Fire Safety Engineering of textile buildings following the prescriptive requirements in Sweden

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Abstract

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This work has been conducted within the European project contex-T, “Textile Architecture – Textile Structures and Buildings of the Future”. Contex-T is an Integrated Project dedicated to SMEs within the 6th Framework Programme and brings together a consortium of over 30 partners from 10 countries. Among the main objectives of the project is the development of new lightweight buildings using textile structures and the development of safe, healthy and economic buildings. Advantages of textile materials in buildings includes their low weight, and in the case of textile membranes, their translucency and architectural possibilities. A common disadvantage, however, is the fire properties of textile materials which highlights the importance of fire safety assessments for building application of such materials.

Prescriptive fire safety regulations which in detail describe the design and classification of building components will, for some applications, exclude the use of textile membranes that do not conform with the required fire rating. In such cases, a performance based approach to comply with the overall fire safety level of the building can be a valid alternative. The Swedish Building Regulations (BBR) presently allow both methods (i.e., prescriptive and performance based) to be used. In the contex-T project the two methods will be described and applied to textile building products, with a focus on textile membranes.

This report will describe the process of finding a fire safety solution following the prescriptive requirements in BBR and the problems a fire engineer runs into when trying to apply the method to the design of new buildings that use textile building elements, in particular textile membranes. The different regulations that apply, depending on whether the building is considered to be a temporary tent, a permanent building or whether the textile material could be regarded as furniture or interior decorations in a building, will be described. The processes of classifying a building, the requirements concerning the building and the different material and building element classes, will be explained. The requirements in some other European countries will also be described briefly .

The final part of the report presents examples of different applications of textile membranes with a discussion of valid requirements.

Key words: textile building material, fire safety engineering, prescriptive codes

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Sammanfattning

Detta arbete har utförts inom det Europeiska projektet **contex-T**, ”Textile Architecture – Textile Structures and Buildings of the Future”. Contex-T är ett ”Integrated Project” inom det 6:e ramprogrammet med ett konsortium bestående av mer än 30 partners från tio länder. Bland projektets syften ingår att utveckla nya lättviktsbyggnader av textila strukturer samt säkra, hälsosamma och ekonomiska byggnader. Fördelar med textila byggnadsmaterial inkluderar deras låga vikt och för textila membran, deras ljusgenomsläpplighet och arkitektoniska möjligheter. Men en gemensam begränsning för textila material är deras brandegenskaper, vilket understryker vikten av en korrekt brandsäkerhetsbedömning vid användande av sådana material i byggnadskonstruktioner.

Preskriptiva brandkrav som i detalj föreskriver design och brandklassificering av material i en byggnad utesluter i många fall användandet av textila membran som ofta inte klarar gällande krav vad gäller brandklasser. I sådana fall kan en funktionsbaserad branddimensionering av byggnaden vara ett alternativ. Båda dessa alternativ är möjliga i Sverige enligt Boverkets författningssamling (BBR). I contex-T projektet kommer båda dessa metoder att beskrivas och i någon mån appliceras för textila byggnads material med ett fokus på textila membran.

Denna rapport beskriver dimensioneringsprocessen man använder sig av när man följer de preskriptiva reglerna i BBR samt de speciella överväganden och problem som är specifika vid applicering av textila byggnadskomponenter och speciellt textila membran. Man tar upp de speciella reglerna som gäller beroende på om byggnaden anses vara en temporär textil byggnad (tält) eller en permanent byggnad och i det senare fallet om det textila materialet skall anses vara en del av byggnaden eller en möbel eller en dekoration. Processen för att klassificera en byggnad, kraven på byggnaden samt de olika klasserna för byggnadselement och material förklaras. Krav och regler i övriga Europeiska länder diskuteras också översiktlig i rapporten.

Den sista delen av rapporten presenterar exempel på olika applikationer av textila membran och diskuterar gällande brandkrav i dessa fall.

1 Introduction

The Swedish Building Regulations (BBR) [1], govern the fire safety of buildings in Sweden. In BBR the recommendations are presently expressed as performance based requirements which means they are described in terms of the overall safety requirements in case of the outbreak of fire. The requirements in BBR were until recently prescriptive, i.e. they described in detail the design and classification of building components (from standardized tests) without stating the expected safety level. The regulations still contain several prescriptive requirements and recommendations that builders typically choose to follow for most traditional buildings.

Prescriptive regulations will, for some applications, exclude the use of building components made of combustible textile materials that do not conform with the required fire rating. In such cases, a performance based approach to comply with the overall fire safety level of the building can be a valid alternative.

It is further important to consider the application of a textile material in a building to know what type of regulations to follow. A temporary building made of textile membranes is classified as a tent, and special national regulations are applied. If the same textile membrane is used in a permanent building, the material may be considered a building material and the building regulations apply. Other textile applications may be regarded as furniture or interior decorations in a building. A Swedish “Law concerning protection against accidents” , governs the responsibility the owner of an establishment may have concerning protection against accidents [2] and includes such materials. The Swedish Rescue Services Agency, SRV, (recently renamed The Swedish Civil Contingencies Agency) has published recommendations concerning the fire properties of furniture and other interior decorations [3].

This report will describe the process of identifying a fire safety solution following the prescriptive requirements in BBR and the problems a fire engineer runs into when trying to apply the method to the design of new buildings that uses textile building elements, in particular textile membranes. The processes of classifying a building, the requirements concerning the building, and the different material and building element classes, will be explained. A comparison with the requirements in other European countries will be made. Finally, the report will give some examples for different applications of textile building components.

Since the method described in this report is the prescriptive fire engineering method, the general performance based requirements are mentioned just briefly. The focus is on the more specific prescriptive requirements and recommendations in terms of fire rating classes on material and building components. For the fire behaviour of interior surfaces, such as wall and ceiling linings, the requirements are specified in BBR in terms of classes according to the European classification system, but also in terms of the classes according to the old national standards. In this report the old Swedish national classes and tests are omitted and only the Euroclasses and the corresponding EN standard are mentioned.

The text in Chapters 3 to 8 is mainly based on an interpretation of the text in the Fire Protection Handbook [4] (available in Swedish only) and of Boverket’s English translation of BBR [5].Information from Boverket on evacuation from buildings is further available in [6].The information in section 9 is based on literature [7] and questionnaires and interviews of the contex-T partners.

2 Background

2.1 Swedish fire safety regulations – prescriptive and analytical design

Swedish fire safety legislations, regarding new construction works, are primarily based on the Planning and Building Act (PBL) [8], the Act on Technical Requirements for Construction Works (BVL) [9] and the Ordinance on Technical Requirements for Construction Works (BVF) [10]. The Planning and Building Act states that the requirements set out in BVL must be fulfilled. The requirements of BVL are further developed in BVF. The following fundamental requirements for fire safety in construction works are found in BVF.

Construction works must be designed and built in such a way that in the event of an outbreak of fire:

1. the load-bearing capacity of the construction can be assumed for a specific period of time;
2. the generation and spread of fire and smoke within the construction is limited;
3. the spread of the fire to neighbouring construction works is limited;
4. people inside the construction works on fire can leave it or be rescued by other means;
5. the safety of rescue teams is taken into consideration.

Boverket, The National Board of Housing, Building and Planning, is authorized to publish any regulations that may be needed for application of the requirements set out in BVF. For this purpose Boverket has published Boverket’s Building Regulations (BBR) which is mainly based on the fundamental requirements in BVF. The building regulations are primarily concerned with the safety of people. This means that BBR isn’t exhaustive. The requirements for technical performance found in BBR are the lowest acceptable and it is therefore not guaranteed that cost effective protection of the property is achieved when an object is design after the requirements in BBR.

Fire safety recommendations were previously mainly prescriptive, i.e. prescribed in detail in the building regulations, and settled the design of the object without stating the expected safety level. Today Boverket has, as extensively as possible, expressed the directions in BBR as performance based requirements.

The fact that the directions in BBR are performance based allows the building contractor to choose an appropriate design method, to accomplish fire protection in accordance with the regulation. For most buildings there are two alternative methods that can be used:

- prescriptive design
- analytical design.

Prescriptive design is in principle the same method as that which was used prior to the introduction of the performance based requirements. Prescriptive design assumes that all the requirements and general advice for the object in question are set out and must be fully met. When using prescriptive design it is not allowed to make any technical exchanges in addition to those already mentioned in the advisory texts in BBR or in other documents published by Boverket. If any other technical exchanges are made, the design is considered to be an analytical (or performance base) one.

As prescriptive design is based on former building standards this design method is not appropriate when designing new types of buildings, where previous experience is lacking.

This also applies to buildings where the conditions for fire safety for any reason diverge from the norm. There are presently no general guidelines describing for which objects prescriptive design is not appropriate. This must be assessed from case to case.

The approach to fire safety is most often taken in prescriptive design, but through using different methods and solutions to a greater or lesser extent, fire protection design will change. One reason to abandon prescriptive design is that a more cost effective design might be possible through a technical exchange. An even more common reason to use analytical design is that fire safety according to standards is combined with limitations regarding for example architectural objectives or activity.

A comprehensive requirement when using analytic design is that the fire safety accomplished in a building should be as good as or better than if all the prescriptive requirements in BBR were set out to be met. A disadvantage when using analytic design is that this method requires more time and knowledge than prescriptive design.

When using prescriptive design, the requirements to verify the results are low. This design method is simple, well known and is in most cases contributes to a conservative fire safety solution. The need to verify the results is high when the starting point for the design is taken in the BVF requirements. The verification concerns the choice of method, the acceptance criteria and the way the uncertainties are managed. The extent of changes made compared to prescriptive design and the complexness of the building determines the demand for verification. When the deviations from a prescriptive design are small it is not reasonable to demand a complete safety evaluation, considering the time and resources that would be needed to make one. It is, however, necessary to study all the relevant cases that will be affected by the deviations from requirements in BBR. Otherwise it will not be possible to prove that the fire protection accomplished through the analytic design is no less than it would have been using prescriptive design.

Fire safety design most commonly begins in the program phase of the construction works. The fire safety design will result in fire protection documentation. A draft of the documentation shall favourably be ready in time for the building consultation. The main reason for this meeting is that the building committee shall be able to evaluate the expertise and work procedure of the fire safety consultant/consultants; but, it is not mandatory that all questions are settled at this time.

The new control system, which was implemented in 1995, states that it is the building contractor who has the entire responsibility regarding the properties of the building. This responsibility is managed through a control plan, which all the consultants in the building process shall follow. Generally the control plans are established by a person responsible for quality matters. This person is employed by the building contractor. Although the person responsible for quality matters often lacks sufficient specialist knowledge about fire safety, he or she usually turns to a qualified fire safety consultant. It should be emphasized that control plans do not solely consider fire safety measurements.

The correctness of fire protection description/documentation is confirmed through internal control. The control might be performed by a colleague consultant who will review the planning based on a check list. The description/documentation shall together with the fire protection drawings show that the intentions in BBR regarding fire safety are fully met. The intention of the control is not to check the fire safety design in detail, i.e. redo all the calculations. The primary reason should rather be to review the consultants' work procedure.

3 The process of using the prescriptive method

In a prescriptive fire engineering solution all requirements and general recommendations described in BBR, relevant for the building, are followed. No exceptions or alternative designs are allowed except those which are described in the general recommendations and in reports published by Boverket. To date, and in the foreseeable future, this will be the most commonly used method for traditional straight forward buildings because of the cost aspect associated with design specific fire safety engineering calculations.

In short the method is as follows: a building shall be constructed to a certain class depending on the risk of injury to persons in the event of a fire. The classification takes into account the activity for which the building is designed, the height of the building, the number of occupants and the possibilities for escape of these occupants. The class of the building then stipulates requirements concerning the building components, such as combustibility of the surface material, load bearing and insulating capacity in the event of a fire and others. The requirements concerning the building components will vary within a building depending on factors such as whether the component is located in an area that will be involved during an evacuation process or will function as a barrier to contain the fire within a certain area, a so called fire compartment. The requirements are specified in terms of different building component fire rating classes, geometrical dimensions or other design rules. BBR also contains recommendations for appropriate classification of and requirements for certain types of buildings.

The actual activities included in the process of prescriptive fire engineering often include specifying the requirements, giving suggestions or recommendations concerning solutions, and ultimately verifying that the requirements are fulfilled and providing suitable documentation of the work and the solutions. The activities to define a fire safety solution may contain the steps shown in Figure 1. The work involves not only the Owner/Purchaser, Fire Engineer Consultant and the Architect but also consultants responsible for air handling installations, VA-installations, electricity, interior design and landscaping. The flow chart shows an example of one way this process might follow, in reality the steps may be taken in another order and the work may consist of several loops or iterations before a satisfactory solution is found.

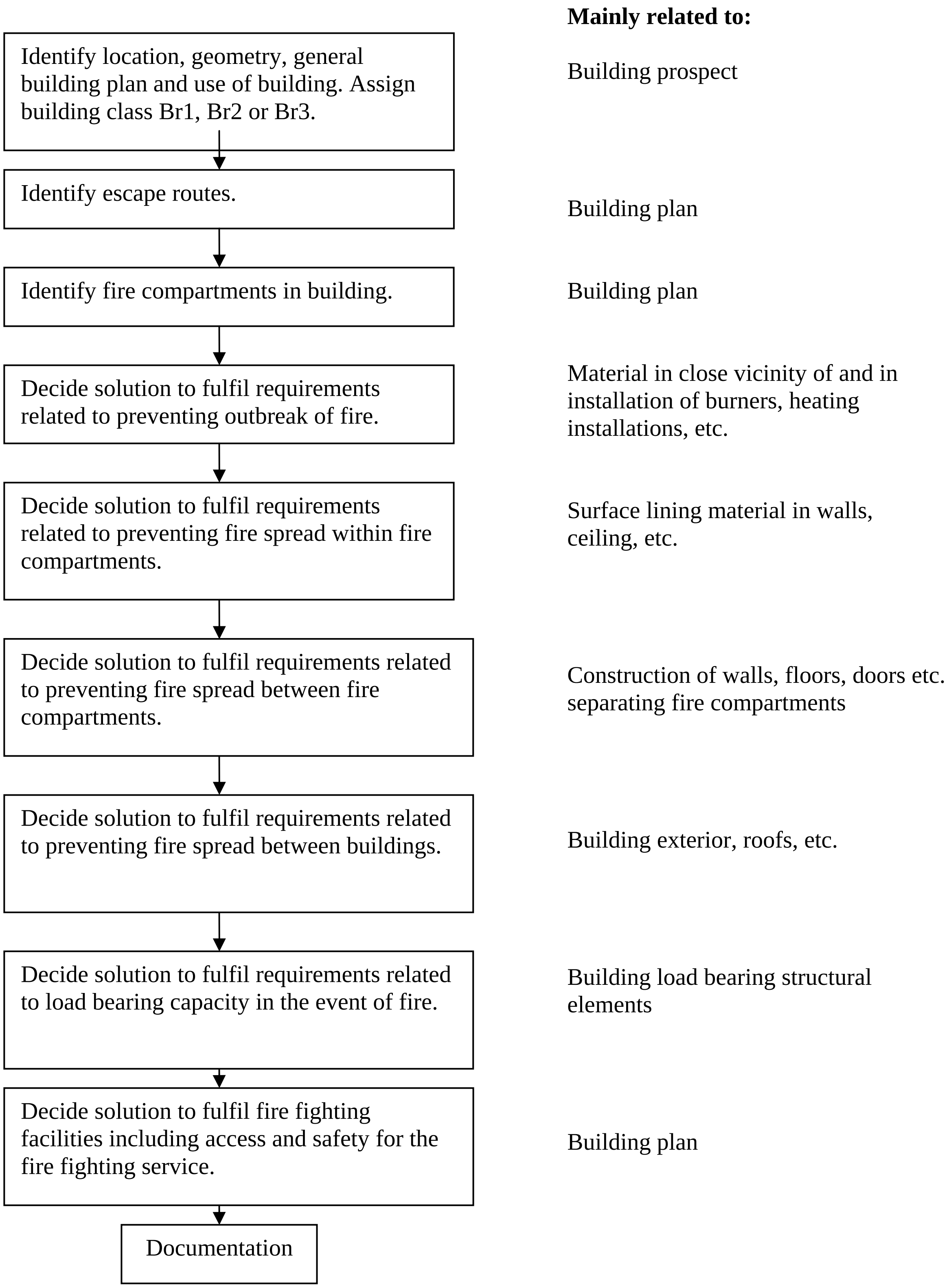


Figure 1 Steps in the process of prescriptive fire safety engineering (example). Possible applications of smoke ventilation, fire detectors and sprinklers are not included in this schematic process diagram.

4 Definitions

4.1 Fire compartments

Buildings shall be divided into fire compartments separated by structural and non-structural elements that prevent the spread of a fire and fire gases between the compartments. A fire compartment consists of a room or several rooms in which the activities inside the compartment have no immediate connection to other activities in the building.

Flats, offices, stairways, garages, hospital wards, guest rooms in hotels and escape routes are all typical examples of fire compartments. Areas in buildings with activities which represent a great risk in the event of fire shall be a separate fire compartment.

4.2 Place of assembly

A place where a large number of people who do not have full knowledge of the surroundings are assembled. Buildings such as an auditorium, cinema, church, restaurant, sports hall or department store are all examples of places of assembly.

4.3 Institutional buildings

Institutional buildings refers to buildings used for medical care, social welfare and care of persons with impaired function.

5 Building classes

A building must be constructed to a certain building class depending on the risk to people occupying the building in the event of a fire. The risk is related to the possibility for people to evacuate and the risk for personal injuries in case of a collapse of the building. A building with many storeys or occupied by people who have limited knowledge of the surroundings or limited ability to evacuate without assistance is, for example, constructed according to the highest class, Br1, while a one story warehouse typically only has to be constructed to the lowest class, Br3.

When considering the possibility for people to evacuate the following factors should be taken into consideration (at a minimum):

- The activity carried out in the building
- The number of people that may be in the building at any given time
- The number of stories of the building
- The ability of the people to evacuate without assistance.

The building classes are designated Br1, Br2 and Br3, where a building with a high risk for people to be injured in case of a fire is constructed to class Br1, a building with a moderate risk is constructed to class Br2 and all other buildings are constructed to class Br3.

BBR gives general recommendations about which class a building should be assigned. A summary of the recommendations is presented in Table 1. The class specified in the right hand column "Building class" refers to the lowest class to which the building should be constructed.

Table 1 Building classes.

No of storeys	Special circumstances	Building class
3 or more		Br1
2	Sleeping accommodation for persons who cannot be expected to have good knowledge of the premises	Br1
	Intended for persons not very likely to reach safety on their own	Br1
	Places of assembly situated on the second storey	Br1
	Intended for more than two flats and in which habitable rooms or workrooms are situated on the attic storey	Br2
	Places of assembly at ground level	Br2
	Building area greater than 200 m^2 and which are not divided into units not exceeding this size by compartment walls constructed to not less than Class REI 60-M	Br2
1	Institutional buildings except nursery schools and similar	Br2
	Places of assembly	Br2
All other 1- and 2-storey buildings with no special circumstances as listed above		Br3

6 Requirements

The requirements in a building concerning safety in case of a fire are in BBR divided into several sections depending on the objective:

- Protection against the outbreak of a fire
- Protection against spread of fire within a fire compartment
- Protection against spread of fire between fire compartments
- Protection against spread of the fire between buildings
- Load bearing capacity of the building in the event of a fire
- Escape in the event of a fire
- Fire fighting facilities.

Several requirements are design or geometrical requirements, e.g. width or number of escape routes, while others are requirements concerning equipments or a specific fire rating class of the building components. For several of the sections above, the level of the requirements varies depending on the building class, i.e. the size of the building, what activities will be conducted in the building and the expected number of occupants in the building and their familiarity with the surroundings.

6.1 Protection against the outbreak of a fire

This section contains requirements with the purpose to prevent an unintentional fire to start. The section stipulates requirements concerning the installation of, for example, heat producing appliances, burners, heating installations and flues.

The general requirements are that they should not give rise to the ignition of nearby structural elements, fixtures or fittings. The temperature of the surface of nearby components shall not exceed 85°C and heating panels or similar shall be protected against being covered. If the installations are insulated to limit the temperature there are requirements concerning the fact that the insulation should be composed of a non-combustible material.

There are also more specific requirements concerning the installation of these products, such as minimum distances and in some cases requirements in terms of classes for material and surface finishes and classes for load bearing, integrity and insulation. The classification of material and surface finishes are described in section 7.2 and the classes for load bearing, integrity and insulation are described in section 7.1.

6.2 Protection against spread of fire within a fire compartment

This is the section that will often be of greatest importance when defining building elements containing textile products, such as membranes and interior wall linings. The general requirement states that materials in structural and non-structural elements, fittings and fixtures shall have such properties that in the event of fire they do not give rise to ignition or rapid spread of fire, large quantities of heat or large quantities fire gases. They shall not melt, drip or fall down outside the immediate vicinity of the seat of fire. The stipulated class of ignition and flame spread performance for the material depends on the quantity of heat and fire gases which can be permitted to evolve in the building, i.e., the material and surface lining class is dictated by the class to which the building is assigned.

In BBR there are several recommendations for appropriate surface finish classes for buildings of different classes, escape routes and in certain types of premises. The general recommendations are listed in short in Table 2. The listed surface finish class is the lowest class recommended for the specific building class. The classification of material and surface finishes are described in section 7.2. For the sake of illustration, a wood wall typically has a class D-s2,d0 and a normal gypsum wall B-s1,d0.

Table 2 Requirements on surface lining classes.

Area	**Surface**	**Surface finish class**[1]
Building of class Br1	Wall	C-s2,d0
	Ceiling	B-s1,d0, mounted on material of Class A2-s1,d0
Building of class Br2	Wall	C-s2,d0
	Ceiling	C-s2,d0, mounted on material of Class A2-s1,d0
Building of class Br3	Wall	D-s2,d0
	Ceiling	D-s2,d0
Escape route in a building of class Br1	Wall	B-s1,d0, mounted on material of Class A2-s1,d0
	Ceiling	B-s1,d0, mounted on material of Class A2-s1,d0
	Floor	Cfl-s1
Escape route in a building of class Br2	Wall	B-s1,d0, mounted on material of Class A2-s1,d0
	Ceiling	B-s1,d0, mounted on material of Class A2-s1,d0
Escape routes in hotels and institutional buildings, or common to two or more dwellings or offices	Wall	C-s2,d0
	Ceiling	B-s1,d0
Escape routes From rooms of assembly	Floors	Cfl-s1
Institutional buildings and catering kitchens	Wall	C-s2,d0 (Class II) mounted on material of Class A2-s1,d0
	Ceiling	B-s1,d0, mounted on material of Class A2-s1,d0
In places of assembly and premises for activity which presents a fire hazard	Wall	B-s1,d0 (Class I) mounted on material of Class A2-s1,d0
	Ceiling	B-s1,d0 (Class I) mounted on material of Class A2-s1,d0
	Floor	Dfl-s1

In small structural or non-structural elements where the surface finish is of no significance for the fire development, the surface finish may be constructed to a lower class but should not be lower than Class D-s2,d0. The same applies for rooms in those cases where the surface finish does not affect the safety of escape from the building.

One requirement is of special interests for textile membranes and attachment of textile membranes. The requirement states that materials in ceilings and walls shall not be deformed when slightly affected by fire and shall not fall down or change in any other way so that the risk of injury to persons or the fire brigade increases. A general recommendation regarding the latter requirement concerns membranes used for tent

[1] Euroclasses for building products as defined in EN 13501-1, se section 7.2.

structures. It states that the material complies with the above requirements if it is made of a single layer of cloth material of low ignitability.

Special requirements for kitchen flues are specified to avoid spread of fire inside the ducts. There are also special requirements concerning pipe insulation material.

6.3 Protection against spread of fire between fire compartments

Each fire compartment shall be separated from other spaces in the building by structural or non-structural elements (including service penetrations, necessary supports, connections and similar). Dwellings or offices, stairways, garages, boiler rooms, refuse storage rooms, hospital wards, guest rooms in hotels, escape routes and large staff rooms are all examples of self contained fire compartments. Fire compartments are further described in the section *Definitions*.

The elements separating fire compartments shall be resistant to the penetration of flames and gases, and shall have such thermal insulation that the temperature on the side not affected by fire does not give rise to fire spread. The elements shall be constructed in such a way that they maintain their separating function for the period of time specified in the requirements. Involved building elements are classified based on their so called integrity (E) and insulation (I) capacity, and the time period in minutes during which they can sustain a certain fire exposure without losing this capacity, e.g. 30, 60 and 120. The fire resistance classes are further described in the section *Fire resistance classes of structural elements*.

There are different requirements depending on whether the building is assigned class Br1, Br2 or Br3. If the building is of class Br1, the so called fire load is taken into considera-tion. The fire load (MJ/m^2) is defined as the energy that would be released at a total combustion of all material in the fire compartment, including all furniture and furnishings and surface materials, divided by the total area surrounding the compartment, i.e. the sum of the area of the floor, ceiling and the four sides. Some general requirements are listed as examples in Table 3.

Table 3 Fire resistance (integrety and insulation) requirements on building elements.

Building class	**Building component**	**Fire Load (MJ/m^2)**	**Requirements**
Br1	Elements separating fire compartments in general, and floors above basements	≤ 200	EI 60
		≤ 400	EI 120
		> 400	EI 240
Br2 and Br3	Elements separating fire compart-ments in general	All	EI 30
	Elements separating flats in a block of flats	All	EI 60

Facade cladding shall not in the event of fire evolve heat and smoke to such an extent that escape and fire fighting are impeded or in such a way that there is a serious risk of injury to persons in its vicinity. The general recommendation is that the facade cladding should be of material at least of surface finish Class D-s2,d0 (Class III).

External walls in a Br1 building shall be constructed so that:

- the wall construction carries out its separating function with respect to other fire compartments (see above),
- the spread of fire inside the wall and along the facade surface is limited with regard to the purpose of the building and the fire fighting facilities,
- the risk of the spread of fire via windows is limited, and
- parts of the wall do not fall down in the event of fire. The fall of e.g. glass fragments, small pieces of rendering etc is, however, disregarded if it is considered that this will not prevent or substantially impede fire fighting, and if escape can be effected without the risk of injury to persons in the building.

Some general recommendations for external walls are as follows:

- External walls which consist only of materials of Class A2s1,d0 (non-combustible material) or are subdivided in such a way that fire inside the wall is prevented from spreading past structural elements separating fire compartments, comply with the requirements of the mandatory provisions regarding protection against the spread of fire inside the wall.
- An external wall construction which in tests is in accordance with SP FIRE 105 [11] satisfies the conditions necessary for approval, as set out in the Boverket's publication No 1993:2, Guidelines for type approval, Fire protection, complies with the requirements of the mandatory provisions regarding the spread of fire along the facade surface.
- External walls may be clad on the outside with material of not less than D-s2,d0 (Class III) if:
    - the building has no more than two storeys,
    - the cladding, irrespective of the height of the building, covers only the ground storey of the building, or
    - special measures are taken so that the total fire safety of the building is not reduced.

Examples of special measures referred to in the previous paragraph are that the building is equipped with an automatic water sprinkler installation, that there is a projecting roof above windows and doors which prevents the spread of fire, or that combustible material of not less than Class D-s2,d0 (Class III) covers only a limited part of the facade surface.

In addition to the above requirements and recommendations, there are requirements for certain elements such as window installations and air handling installations, and for special areas such as attics and glazed balconies.

6.4 Protection against fire spread between buildings

Fire spread between buildings is prevented by limiting the level of radiation to the adjacent building in case of fire. This is achieved by a sufficient distance between the buildings, the fire properties of the exposed wall or by limiting the fire by the use of fire gas ventilation or water sprinkler systems.

Roof coverings on a material of Class A2-s1,d0 (non-combustible backing) may be made of Class B_{ROOF} (T2) [12]. Roof coverings on a combustible backing shall in general be made of material of Class A2-s1,d0 (non-combustible material), but there is an exception for buildings where some spread of fire may be permitted to occur, such as on a free-standing building. Roof covering on a combustible backing may in such case be made of a combustible material of class T.

6.5 Load bearing capacity in the event of a fire

Load bearing structures shall be designed and sized so that in the event of fire there is adequate structural safety with respect to material failure and instability in the form of local, overall and lateral torsional buckling or similar deformation during a fire. Parts of the load bearing structure including supports, joints, connections etc shall be designed so that collapse does not occur during a specified period of time in accordance with the fire resistance classes for structural elements. If following the prescriptive requirements this is also relevant for textile buildings. The fire resistance classes are described in the section *Fire resistance classes of structural elements.*

After a special investigation, the consequences of collapse may in certain cases be accepted. A departure may then be made from the fire resistance classes set out in Table 4 and Table 5. Examples of such cases are eaves, balconies and ceilings which do not have a separating function.

Table 4 Fire resistance (load bearing capacity) requirements on a building of class Br1.

Type of structural element	Fire resistance class for fire load intensity *f* (MJ/m2)		
	f <200*	*f* <400	*f* >400
1. Vertical loadbearing structure and horizontal structure which provides stability for the structural frame			
a) in a building of not more than two storeys	R 60	R 120	R 240
b) in a building of 3-4 storeys			
– floors	R 60	R 120	R 240
– other loadbearing structure	R 60	R 120	R 240
c) in a building of 5 - 8 storeys			
– floors	R 60	R 120	R 240
– other loadbearing structure	R 90	R 180	R 240
d) in a building of more than eight storeys	R 90	R 180	R 240
e) below topmost basement storey	R 90	R 180	R 240
2. Horizontal structure which does not provide stability	R 60	R 120	R 240
3. Flights and landings in stairways	R 30	R 30	R 30

* Also for higher fire load if the building is equipped with automatic water sprinkler system.

For a building of class Br1 the requirements varies depending on the so called fire load. The fire load is calculated as the energy that would be released during total combustion of all material in the fire compartment (including all furniture, furnishings and surface materials), divided by the total area surrounding the compartment (i.e. the sum of the area of the floor, ceiling and the four sides). Column 1 ($f \leq 200$) in Table 4 may be applied, e.g., to dwellings and offices, schools, hotels, garages for cars, shops for the sale of food, occupants' store rooms and comparable fire compartments. Column 1 may also be applied for fire load intensities higher than 200 MJ/m^2 if the building is equipped with an automatic water sprinkler installation or if the conditions exist for a fire to be completely extinguished by the action of the rescue service not later than 60 minutes after the out-break of fire.

The load bearing capacity may be determined by fire tests according to EN 13501-2, by calculations or by a combination of both. The temperature curve could be the one specified in EN 13501-2 section 4.2, the so called standard curve, or in accordance with a design fire based on a model of a natural fire sequence.

Table 5 Fire resistance (load bearing capacity) requirements on a building of class Br2 and Br3.

Type of structural element	Fire resistance class for building of class Br2 Br3
1. Vertical loadbearing structure and horizontal structure which provides stability for the structural frame	
a) residential building	R 30 R 15
b) building other than residential building	R 30 –
c) below topmost basement storey	R 90 R 90
2. Horizontal structure which does not provide stability	
a) residential building	
b) ground floor in dwellings where there is a contiguous crawling space below the floor	R 30 R 15
c) building other than residential building	R 30 R 30
3.Flights and landings in stairway below the topmost basement storey	R 30 R 30

6.6 Evacuation in case of fire

Buildings shall be designed so that satisfactory escape can be conducted in the event of fire. Special attention shall be paid to the risk that persons may be injured by the fall of structural or non-structural elements or due to falls and congestion, and to the risk that persons may be trapped in recesses or dead ends. Satisfactory escape implies either complete evacuation of all persons who are present in a building or, as may arise in e.g. institutional buildings or very tall buildings, escape by persons who are in the part of the building directly affected by the fire to a place of safety inside the building.

BBR specifies requirements concerning dimensions and number of escape routes, requirements concerning stairways as part of an escape route and requirements concerning components such as markings, light and alarms. The section also includes critical levels for visibility, heat flux, temperature the occupants will be exposed to during evacuation to be used if a performance based analysis is conducted.

There are specific requirements on the material selected for interior lining of walls, ceiling and floors of escape routes. The requirements vary depending on the building class and are included in Table 2 in section *Protection against spread of fire within a fire compartment.*

7 Classes of building components

As described in previous sections the building class, for which the building should be constructed, stipulates requirements on the design of the building and on the construction and material of the building components. The requirements are often in terms of classes related to fire resistance of building elements or classes related to ignitibility, flame spread and smoke production of surface lining material. The different classes are described below.

7.1 Fire resistance classes of structural elements

Structural elements such as beams, columns, walls, doors, etc. are classified depending on their function regarding their ability to resist fire. The classes are defined, including criteria levels, for each type of product in EN 13501-2 [13]:

R	loadbearing capacity (ability to, under a specified load, withstand fire exposure without any loss of structural stability)
RE	loadbearing capacity and integrity (ability to withstand a fire exposure without a transmission of fire to the unexposed side as a result of a passage of flames or hot gases)
REI	loadbearing capacity, integrity and insulation (ability to withstand a fire exposure while allowing a limited transmission of heat to the unexposed side)
E	integrity
EI	integrity and insulation
EW	integrity and limited heat radiation(ability to withstand fire exposure without a significant radiated heat through the element or from its unexposed surface to adjacent material)

The above designations are followed by digits specifying a time, 15, 30, 45, 60, 90, 120, 180, 240 or 360 minutes. The time tells the time period for which the element satisfactorily shows the relevant capacity while it is exposed to a certain temperature-time curve. The temperature curve could be the one specified in EN 13501-2, the so called standard curve, or in accordance with a design fire based on a test or model of a natural fire sequence. The load bearing capacity may be determined by fire tests according to EN 13501-2, by calculations or by a combination of both.

The classes may be combined with an additional designation:

M	where special consideration must be given to mechanical action
C	for doors with an automatic closing device.
S	smoke leakage (ability of the element to reduce or eliminate the passage of gases or smoke from one side of the element to the other)

The standard EN 13501 refers to different test standards depending on the type of product. These standards in turn refer to the general fire resistance test standard EN 1363-1 [14].

7.2 Reaction to fire classes of surface lining material

Building products used for interior linings of walls and ceilings are classified according to the standard EN 13501-1 [15]. The products are evaluated regarding their reaction to fire behaviour, i.e. ignitability, burning rate, smoke generation and tendency for dripping using several test methods. The products are ranked as A1, A2 (non-combustible material) and B, C, D and E (combustible material). Class A1 has the highest requireements and is almost incombustible, while class E has the lowest.

The criteria for a certain class are different for pipe insulation products as well as for floor coverings. For these products the class designations are followed by the suffix $_L$ or $_{fl}$ respectively.

The classes are combined with classes indicating the products smoke generation and dripping behaviour as follows:

s1	the building element may only emit a very limited amount of smoke.
s2	the building element may emit a limited amount of smoke.
s3	no requirement on limitation of fire gases.
d0	burning drops or particles may not be emitted from the building element. (Not applicable to floor coverings)
d1	burning drops or particles may be emitted in a limited amount. (Not applicable to floor coverings)
d2	no requirement regarding burning drops or particles. (Not applicable to floor coverings)

Additional classes referred to in the requirements are Material of low ignitability, Roof covering class B_{ROOF} (T2)[12] and Fire protection cladding class $K_2$10/B-s,d0.

8 Documentation

The fire protection documentation shall present the fire resistance classes of the building and its components, compartmentation, escape strategy, the function of the air handling installation in the event of fire and, where relevant, a description of fire engineering installations, and control and maintenance schedule. The documentation shall further include a fire protection design plan.

9 Prescriptive regulations in Europe

Below follows a short description of the situation in some European countries. The text is based on information from contex-T partners in form of interviews and questionnaires, complemented by information from literature[7]. Consequently the countries covered below are limited to the countries in which partners responded to the questionnaire. A summary of the questionnaires is reported in the contex-T report *A summary of fire regulations, requirements and test methods for technical textiles used in buildings* [16].

9.1 Germany

Building material is classified according to DIN 4102. Part 1 concerns reaction to fire behaviour of materials and Part 2 relates to resistance to fire of structural parts. In short, for surface linings, class A2 (non-flammability) is required for public buildings and B1 for private buildings. According to the questionnaires B2 may be sufficient for textile membranes, but it is not clear for what type of building.

The classification procedure consist of several tests, e.g. a furnace test and a calorific potential test for class A1 and A2 and a small flame test for class B. The test program does not include the European SBI (EN 13823) test, instead a “Brandschacht” test is used and thus the classes are only partly comparable with the classes of the European classification system.

The PVC/PES, Silicon/glass-fibre and PTFE/glass-fibre membranes tested in contex-T WP1.7 have a B1 class according to the manufacturers.

As an alternative to national tests, large scale fire tests and/or computational modelling could be used to show the fire safety performance is satisfying. Full scale testing of membranes have been conducted for several station roofs and for the covering the roof of the Reichstag building in Berlin.

9.2 France

In France, a decree of 21 November 2002 (JO of 31 December 2002), relating to the fire behaviour of products for building construction and decoration, introduced the Euroclasses according to EN 13501-1. Parallel to the Euroclass system the national “M” classification system is still in use particularly for products such as furniture, curtains, etc that are not covered by product standards.

In the decree one distinguishes between 2 categories of materials:

1. Building construction products.
2. Decorative/furnishing materials or materials not covered in the above category.

Building Construction Products

Category 1 is any product which is manufactured with a view of being incorporated in a lasting manner in any work of construction, which covers both buildings as such but also civil engineering works. Examples of building construction products are floor coverings, stretched ceilings, thermal insulation products, etc. The classification of the Building Construction Products is done according to the European standard of classification EN 13501-1 (classification A1, A2, B, C, D, E and F).

Decorative/furnishing materials (or materials not covered in the first category of products)

In contrast, the second group of products are decorative/furnishing materials or materials that are not being subjected to the harmonized standard and uses the “M” fire reaction classification system NF P 92-507 (classification M0, M1, M2, M3 and M4). It is to some extent the equivalent to the European standard EN 13501-1.This concerns (among others) furniture, blinds, curtains, net curtains, hangings, wallpapers, etc. There are no product standards concerning these products.

The principal testing standards are:

- NF P 92-501: Radiation test (Epiradiator) for rigid materials or flexible material thicker than 5 mm.
- NF P 92-503: Electrical burner test for flexible materials.
- NF P 92-506: Test for flooring for carpets, floor coverings
- NF P 92-504: Flame persistence and rate of spread of flame test for fusible materials.
- NF P 92-505: Dripping test for fusible materials.

The classification of rigid materials or flexible materials thicker than 5mm is made based on the results of the tests carried out according to the testing standard NF P 92-501 (epiradiator) with complementary tests NF P 92-504 and NF P 92-505 for fusible materials [M1, M2, M3, M4 classification].

For flexible materials with a thickness less than or equal to 5 mm, the criteria of classification are defined starting from the results obtained according to the testing standard NF P 92-503 (electric burner) with complementary tests NF P 92-504 and NF P 92-505 for fusible materials. An M0 classification requires the determination of the HCV (Maximum calorific value) according to the testing standard EN ISO 1716 (Heat of combustion).

The only textile products concerned with the directive for building construction products (DPC) are:

- Stretched ceilings: product standard EN 14716
- Wall coverings into lay (wallpapers, cork...): draft product standard EN 15102 in project (not yet EC marking at the moment)
- Textile floor coverings (Pile carpets or moquette): product standard 14041

According to the questionnaire answered by the contex-T members, textile membranes to be used in most building applications require a class M2.

The PVC/PES membranes tested in contex-T WP1.7 have an M2 class according to the manufacturers.

9.3 Belgium

Classification and testing of the fire performance of building materials are described in the Basic Standards (KB 7/7/1994, modified by KB 19/12/1997). In this standard building materials are divided into five classes, A0 to A4, depending on their combustibility. The system relates to the standards ISO 1182 (non-combustibility furnace test), the French standard NF P 92-501 (radiation or epiradiator test) and NF P 92-504 (rate of spread of flame test) and to the British standard BS 476 part 7 (lateral spread of flame test).

There are no product standard or specific regulations concerning membranes. The requirements are often in terms of and in line with the French and the German system.

Euroclasses are not yet used in Belgium but the regulations is expected to be adapted to the European classification system in the near future.

9.4 Spain

In Spain the requirements are in terms of the classes defined in UNE 23-727, reaction to fire of building materials, class M0-M4. The classification is mainly based on the test method UNE 23-723, an electrical burner test for building material up to a thickness of 5 mm. M0 is a material with the highest fire performance, while a M4 is a material with high flammability and “Not Classifiable”. For building materials in general, M2 is required for outside application and M1 or M2 for inside applications.

The PVC/PES membranes tested in contex-T WP1.7 have an M2 class according to the manufacturer.

The European classification system is not used today although in some cases for textile architecture it is taken into account.

9.5 Italy

Classification criteria for building material is specified in UNI 9177. For textile membranes normally Class 1 is required. For tent structures, such as show or circus tents, or similar buildings and for air supported structures for sport activities sometimes Class 2 is required. The classification is mainly based on a small flame test basically similar to EN ISO 11925-2, UNI 8456, and a spread of flame test, UNI 9174.

The PVC/PES membranes tested in contex-T WP1.7 have a B1 class according to the manufacturers.

The European classification system is not used today but the intention is to adopt it in the future.

10 Application examples

Below follows some examples of different textile building products and evaluations based on the strict prescriptive requirements in BBR. The purpose of the examples is to show the problems that can arise when applying this method to a building with textile components. The photos are to exemplify the textile building component, most are taken outside of Sweden and the fire safety requirements on the buildings are unknown to the authors.

10.1 Curtains, draperies, carpets, throw rugs

Interior decorations such as furniture, curtains and throw rugs, are known to be the potentially most important factor in the initialization phase of most building fires. At the same time such items are in most cases not considered a part of the building and are therefore not covered by BBR. SP has recently published a report which in detail accounts for the Swedish regulations and fire safety issues regarding interior decorations, furniture and fittings [17].

Figure 2 Examples of furniture and textile wall decorations.

There is a distinction between stationary and movable interior details, furniture and fittings in BBR. Interior details that are fitted permanently to the building are considered as stationary items and are treated as part of the building and are thus covered by BBR. All content of the building that can easily be removed or displaced in the building is not covered by BBR. As an example, textile membranes mounted for sun protection in a greenhouse is considered as a part of the building. Examples of typical movable interior details are shown in Figure 2.

Large textile wall-coverings and/or tapestries covering a large area of a wall may, when the prescriptive fire safety solution is used, be considered as a wall surface lining material. In that case it must comply with the BBR requirements in Table 2. It may also be considered as being interior decoration, i.e. not a part of the building. For these types of products there are no recommendations in BBR. However, a Swedish law regarding an owner's (of an establishment) responsibility concerning protection against accidents[2] governs this area. The owner is responsible to take necessary actions to prevent an out-break of a fire and to minimize the damage caused by a fire. The Swedish Rescue Services Agency, SRV, (renamed The Swedish Civil Contingencies Agency 2010) has published guidelines for recommended actions. The actions include ongoing systematic work on the overall fire safety level of the building and covers both management and technical solutions, such as furniture and furnishings, the conditions of the escape routes and fire fighting facilities. The work should continue during the whole lifetime of the building.

SRV has also published a guideline for fire properties of furniture and other interior decorations[3]. The guideline states that lining material on walls and ceilings shall be designed to minimize the risk of flashover and spread of smoke. Unfixed or fixed interior decorations must not reduce the safety level of the building obtained by the building regulations.

Regarding hanging textiles, SRV emphasizes the risk they generate if they cover a large section of a wall with certain fire resistance requirements. A smaller covering area could constitute the same risk if it is placed in an area such as an escape route. The risk should be evaluated based on the effect on the ability to evacuate people and the contribution to the radiative heat. These are performance based considerations but the document also lists some useful test methods and performance criteria levels for hanging textiles for several different environments:

- EN 13773 Textiles and textile products – Burning behaviour – Curtains and Drapes – Classification scheme
- EN 1101 Textiles and textile products – Burning behaviour – Curtains and Drapes – Detailed procedure to determine the ignitability of vertical oriented specimens (small flame)
- EN 1102 Textiles and textile products – Burning behaviour – Curtains and Drapes – Detailed procedure to determine the flame spread of vertical oriented specimens
- EN 13772 Textiles and textile products – Burning behaviour – Curtains and Drapes – Measurement of flame spread of vertically oriented specimens with large ignition source
- NT Fire 043 Full scale test method for large textile curtains and drapes

Wall-to-wall carpets will be regarded as floor coverings and hence be covered by the prescriptive requirements for floors in BBR.

<u>Example 1</u>
A restaurant owner wanted to decorate a wall separating a dining room from the larger dining area. The owner wanted to decorate the wall with large draperies. The require-ments on the wall and ceiling linings without draperies were B-s1,d0. Many questions

[2] Lagen om skydd mot olyckor (2003/778)

arose concerning the fire performance requirements on the draperies. According to the SRV recommendations the draperies should not decrease the fire performance of the wall. What requirements should be used for the drapery alone? Is there a useful test method to compare the fire performance of the drapery to the wall? Must performance base fire engineering method be used here?

Example 2
A Swedish school was intending to purchase stage draperies for a large auditorium. Both the fire consultant and the rescue services agreed that the recommendations in the SRV publication were appropriate in this case and in particular some requirements based on the test method NT Fire 043. Later it turned out that at that time no suitable draperies, tested according to this method, were available on the market.

Example 3
The fire safety solution for an opera house in Stockholm required all textile material used in the decorations on stage to be fire retardant treated. However, the fire protection documentation did not specify the minimum criteria level for resistance to ignition or flame spread.

10.2 Detached textile ceiling in atrium

A large detached textile ceiling in, for example, an atrium may be regarded as a ceiling that must comply with the requirements of BBR or as a part of the interior decoration and therefore be covered by the SRV recommendations. An important factor would be how large a percentage of the total open area is covered by the ceiling. If the ceiling is relatively small and temporary, equivalent to a horizontal sun blind, it may be considered to be an interior decoration. The recommendations for interior decorations are discussed in section 10.1.

School in Bobinen, Germany

Figure 3 Example of detached ceiling.

Suppose a relatively large and permanent, detached ceiling is present in an atrium in a three storey building. Since the building is three storeys the requirements of a Br1 building will be applicable. If the building must comply with the prescriptive requirements in BBR the ceiling must:

- Be of a class at least B-s1,d0 mounted on A2-s1,d0.
- Not melt, drip or fall down in areas that may be occupied by people.
- Not obstruct the fire gas ventilation or aggravate activation of alarm or effect of sprinkler systems.
- If the area below is a part of an escape route the requirements will be higher.

As seen above, BBR assumes the ceiling has a surface material mounted on a backing material. There are no prescriptive requirements or recommendations in terms of surface lining class for a thin ceiling material not mounted on another material.

10.3 Textile walls

10.3.1 Large draperies functioning as a room dividers

There are no general recommendations in BBR concerning large draperies functioning as a wall dividing a room into several smaller rooms. If the drapery is considered a wall as a part of the building the prescriptive requirements are as follows:

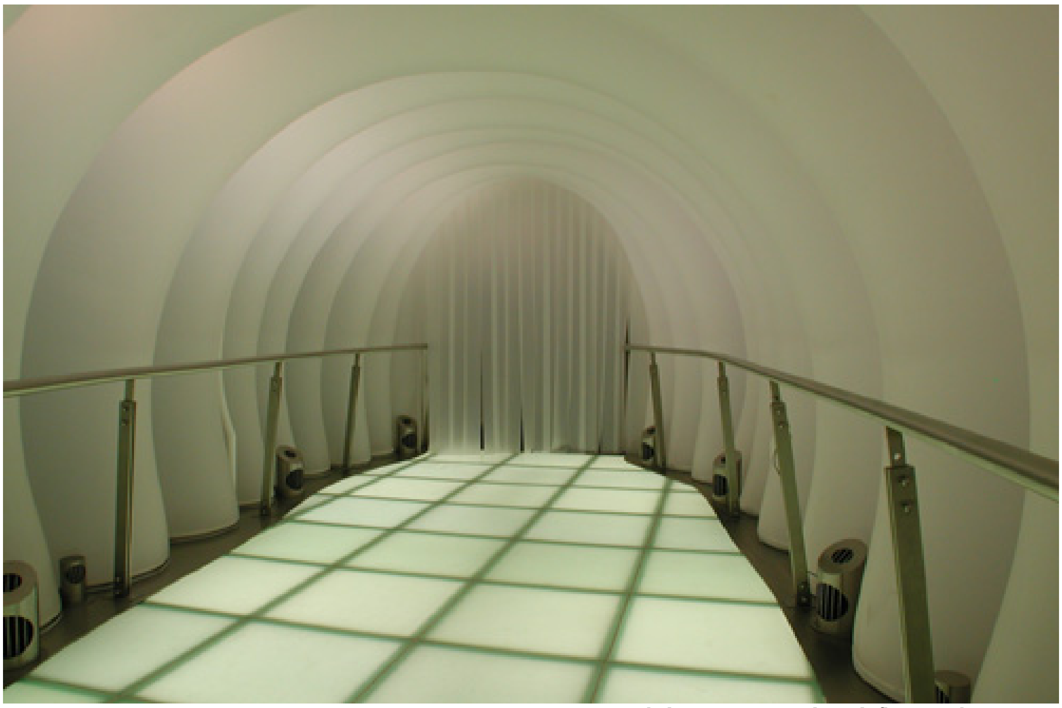
- For a place of assembly be of a class at least B-s1,d0 mounted on A2-s1,d0.
- For an institutional building or a catering kitchen be of a class at least C-s1,d0 mounted on A2-s1,d0.
- For a Br1 building be of a class at least C-s2,d0.
- For a Br2 building be of a class at least D-s2,d0.
- For a Br3 building be of a class at least D-s2,d0.
- No melting and dripping in areas that may be occupied by people before and during evacuation.
- Not obstruct the fire gas ventilation.
- If it is a wall of an escape route the requirements will be higher.

As for the detached ceiling, some prescriptive requirements assume the walls to consist of a surface layer mounted on a backing material.

The level of fire safety of large draperies in buildings are often demonstrated using a large scale tests, NT FIRE 043 [[18]].

<u>Example 4</u>
In the same opera house as in the example above the stage and the auditorium must be separated into two fire compartments in case of a fire. This is not possible with the original stage drapery. Instead it is achieved by an E60 rated iron curtain that will be descended at the front of the stage in case of a fire.

10.3.2 Inner walls consisting of textile membranes, permanent or non-permanent

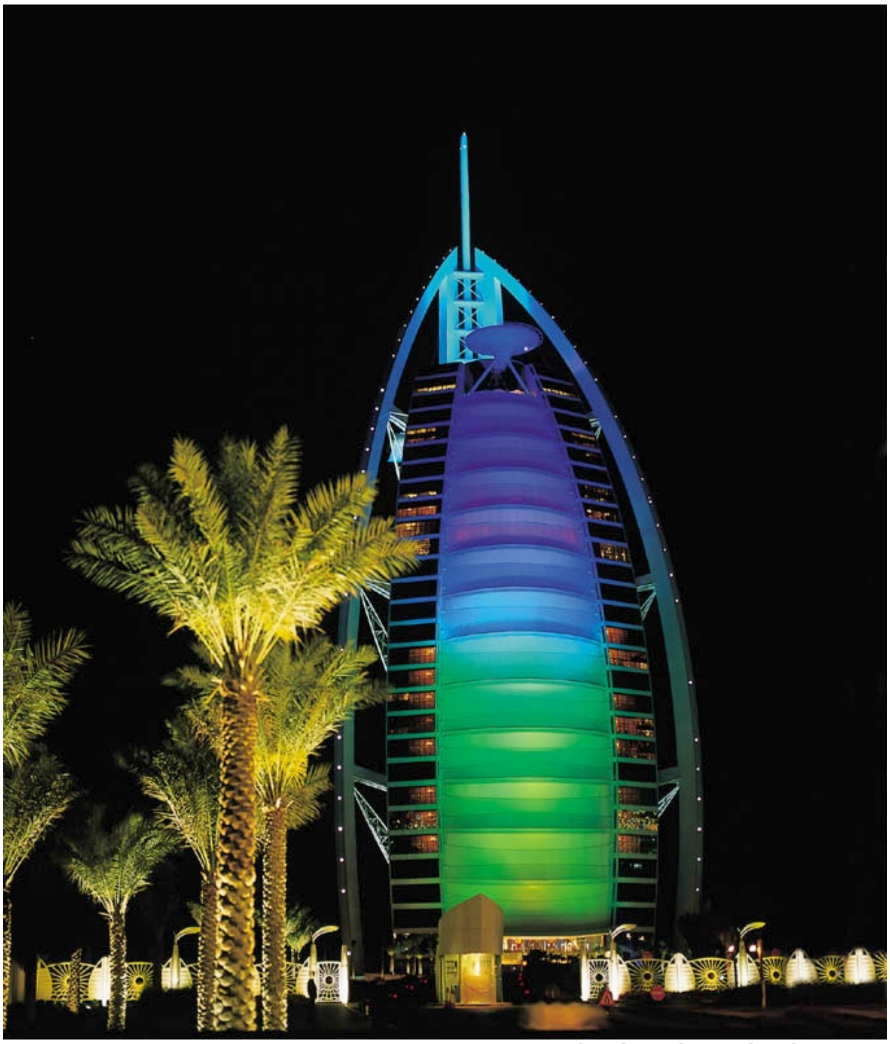


Nebelgang at Autostadt Wolofburg GmbH, Germany

Figure 4 Example of textile inner walls.

As for the case with a drapery there are no special prescriptive requirements in BBR for these building components. Most likely they would be considered as a part of the building and therefore the requirements listed in section 10.3.1 would be applicable.

10.3.3 External walls

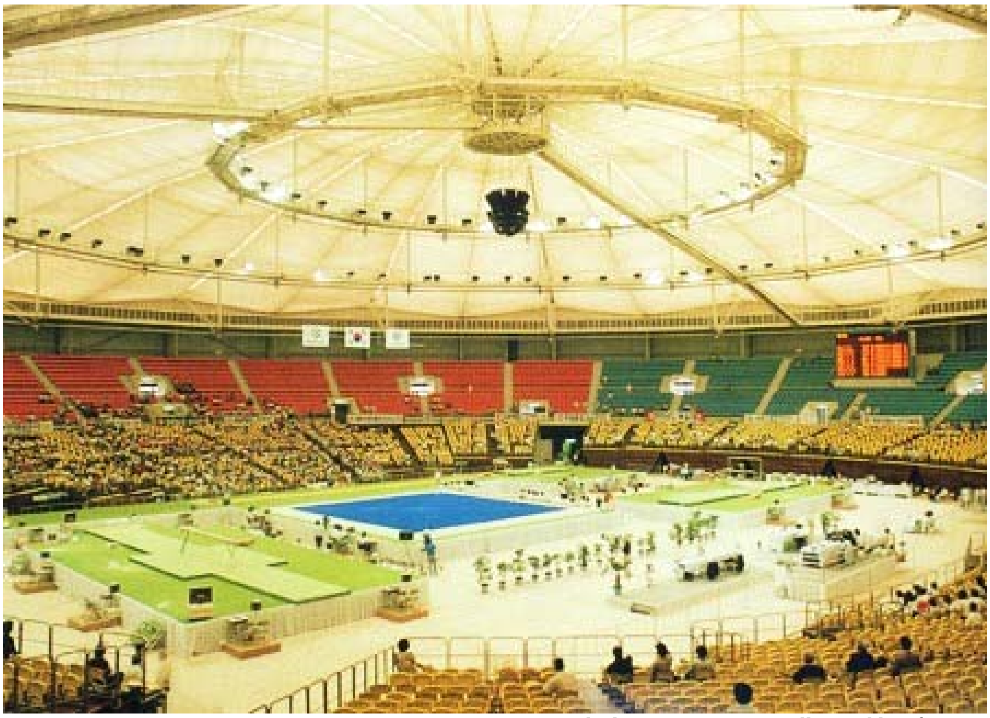


Burj Al Arab Hotel, United Arab Emirates

Figure 5 Example of textile membrane outer walls.

An external wall constructed by textile membrane shall, if it must fulfil the prescriptive requirements, be of at least surface finish class Class D-s2,d0. If the wall has a fire separating function, which most external walls have, it shall have an integrity and insulating capacity corresponding to at least class EI 30. There are several more severe requirements in the case pictured above if it is a Br1 building. Furthermore, the inside of the membrane must comply with the general requirements for surface lining material of walls as mentioned above under 10.3.1.

10.4 Roof construction with textile membranes



Seol Olympic Gymnastic Hall, Republic of Korea

Figure 6 Example of roof construction of textile membranes.

If a roof construction consisting of textile membranes is required to comply with the prescriptive requirements, the outside of the roof must be considered a roof covering that should fulfil the requirements to prevent fire spread between buildings and the inside of the membrane must fulfil the requirements for preventing fire spread within a fire compartment.

The BBR requirements about preventing fire spread between buildings states:

- Roof coverings mounted on a material of Class A2-s1,d0 (non-combustible backing) may be made of Class B_{ROOF} (T2).
- Roof covering on a combustible backing shall be made of material of Class A2-s1,d0 (non-combustible material).
- In detached/semidetached houses and other buildings in a residential area outside a concentrated town centre development and on free-standing buil-dings, roof covering of Class B_{ROOF} (T2) may also be used on a combustible backing. This exception is also allowed on a building in a concentrated town centre development if the building has a certain type of attic construction.

The requirements related to preventing fire spread within a fire compartment are the same as listed in section 10.3.1.

10.5 Temporary tent

Figure 7 Example of a temporary tent structure, a circus tent.

Tents for assembly for more than 150 people [19] or larger than 50 m^2 [20] that are temporary and therefore not governed by the building regulations must be inspected and approved according to the guidelines of the Swedish Rescue Service Agency [21]. The approval requires the tent membrane to be of a “material difficult to ignite” according to a small scale ignition and flame spread tests, SIS 650082 [22] if thickness < 3.5 mm or NT Fire 002 [23] if the thickness > 3.5 mm, or equivalent confirmed by a full scale fire test (e.g. according to SP Method 2205 [24]).

No tent membrane thicker than 3.5 mm has yet been tested and evaluated in Sweden. A material consisting of two layers of membranes with insulation or an air gap in between is not suitable to test according to the small scale test method NT Fire 002 and a large scale fire test, such as SP Method 2205, would therefore be required.

10.6 Permanent textile building with walls and roof of textile membranes

Chemical Research Centre in Venafro, Italy

Figure 8 Example of permanent building with wall and roof construction of textile membranes.

The requirements will be all of those specified in section 10.3.1 for the inner walls, section 10.3.3 for the external walls and 10.4 for the ceiling and roof.

11 Application to existing membranes tested in contex-T during 2007-2008

Textile membranes of common types available on the market today, have been evaluated and tested as a part of WP 1.7 of contex-T. The membranes were tested early in the project and have not been developed within contex-T. To investigate how useful they would be in the application examples above, a preliminary classification of the material were conducted and a comparison with the requirements in the application examples was made.

The materials were: four membranes with polyester fabric and PVC coating of different thickness, and two membranes with glass fiber fabric, one coated with silicone and one with PTFE. The materials are listed in Table 6. The membranes are further described in the report *Fire tests with textile membranes on the market – results and method development of cone calorimeter and SBI test methods* [25].

Table 6 Membranes tested.

Textile membrane	Fabric	Coating	Thickness (mm)	Mass per unit area (g/m^2)
PVC 1	100% PES 1100 dtex	PVC, fire retarded “M2-quality”	0.5	640
PVC 2	100% PES 1100 dtex	-"-	0.6	720
PVC 3	100% PES 1100 dtex	-"-	0.8	1070
PVC 4	100% PES 1670 dtex	-"-	1.1	1290
Silicone	“glass fibre”	“silicone”	1.0	1270
PTFE	-"-	“PTFE”	0.7	1150

The test data and the resulting preliminary classification are presented in Table 7. As is seen in the table the two membranes consisting of glass fibre fabric coated with silicone or PTFE performed to a class A1, A2 or B. A distinction between theses classes requires results from additional types of tests, that have not been conducted within the contex-T project. The 1.1 mm thick PVC membrane received a D class while the three thinner PVC membranes performed to a C class. There were no flaming particles or droplets outside the allowed area, consequently they all got a d0 class. The silicone and PTFE membrane got a s1 class for smoke due a very small amount of smoke were generated. The PVC membranes generated more smoke, the three thinner PVC membranes corresponding to an s2 class and the thicker one corresponding to an s3 class.

Table 7 Test results and preliminary classification.

Textile membrane	EN 13823							EN ISO 11925-2		Preliminary classification acc to EN 13501
	Average* $FIGRA_{0.2MJ}$ (W/s)	Average* $FIGRA_{0.4MJ}$ (W/s)	Average* THR_{600s} (MJ)	Average* SMOGRA (m^2/s^2)	Average* TSP_{600s} (m^2)	Flames reached edge specimen (Yes/No)	Flaming droplets/ particles (Yes/No)	Flame reached 150 mm (minimum) (s)	Ignition of paper (Yes/No)	
PVC1	321	165	1.5	169	146	No	No	23	No	E
PVC2	340	210	1.3	145	136	No	No	26	No	E
PVC3	241	187	1.7	93	150	No	No	-	No	C-s2,d0
PVC4	381	376	5.5	147	366	No	No	-	No	D-s3,d0
Silicone	0	0	0.9	0	35	No	No	-	No	A1/A2/B** -s1,d0
PTFE	0	0	0.1	0	13	No	No	-	No	A1/A2/B** -s1,d0

* Average based on two tests instead of the three stipulated in the standard.
** To obtain a class A1 or A2 compliance with additional tests are required.

Detailed descriptions of the tests and mounting methods used during the tests are presented in the test report. The SBI data are taken from the tests where the sample materials were mounted with a metal bar as a support in the corner. This is the recommended mounting method in the test report. The classification is described as preliminary due to the fact that only two SBI tests of each material were conducted instead of the stipulated three tests.

A comparison with the requirements in the application examples shows that provided the silicone and PTFE membranes were classified to at least a A2-s1,d0 class (i.e. passing the additional tests) they could be used as ceiling, roof or inner walls in all types of buildings mentioned above, also in areas designated as escape routes. If it receives a class B-s1,d0 and it is accepted that the wall or ceiling consists of a thin single layer of material (not required to be mounted on a A2-s1,d0 backing material) the membranes could still be used in the wall and ceiling applications. For the roof application it requires additional tests to see if it will be classified as Class B_{ROOF} (T2). For an external wall the combustibility, smoke and dripping properties are sufficient, but it needs an integrity and insulating capacity corresponding to at least class EI 30 if it is a wall of a fire compartment which most external walls are.

The PVC membranes cannot be used as detached ceilings or as walls in places of assembly. Assuming it is accepted that the wall or ceiling consists of a thin single layer of material (not required to be mounted on a A2-s1,d0 backing material) the PVC1, PVC2 and PVC3 membrane can be used as walls in all types of buildings except in places of assembly, institutional buildings, catering kitchens and escape routes in Br1 and Br2 buildings. For the roof application a roof classification investigation is required.

PVC4 cannot be used in any of the wall, ceiling or roof applications due to its propensity to generate to large amounts of smoke.

For the application example of a temporary tent all membranes require additional tests to be conducted, see under the example *5. Temporary tent*.

12 References

[1] Swedish Building Regulations (BBR), published by the Swedish National Board of Housing, Building and Planning (Boverket), Boverkets Författningssamling.

[2] Regulation concerning protection against accidents, “Lagen om skydd mot olyckor” (avaiable in Swedish only), 2003:778.

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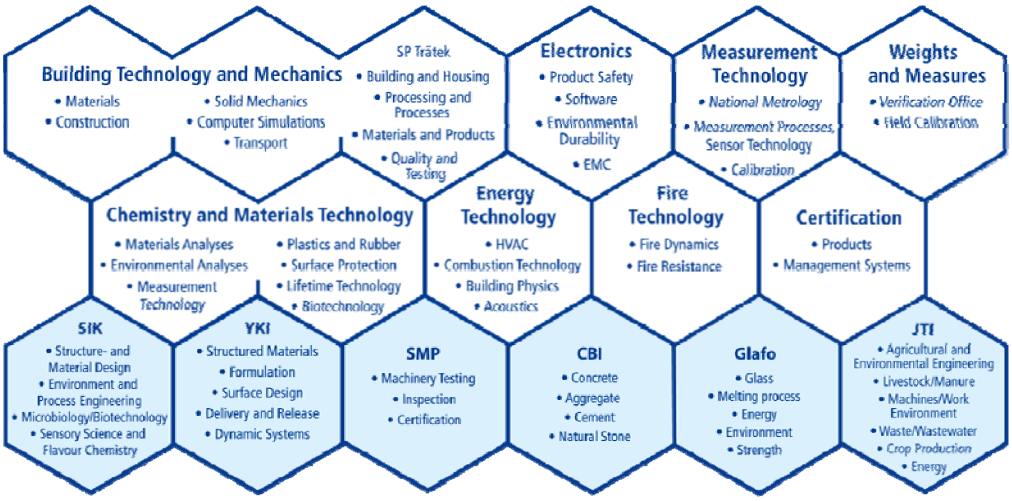

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