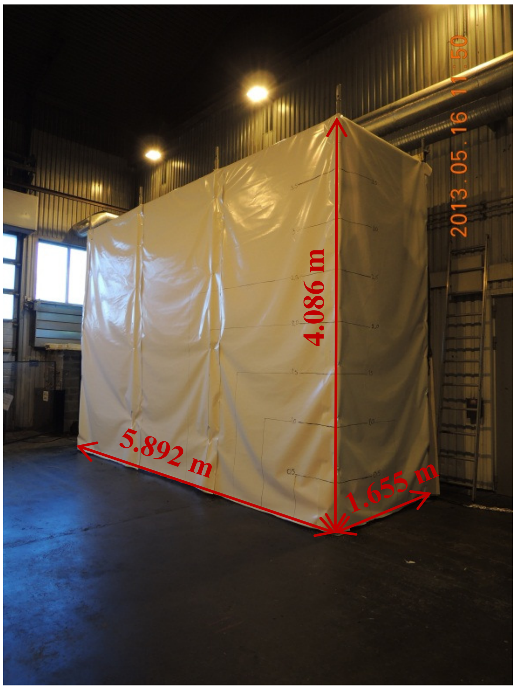


Figure 19 Front-side and the short side exposed to the ignition source.

Figure 20 Rear-side of the supporting structure covered with non-combustible fabric and non-combustible board.

Scenario 3 – Textile building structure with an inserted floor

A temporary textile building was simulated with a total height of 4.086 m, a length of 5.892 m and a depth of 1.655 m. An inserted floor made of 12 mm plywood supported by a steel construction was introduced at a height of 2.5 m (see Figure 21).

The textile membrane covered the ceiling, front side, short side exposed to the flames (right side) and the upper part of the left side (see Figure 18 and Figure 19). To create an enclosed room, the upper half of the rear side was covered with a non-combustible fabric and the lower half was covered with non-combustible boards (see Figure 20).

Figure 21 Inserted floor of plywood supported by a steel construction.

4.3.2 Mounting of textile membranes

Several sheets of a textile membrane were mounted vertically as shown in Figure 22. Three sheets having a width of 2.2 - 2.4 m were used to cover the ceiling and the front side. Sheets with a width of 1.8 – 1.9 m were used to cover the left and right wall. The sheets overlapped each other by 0.1 – 0.2 m on each side. Those overlaps were used to tie the sheets to each other and to the supporting structure. Different ways of bindings are shown in Figure 23.

Figure 22 Fixing of vertical sheets.

Figure 23 Techniques used to bind the sheets together and to the supporting structure (top left: binding of PVC membrane to supporting structure from the inside | top right: binding of PVC membrane to supporting structure from the outside | bottom left: binding of weather protection membrane to supporting structure from the inside | bottom right: binding of weather protection membrane to supporting structure from the outside).

4.3.3 Ignition source

A sand burner with propane fuel was used as the ignition source. The sand burner had an area of 289 cm^2 (17 cm × 17 cm) and was placed in the right outer corner of the test building (standing in front of the building), see Figure 24.

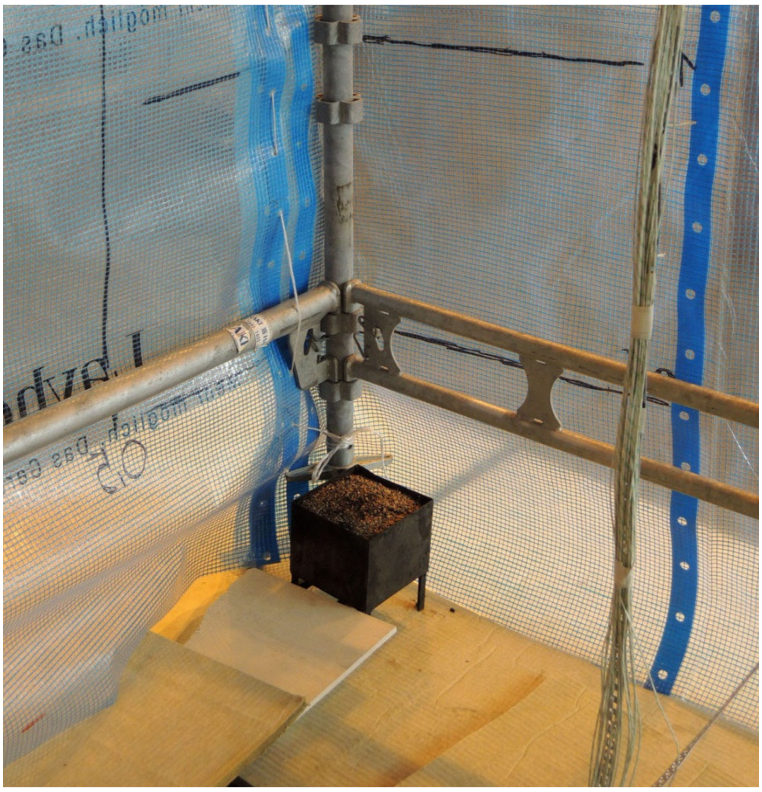


Figure 24 The sand burner placed in the corner of the test building.

4.3.4 Measurements

Two thermocouple piles, having 24 thermocouples each, were installed inside the test building (see Figure 25). Their lowest measuring point was 1 m above the floor; their highest measuring point was on top of the roof. Detailed drawings of the position of each thermocouple are given in appendix G, Figure 34 and Figure 35. The thermocouple piles were located in the centre of the segment in the middle of the test building (position A) and in the centre of the segment containing the burner (position B). The exact positions are shown in appendix G, Figure 29 to Figure 33.

Besides two thermocouple piles, additional temperatures were measured with plate thermometers [4]. In order to calculate the incident heat flux and the adiabatic surface temperature[xxiv] [5] a reference thermocouple was installed in close vicinity to each plate thermometer, see Figure 26. The plate thermometers were positioned at the rear wall of the test building (position C and D) and at the side wall exposed to the burner flames (position E), see Figure 27. The exact positions are shown in appendix G, Figure 29 to Figure 33.

[xxiv] The adiabatic surface temperature corresponds to the temperature of a surface having a very thick insulation layer behind.

Figure 25 The thermocouple trees at position A (foreground) and position B (background) continued up to ceiling level.

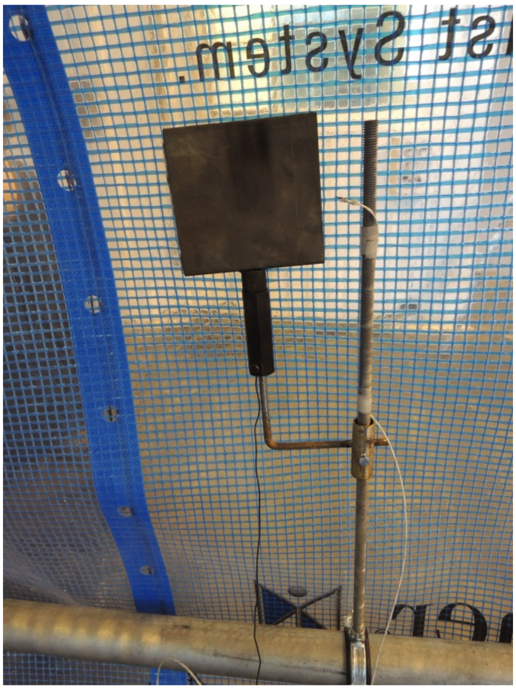


Figure 26 One of the plate thermometers and the reference thermocouple (white wire).

Figure 27 Thermocouple trees (position A and B) and plate thermometers (position C, D and E).

Vertical and horizontal markings as shown in Figure 28 were used to estimate the damaged length and the flame spread during the tests.

Figure 28 Markings for flame spread observations.

4.3.5 Test procedure

The test procedure was identical for the major tests using the sand burner as the ignition source:

- All Measurements were started (time: 0:00) and a base line of the ambient conditions was measured.
- After a period of two minutes the burner was turned on and a heat output of 100 kW was established (time: 2:00).
- The heat output was then increased to 300 kW after 10 minutes (time: 12:00).
- The burner was turned off after a further 10 minutes (time: 22:00) and any self-sustaining flames spread was observed for 10 minutes.
- The test ended and all measurements were stopped after a total duration of 32 minutes (time: 32:00). At this time the damages of the textile membrane were documented.

Practical ignition tests using a fire lighter were conducted after some of the major tests. The test procedure was to start with surface application of the flame (15 s and 30 s application time) on the front side of the membrane mounted on the building, continue with edge application (15 s and 30 s application time), and then repeat this procedure with the back-side of the membrane.

4.3.6 Test conducted

A total of five instrumented large-scale reference tests were conducted with a sand burner as ignition source. Single tests were run in all cases and the tests conducted are summarized in Table 10.

Table 10 Summary of the instrumented tests conducted with a sand burner as ignition source.

Scenario	Number of tests conducted	Textile membranes tested
1 - weather protection of scaffolding	1	• N (polyethylene membrane)
2 - Textile building structure without an inserted floor	2	• B (low surface weight PVC membrane) • J (high surface weight PVC membrane)
3 - Textile building structure with an inserted floor	2	• B • J

4.3.7 Test results

The results of the large scale tests are summarized in this section. Detailed observations and measurement data are given in Appendix G.1 for the burner tests. Results from the practical ignition tests are given in Appendix G.2.

Burner tests

Weather protection of scaffolding (scenario 1)

The results of the single burner test conducted with membrane N are summarized in Table 11 - Table 13.

The polyethylene membrane gave continuous fire spread away from the position of the burner and the total fire spread extended to somewhat less than half of the long side of the building. The velocity of the fire spread was about 10 cm/min. Much of the short wall was consumed, but this was seen to be largely due to direct impact of the burner flames.

The temperatures in the building reached above 100 °C in the upper parts of both floors and the highest temperatures were measured under the ceiling at the second floor. The visibility was good in both floors during the tests due to the very limited smoke production of the material. The material melted continuously and dripped down to the floor. This produced pool fires on the floor which was the most dangerous feature during this test.

After the burner test, a practical ignition test using a small flame was initiated. The detailed results of this test are given in Appendix G.2. The consequences of applying a small flame against the membrane were substantial. The material ignited immediately and continuous self-sustaining fire spread started which resulted in most of the building, including part of the roof, being consumed in the fire before the test was terminated by extinguishing the fire manually. The fire spread rate was of the same order as of that in the burner test.

The reason why the fire-spread in the burner tests declined and stopped, whilst the fire-spread in the ignition test did not, is not clear. One observation, however, was that the impact of the burner made the burning edges of the material thick from melted material which lead to self-extinguishment when the distance from the burner reach a certain length.

Table 11 Summary of test results on burning behaviour (burner ignited at 2 min).

Test	Time for hole (burn through) in corner [min:s]	First burning droplets or debris [min:s]	Final extent of consumed material:			
			Long wall: length of hole [m]	Long wall: height of hole [m]	Short wall: length of hole [m]	Short wall: height of hole [m]
Membrane N (polyethylene)	2:20	2:24	2.9	3.3	1.2	3.5

Table 12 Summary of test results on measured temperatures (maximum temperatures in upper parts of respective floor).

Test	Position A (centre):		Position B (corner):	
	Temperature floor 1 [°C]	Temperature floor 2 [°C]	Temperature floor 1 [°C]	Temperature floor 2 [°C]
Membrane N (polyethylene)	37	96	52	122

Table 13 Summary of observations on smoke development.

Test	Smoke/visibility:	
	floor 1	floor 2
Membrane N (polyethylene)	Low smoke production Good visibility	Low smoke production Good visibility

Textile building structure without an inserted floor (scenario 2)

The results of the burner tests conducted with the two PVC membranes are summarized in Table 14 - Table 16.

The time for burn through in the corner at the burner was about 20 seconds, and the fire spread was limited to the vicinity of the burner flames in both tests. There was therefore no significant self-sustaining fire spread for either of the two PVC membranes.

The temperatures reached to about 200 °C in the upper part of the building and the highest temperatures were measured in the corner where the burner was placed. The temperatures at mid-height of the building were much lower, below 70 °C. There was no major difference between the two tests; however, in the test with the thicker membrane product (J) somewhat lower temperatures were generally measured. The explanation must be that the somewhat larger opening caused by the flames from the burner in the test with membrane J resulted in better ventilation of the building and correspondingly lower temperatures.

The visibility in the building was reduced due to substantial smoke production from both materials. The smoke production from membrane J was regarded as higher resulting in lower visibility. The smoke layer extended, however, only down to about 2.0 m from the floor.

Burning material did fall down on the floor in both tests. This started much earlier in the test with membrane J. The material fell, however, only close to the burner due to the limited fire spread in both tests.

Table 14 Summary of test results on burning behaviour (burner ignited at 2 min).

Test	Time for hole (burn through) in corner [min:s]	First burning droplets or debris [min:s]	Final extent of consumed material:			
			Long wall: length of hole [m]	Long wall: height of hole [m]	Short wall: length of hole [m]	Short wall: height of hole [m]
Membrane B (low surface weight)	2:20	12:33	0.4	2.3	0.7	2.6-2.7
Membrane J (high surface weight)	2:24	3:25	0.4-0.5	2.7	0.7-0.8	3.1

Table 15 Summary of test results on measured temperatures (maximum temperatures in upper parts of respective floor).

Test	Position A (centre):		Position B (corner):	
	Temperature mid-height [°C]	Temperature top of room [°C]	Temperature mid-height [°C]	Temperature top of room [°C]
Membrane B	55	166	68	218
Membrane J	41	162	62	204

Table 16 Summary of observations on smoke development.

Test	Smoke/visibility
Membrane B	Smoke layer from ~2.0 m at ~3.0 min
Membrane J	Smoke layer from ~2.0 m at ~3.0 min (thick smoke)

Textile building structure with an inserted floor (scenario 3)

The results of the burner tests conducted with the two PVC membranes are summarized in Table 17 - Table 19.

The time for burn through in the corner at the burner was about 20 seconds, and the fire spread was limited to the vicinity of the burner flames also in these tests.

The inserted wood floor seems to have had a major impact on the conditions in the building as compared to the tests with a high ceiling height. The measured temperatures were significantly lower, especially in the top of the second floor. The inserted floor must have protected the second floor from the heat from the burner. There was only limited burning of the wood floor itself, close to the burner.

The smoke production from the materials resulted in reduced visibility on the second floor, but had limited impact on the visibility in the first floor. The visibility at the second floor was significantly reduced in the tests with membrane B, and in the tests with the thicker membrane (J) the visibility was reduced almost to zero already one and a half minute after starting the burner.

Burning material was observed falling down onto the floor in both tests as in the case without an inserted floor. Even in this case the burning material began falling earlier in the test with membrane J.

Table 17 Summary of test results on burning behaviour (burner ignited at 2 min).

Test	Time for hole (burn through) in corner [min:s]	First burning droplets or debris [min:s]	Final extent of consumed material:			
			Long wall: length of hole [m]	Long wall: height of hole [m]	Short wall: length of hole [m]	Short wall: height of hole [m]
Membrane B (low surface weight)	2:16	6:42	0.4	2.1	0.6	2.4
Membrane J (high surface weight)	2:19	3:08	0.5	2.3-2.4	0.8	2.6

Table 18 Summary of test results on measured temperatures (maximum temperatures in upper parts of respective floor).

Test	Position A (centre):		Position B (corner):	
	Temperature floor 1 [°C]	Temperature floor 2 [°C]	Temperature floor 1 [°C]	Temperature floor 2 [°C]
Membrane B	48	90	63	92
Membrane J	38	95	57	87

Table 19 Summary of observations on smoke development.

Test	Smoke/visibility:	
	floor 1	floor 2
Membrane B	Good visibility, smoke starting at ~2.1 m	Smoke filled, reduced visibility to ~4.5 m at 3:30
Membrane J	Good visibility	Very thick smoke, reduced visibility to <0.5 m at 3:30

Ignition tests

Ignitability tests similar to those described in EN ISO 11925-2 were performed on the textile membranes when mounted in the building structures. Both edges and the surfaces were exposed to a direct small flame impingement. The reason for conducting these tests was to investigate whether it was possible to ignite the membranes only using a small flame in practice.

The tests showed that neither of the two PVC/PES membranes could be ignited and continue to burn by impingement of a small flame. They both self-extinguished. The polyethylene membrane (N), however, was ignited by flame impingement on the surface and showed continuous self-sustaining fire spread.

The test procedure and the detailed results of these tests are given in Appendix G.2.

5 Conclusions and recommendations

5.1 General discussion

The requirements concerning the reaction-to-fire performance of textile membranes for large temporary tents are under revision by MSB. The exact formulation of the revised regulation was not known during the work with this report but most likely EN 13782:2005 will be referred to regarding the general safety. EN 13782:2005 does not give reference to specific test requirements regarding fire safety but states that burning behaviour of the fabric is one parameter to be tested and that EN standards, if existing, shall be used for such testing.

The existing EN standard that specifies tests procedures for textile fabrics with polymer coatings intended for tents is EN 15619:2008+A1:2010. In this standard the test procedure is based on EN 14115:2001, a former French test which now is a European standard. An amendment to that standard was included in 2010 where EN ISO 11925-2 with 30 s application time of the flame was added as a complementary test for the highest classification in EN 15619. EN 15619 is now under revision and there will most probably be a change in the test procedure which will allow EN 13501-1 classification to replace the former classification based on EN 14115.

With the identified increasing use of tests according to EN 13501-1 for textile membranes in temporary tent buildings in Europe it seems logical to implement the same type of tests also in Sweden. Further, with the introduction of Euroclass E (as a minimum requirement) for single layer textile membranes in permanent buildings in Sweden, with BBR 19 (2012), it would form a more consistent system to use the same type of classification system also for temporary buildings.

The tests methods proposed as a basis for the fire safety requirements for textile membranes in temporary buildings is therefore those defined in EN 13501-1. The requirements proposed for various applications are discussed below.

5.2 Temporary textile buildings structures

The requirement levels for temporary textile building structures are proposed to be based on the type of building and the use of the building. This is the same type of criteria which is the basis of the requirement system for permanent buildings which was introduced with BBR 19 (2012). The specific requirement levels for textile membranes are, however, proposed to be different from those applied to solid materials. The reason for requiring lower Euroclasses for textile membranes is that these materials have shown better reaction-to-fire behaviour in large scale reference tests than what is given from the EN 13501-1 classification.

Another generic difference between a textile membrane and a solid wall or ceiling lining product is that a fire quickly burns a hole in the textile membrane. By burning a hole, heat and smoke can be ventilated out from the building and the consequences of the fire can be restricted if the material has good flame spread behaviour, i.e. is self-extinguishing.

However, a fire in a textile building structure will only open up a hole in the textile membrane where the flames directly impinging on the textile material. In a single layer textile structure the heat losses are generally too great for self-ignition or even melting of a PVC/PES membrane from the influence of a hot upper layer, which was showed in the large-scale tests conducted in this project which confirm results from previous work [3]. This has as a consequence that there will be no smoke gas ventilation of from the top of the building if the flames from the fire are lower than the ceiling.

A proposed requirement system for **single layer textile membranes** used for temporary building structures in Sweden is given in Table 20.

Table 20 Proposed reaction-to-fire requirement for single layer textile membranes in temporary building structures.

Occupancy class[xxv]	Explanation of Occupancy class	Type of textile building structure	
		Freestanding 1-floor structure	Freestanding structure with ≥ 2 floors*
Vk 1	Industrial buildings or warehouses etc.	E***	D-s2, d0
Vk 2a**	Places of assembly < 150 people	E***	D-s2, d0
Vk 2b	Places of assembly > 150 people	E***	C-s2, d0
Vk 2c	Places of assembly > 150 people, alcoholic beverages are served	C-s2, d0	C-s2, d0

* Includes also 1-floor buildings with raised floor or seating in some part of the building that is higher than half the maximum ceiling height.
** Temporary buildings for < 150 persons are not regulated by the recommendations from MSB.
*** Class E with edge application.

For **multiple layer** textile membranes and **textile membranes with insulation**, and also for **structures raised against a permanent building**, the same reaction-to-fire requirements as those used for permanent buildings are proposed for temporary buildings.

The proposal on requirements of EN 13501-1 classification is thus that the base level for single layer membranes in temporary buildings shall be Euroclass E. The EN ISO 11925-2 small flame tests shall be conducted using edge application. This is the more demanding type of flame application which is currently used in the SIS 650082 test. The results of the tests conducted in this project show that implementing Euroclass E, as a base criterion, would not imply a reduction of the fire safety requirements and would not significantly change the classification of the products now on the market.

The proposal is to have higher requirements on multi-storey buildings. Ranging from class D for warehouses (Vk 1) to class C for places of assembly (> 150 people) where alcoholic beverages are served (Vk 2c). In all cases restrictions are required concerning smoke production and burning droplets/debris. The proposal for a restriction of smoke production is based on the large-scale demonstration tests conducted in this project, where it was seen that a fire on the first floor quickly resulted in limited visibility on the second floor, which would obstruct evacuation of the building.

[xxv] *Verksamhetsklass* in BBR 2012. Vk1 denotes industrial buildings or warehouses etc., Vk 2 denotes places of assembly in where people by definition are unfamiliar with the environment. Vk 2a: < 150 people; Vk 2b: > 150 people; Vk 2c: > 150 people and alcoholic beverages are served.

For Euroclasses ≥ D the flame application in the EN ISO 11925-2 small flame tests should be surface application only. It was seen in the test programme in this project that the results of surface application were more coherent with the results of the EN 13823 test (SBI) and the behaviour of the textile membrane in the large-scale reference tests conducted.

The requirements on the mounting of the textile membranes in the EN 13823 test (SBI) should be changed to avoid poor repeatability and ambiguous test results. The proposal is to include a requirement of a corner support which is described in section 4.2.2.

It should further be stated in the requirements that the side of the textile membrane facing inwards in the building should be exposed to the heat/ignition source in the classification test.

5.3 Permanent textile building structures

EN 13501-1 classification of textile building materials in permanent buildings is now included in the present Building Regulations from Boverket, BBR 19 (2012). The basic requirement is Euroclass E for single layer textile membranes.

The new requirement in BBR 19 (2012) shall be interpreted as a minimum level and the required level should be regulated by the use of the tent building. The intention from Boverket is that the required fire technical class (Euroclass) should be higher than class E if the tent building is not used exclusively as a warehouse or similar use.

It is important that the change in requirements for the application of textile membranes in permanent building structures is communicated to builders and constructors. It is also very important that the interpretation of the regulation for more demanding applications than warehouses is communicated.

The test procedure for textile membranes in the EN 13501-1 classification needs further to be more clearly specified as was discussed above for temporary buildings.

For the future it is desirable that the requirements on permanent and temporary textile building structures would be harmonized.

5.4 Textile membranes for weather protection

Euroclass E with edge application is proposed as the lowest requirement for textile membranes for weather protection.

In cases where the building is in use, higher requirements are needed. We believe that the requirements on buildings given in the Building Regulations from Boverket (BBR) should be applied in such cases.

Arbetsmiljöverket has the overall responsibility in this case and should specify and clarify the regulations regarding fire safety of using textile membranes for weather protection.

5.5 Summary of work and limitations

The present work has involved a thorough study of the reaction-to-fire behaviour of textile membranes in building applications. Regulations and tests methods for applications in temporary and permanent buildings have been investigated.

Recommendations on test requirements for temporary building applications and for applications of textile membranes as weather protection have been given.

A relatively large number of PVC/PES textile membranes were included in this study and we feel confident that the results of the study generally describe these types of products. There was, however, only two membrane product used for weather protection applications included in the study and it is not possible to ascertain whether these products are representative of such products on the market.

Risks regarding the load carrying structure and the requirements on evacuation possibilities have not been investigated in this project. These are both important issues and must be taken into consideration in a fire safety assessment of a textile building.

6 References

[1] AFS 2009:2 “Arbetsplatsens utformning – Arbetsmiljöverkets föreskrifter om arbetsplatsens utformning samt allmänna råd om tillämpningen av föreskrifterna “, Arbetsmiljöverket, 2009.

[2] Memo med CTB Registration number 2004/34762, dated 2004-09-16.

[3] Blomqvist, P., and Andersson, P., "A study of fire performance of textile membranes used as building components", Fire and Materials, 36, 8, 648–660, 2012.

[4] Wickström, U., “The plate thermometer - a simple instrument for reaching harmonized fire resistance tests”, Fire Technology, May 1994, Volume 30, Issue 2, pp. 195-208.

[5] Byström, A., et al., “Measurement and calculation of adiabatic surface temperature in a full-scale compartment fire experiment”, Journal of Fire Sciences, January 2013, vol. 31, no. 1, pp. 35-50.

Appendix A European standards

Table 21 European standards for temporary textile structures.

EN 13782:2005, Temporary structures – Tents – safety *Type:* European standard that specifies safety requirements *Standardisation committee:* CEN /TC 152, "Fairground and amusement park machinery and structures - Safety" *Summary:* The standard specifies safety requirements which need to be observed at design, calculation, manufacture, installation, maintenance, operation, examination and testing of mobile, temporary installed tents of more than 50 m^2 ground area. The field of application for the standard covers all kind of temporary covered structures. The content of the standard collects the different existing national regulations and guidelines as far as possible. Regarding fire safety the standards states (section 5.2.1 in the standard) that burning behaviour of the fabric is one parameter to be tested and that EN standards shall be used for testing if existing. Annex A (informative) says that “Walls, fabrics used for textile decorations and other materials should have permanent flame retardance”. Annex A further lists all European and identified national standards about burning behaviour of textile fabrics relevant for covering of temporary structures. The Swedish regulations and the SIS 650082 test are not included in this list. *Status:* Revision – under drafting (DAV 2015-03)
EN 15619:2008+A1:2010, Rubber or plastic coated fabrics – Safety of temporary structures (tents) – Specification for coated fabrics intended for tents and related structures *Type:* European standard that specifies requirements on textile membranes for textile structures (not a product standard) *Standardisation committee:* CEN/TC 248 “Textiles and textile products” *Summary:* The purpose of this European Standard is to specify the characteristics, the requirements and the test methods for coated fabrics intended for temporary structure and tents. Particular care has been taken not to come in conflict with the items that have already been treated in EN 13782. This European Standard has been drawn up according to past experience and risk analysis. The content of this European Standard collects the different existing national regulations and refers to the different European test standards available for coated fabrics. This European Standard also introduces a system of levels. It is not possible to divide coated fabric for tents into just a few performance levels, because of the enormous variety of conditions of use. This European Standard proposes different level of performance (A, B, C) for each characteristic – or T1, T2, T3, T4 for the fire behaviour. The standard refers to EN 14115:2001 for test of fire behaviour. Tests according to EN ISO 11925-2 with 60 s flame application are additionally required for the highest class (T1) for materials that opens up from the pilot flame in the EN 14115 test (introduced with A1:2010). *Status:* Revision – under approval (DAV 2014-08)

EN 14115:2001, Textiles – Burning behaviour of materials for marquees, large tents and related products – Ease of ignition

Type:
Test standard
Standardisation committee:
CEN/TC 248 "Textiles and textile products"
Summary:
This standard specifies a test method for the burning behaviour of industrial and technical textiles used for tarpaulins, large tents, marquees, related structures, airducts, etc. A test apparatus consisting of an electrical heater and a small flame is used. The test specimen is mounted in an angle of 30 degrees relative the horizontal plane and the electrical heater is placed under the sample. The sample has the dimensions 600 mm x 180 mm. The test is a French test method.
Status:
Published

Table 22 European standards for working scaffolds.

prEN 16508, Temporary works equipment - Encapsulation constructions - Performance requirements and general design

Type:
Standard giving general requirements (not a product standard)
Standardisation committee:
CEN/TC 53 "Temporary Works Equipment"
Summary:
The purpose of a temporary roof and encapsulation construction (encapsulation) according to this standard is to protect the area inside from climatic influences and dust. It is also used to protect the public from effects from inside. This European Standard sets out general requirements. These are substantially independent of the materials of which the construction is made. This standard is intended to be used as the basis for enquiry and design.
The standard says that "Materials shall fulfil the requirements given in European Standards, where design data are provided. If European Standards do not exist, International Standards may be applied." and "The components shall be designed so they can be safely erected, used, maintained and dismantled." Fire safety is thus not specifically mentioned in the document.
Status:
Under approval (DAV 2014-09)

Table 23 European standards for permanent buildings relevant for applications of textile membranes.

EN 13501-1:2007, Fire classification of construction products and building elements –Part 1: Classification using data from reaction to fire tests *Type:* Classification standard *Standardisation committee:* CEN/TC 127 "Fire safety in buildings" *Summary:* The aim of this European Standard is to define a harmonized procedure for the classification of reaction to fire of construction products. This classification is based on the test procedures listed in Appendix 2 *Status:* Published
EN 13823:2010, Reaction to fire tests for building products – Building products excluding floorings exposed to the thermal attack by a single burning item *Type:* Test standard *Standardisation committee:* CEN/TC 127 "Fire safety in buildings" *Summary:* This European Standard specifies a method of test for determining the reaction to fire performance of construction products excluding floorings, when exposed to thermal attack by a single burning item (SBI). The test is required for class A2-D in EN 13501-1. This is a medium-sized test where the sample is placed in a corner configuration. Each test requiring one sample of 0.5×1.5m and one sample of 1.0×1.5m. A gas burner with 30 kW heat output (equal to that of a burning waste paper basket filled with crumpled newspaper) is placed in the corner. Classification is based on FIGRA, THR600s and maximum flame spread. Additional classification is based on SMOGRA, TSP600s and droplets/particles. *Status:* Published
EN ISO 11925-2, Reaction to fire tests – Ignitability of products subjected to direct impingement of flame – Part 2: Single-flame source test (ISO 11925-2:2010) *Type:* Test standard *Standardisation committee:* CEN/TC 127 "Fire safety in buildings" *Summary:* This fire test method has been developed to define reaction to the fire performance of products. The test is required for class B-E in EN 13501-1. The method specifies a test for determining the ignitability of products by direct small-flame impingement under zero impressed irradiance using vertically oriented test specimens. Although the method is designed to assess ignitability, this is addressed by measuring the spread of a small flame up the vertical surface of a specimen following application of a small (match-sized) flame, 20 mm high, to either the surface or edge of a specimen for either 15 s or 30 s. The determination of the production of flaming droplets depends on whether or not the filter paper placed beneath the specimen ignites. The dimensions of the test specimens are 250 mm long by 90 mm wide. *Status:*

Published
EN 14716:2004, Stretched ceilings – Requirements and test methods *Type:* Product standard *Standardisation committee:* CEN/TC BT/TF 119 “Stretched ceilings” (the TC does no longer exist?) *Summary:* This document specifies the characteristics, specifications and test methods for stretched ceilings made up of single or multi-layer sheets, coated fabrics or fabrics made up of coated or monofilament yarn with a fastening system. Reaction-to-fire test procedures are given in section 4.1.1 of the standard and the tests required are those for classification according to EN 13501-1 (EN 13823 and EN ISO 11925-1). A special frame for mounting the test specimen is described in Annex A of the standard. *Status:* Published
EN …, “Minimum criteria for the design, analysis and construction of permanent tensile surface structures” *Type:* Proposed project in CEN/TC 250/ WG 5 *Standardisation committee:* CEN/TC 250/ WG 5 “Structural Eurocodes / Membrane structures” Summary: Best practice report from CEN/TC 250/WG 5 ’Membrane structures’ and TensiNet Association is the basis for this work. *Status:* Work not started officially

Table 24 European standards for textile fabrics.

EN 13772:2003, Textiles and textile products –Burning behaviour – Curtains and drapes – Measurement of flame spread of vertically oriented specimens with large ignition source *Type:* Test standard *Standardisation committee:* CEN/TC 248 “Textiles and textile products” *Summary:* This European Standard specifies a method for the measurement of flame spread of vertically oriented textile fabrics intended for curtains and drapes in the form of single or multi-component (coated, quilted, multilayered, sandwich construction and similar combinations) fabrics using a large ignition source. In order to assess the burning behaviour of curtains and drapes two test methods were established, i.e. EN 1101 for the measurement of ignitability (based on EN ISO 6940) and EN 1102 for the measurement of flame spread (based on EN ISO 6941). EN ISO 6941 measures the flame spread of vertically oriented specimens exposed to a defined small flame. This allows the flame spread properties of ignitable products to be determined. Nevertheless this test method is not suitable to assess products that do not ignite. The measurement of the length or area destroyed by the small flame is questionable as shown by round robin testing. There is a risk that products which pass the small flame test, can still be ignited with a larger ignition source. The equipment used in EN ISO 6941 has therefore been modified by adding a radiator, which radiates on the lower part of the specimen in order to boost locally and temporarily the ignition of

the specimen. The combination of this radiation and the small flame application simulates the action from a larger flaming source. With this combined ignition source some materials, not ignitable with the small flame, may ignite. Some of these will self-extinguish, when the action from the ignition source has ceased, while others will self-propagate.
Status:
Published

EN 1101:1996, Textiles and textile products - Burning behaviour- Curtains and drapes - Detailed procedure to determine the ignitability of vertically oriented specimens (small flame)

Type:
Test standard (describes test procedure)
Standardisation committee:
CEN/TC 248 “Textiles and textile products”
Summary:
This European Standard specifies a procedure to determine the ignitability of textiles for curtains and drapes by testing in accordance with EN ISO 6940.
Status:
Published

EN 1625:1999, Textiles and textile products - Burning behaviour of industrial and technical textiles - Procedure to determine the ignitability of vertically oriented specimens

Type:
Test standard (describes test procedure)
Standardisation committee:
CEN/TC 248 “Textiles and textile products”
Summary:
This European Standard specifies a procedure to determine the ignitability of vertically oriented specimens for industrial and technical textiles when tested according to EN ISO 6940.
Status:
Published

EN ISO 6940:2004, Textile fabrics - Burning behaviour - Determination of ease of ignition of vertically oriented specimens (ISO 6940:2004)

Type:
Test standard
Standardisation committee:
CEN/TC 248 “Textiles and textile products”
Summary:
This International Standard specifies a method for the measurement of ease of ignition of vertically oriented textile fabrics and industrial products in the form of single or multi-component fabrics (coated, quilted, multi-layered, sandwich constructions, and similar combinations), when subjected to a small, defined flame. The dimensions of the test specimens are 200 mm long by 80 mm wide.
Status:
Published

EN 1102:1995, Textiles and textile products - Burning behaviour- Curtains and drapes - Detailed procedure to determine the flame spread of vertically oriented specimens *Type:* Test standard (describes test procedure) *Standardisation committee:* CEN/TC 248 “Textiles and textile products” *Summary:* The test used is a modified EN ISO 6941. These modifications are listed in this document. *Status:* Published
EN 1624:1999, Textiles and textile products - Burning behaviour of industrial and technical textiles - Procedure to determine the flame spread of vertically oriented specimens *Type:* Test standard (describes test procedure) *Standardisation committee:* CEN/TC 248 “Textiles and textile products” *Summary:* This European Standard specifies a procedure to determine the flame spread of vertically oriented specimens of industrial and technical textiles, when tested according to EN ISO 6941. *Status:* Published
EN ISO 6941:2004, Textile fabrics - Burning behaviour - Measurement of flame spread properties of vertically oriented specimens (ISO 6941:2003) *Type:* Test standard *Standardisation committee:* CEN/TC 248 “Textiles and textile products” *Summary:* This method is one of two closely related methods of test for the inflammability of textile fabrics. This method determines the “flame spread time” — vocabulary in relation to the term defined in ISO 4880 — the other method observes and measures “ease of ignition” (see ISO 6940). *Status:* Published

Appendix B EN 13501-1 classification system

Table 25 Classes of reaction to fire performance for construction products excluding floorings.

Class	Test method(s)	Classification criteria	Additional classification
A1	EN ISO 1182 (1); *And*	ΔT ≤ 30°C; *and* Δm ≤ 50%; *and* t_f = 0 (i.e. no sustained flaming)	-
	EN ISO 1716	PCS ≤ 2.0 MJ.kg^{-1} (1); *and* PCS ≤ 2.0 MJ.kg^{-1} (2) (2a); *and* PCS ≤ 1.4 MJ.m^{-2} (3); *and* PCS ≤ 2.0 MJ.kg^{-1} (4)	-
A2	EN ISO 1182 (1); *Or*	ΔT ≤ 50°C; *and* Δm ≤ 50%; *and* t_f ≤ 20s	-
	EN ISO 1716; *and*	PCS ≤ 3.0 MJ.kg^{-1} (1); *and* PCS ≤ 4.0 MJ.m^{-2} (2); *and* PCS ≤ 4.0 MJ.m^{-2} (3); *and* PCS ≤ 3.0 MJ.kg^{-1} (4)	-
	EN 13823 (SBI)	FIGRA ≤ 120 W.s^{-1}; *and* LFS < edge of specimen; *and* THR_{600s} ≤ 7.5 MJ	Smoke production(5); *and* Flaming droplets/ particles (6)
B	EN 13823 (SBI); *And*	FIGRA ≤ 120 W.s^{-1}; *and* LFS < edge of specimen; *and* THR_{600s} ≤ 7.5 MJ	Smoke production(5); *and* Flaming droplets/ particles (6)
	EN ISO 11925-2(8): *Exposure = 30s*	Fs ≤ 150mm within 60s	
C	EN 13823 (SBI); *And*	FIGRA ≤ 250 W.s^{-1}; *and* LFS < edge of specimen; *and* THR_{600s} ≤ 15 MJ	Smoke production(5); *and* Flaming droplets/ particles (6)
	EN ISO 11925-2(8): *Exposure = 30s*	Fs ≤ 150mm within 60s	
D	EN 13823 (SBI); *And*	FIGRA ≤ 750 W.s^{-1}	Smoke production(5); *and* Flaming droplets/ particles (6)
	EN ISO 11925-2(8): *Exposure = 30s*	Fs ≤ 150mm within 60s	
E	EN ISO 11925-2(8): *Exposure = 15s*	Fs ≤ 150mm within 20s	Flaming droplets/ particles (7)
F	No performance determined		

(*) The treatment of some families of products, e.g. linear products (pipes, ducts, cables etc.), is still under review and may necessitate an amendment to this decision.

(1) For homogeneous products and substantial components of non-homogeneous products.

(2) For any external non-substantial component of non-homogeneous products.

(2a) Alternatively, any external non-substantial component having a PCS ≤ 2.0 MJ.m^{-2}, provided that the product satisfies the following criteria of EN 13823(SBI) : FIGRA ≤ 20 W.s^{-1}; *and* LFS < edge of specimen; *and* THR_{600s} ≤ 4.0 MJ; *and* s1; *and* d0.

(3) For any internal non-substantial component of non-homogeneous products.

(4) For the product as a whole.

(5) **s1** = SMOGRA ≤ 30m^2.s^{-2} *and* TSP_{600s} ≤ 50m^2 ; **s2** = SMOGRA ≤ 180m^2.s^{-2} *and* TSP_{600s} ≤ 200m^2; **s3** = not s1 or s2.

(6) **d0** = No flaming droplets/ particles in EN13823 (SBI) within 600s; **d1** = No flaming droplets/ particles persisting longer than 10s in EN13823 (SBI) within 600s; **d2** = not d0 or d1; Ignition of the paper in EN ISO 11925-2 results in a d2 classification.

(7) Pass = no ignition of the paper (no classification); Fail = ignition of the paper (**d2** classification).

(8) Under conditions of surface flame attack and, if appropriate to end–use application of product, edge flame attack.

Symbols: The characteristics are defined with respect to the appropriate test method.

ΔT	temperature rise
Δm	mass loss
t_f	duration of flaming
PCS	gross calorific potential
FIGRA	fire growth rate
THR_{600s}	total heat release
LFS	lateral flame spread
SMOGRA	smoke growth rate
TSP_{600s}	total smoke production
Fs	flame spread

Definitions

Material: A single basic substance or uniformly dispersed mixture of substances, e.g. metal, stone, timber, concrete, mineral wool with uniformly dispersed binder, polymers.

Homogeneous product: A product consisting of a single material, of uniform density and composition throughout the product.

Non-homogeneous product: A product that does not satisfy the requirements of a homogeneous product. It is a product composed of one or more components, substantial and/or non-substantial.

Substantial component: A material that constitutes a significant part of a non-homogeneous product. A layer with a mass per unit area ≥ 1.0 kg/m^2 or a thickness ≥ 1.0 mm is considered to be a substantial component.

Non-substantial component: A material that does not constitute a significant part of a non-homogeneous product. A layer with a mass per unit area < 1.0 kg/m^2 and a thickness < 1.0 mm is considered to be a non-substantial component.

Two or more non-substantial layers that are adjacent to each other (i.e. with no substantial component(s) in-between the layers) are regarded as one non-substantial component and, therefore, must altogether comply with the requirements for a layer being a non-substantial component.

For non-substantial components, distinction is made between internal non-substantial components and external non-substantial components, as follows:

Internal non-substantial component: A non-substantial component that is covered on both sides by at least one substantial component.

External non-substantial component: A non-substantial component that is not covered on one side by a substantial component.

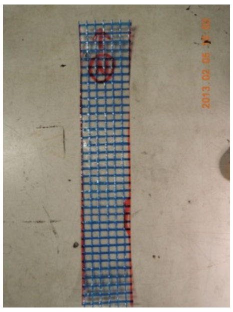
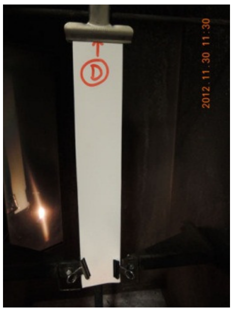
A Euroclass is intended to be declared as for example **Bd1s2**. **B** stands for the main class, **d1** stands for droplets/particles class no 1 and **s2** stands for smoke class no 2. This gives theoretically a total of about 40 classes of linings and 11 classes of floor coverings to choose from. However, each country is expected only to use a very small fraction of the possible combinations.

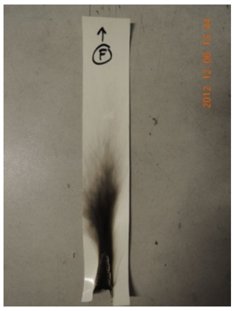
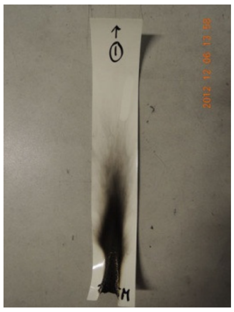
Appendix C Information on existing classification of textile membrane products in the project

Product id	**EU** EN 13823 EN ISO 11925-2	**Scandinavia** SIS 65 00 82	**Germany** DIN 4102, Teil 1	**France** NFP 92-507	**UK** 1BS 7837 2BS 5867:Part 2	**Italy** CSE RF 1/75/A CSE RF 1/77	**Poland** EN ISO 6940 EN ISO 6941	**Switzerland** SN 198898	**Spain** UNE 23727-90
A	*	Pass	B1	M2	Pass1	*	*	VKF 5.2	M.2
B	*	*	B1	M2	Pass1	*	*	VKF 5.3	M.2
C	*	Pass	B1	M2	Pass1	*	*	VKF 5.2	M.2
D	B-s2,d0	*	B1	M2	Pass1	*	*	VKF 5.3	M.2
E	B-s2,d0	Pass	B1	M2	Pass1	Klass 2	Pass	VKF 5.2	M.2
F	B-s2,d0	Pass	*	M2	Pass1/Type B2	Klass 2	Pass	VKF 5.2	M.2
G	B-s2,d0	Pass	B1	M2	Pass1/Type B2	Klass 2	Pass	VKF 5.2	M.2
H	*	Pass	B1	*	Pass1	*	*	*	*
I	*	*	B1	M2	*	*	*	*	M.3
J	C-s3,d2	Pass	B1	*	Pass1/Type B2	*	*	VKF 5.2	M.2
K	C-s3,d2	*	B1	*	Pass1	Klass 2	*	VKF 5.3	*
L	C-s3,d2	Pass	B1	*	Pass1/Type B2	*	*	VKF 5.2	M.2
M	C-s3,d2	*	B1	*	Pass1	Klass 2	*	VKF 5.3	*
N	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
O	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

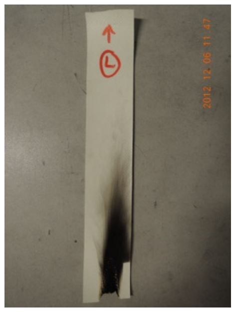
* Not classified.
N.A. = Information not available.

Appendix D SIS 650082 test results

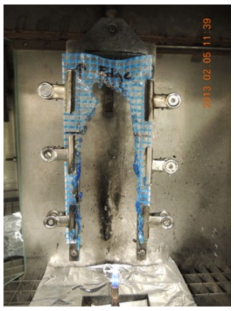
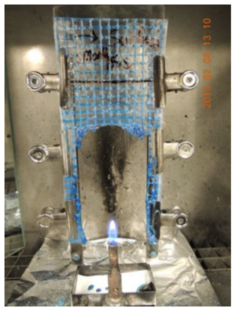
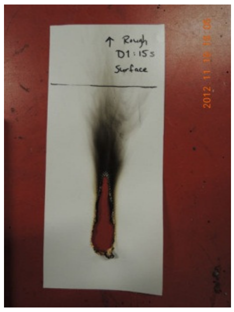
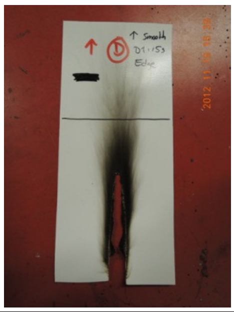
Product	Surface weight (g/m²)	SIS 650082		
		Result	Photographs	
N	280	Fail		
The product burns with small flames both on the back and front side of the specimens. The material melts away quickly from the ignition point. During most of the test time, there is melted material dripping from the specimens. The major part of these drops is flaming drops which create a pool fire under the specimens. The after flame time varies from 93 to 114 seconds. The average after flame time is 100 second. All specimens are completely consumed during the test.				
D	490	Fail		
The product burns with large flames on the back side of the specimens. The average after flame time is 0 seconds. The damaged length varies from 91 to 102 mm. The average damaged length of the specimens is 93 mm.				
B	590	Pass		
The product burns with irregular flames, both small and large. The larger flames are mostly observed on the back side of the specimens. The product also produces a large amount of smoke. The after flame time varies from 0 to 2 seconds. The average after flame time is 1 second. The damaged length varies from 83 to 95 mm. The average damaged length of the specimens is 90 mm.				
E	630	Fail		
The product burns with large flames on the back side of the specimens. The material melts away quickly from the ignition point. The after flame time varies from 0 to 14 seconds. The average after flame time is 4 second. The damaged length varies from 71 to 112 mm. The average damaged length of the specimens is 90 mm.				

O	650	Fail		
The product burns with large irregular flames both on the back and front side of the specimens. The flames spread rapidly along the whole length of the specimens. The material melts away quickly from the ignition point, before the ignition time has passed. After about 25 seconds the specimens split due to the flaming and parts of material falls down on ground and continues to flame. The specimens are extinguished after approximately 150 seconds. All specimens are almost entirely consumed during the test.				
F	650	Pass		
The product burns with large flames both on the back and front side of the specimens. The material melts away quickly from the ignition point. The after flame time varies from 0 to 2 seconds. The average after flame time is 1 second. The damaged length varies from 74 to 101 mm. The average damaged length of the specimens is 85 mm.				
C	750	Pass		
The product burns with irregular flames around the ignition point. The flames are larger on the back side of the specimens. The after flame time varies from 0 to 1 seconds. The average after flame time is 1 second. The damaged length varies from 69 to 85 mm. The average damaged length of the specimens is 78 mm.				
I	800	Pass		
The product burns with small flames both on the back and front side of the specimens. The material melts away quickly from the ignition point. The after flame time varies from 0 to 1 seconds. The average after flame time is 1 second. The damaged length varies from 64 to 79 mm. The average damaged length of the specimens is 75 mm.				

A	850	Pass		
The product burns with small flames concentrated around the ignition point. The after flame time varies from 0 to 1 seconds. The average after flame time is 0 seconds. The damaged length varies from 80 to 92 mm. The average damaged length of the specimens is 86 mm.				
G	850	Pass		
The product burns with small irregular flashing flames concentrated around the ignition point. The after flame time varies from 0 to 1 seconds. The average after flame time is 0 second. The damaged length varies from 72 to 86 mm. The average damaged length of the specimens is 79 mm.				
H	900	Pass		
The product burns with small flames both on the back and front side of the specimens. The after flame time varies from 0 to 2 seconds. The average after flame time is 1 second. The damaged length varies from 64 to 79 mm. The average damaged length of the specimens is 71 mm.				
J	900	Pass		
The product burns with a single steady small flame both on the back and front side of the specimens. The material melts away slowly from the ignition point. The after flame time varies from 0 to 1 seconds. The average after flame time is 0 second. The damaged length varies from 57 to 69 mm. The average damaged length of the specimens is 64 mm.				

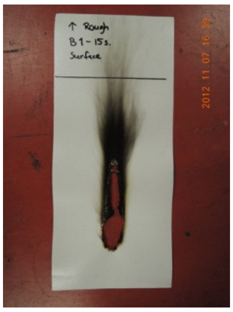
L	900	Pass		
The product burns with a single steady small flame both on the back and front side of the specimens. The material melts away slowly from the ignition point. The after flame time varies from 0 to 1 seconds. The average after flame time is 0 second. The damaged length varies from 55 to 65 mm. The average damaged length of the specimens is 62 mm.				
K	1100	Pass		
The product burns with a single steady small flame both on the back and front side of the specimens. The material melts away slowly from the ignition point. The after flame time varies from 0 to 1 seconds. The average after flame time is 1 second. The damaged length varies from 52 to 72 mm. The average damaged length of the specimens is 61 mm.				
M	1100	Pass		
The product burns with a single steady small flame both on the back and front side of the specimens. The material melts away slowly from the ignition point. The after flame time varies from 0 to 1 seconds. The average after flame time is 1 second. The damaged length varies from 58 to 67 mm. The average damaged length of the specimens is 61 mm.				

Appendix E EN ISO 11925-2 test results

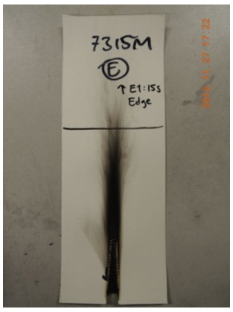
Product	Surface weight (g/m²)	EN ISO 11925-2	
		Result	Photographs
N	280	F	
Edge ignition - 15 s. The product burns with small flames on both back and front side. The material melts away quickly to the sides. Multiple burning droplets are produced and they continue to burn on the filter paper. Ignition time is 1-2 seconds. *Surface ignition - 15 s.* The product burns with small flames on both back and front side. The material melts away quickly from the ignition source and a hole is created. Multiple burning droplets are produced and they continue to burn on the filter paper. Ignition time is 3-5 seconds.			 
D	490	E	
Edge ignition - 15 s. The product burns with large flames, mostly on the back side of the specimens, close to the 150 mm marking. Ignition time is 1-2 second. *Surface ignition (Smooth) - 15 s.* The product burns with small flames, mostly on the front side of the specimens. The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 12 seconds. Ignition time is 2-4 seconds. *Surface ignition (Rough) - 15 s.* The product burns with flames, reaching about half way to 150 mm marking, both on the front and back side of the specimens. The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 7 seconds. Ignition time is 3-5 seconds.			  

<table>
<tr><td>B</td><td>590</td><td>E</td><td></td></tr>
<tr><td colspan="3">Edge ignition - 15 s.
The product burns with large flames, about half way to the 150 mm marking, on the back side and smaller flames on the front side of the specimens. Ignition time is 1 second.

Surface ignition (Smooth) - 15 s.
The product burns with flames on the front side of the specimens. No flames burn through the specimens. Ignition time is 3-4 seconds.

Surface ignition (Rough) - 15 s.
The flames burn through to the back side of the specimens during ignition. When the hole is created the flames start flashing on the back side of specimens. The time for burn through is approximately 7 seconds. Ignition time is 3-5 seconds.</td><td>  </td></tr>
<tr><td>E</td><td>630</td><td>E</td><td></td></tr>
<tr><td colspan="3">Edge ignition - 15 s.
The product burns with small flashing flames on both the back and front side of the specimens. Ignition time is 1-4 seconds.

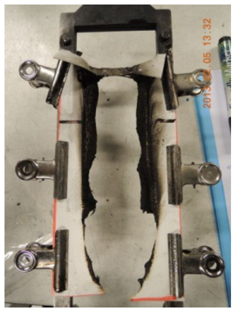
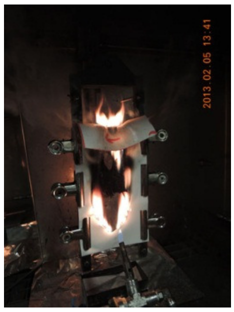
Surface ignition (Smooth) - 30 s.
The product burns with large flames on the front side, about ¾ of the way to the 150 mm marking, of the specimens. The flames burn through to the back side of the specimens during ignition. When the hole is created the flames start flashing on the back side of specimens. The time for burn through is approximately 16 seconds. Ignition time is 3 seconds.

Surface ignition (Rough) - 30 s.
The flames burn through to the back side of the specimens during ignition. When the hole is created the flames start flashing on the back side of specimens. The time for burn through is approximately 11 seconds. Ignition time is 2-3 seconds.</td><td>  </td></tr>
</table>

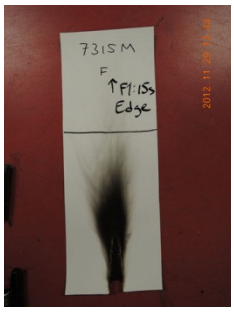
<table>
<tr><td>O</td><td>650</td><td>F</td><td></td></tr>
<tr><td colspan="3">
Edge ignition -15 s.
The product burns with large and intense flames on both back and front side. The flame spread is rapid and the specimens are mostly consumed during the test. Flame tip reaches the 150 mm marking at 8 seconds. Ignition time is 1 second.

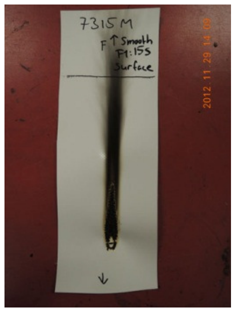
Surface ignition (Smooth) - 15 s.
The product burns with large and intense flames on both back and front side. The flame spread is rapid and the specimens are mostly consumed during the test. Flame tip reaches the 150 mm marking at 16 seconds. In one specimen the flames die out directly after the removal of the ignition source. Ignition time is 4 seconds.

Surface ignition (Rough) – 15 s.
The product burns with large and intense flames on both back and front side. The flame spread is rapid and the specimens are mostly consumed during the test. Flame tip reaches the 150 mm marking at an average of 15 seconds. Ignition time is 4 seconds.
</td><td>



</td></tr>
<tr><td>F</td><td>650</td><td>E</td><td></td></tr>
<tr><td colspan="3">
Edge ignition - 15 s.
The product burns with small flames in the beginning and then larger flames, about half way to the 150 mm marking, on both the back and front side of the specimens. Ignition time is 1 second.

Surface ignition (Smooth) - 15 s.
In one specimen the flames burn through to the back side during ignition. The time for burn through is 15 seconds. Ignition time is 3-4 seconds.

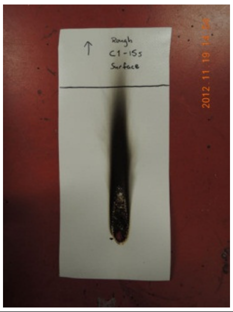
Surface ignition (Rough) - 15 s.
The product burns with flames, about half way to the 150 mm marking, on the front side of the specimens. The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 12 seconds. Ignition time is 3-4 seconds.
</td><td>




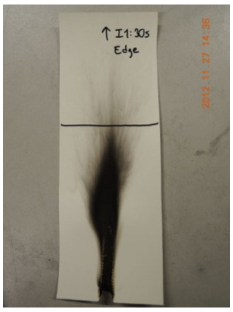
</td></tr>
</table>

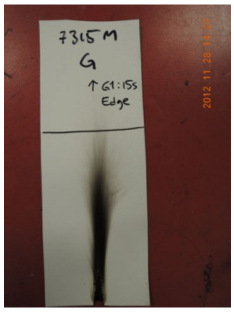
<table>
<tr><td>C</td><td>750</td><td>E</td><td></td></tr>
<tr><td colspan="3">Edge ignition - 15 s.
The product burns with large flames on the back side and smaller flames on the front side of the specimens. Ignition time is 1 second.

Surface ignition (Smooth) - 15 s.
The product burns with a single steady flame on the front side of the specimens. No flames burn through the specimens. Ignition time is 3-5 seconds.

Surface ignition (Rough) - 15 s.
The product burns with a single steady flame on the front side of the specimens. The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 24 seconds. Ignition time is 2-3 seconds.</td><td>  </td></tr>
<tr><td>I</td><td>800</td><td>> E</td><td></td></tr>
<tr><td colspan="3">Edge ignition - 30 s.
The product burns with small flames on both back and front side. Ignition time is 2-6 seconds.

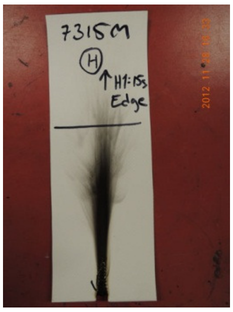
Surface ignition (Smooth) - 30 s.
The product burns with a single steady flame on the front side of the specimens. The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 27 seconds. Ignition time is 3-4 seconds.

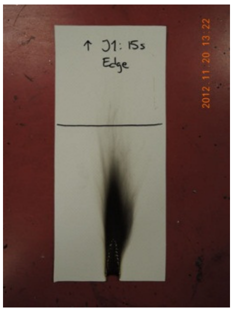
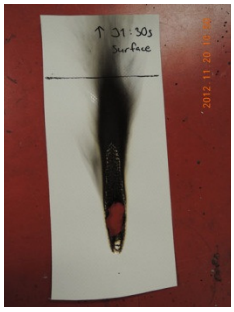
Surface ignition (Rough) - 30 s.
The product burns with flames mostly on the front side of the specimens. In three of the specimens the flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 15 seconds. Ignition time is 3 seconds.</td><td>  </td></tr>
</table>

A	850	> E	
Edge ignition - 30 s. Intense flaming during the application time, afterwards more subtle. Ignition time is 1-2 seconds. *Surface ignition (Smooth) - 30 s.* No flames burn through the specimens. Ignition time is 4-6 seconds. *Surface ignition (Rough) - 30 s.* The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 12 seconds. Ignition time is 3 seconds.			  
G	850	E	
Edge ignition - 15 s. The product burns with small flames on both back and front side. Ignition time is 2-6 seconds. *Surface ignition (Smooth) - 30 s.* The product burns with small flames mostly on the front side of the specimens. The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 24 seconds. Ignition time is 3-4 seconds. *Surface ignition (Rough) - 30 s.* The flames burn through to the back side of the specimens during ignition. When the hole is created the flames start flashing on the back side of specimens. The time for burn through is approximately 23 seconds. Ignition time is 2-4 seconds.			  

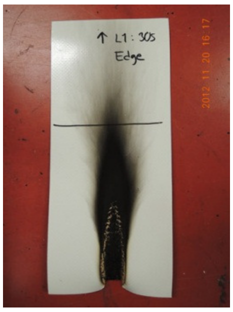
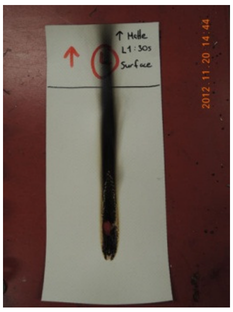
<table>
<tr><td>H</td><td>900</td><td>E</td><td></td></tr>
<tr><td colspan="3">Edge ignition - 15 s.
The product burns with small flames on both back and front side. Ignition time is 1-3 seconds.

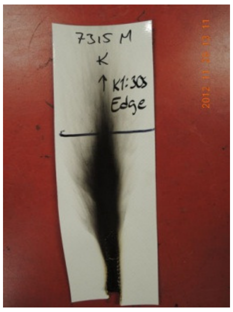
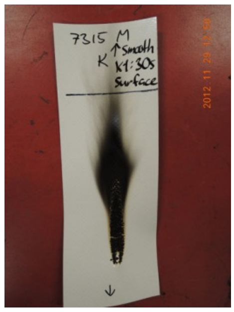
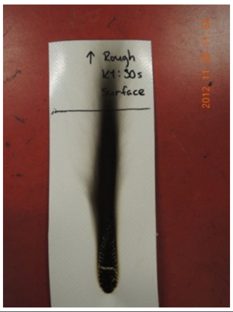
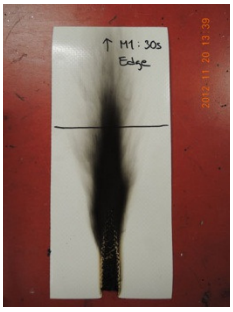
Surface ignition (Smooth) - 15 s.
The product burns with a single steady flame on the front side of the specimens. No flames burn through the specimens. Ignition time is 3-5 seconds.

Surface ignition (Rough) - 15 s.
The product burns with a single steady flame on the front side of the specimens. No flames burn through the specimens. Ignition time is 3-4 seconds.</td><td></td></tr>
<tr><td>J</td><td>900</td><td>E</td><td></td></tr>
<tr><td colspan="3">Edge ignition - 15 s.
The product burns with small flames on both back and front side. Ignition time is 1 second.

Surface ignition - 30 s.
The product burns with flames mostly on the front side of the specimens. The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 18 seconds. Ignition time is 3-5 seconds.</td><td></td></tr>
<tr><td>L</td><td>900</td><td>> E</td><td></td></tr>
<tr><td colspan="3">Edge ignition - 30 s.
The product burns with flames on both back and front side. Ignition time is 1-2 seconds.

Surface ignition (Smooth) - 30 s.
The product burns with large flames, around half way to the 150 mm marking, both on the front and back side of the specimens. The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 20 seconds. Ignition time is 2-3 seconds.

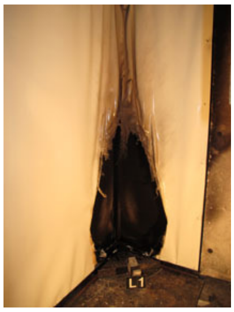
Surface ignition (Rough) - 30 s.
The product burns with flames on both back and front side. The flames burn through to the back side of the specimens during ignition. The flames are smaller on the back side. The time for burn through is approximately 24 seconds. Ignition time is 3-4 seconds.</td><td></td></tr>
</table>

K	1100	> E	
Edge ignition - 30 s. The product burns with small flashing flames mostly on the front side of the specimens. Ignition time is 1-4 seconds. *Surface ignition (Smooth) - 30 s.* The product burns with small flames on the front side of the specimens. No flames burn through the specimens. Ignition time is 3-5 seconds. *Surface ignition (Rough) - 30 s.* The product burns with small flames, mostly on the front side of the specimens. The flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 9 seconds. Ignition time is 3-5 seconds.			  
M	1100	> E	
Edge ignition - 30 s. The product burns with flames on both back and front side. The flames are larger, around ¾ of the way to the 150 mm marking, on the front side. Ignition time is 1 second. *Surface ignition (Smooth) - 30 s.* The product burns with small flames mostly on the front side of the specimens. In three of the specimens the flames burn through to the back side of the specimens during ignition. The time for burn through is approximately 28 seconds. Ignition time is 3 seconds. *Surface ignition (Rough) - 30 s.* The product burns with small flames on the front side. No flames burn through the specimens. Ignition time is 2-4 seconds.			  

Appendix F EN 13823 test results

Results from tests:
Normal mounting of textile membrane (EN 14716:2004)

Product	Class from SBI	Test results – average of three tests		Photographs
B	B-s2,d0			
The flames burn a hole in the product early during the test and the cloth pulls away from the burner flames. During the rest of the test, not much damage is done to the product.		$FIGRA_{0.2}$	0	
		$FIGRA_{0.4}$	0	
		THR_{600}	0.3	
		SMOGRA	49	
		TSP_{600}	128	
		LFS < edge	Yes	
E	B-s2,d0			
The flames burn a hole in the product early during the test and the cloth pulls away from the burner flames. Some flames linger on the edges of the hole. During the rest of the test, not much damage is done to the product.		$FIGRA_{0.2}$	78	
		$FIGRA_{0.4}$	20	
		THR_{600}	1.3	
		SMOGRA	83	
		TSP_{600}	116	
		LFS < edge	Yes	
J	B-s3,d0			
The flames burn a hole in the product early during the test and the cloth pulls away from the burner flames. Flames linger on the edges of the hole. Puffs of smoke rises from the product. During the rest of the test, not much damage is done to the product.		$FIGRA_{0.2}$	36	
		$FIGRA_{0.4}$	35	
		THR_{600}	1.4	
		SMOGRA	108	
		TSP_{600}	209	
		LFS < edge	Yes	

L	C-s3,d2			
The flames burn a hole in the product early during the test. The cloth is stiff and does not pull away from the burner flames. This causes the cloth to burn for a longer period of time, hence producing more heat and smoke than the thinner cloths.		$FIGRA_{0.2}$	230	
		$FIGRA_{0.4}$	166	
		THR_{600}	2.6	
		SMOGRA	212	
		TSP_{600}	255	
		LFS < edge	Yes	
N	D-s2,d2			
The flames burn a hole in the product early during the test and the cloth pulls away from the burner flames. Some small flames start melting the lower edges of the cloth and burning droplets are produced. Soon there are flames around the edges of the hole and a lot of burning droplets are produced which starts pool fires on the ground beneath the product. Most of the product is consumed within the test period.		$FIGRA_{0.2}$	74	
		$FIGRA_{0.4}$	74	
		THR_{600}	9.3	
		SMOGRA	5	
		TSP_{600}	62	
		LFS < edge	No	

Results from tests: *Addition of corner support*				
Product	Class from SBI	Test results – average of three tests		Photographs
B	B-s2,d0			
The flames burn a hole in the product early during the test. The additional corner support prevents the cloth from pulling away from the burner flames. This causes the cloth to be exposed to the flames for a longer period of time.		$FIGRA_{0.2}$	52	
		$FIGRA_{0.4}$	27	
		THR_{600}	0.8	
		SMOGRA	105	
		TSP_{600}	139	
		LFS < edge	Yes	

<table>
<tr><td>E</td><td>C-s2,d0</td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2" rowspan="6">The flames burn a hole in the product early during the test. The additional corner support prevents the cloth from pulling away from the burner flames. This causes the cloth to be exposed to the flames for a longer period of time.</td><td>$FIGRA_{0.2}$</td><td>206</td><td rowspan="6">
</td></tr>
<tr><td>$FIGRA_{0.4}$</td><td>100</td></tr>
<tr><td>THR_{600}</td><td>1.3</td></tr>
<tr><td>SMOGRA</td><td>142</td></tr>
<tr><td>TSP_{600}</td><td>100</td></tr>
<tr><td>LFS < edge</td><td>Yes</td></tr>
<tr><td>J</td><td>D-s3,d2</td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2" rowspan="6">The flames burn a hole in the product early during the test. The additional corner support prevents the cloth from pulling away from the burner flames. This causes the cloth to be exposed to the flames for a longer period of time.</td><td>$FIGRA_{0.2}$</td><td>366</td><td rowspan="6">
</td></tr>
<tr><td>$FIGRA_{0.4}$</td><td>281</td></tr>
<tr><td>THR_{600}</td><td>2.5</td></tr>
<tr><td>SMOGRA</td><td>283</td></tr>
<tr><td>TSP_{600}</td><td>268</td></tr>
<tr><td>LFS < edge</td><td>Yes</td></tr>
<tr><td>L</td><td></td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2">The cloth was not tested with a corner support due to the fact that it did not pull away from the burner flames during the test without the support.</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>N</td><td>D-s1,d2</td><td colspan="2"></td><td></td></tr>
<tr><td colspan="2" rowspan="6">The flames burn a hole in the product early during the test. The additional corner support prevents the cloth from pulling away from the burner flames. This causes the cloth to be exposed to the flames for a longer period of time. Flames start melting the edges of the cloth and burning droplets are produced. Soon there are flames around the edges of the hole and a lot of burning drops are produced which starts pool fires on the ground beneath the product. Most of the product is consumed within the test period.</td><td>$FIGRA_{0.2}$</td><td>94</td><td rowspan="6">
</td></tr>
<tr><td>$FIGRA_{0.4}$</td><td>94</td></tr>
<tr><td>THR_{600}</td><td>5.2</td></tr>
<tr><td>SMOGRA</td><td>1</td></tr>
<tr><td>TSP_{600}</td><td>31</td></tr>
<tr><td>LFS < edge</td><td>No</td></tr>
</table>

Appendix G Large-scale test results

G.1 Large-scale burner tests

Measurements

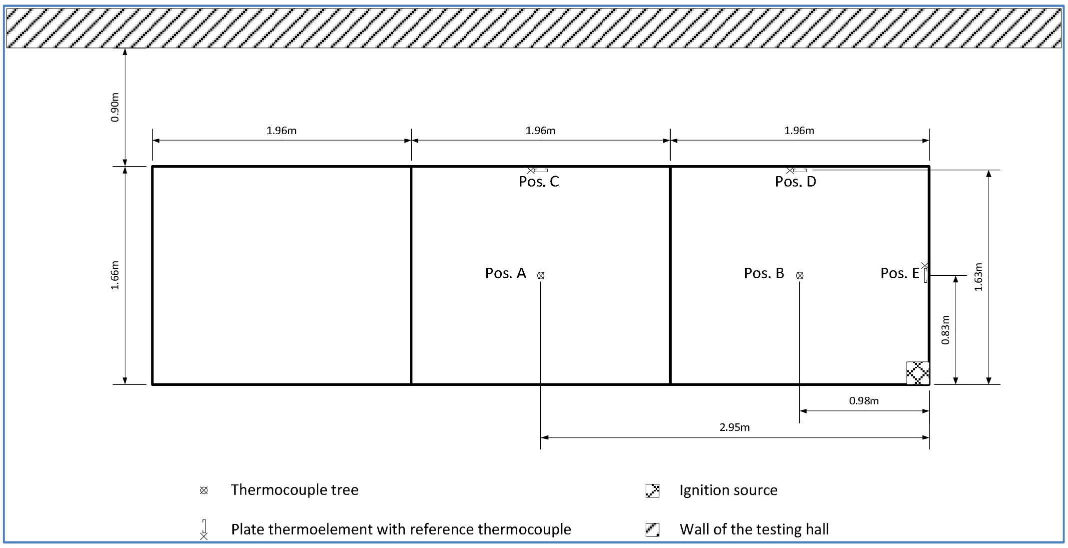


Figure 29 Top-view on test setup of scenario A.

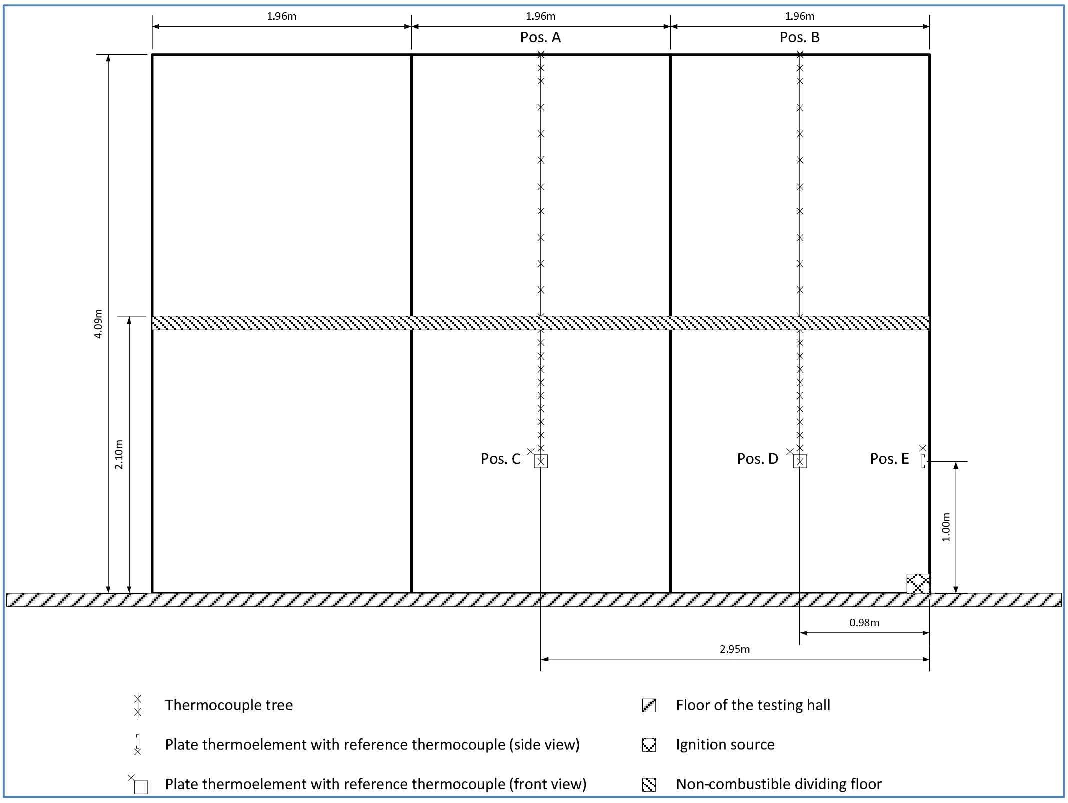


Figure 30 Side-view on test setup of scenario A.

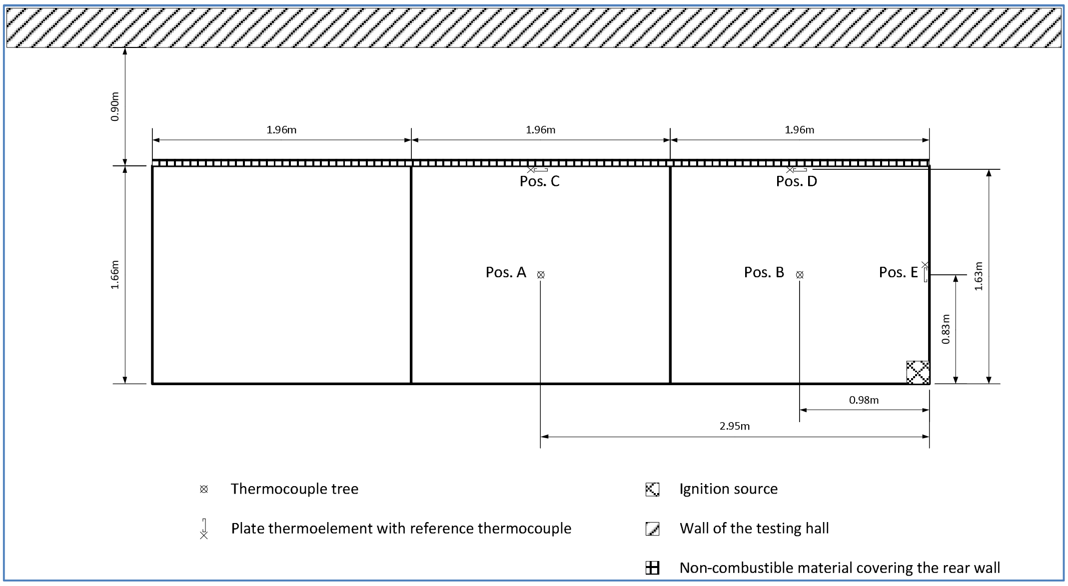


Figure 31 Top view on test setup of scenario B and C.

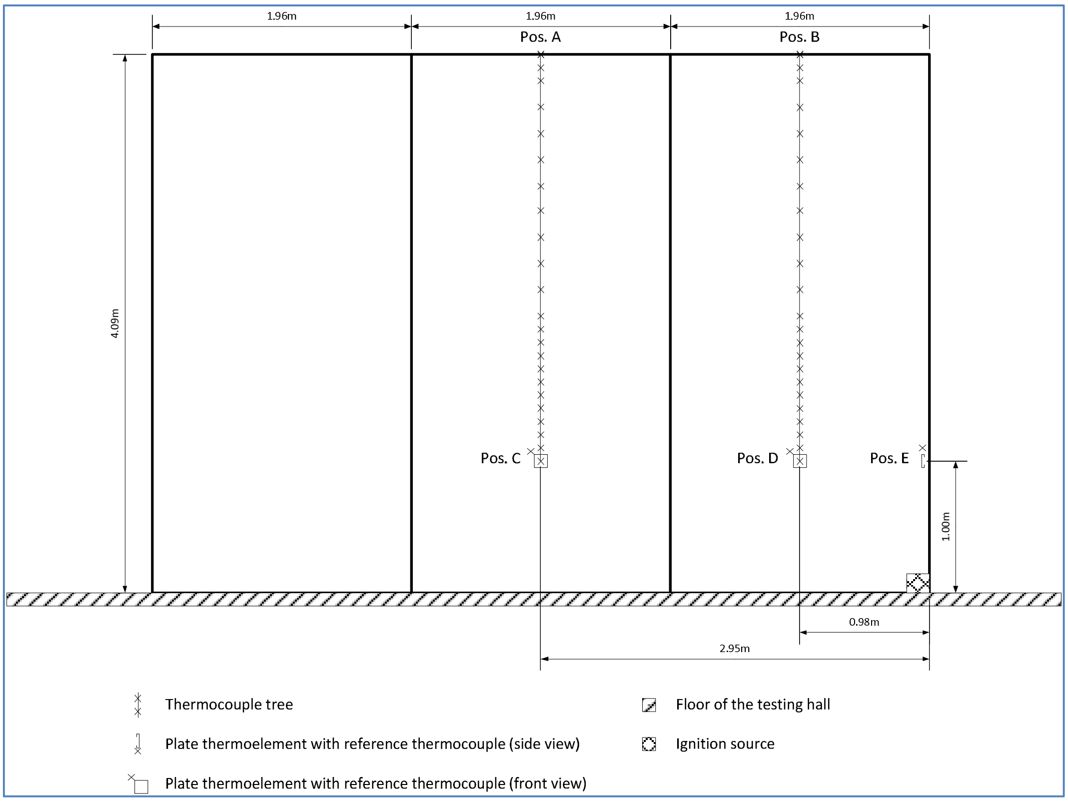


Figure 32 Side view on test setup of scenario B.

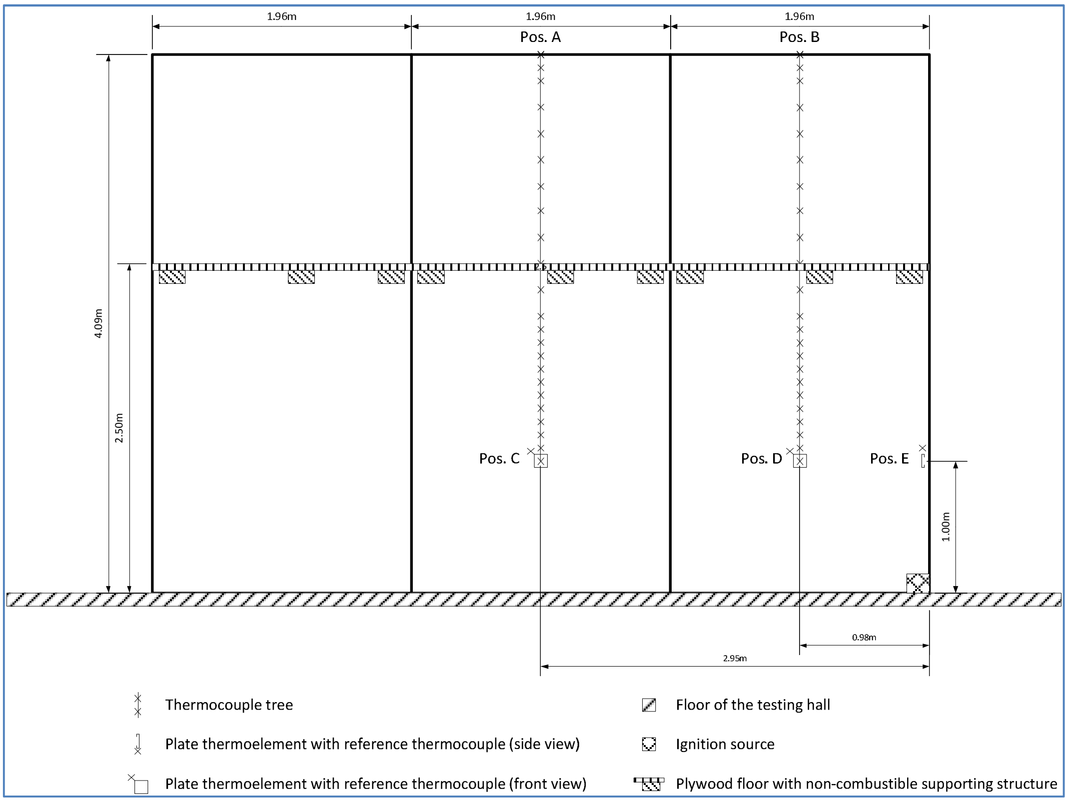


Figure 33 Side view on test setup of scenario C.

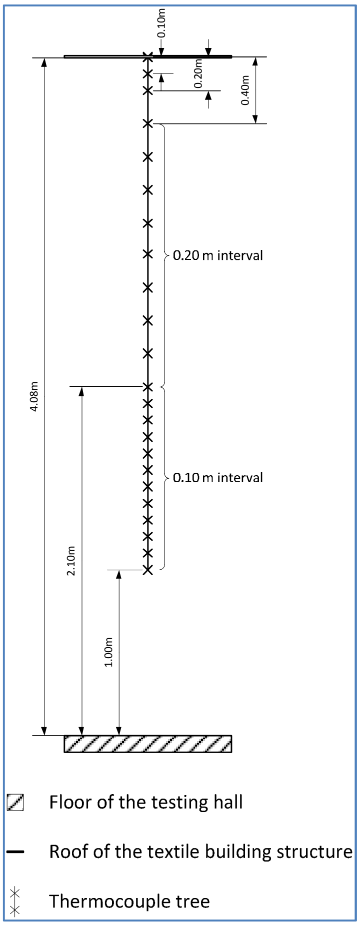


Figure 34 Details of thermocouple trees at position A and B.

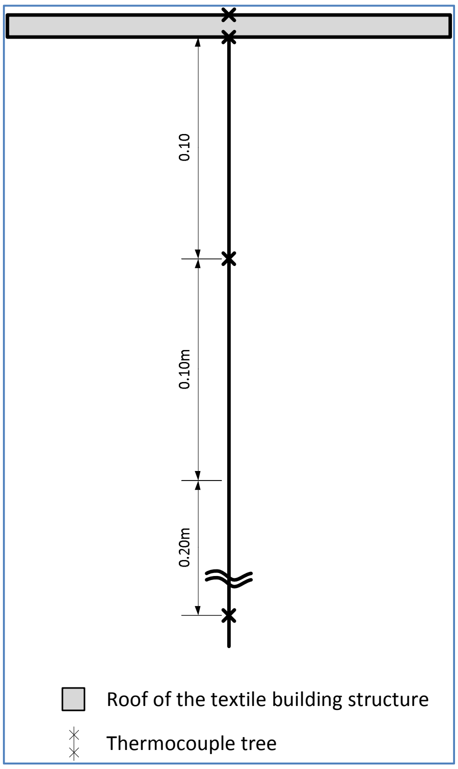


Figure 35 Details of thermocouple locations in vicinity of the roof at position A and B.

Test results

Scenario 1 test - product N

Scenario
Scenario 1 – Weather protection of scaffolding.

Test date: May 15, 2013

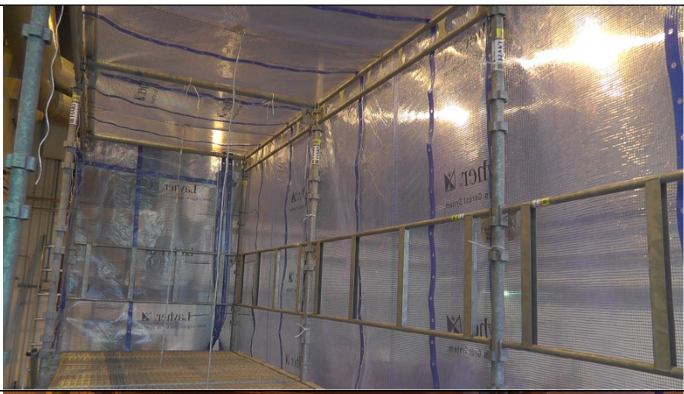
Table 26 General observations in the large-scale burner test with product N.

Time [min:s]	Observation
0:00	Recording of measurements started.
1:00	Video camera facing the burner corner started recording.
1:20	Video cameras inside the scaffolding on the first and second floor started recording.
2:00	Burner heat output increased to 100 kW.
2:11	The textile membrane started to shrink.
2:20	Flames burnt through the textile membrane in the burner corner.
2:34	Burning droplets started to occur which started a pool fire on the floor.
2:50	Flames leant towards the short side of the scaffolding causing a heavier impact on the textile membrane on the short side.
3:40	Flames at the edge of the textile membrane at the front side increased. Flames at the edge of the textile membrane at the short side extinguished.
4:40	A larger burning piece dropped down. The flames sustained on the floor.
5:30	Maximum flame spread at the front side was 30-40 cm.
6:09	Flames at the edge of the textile membrane at the front side increased.
6:45	Increasing burning at the edge of the textile membrane at the front side in a height of about 0.75 m.
8:00	Flames spread at the front side about 1.0 m vertically and 0.4-0.6 m horizontally.
8:40	Flames spread at the front side about 1.0 m vertically and 0.5-0.6 m horizontally.
9:30	Flames spread at the front side about 1.2 m vertically and 0.75 m horizontally.
10:10	Flames spread at the front side about 1.4 m vertically and 0.9 m horizontally.
10:30	Flames spread at the front side about 1.5 m vertically and 0.9 m horizontally.
11:30	Flames spread at the front side about 1.6 m vertically and 1.0 m horizontally.
12:00	Burner heat output increased to 300 kW.
12:10	Further fire damage on the short side. The textile membrane was damaged up to a height of about 3 m. The textile membrane at the short side did shrink but not ignite.
12:35	Flames spread at the front side about 1.7 m vertically and 1.2 m horizontally.
14:00	Flames spread at the front side about 1.9 m vertically and 1.3 m horizontally.
15:00	Flames spread at the front side about 2.0 m vertically and 1.4 m horizontally.
16:30	Flames spread at the front side about 2.1 m vertically and 1.5 m horizontally.
17:25	Flames at the edge of the textile membrane above the burner corner extinguished in height of the inserted floor.
18:30	Flames spread at the front side about 2.1 m vertically and 1.8 m horizontally.
19:00	Flames spread above the inserted floor in a distance of about 0.5 m and 1.0 m to the burner corner.
19:30	Vertical flame spread reached the joint of two sheets.
21:10	Flames spread at the front side about 2.3 m vertically and 2.0 m horizontally.
21:40	The textile membrane on the short side was damaged up to a height of about 3.5 m.
22:00	The burner turned off. Flames spread at the front side about 2.4 m vertically and

	2.2 m horizontally.
23:30	Flames spread at the front side about 2.5 m vertically and 2.3 m horizontally.
25:30	Flames spread at the front side about 2.6 m vertically and 2.5 m horizontally.
26:30	Flames spread at the front side about 2.7 m vertically and 2.6 m horizontally.
28:00	Flames spread at the front side about 2.8 m vertically and horizontally.
29:00	Flames spread at the front side about 2.9 m vertically and horizontally.
30:00	Flames spread at the front side about 3.0 m vertically and 2.0 m horizontally.
31:00	Flames spread at the front side about 3.1 m vertically and 3.2 m horizontally.
32:00	Test end. Flames spread at the front side about 2.9 m vertically and 3.3 m horizontally. Extinguishment started.
35:00	Recording of measurements ended.

Table 27 Observations of visibility in the large-scale burner test with product N.

Time [min:s]	Photo	Observation
0:00		Situation in the first floor.
0:00		Situation in the second floor.
3:00		Good visibility in the first floor.

3:00		Good visibility in the second floor.
11:55		Good visibility in the first floor.
11:55		Good visibility in the second floor.
21:55		Good visibility in the first floor.

21:55		Good visibility in the second floor.

Further observations
Burning droplets caused a pool fire on the floor which ignited the lower edge of the textile membrane. Very limited smoke production in this test. Good visibility in the first and second floor.

Observations after the test
The situation at the end of test is shown in Figure 36. The short side was damaged up to a height of about 3.5 m and a width of about 1.2 m. The damage was caused by the heat impact of the burner flame but not by flames spread. The front side was damaged up to a height of 3.3 m and a width of about 2.9 m. This damage was mainly caused by continuous flame spread. Because the flame spread also caused burning droplets a pool fire along the lower edge of the textile membrane emerged.

Figure 36 The test setup at the end of test and right before extinguishment.

Graphs

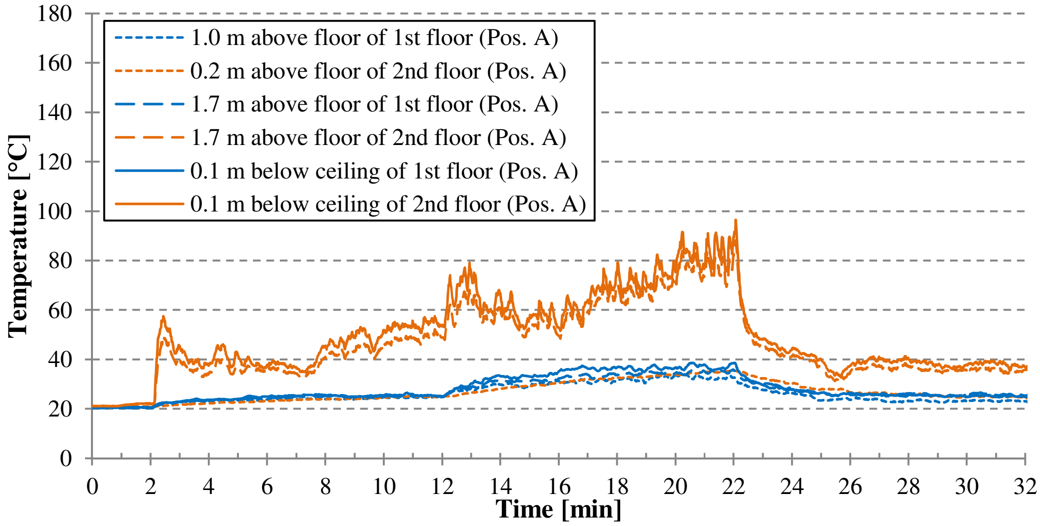


Figure 37 Temperatures at different heights inside the test room at position A.

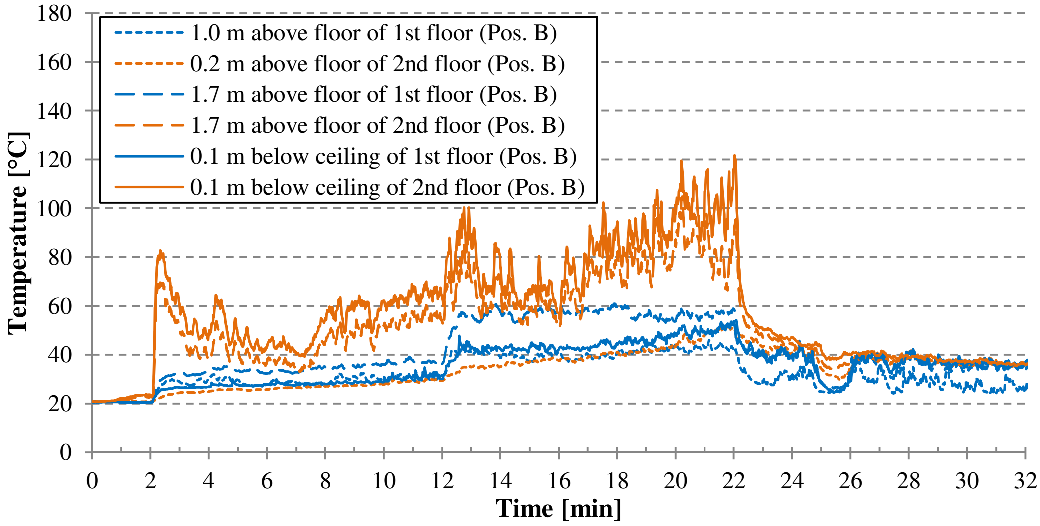


Figure 38 Temperatures at different heights inside the test room at position B.

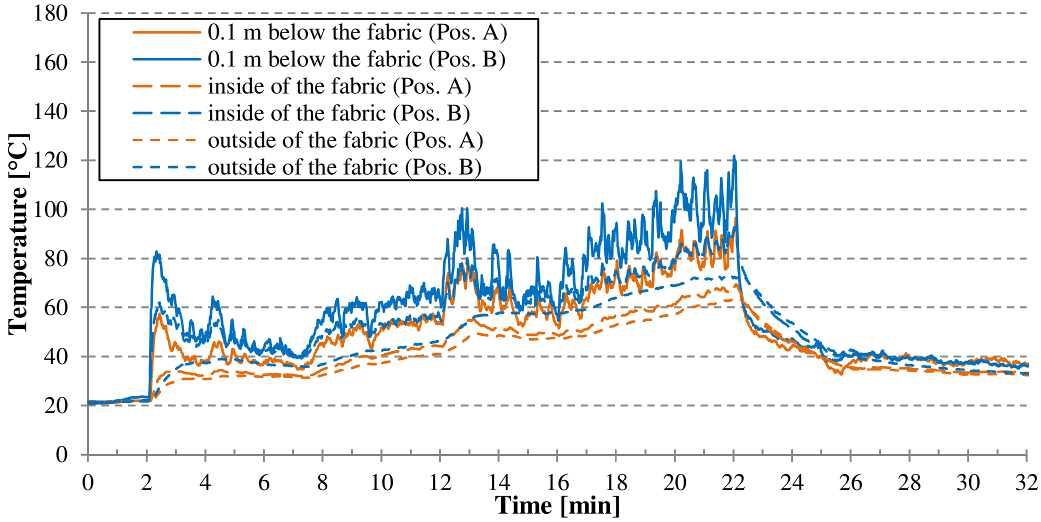


Figure 39 Temperatures in the ceiling of the test room and at the inside and outside of the textile at position A and B.

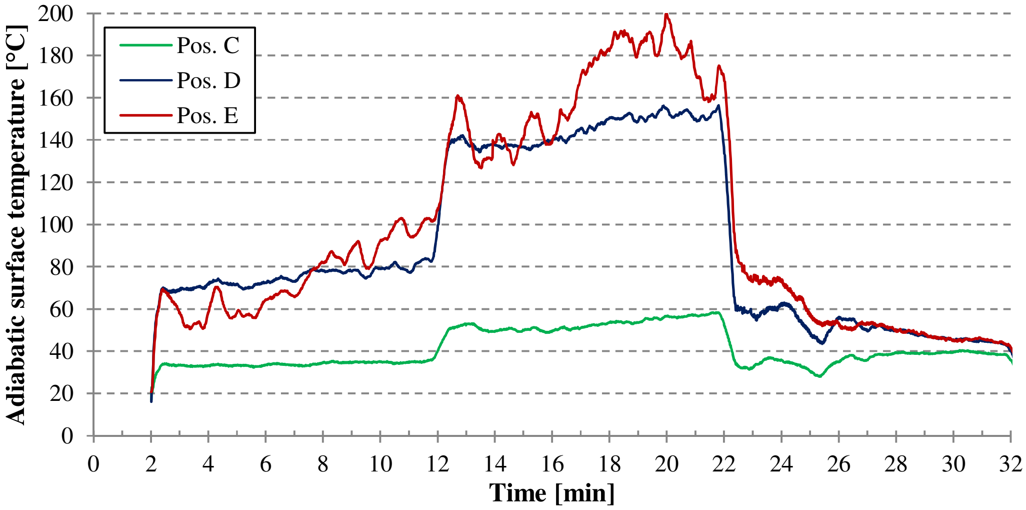


Figure 40 Adiabatic surface temperatures at position C, D and E.

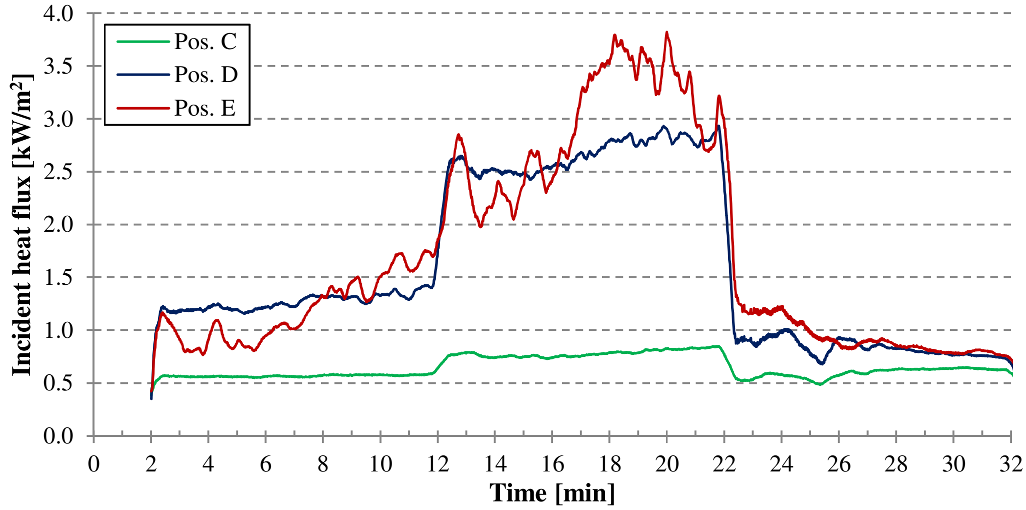


Figure 41 Calculated incident heat flux at position C, D and E.

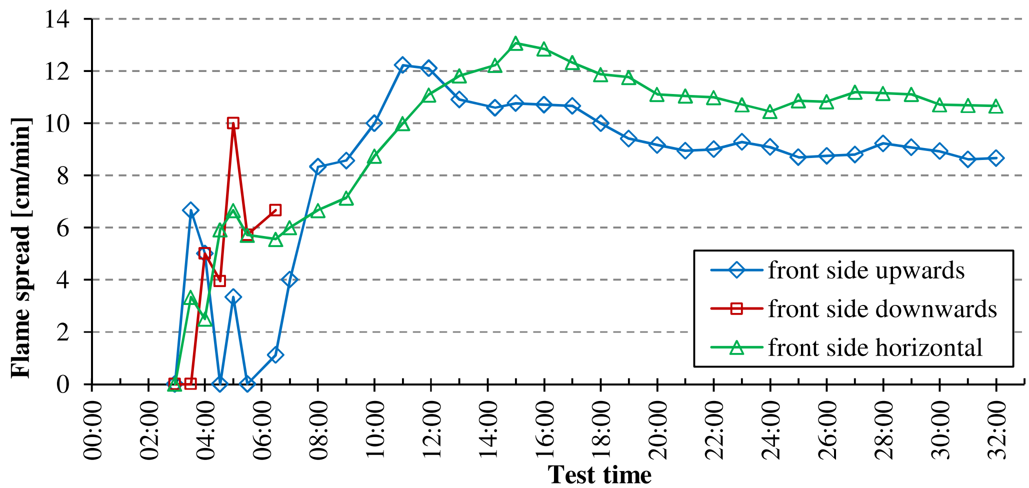


Figure 42 Development of horizontal and vertical flame spread along the front side.*

* Note that the flames spread only at the front side. The material at the short side did not burn self-sustainingly.

Scenario 2 test - product B

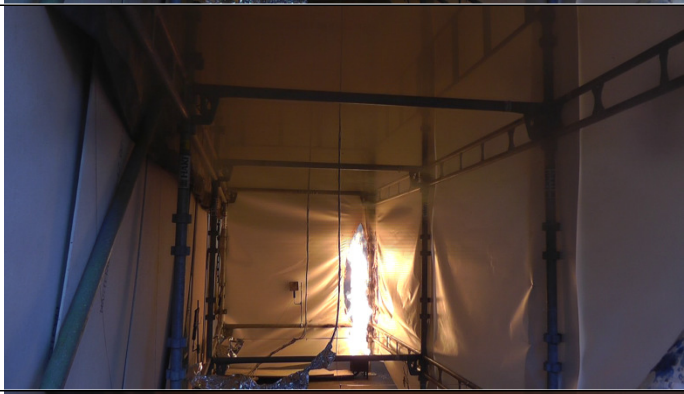
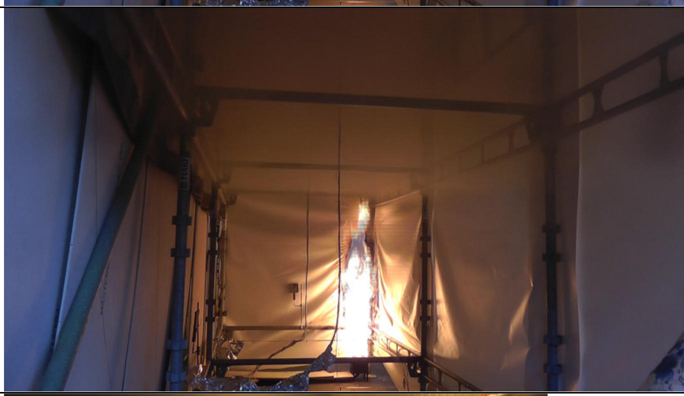
Scenario
Scenario 2 – Textile building structure without inserted floor.

Test date: May 16, 2013

Table 28 General observations in the scenario 2 test with product B.

Time [min:s]	Observation
0:00	Recording of measurements started.
1:00	Video cameras started recording.
2:00	Burner heat output increased to 100 kW.
2:13	The textile membrane started to deform.
2:20	Flames burnt through the textile membrane in the burner corner at a height of about 1 m.
3:00	Smoke filled the inside space in a height of about 2.1 m and above. (See table below)
3:15	The front side was damaged at a height of 0.5 – 1.5 m. The short side was damaged at a height of 0.5 – 1.7 m. The horizontal damage was about 0.3 m at both sides.
3:50	The entire inside space between the opening and the roof was filled with smoke. (See table below)
4:05	Flames at the edge of the fabric at the short side emerged at a height of 0.6 m.
5:20	The front side was damaged at a height of 0.3 – 1.6 m. The short side was damaged at a height of 0.25 – 1.75 m. The horizontal damage was about 0.3 m at both sides.
8:00	The upper part of the sheets seemed to be blown up due to the hot smoke gas layer. (See table below)
10:20	Flames emerged at the front side in a height of about 0.4 m.
12:00	Burner heat output increased to 300 kW.
12:15	Burnt particles fell down. Flames emerged at the short side in a height of about 1 m.
12:33	Burning particle fell down.
12:45	Damaged area increased. The front side was damaged at a height of 0.3 – 2.3 m. The short side was damaged at a height of 0.25 – 2.6 m. The horizontal damage was about 0.4 – 0.5 m at both sides.
13:30	Volume flow of the exhaust system increased due to increased smoke production.
13:45	Burning material attached to the corner in burner height fell down.
14:00	Flame started to tilt outside the construction.
15:00	Smoke layer reduced up to a height of about 2.6 m. (See table below)
15:36	Burnt material attached to the construction above the burner fell down.
19:15	Flames extinguished at the short side in a height of about 1 m.
22:00	The burner turned off. The front side was damaged up to a height of 2.3 m. The short side was damaged up to a height of 2.6 – 2.7 m. The horizontal damage of the front side was about 0.4 m and about 0.7 m at the short side.
32:00	Test end. Recording of measurements ended.

Table 29 Observations of visibility in scenario 2 test with product B.

Time [min:s]	Photo	Observation
0:00		Situation inside the test room.
3:00		Smoke filled the inside space in a height of about 2.1 m and above.
3:50		The entire inside space between the opening and the roof was filled with smoke.
8:00		The upper part of the sheets seemed to be blown up due to the hot smoke gas layer.

15:00		Smoke layer reduced up to a height of about 2.6 m.

Observations after the test

The front side was damaged up to a height of 2.3 m. The short side was damaged up to a height of 2.6 – 2.7 m. The horizontal damage of the front side was about 0.4 m and about 0.7 m at the short side. As shown in Figure 43, burned or partly burned material covered the floor in vicinity of the burner corner.

Figure 43 Fire damage of the material after the burner was turned off (left: front side | right: short side).

Graphs

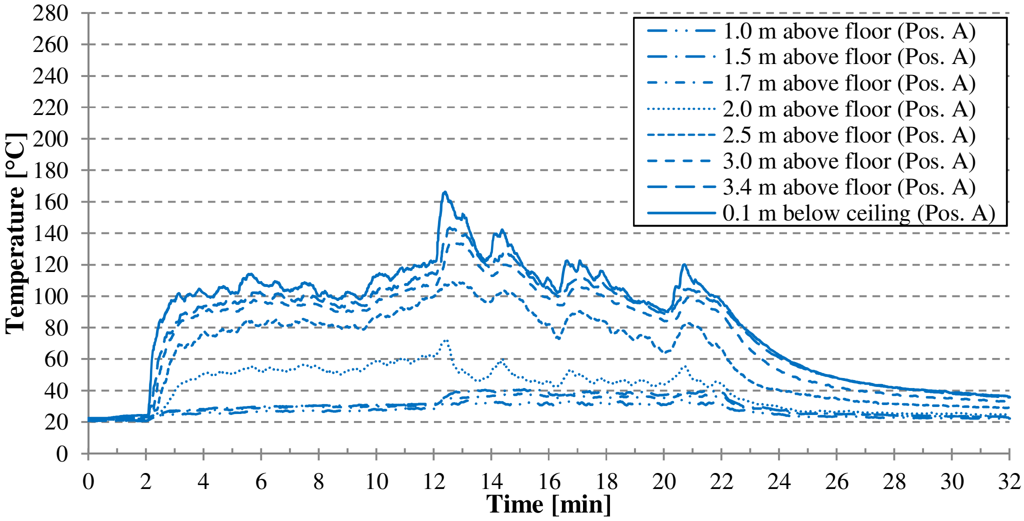


Figure 44: Temperatures at different heights inside the test room at position A.

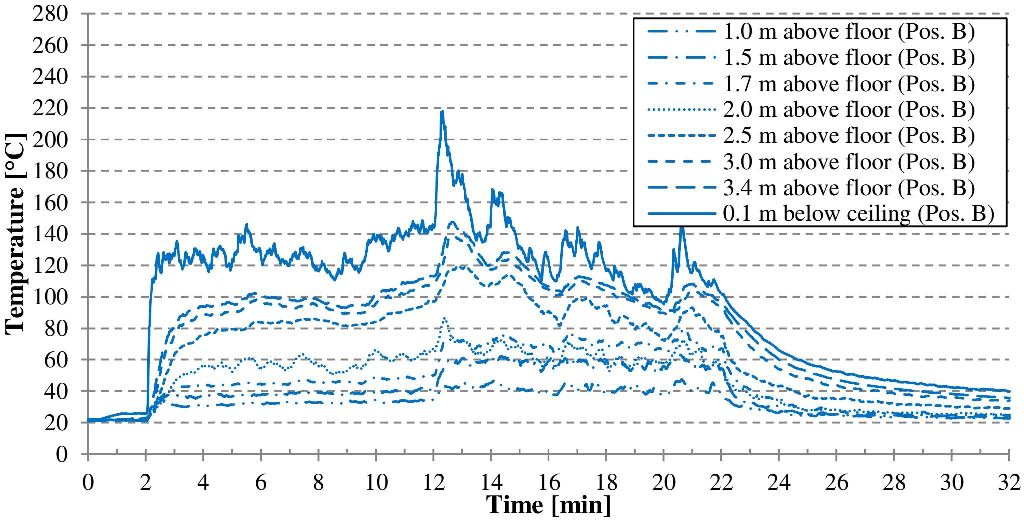


Figure 45: Temperatures at different heights inside the test room at position B.

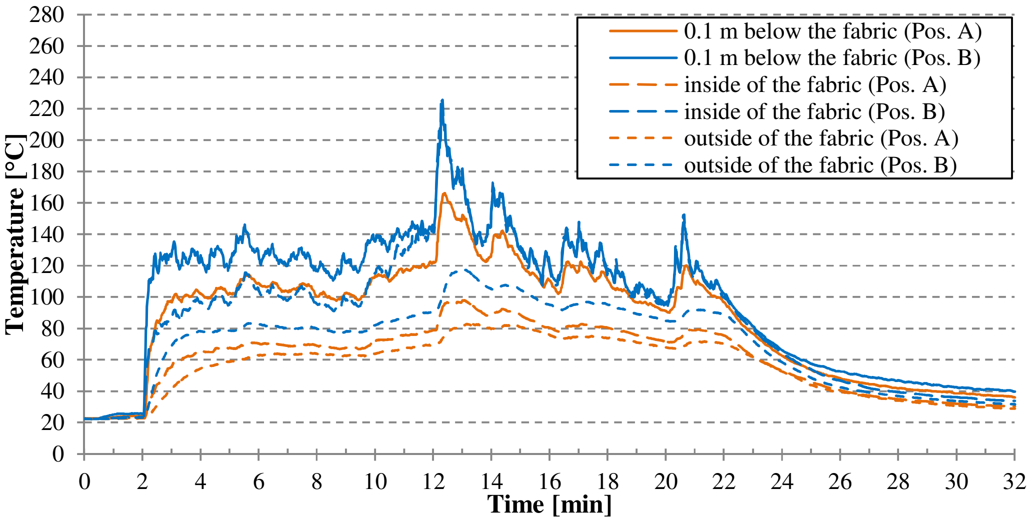


Figure 46: Temperatures in the ceiling of the test room and at the inside and outside of the textile at position A and B.

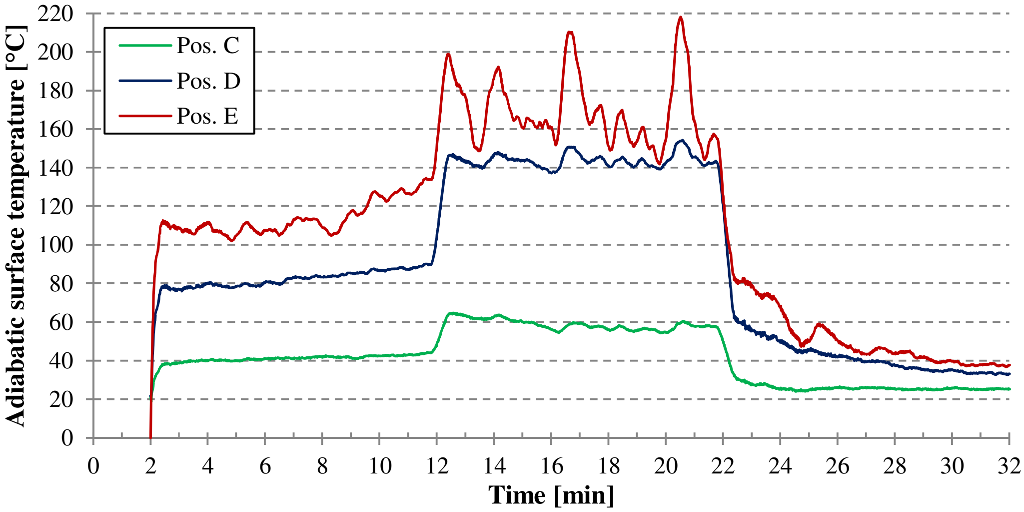


Figure 47: Adiabatic surface temperatures at position C, D and E.

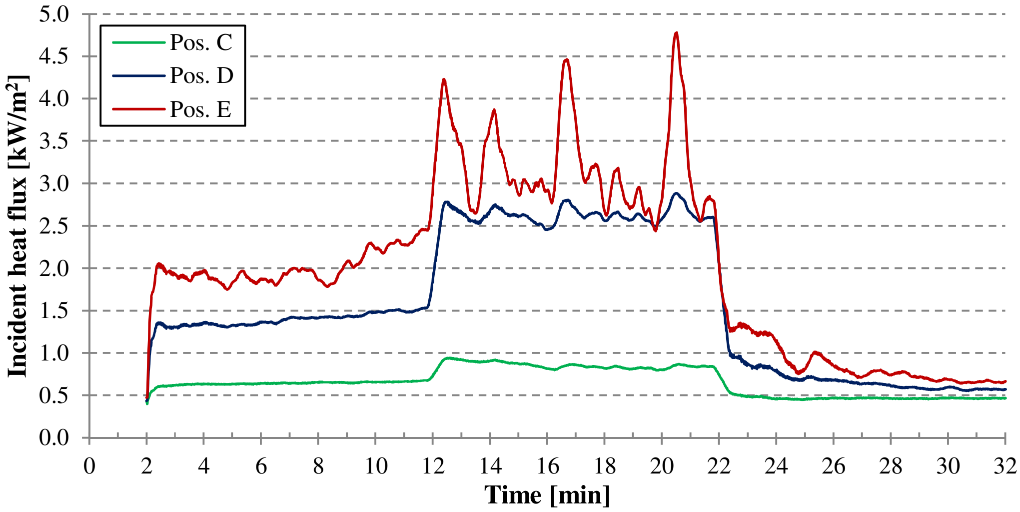


Figure 48: Calculated incident heat flux at position C, D and E.

Scenario 2 test - product J

Scenario
Scenario 2 – Textile building structure without inserted floor.

Test date: May 17, 2013

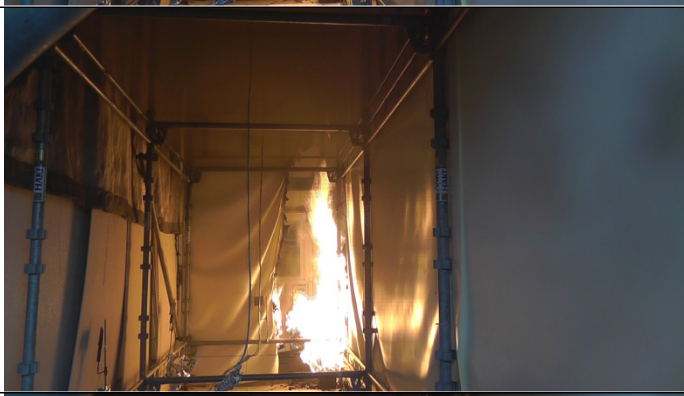
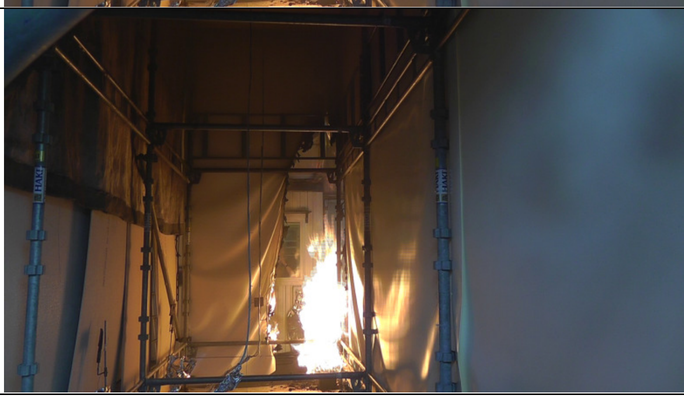
Table 30 General observations in the scenario 2 test with product J.

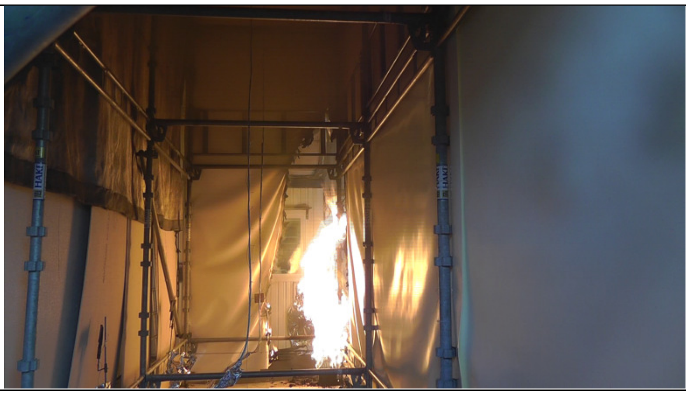
Time [min:s]	Observation
0:00	Recording of measurements started.
1:00	Video camera facing the burner corner started recording.
2:00	Burner heat output increased to 100 kW.
2:19	The textile membrane started to shrink.
2:24	Flames burnt through the textile membrane in the burner corner at the front side at a height of about 0.7 – 1.5 m.
2:38	Flames burnt through the textile membrane in the burner corner at the short side at a height of about 0.7 – 1.3 m.
2:55	Flames emerged along the edges of the material up to a height of 1.5 m at the front side and 1.0 m at the short side.
3:00	The front side was damaged at a height of 0.5 – 1.5 m. The short side was damaged at a height of 0.5 – 1.7 m. The horizontal damage was about 0.2 - 0.3 m at both sides. A smoke layer formed about 2.1 m above the floor. Smoke density within the smoke layer increased. (See table below)
3:25	Burning particles fell down.
3:50	Flames sustained along the edges of the material up to a height of 1.2 m at the front side and 1.2 m at the short side.
4:00	Formation of a stable smoke layer at a height of about 2.1 m. Smoke density within the smoke layer increased. (See table below)
4:05	Burning particles fell down.
4:34	Burning particles fell down.
4:48	Burning particles fell down.
5:00	Smoke free layer up to a height of the opening at the left side.
6:00	Thickness and smoke density of smoke layer decreased slowly.
6:30	Flames sustained along the edges of the material up to a height of 1.0 m at the front side and 0.5 m at the short side.
6:45	Smoke density of the smoke layer decreased. (See table below)
7:00	The front side was damaged at a height of 0.3 – 2.2 m. The short side was damaged at a height of 0.3 – 2.4 m. The horizontal damage was about 0.4 m at both sides.
7:20	Burning particles fell down.
7:41	Flames slowly spread upwards at the front side at a height of 0.5 m and 0.9 – 1.1 m.
8:00	The roof became visible through the smoke layer. (See table below)
8:20	Flames slowly spread upwards at the short side at a height of 0.6 m.
8:55	All flames extinguished at the short side.
9:35	All flames extinguished at the front side.
10:00	The front side was damaged at a height of 0.3 – 2.2 m. The short side was damaged at a height of 0.3 – 2.4 m. The horizontal damage was about 0.4 m at both sides.
11:00	The inside space was filled only with a limited amount of smoke. (See table below)
12:00	Burner heat output increased to 300 kW.

12:16	Burning particles fell down.
12:20	Burning particles fell down.
12:27	Flames emerged along the edges of the material up to a height of 3.2 m at the short side.
13:30	Upper part of the inside space started to fill with smoke.
13:00	Formation of a smoke gas layer at a height of about 2.1 m. Increasing smoke density.
13:10	The front side was damaged at a height of 0.3 – 2.7 m. The short side was damaged at a height of 0.3 – 3.1 m. The horizontal damage was about 0.5 m at both sides.
13:30	Flames of the burner tilted towards the short side. The material at the short side burnt at a height of 0.5 – 3.0 m and at the front side at a height of about 1.5 m.
13:59	All flames extinguished at the front side.
14:40	Volume flow of the exhaust system increased due to increased smoke production.
15:00	The material at the short side burnt at a height of 0.5 – 2.0 m.
15:45	The material at the short side burnt at a height of 0.5 – 1.4 m.
16:00	Smoke density of the smoke layer started to decrease. (See table below)
16:30	The smoke gas layer rose to a height of about 2.5 m.
16:40	The roof became visible through the smoke layer. (See table below)
17:00	The material at the short side burnt at a height of 0.4 – 1.2 m.
17:20	Smoke free layer up to a height of about 2.6 m. (See table below)
18:00	The material at the short side burnt at a height of 0.3 – 0.8 m. A limited amount of smoke was left in the inside space of the construction.
19:30	The material at the short side burnt at a height of 0.3 m and 0.8 m.
21:00	The material at the short side burnt at a height of 0.7 m.
22:00	The burner turned off. The front side was damaged at a height of 0.3 – 2.7 m. The short side was damaged up to a height of 3.1 m. The horizontal damage of the front side was about 0.4 – 0.5 m and about 0.7 – 0.8 m at the short side (See Figure 49).
32:00	Test end. Recording of measurements ended.

Table 31 Observations of visibility in the scenario 2 test with product J.

Time [min:s]	Photo	Observation
0:00		Situation inside the test room.
3:00		A smoke layer formed about 2.1 m above the floor. Smoke density within the smoke layer increased.
4:00		Formation of a stable smoke layer at a height of about 2.1 m. Smoke density within the smoke layer increased.
6:45		Smoke density of the smoke layer decreased.

8:00		The roof became visible through the smoke layer.
11:00		The inside space was filled only with a limited amount of smoke.
16:00		Smoke density of the smoke layer started to decrease.
16:40		The roof became visible through the smoke layer.

17:20		Smoke free layer up to a height of about 2.6 m.

Observations after the test

The front side was damaged at a height of 0.3 – 2.7 m. The short side was damaged up to a height of 3.1 m. The horizontal damage of the front side was about 0.4 – 0.5 m and about 0.7 – 0.8 m at the short side. As shown in Figure 49, burned or partly burned material covered the floor in vicinity of the burner corner.

Figure 49 Fire damage of the material after the burner was turned off (left: front side | right: short side)

Graphs

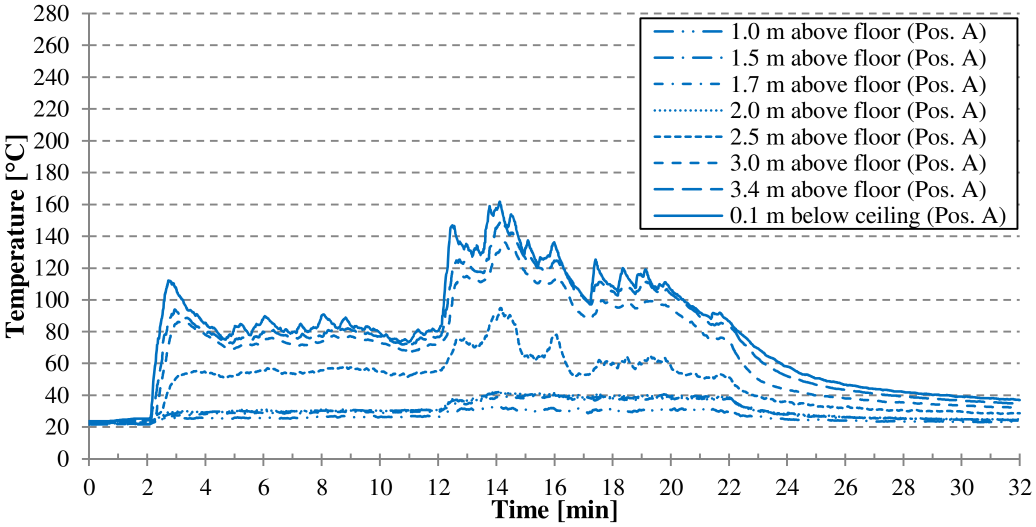


Figure 50 Temperatures at different heights inside the test room at position A.

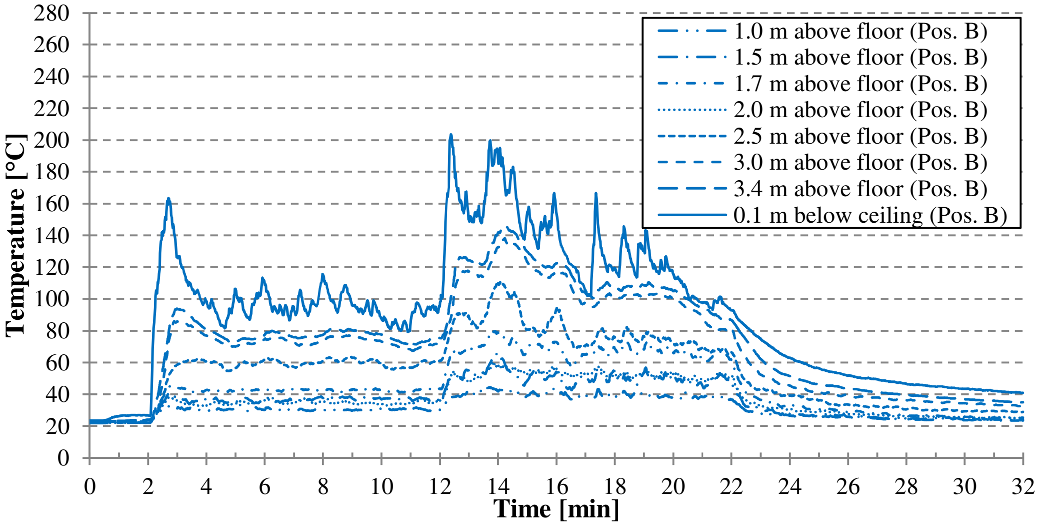


Figure 51 Temperatures at different heights inside the test room at position B.

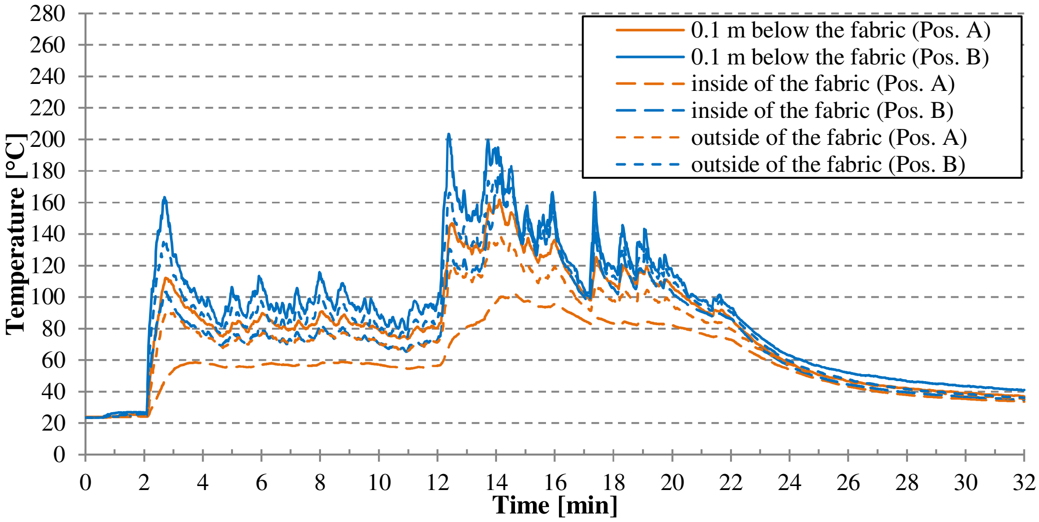


Figure 52 Temperatures in the ceiling of the test room and at the inside and outside of the textile at position A and B.

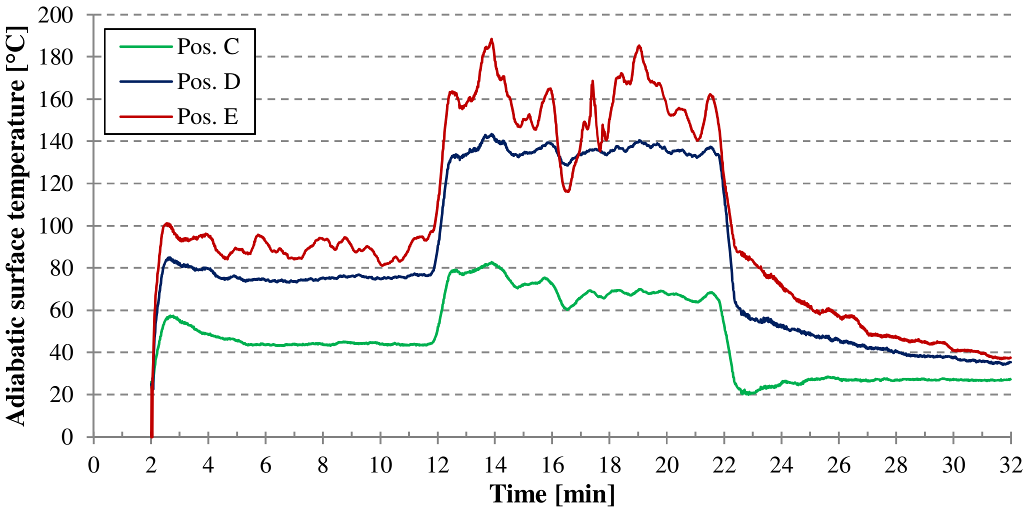


Figure 53 Adiabatic surface temperatures at position C, D and E

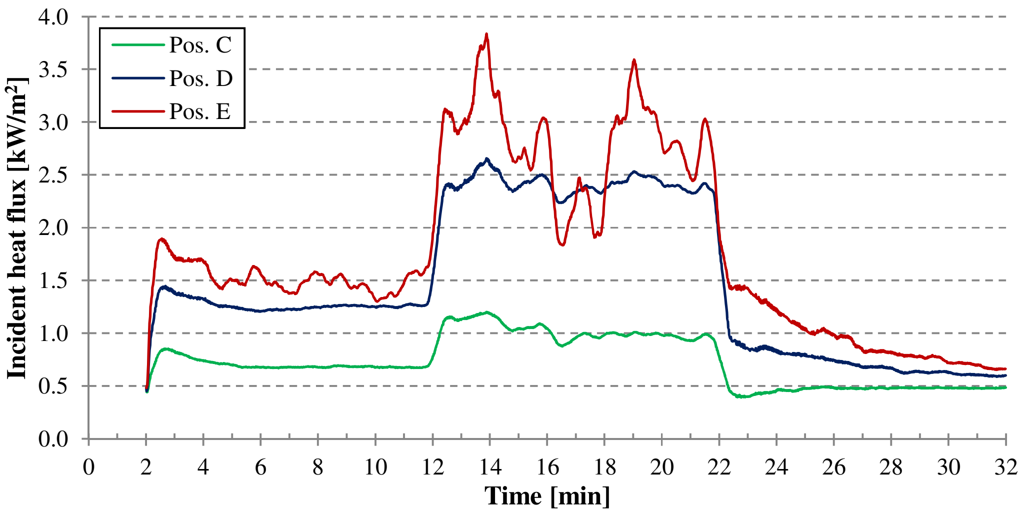


Figure 54 Calculated incident heat flux at position C, D and E.

Scenario 3 test - product B

Scenario

Scenario 3 – Textile building structure with inserted floor.

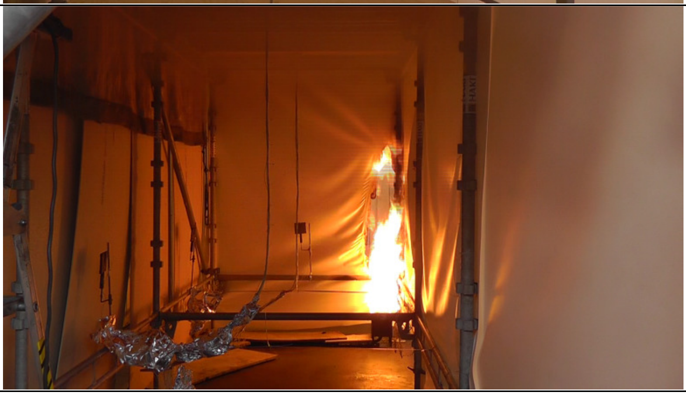
Test date: May 16, 2013

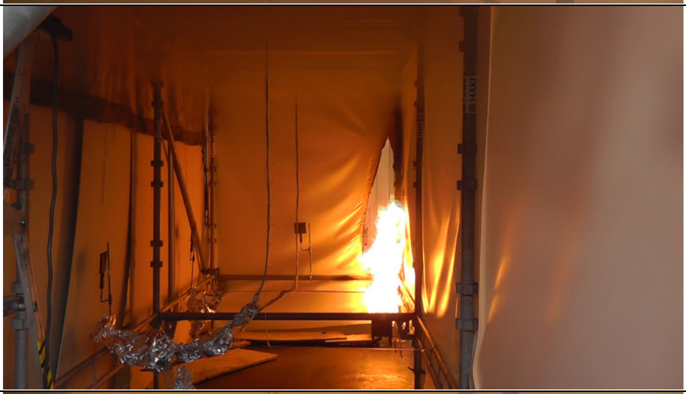
Table 32 General observations in the scenario 3 test with product B.

Time [min:s]	Observation
0:00	Recording of measurements started.
1:00	Video cameras started recording.
2:00	Burner heat output increased to 100 kW.
2:12	The textile membrane started to deform.
2:16	Flames burnt through the textile membrane in the burner corner at the short side at a height of about 0.75 – 1.5 m.
2:25	Flames burnt through the textile membrane in the burner corner at the front side at a height of about 0.5 – 1.25 m.
2:30	Visibility started to decrease in the second floor. (See table below)
2:50	The front side was damaged at a height of 0.5 – 1.5 m. The short side was damaged at a height of 0.5 – 1.7 m. The horizontal damage was about 0.2 - 0.3 m at both sides.
3:00	Smoke filled the inside space in a height of about 2.1 m and above. (See table below)
3:30	Visibility distance in the second floor was about 4.5 m. (See table below)
4:00	The front side was damaged at a height of 0.3 – 1.5 m. The short side was damaged at a height of 0.3 – 1.8 m. The horizontal damage was about 0.3 m at both sides. Less smoke in the first floor caused improved visibility. (See table below)
4:26	The front side was damaged at a height of 0.2 – 1.5 m. The short side was damaged at a height of 0.2 – 1.8 m. The horizontal damage was about 0.3 m at both sides.
4:50	Flames emerged from the material attached to the burner corner.
5:00	Visibility in the second floor got better. (See table below)
5:30	Flames emerged from the material attached to the burner corner.
6:00	The front side was damaged at a height of 0.2 – 1.55 m. The short side was damaged at a height of 0.2 – 1.8 m. The horizontal damage was about 0.4 m at both sides.
6:42	Burning particles fell down just outside the burner corner.
9:30	Flames started to tilt outside the construction.
12:00	Burner heat output increased to 300 kW.
12:13	Burning particles fell down around the burner corner.
12:22	The front side was damaged at a height of 0.2 – 2.1 m. The short side was damaged at a height of 0.2 – 2.4 m. The horizontal damage was about 0.4 m at the front side and about 0.5 m at the short side.
12:30	Sustained burning at the short side in a height of about 0.7 – 1.0 m. Visibility in the second floor decreased. (See table below)
13:00	Volume flow of the exhaust system increased due to increased smoke production.
14:00	Good visibility in the first floor. (See table below)
14:10	Burning particles fell down at the short side.
15:00	Visibility in the second floor increased. (See table below)
22:00	The burner turned off. The front side was damaged at a height of 0.1 –

	2.1 m. The short side was damaged up to a height of 2.4 m. The horizontal damage of the front side was about 0.4 m and about 0.6 m at the short side (See Figure 55).
32:00	Test end. Recording of measurements ended.

Table 33 Observations of visibility in the scenario 3 test with product B.

Time [min:s]	Photo	Observation
0:00		Situation in the first floor.
0:00		Situation in the second floor.
2:30		Visibility started to decrease in the second floor.
3:00		Smoke filled the inside space in a height of about 2.1 m and above.

3:30		Visibility distance in the second floor was about 4.5 m.
4:00		Less smoke in the first floor caused improved visibility.
5:00		Visibility in the second floor got better.
12:30		Visibility in the second floor decreased.

14:00		Good visibility in the first floor.
15:00		Visibility in the second floor increased.

Observations after the test

The front side was damaged at a height of 0.1 – 2.1 m. The short side was damaged up to a height of 2.4 m. The horizontal damage of the front side was about 0.4 m and about 0.6 m at the short side. As shown in Figure 55, burned or partly burned material covered the floor in vicinity of the burner corner.

Figure 55 Fire damage of the material after the burner was turned off (left: front side | right: short side).

Graphs

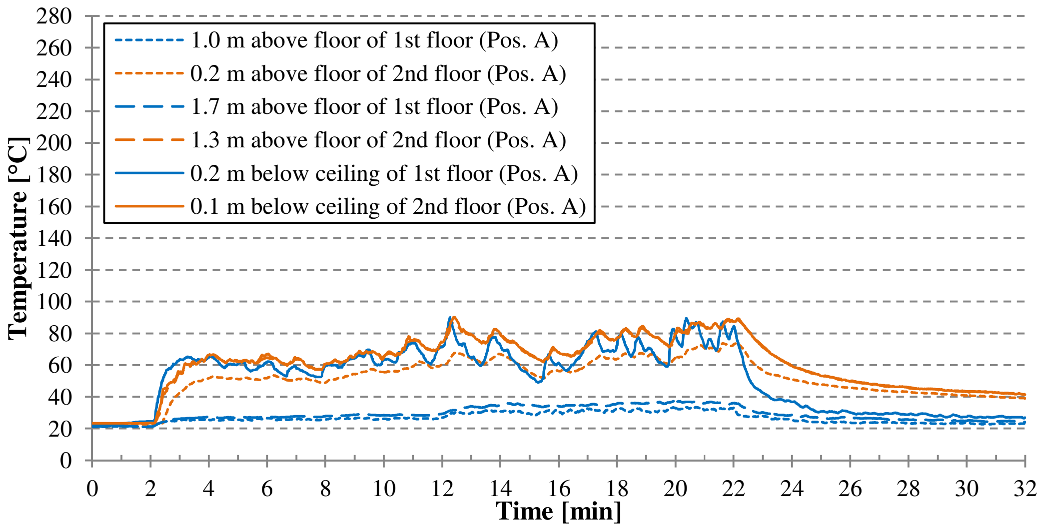


Figure 56 Temperatures at different heights inside the test room at position A.

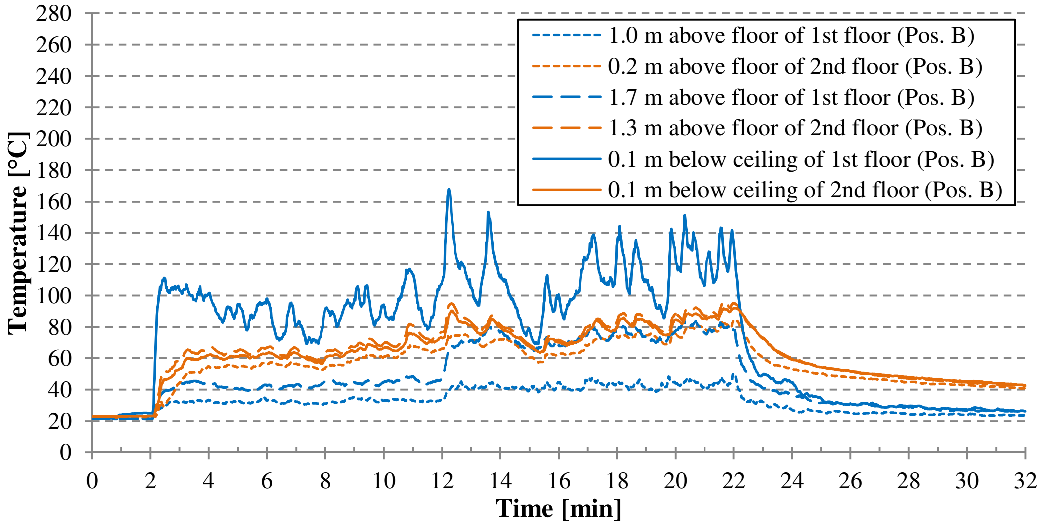


Figure 57 Temperatures at different heights inside the test room at position B.

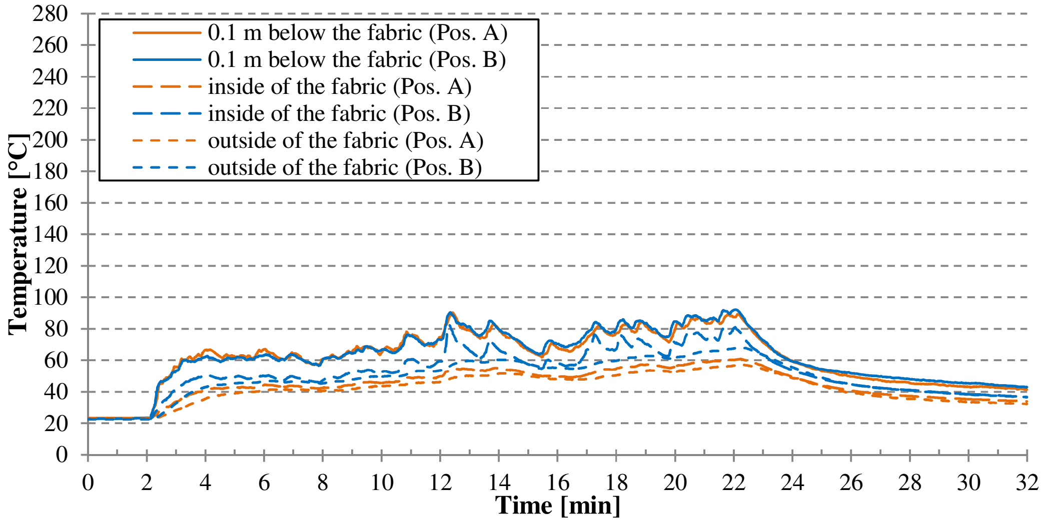


Figure 58 Temperatures in the ceiling of the test room and at the inside and outside of the textile at position A and B.

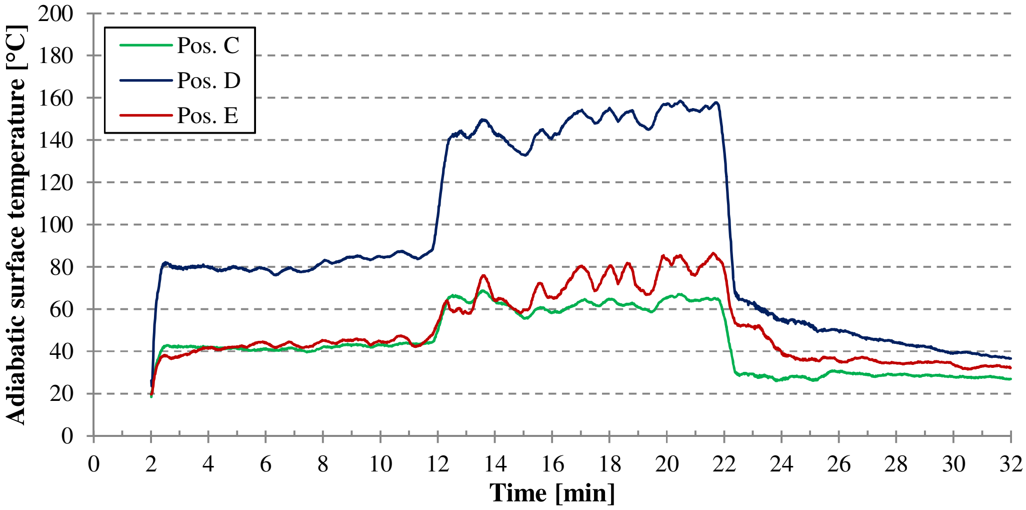


Figure 59 Adiabatic surface temperatures at position C, D and E.

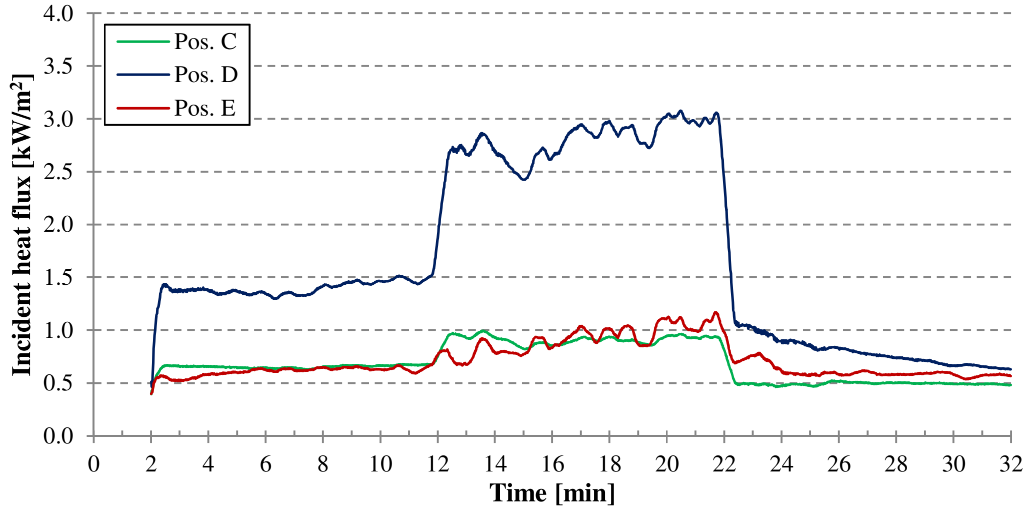


Figure 60 Calculated incident heat flux at position C, D and E.

Scenario 3 test - product J

Scenario
Scenario 3 – Textile building structure with inserted floor.

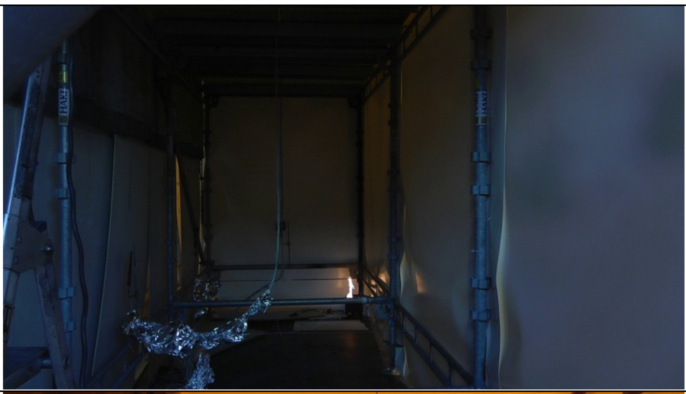
Test date: May 17, 2013

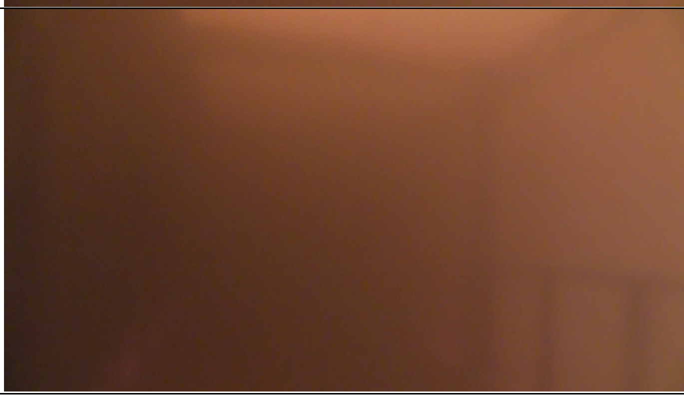
Table 34 General observations in the scenario 3 test with product J.

Time [min:s]	Observation
0:00	Recording of measurements started.
1:00	Video cameras started recording.
2:00	Burner heat output increased to 100 kW.
2:13	The textile membrane started to deform.
2:19	Flames started to burn through the textile membrane in the burner corner at the front side.
2:30	Smoke emerged in the second floor.
2:40	Flames started to burn through the textile membrane in the burner corner at the short side. Decreased visibility in the second floor.
2:45	Visibility distance in the second floor was about 4.5 m. (See table below)
2:55	Visibility distance in the second floor was less about 3.8 m. (See table below)
3:00	The front side was damaged at a height of 0.5 – 2.0 m. The short side was damaged at a height of 0.5 – 2.0 m. The horizontal damage was about 0.3 m at both sides. A smoke layer emerged about 2.3 m above the floor of the first floor. Visibility distance in the second floor was about 3.2 m. (See table below)
3:05	Visibility distance in the second floor was about 2.5 m. (See table below)
3:08	Burning particles fell down.
3:30	Burning particles fell down at the short side having a damage at a height of 0.5 – 2.3 m. Visibility distance in the second floor was 0.0 m. (See table below)
4:00	The horizontal damage was about 0.3 – 0.4 m at both sides. The edges of the textile membrane burnt up to a height of about 1.5 m. Excellent visibility in the first floor.
5:00	Visibility in the second floor got better.
5:30	Visibility distance in the second floor was about 2.5 m. (See table below)
6:00	The edges of the textile membrane burnt up to a height of about 1.0 m.
6:30	Burning particles fell down at the short side. Flames sustained on the floor.
7:45	Flames at the edges of the textile membrane at the short side extinguished.
7:50	Volume flow of the exhaust system increased due to increased smoke production.
8:00	Visibility distance in the second floor was about 4.0 m. (See table below)
8:15	Only small flames at the edge of the textile membrane at the front side at a height of about 1.0 m and at the burner corner at a height of about 0.5 – 0.75 m.
8:20	Visibility distance in the second floor was about 4.5 m. (See table below)
9:20	Flames at the edges of the textile membrane at the front side extinguished.
9:30	Good visibility in the first floor.
10:05	Burning particles fell down at the burner corner.
10:30	The front side was damaged at a height of 0.25 – 2.0 m. The short side was damaged at a height of 0.25 – 2.3 m. The horizontal damage was about

	0.4 m at the front side and about 0.5 m at the short side.
11:00	Limited amount of smoke in the second floor. (See table below)
12:00	Burner heat output increased to 300 kW.
12:21	The material got damaged up to a height of about 2.4 m at the front side and about 2.5 m at the short side.
12:30	Second floor started to fill with smoke.
12:33	Burning particle at the burner corner fell down. The edges in the upper part of the damaged area burnt.
13:13	The flames of the burner tilted towards the short side. The short side was damaged at a height of 0.2 – 2.6 m. The horizontal damage was about 0.7 m at the short side.
13:30	Visibility distance in the second floor was about 4.5 m. (See table below)
14:00	Visibility in the second floor got better. (See table below)
14:08	Edges of material at the short side burnt at a height of about 0.5 – 2.0 m.
15:00	Edges of material at the short side burnt at a height of about 0.5 – 2.1 m. The horizontal damage was about 0.7 m at the short side.
16:00	Edges of material at the short side burnt at a height of about 0.4 – 2.3 m. The horizontal damage was about 0.7 m at the short side.
16:37	The material at the front side ignited at a height of about 0.3 m
17:05	Edges of material at the short side burnt at a height of about 0.4, 1.1 and 2.3 m.
18:00	Edges of material at the short side burnt at a height of about 0.4 m. Edges of material at the front side burnt at a height of about 0.4 – 0.5 m.
18:30	All flames at the short side extinguished.
20:40	Good visibility in the first and second floor.
21:10	All flames at the front side extinguished.
22:00	The burner turned off. The front side was damaged up to a height of 2.3 – 2.4 m. The short side was damaged up to a height of about 2.6 m. The horizontal damage of the front side was about 0.5 m and about 0.8 m at the short side (See Figure 61).
32:00	Test end. Recording of measurements ended.

Table 35 Observations of visibility in the scenario 3 test with product J.

Time [min:s]	Photo	Observation
0:00		Situation in the first floor.
0:00		Situation in the second floor.
2:45		Visibility distance in the second floor was about 4.5 m.
2:55		Visibility distance in the second floor was less than about 3.8 m.

3:00		Visibility distance in the second floor was about 3.2 m.
3:05		Visibility distance in the second floor was about 2.5 m.
3:30		Visibility distance in the second floor was 0.0 m.
5:30		Visibility distance in the second floor was about 2.5 m.

8:00		Visibility distance in the second floor was about 4.0 m.
8:20		Visibility distance in the second floor was about 4.5 m.
11:00		Limited amount of smoke in the second floor.
11:55		Very limited smoke in the first floor.

13:30		Visibility distance in the second floor was about 4.5 m.
14:00		Visibility in the second floor got better.
21:55		Very limited smoke in the first floor.

Further observations
Very limited smoke in the first floor during the entire testing time. See table above.

Observations after the test
The front side was damaged up to a height of 2.3 – 2.4 m. The short side was damaged up to a height of about 2.6 m. The horizontal damage of the front side was about 0.5 m and about 0.8 m at the short side. As shown in Figure 61, burned or partly burned material covered the floor in vicinity of the burner corner.

Figure 61 Fire damage of the material after the burner was turned off (left: front side | right: short side).

Graphs

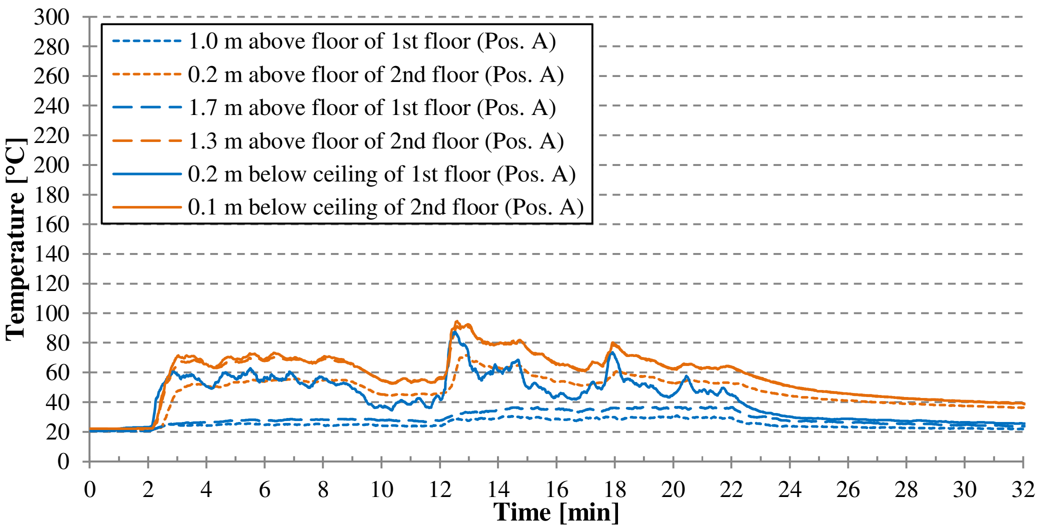


Figure 62 Temperatures at different heights inside the test room at position A.

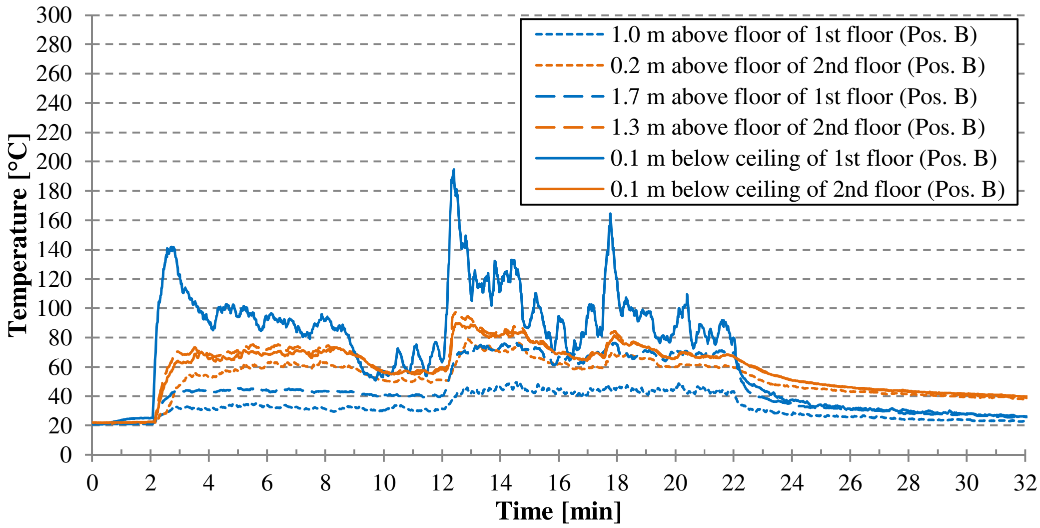


Figure 63 Temperatures at different heights inside the test room at position B.

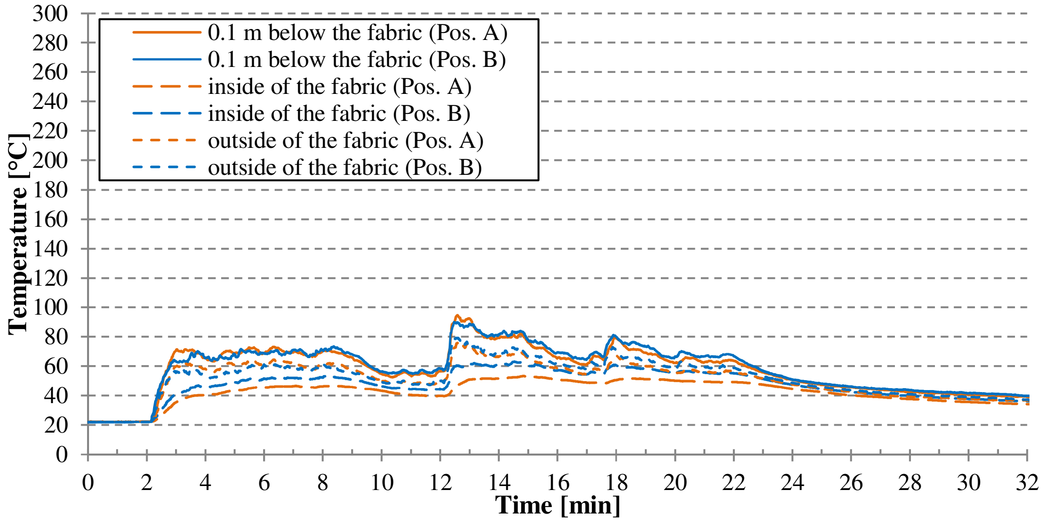


Figure 64 Temperatures in the ceiling of the test room and at the inside and outside of the textile at position A and B.

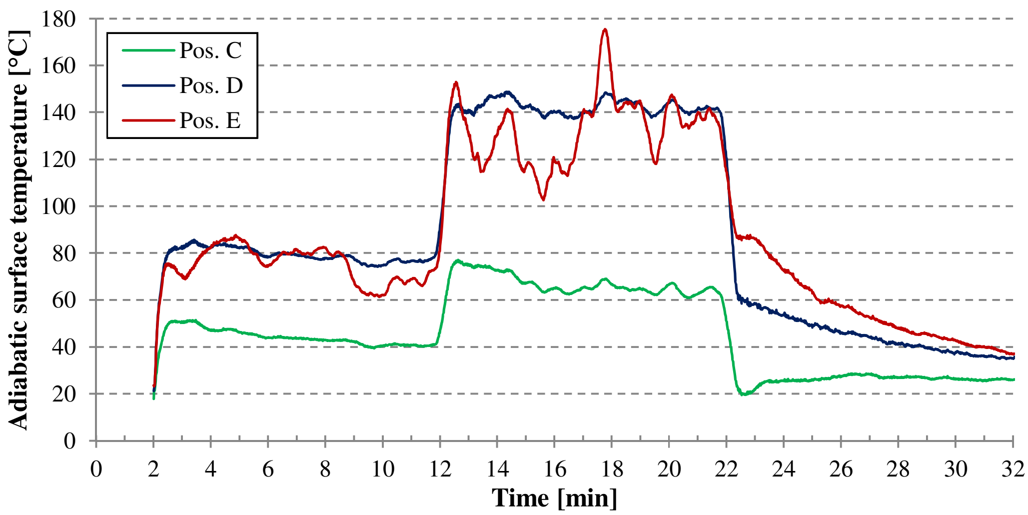


Figure 65 Adiabatic surface temperatures at position C, D and E.

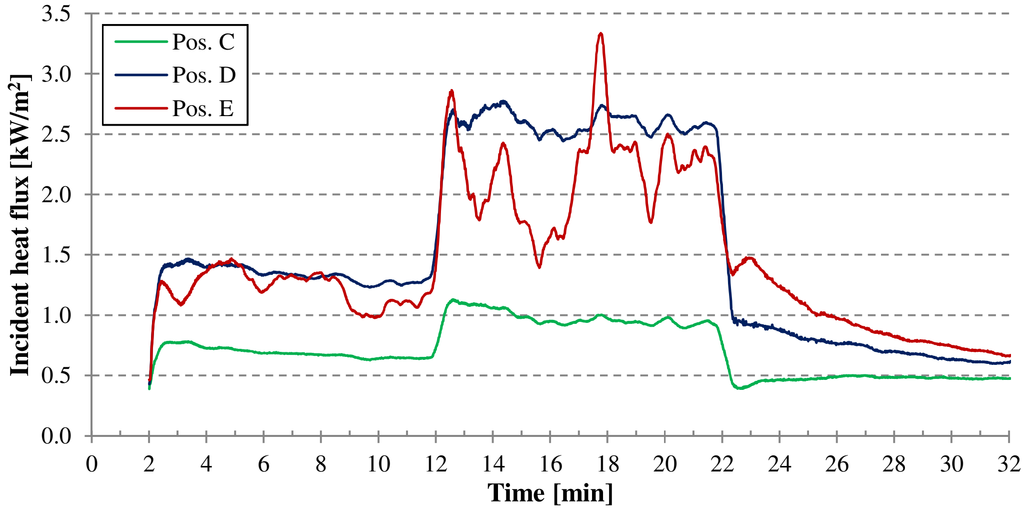


Figure 66 Calculated incident heat flux at position C, D and E

G.2 Practical ignitability tests

Test procedure

Ignitability tests similar to those described in EN ISO 11925-2 were performed on the textile membranes when mounted in the building structures. Both edges and the surfaces were exposed to a direct small-flame impingement. The application of the small flame was both to the outside and inside of the textile for 15 s and 30 s, see Figure 67 and Figure 68.

These tests were conducted at one occasion with each membrane after that a burner test had been concluded. Ignition of the material, occurrence of burning droplets, the flame spread and the time when flames extinguished were recorded in the ignitability tests. There were no recordings made of temperatures from the thermocouple trees in these tests.

Figure 67 Ignitability tests with edge exposure.

Figure 68 Ignitability tests with surface exposure.

Test results from product B

Scenario
Scenario 3 – Textile building structure with inserted floor.

Application
Edge exposure.

Test results

Exposed surface	outside		inside	
Flame exposure time, s	15	30	15	30
The sample ignited, s	NI	23	3	11
The flames reach 150 mm, s	-	-*	-*	-*
Burning droplets	No	No	No	No
Time when flames extinguished, s	-	30	17	30

NI = No ignition.
*Flaming ceased before the flame tip reached 150 mm.

Figure 69 Fire damage after edge exposure from the outside (right: 15 s flame exposure; left: 30 s flame exposure).

Figure 70 Fire damage after edge exposure from the inside (right: 30 s flame exposure; left: 15 s flame exposure).

Application
Surface exposure. Both surfaces of the product were exposed.

Test results

Exposed surface	outside		inside	
Flame exposure time, s	15	30	15	30
The sample ignited, s	NI	NI	8	8
The flames reach 150 mm, s	-	-	-*	-*
Burning droplets	No	No	No	No
Time when flames extinguished, s	-	-	15	36

NI = No ignition.
*Flaming ceased before the flame tip reached 150 mm.

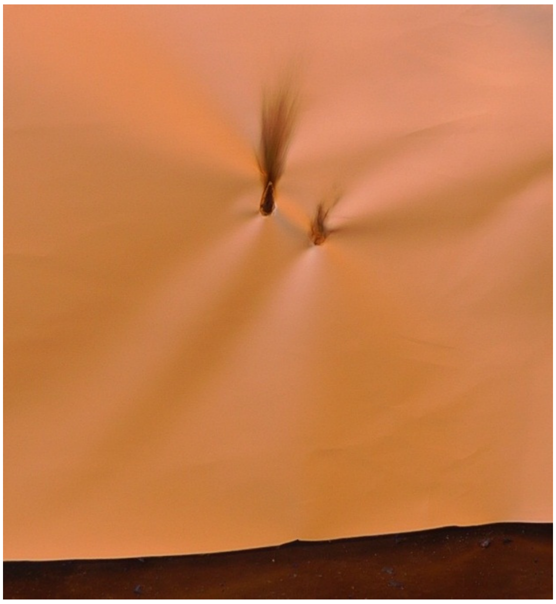


Figure 71 Fire damage after surface exposure at the outside (right: 15 s flame exposure; left: 30 s flame exposure).

Figure 72 Fire damage after surface exposure at the inside (right: 15 s flame exposure; left: 30 s flame exposure).

Note
The ignition of the sample when exposed from the inside happened at the same time as the flames burnt through the sample.

Date of test
May 16, 2013.

Test results from product J

Scenario
Scenario 2 – Textile building structure without inserted floor.

Application
Edge exposure.

Test results

Exposed surface	outside		inside	
Flame exposure time, s	15	30	15	30
The sample ignited, s	NI	-[x]	NI	NI
The flames reach 150 mm, s	-	-*	-	-
Burning droplets	No	No	No	No
Time when flames extinguished, s	-	34	-	-

NI = No ignition.
[x]A certain time of ignition was not observed; it was not possible to distinguish the pilot flame and flames from the product.
*Flaming ceased before the flame tip reached 150 mm.

Figure 73 Fire damage after edge exposure from the outside (right: 15 s flame exposure; left: 30 s flame exposure).

Figure 74 Fire damage after edge exposure from the inside (right: 30 s flame exposure; left: 15 s flame exposure).

Application
Surface exposure. Both surfaces of the product were exposed.

Test results

Exposed surface	outside		inside	
Flame exposure time, s	15	30	15	30
The sample ignited, s	NI	26	NI	NI
The flames reach 150 mm, s	-	-*	-	-
Burning droplets	No	No	No	No
Time when flames extinguished, s	-	34	-	-

NI = No ignition.
*Flaming ceased before the flame tip reached 150 mm.

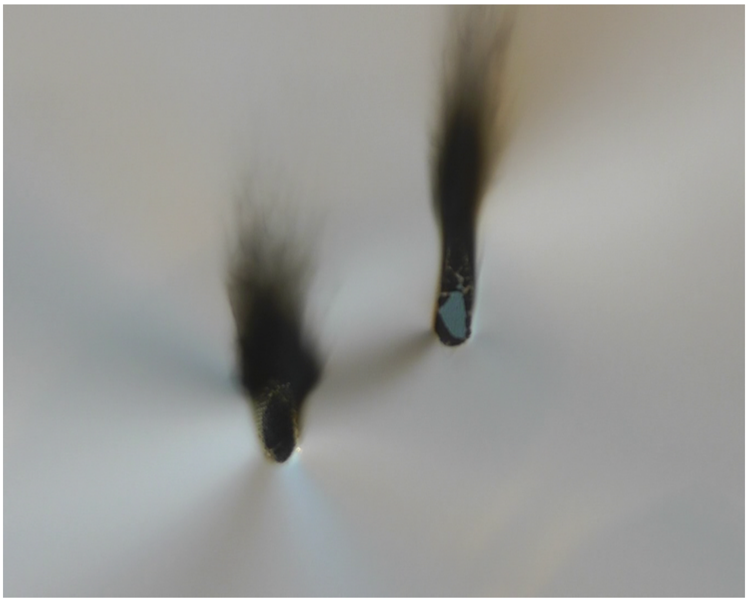


Figure 75 Fire damage after surface exposure at the outside (right: 30 s flame exposure; left: 15 s flame exposure).

Figure 76 Fire damage after surface exposure at the inside (right: 30 s flame exposure; left: 15 s flame exposure).

Note
The ignition of the sample happened at the same time as the flames burnt through the sample.

Date of test
May 17, 2013.

Test results from product N

Scenario
Scenario 1 – Weather protection of scaffolding.

Application
Surface exposure. The outside surface of the product was exposed.
Flame exposure time was 15 s.

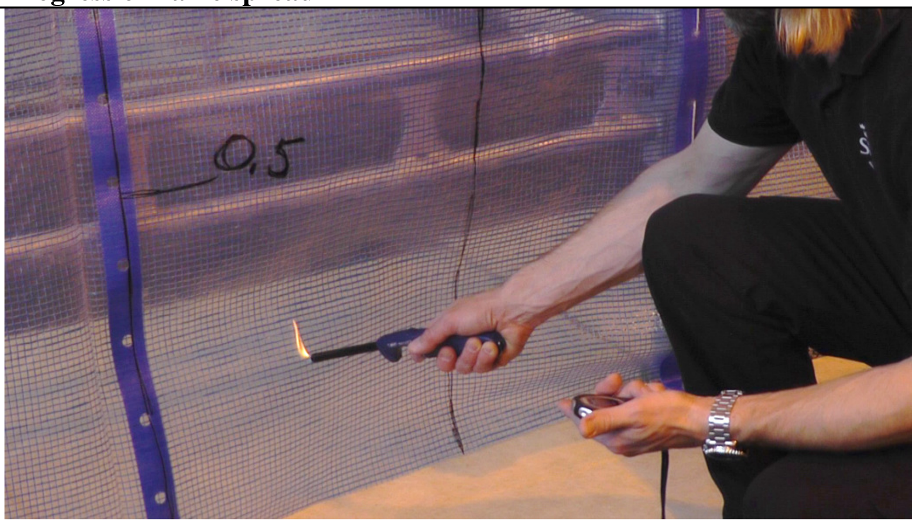
Test results
The product ignited after 12 s of flame application. The flame spread and burning behaviour are reported in the tables below.

Table 36 Numerical documentation of flame spread.

Test time [min:s]	Flame spread [m] Upwards	Downwards	To left	To right	Comments
00:00	0	0	0	0	Start (See table below)
00:30	0.05	0.05	0.05	0	
01:00	0.1	0.1	0.1	0.05	Pool fire developed below the fabric.
01:30	0.15	0.25	0.2	0.1	Lower flame front reached the floor.
02:00	0.25	-	0.25	0.15	
02:30	0.35	-	0.3	0.2	
03:00	0.4	-	0.35	0.2	
03:30	0.42	-	0.4	0.25	
04:00	0.45	-	0.45	0.3	
04:30	0.5	-	0.48	0.35	
05:00	0.55	-	0.5	0.45	
06:00	0.6	-	0.55	0.6	
07:00	0.65	-	0.65	0.714	
08:00	0.7	-	0.68	0.8	
09:00	0.95	-	0.7	0.85	
10:00	1.05	-	0.75	0.9	See table below.
11:00	1.15	-	0.85	0.95	
12:00	1.25	-	0.9	1.05	
13:00	1.35	-	0.95	1.15	
14:00	1.55	-	1	1.2	
15:00	1.65	-	1.05	1.25	
16:00	1.75	-	1.1	1.3	Flame front to right reached edge.
17:00	1.8	-	1.15	-	
18:00	1.9	-	1.18	-	
19:00	2	-	1.2	-	
20:00	2.05	-	1.23	-	See table below
21:00	2.15	-	1.25	-	Flame front to left reached edge.
22:00	2.2	-	-	-	
23:00	2.25	-	-	-	
24:00	2.35	-	-	-	
25:00	2.45	-	-	-	

26:00	2.65	-	-	-	
27:00	2.8	-	-	-	
28:00	2.85	-	-	-	
29:00	2.95	-	-	-	
30:00	3.25	-	-	-	See table below
31:00	3.35	-	-	-	
32:00	3.5	-	-	-	
33:00	3.6	-	-	-	
34:00	3.75	-	-	-	
35:00	3.85	-	-	-	
36:00	3.95	-	-	-	
37:00	4.05	-	-	-	
38:00	4.1	-	-	-	
38:30	4.148	-	-	-	Flame front upwards reached upper edge. (See table below)
53:00	-	-	-	-	Further flame spread in the ceiling. (See table below)

Table 37 Visual documentation of flame spread.

Test time [min:s]	Progress of flame spread
00:00	

10:00

20:00

30:00

38:30	
53:00	

Graphs

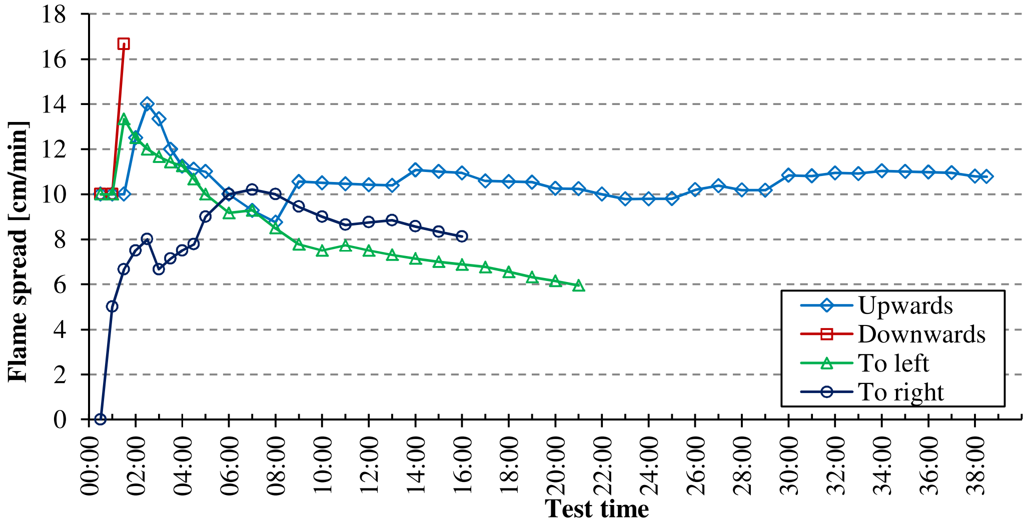


Figure 77 Development of horizontal and vertical flame spread.

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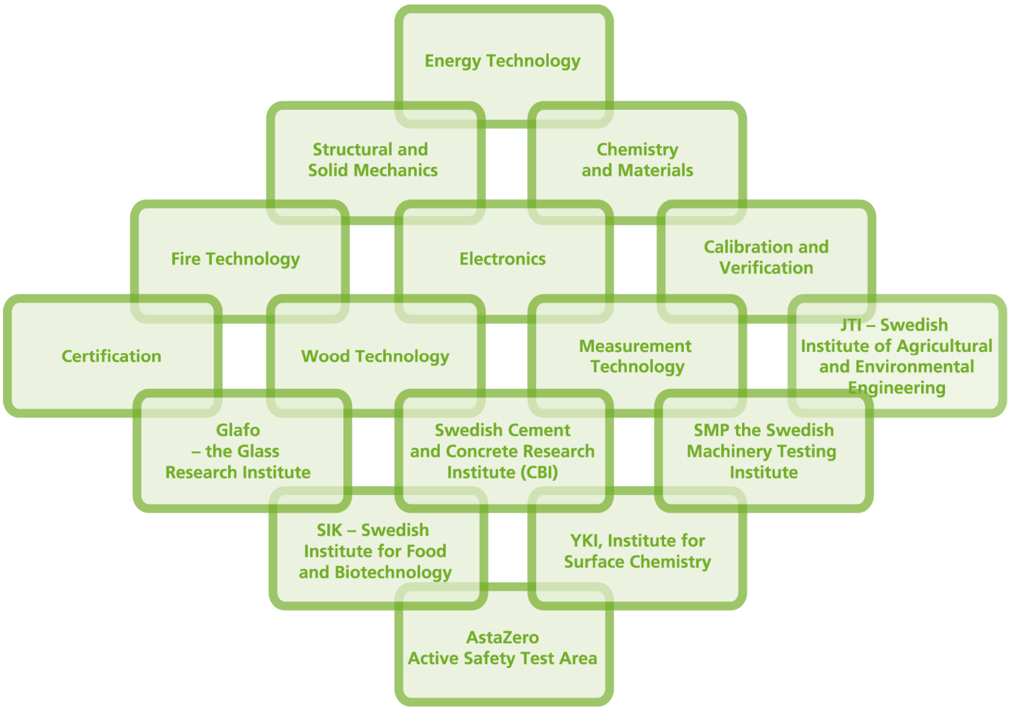

SP Sveriges Tekniska Forskningsinstitut
Box 857, 501 15 BORÅS
Telefon: 010-516 50 00, Telefax: 033-13 55 02
E-post: info@sp.se, Internet: www.sp.se
www.sp.se

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