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The Swedish National Board of Housing, Building and Planning’s general recommendations 2011:xx on analytical design of fire protection for buildings

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1 Introduction

This statute contains general recommendations on Chapter 8(9) and Chapter 10(6) of the Planning and Building Act (PBA), Chapter 3(8) of the Planning and Building Ordinance (PBO) and Section 5 of Boverket's (National Board of Housing, Building and Planning) Building Regulations (BBR).

1.1 Analytical design

According to BBR 5:112, analytical design shall be applied if the building is not constructed with a simplified design. A simplified design according to BBR 5:111 means that the building's design follows the general recommendations in the BBR. For modifications to the building according to BBR 5:8, analytical design shall be applied if there are any deviations from the regulations or general recommendations in Sections 5:2-5:8. Analytical design allows for more flexible fire protection solutions. The general recommendations for analytical design contain rules and methods, design criteria and design requirements.

The design of the building's fire protection is selected by the client and the verification includes testing to ascertain whether the fire safety is satisfactory. For new buildings, the fire protection is tested by ensuring that all the regulations in BBR Section 5 are satisfied. BBR Section 5:8 shall be applied to building alterations.

Only analytical design is appropriate under BBR 5:22 for buildings in building class BR0.

General recommendations:

The general recommendations in this statute can be used to verify analytical design in accordance with BBR Section 5:112. Verification according to analytical design covers the regulations that are not satisfied according to a simplified design. For verification, particular attention should be given to the building's fire protection from a holistic perspective.

Where applicable, this statute can be applied for verification of fire protection for modification of a building according to BBR Section 5:8.

Where applicable, this statute can be applied for verification of load-bearing capacity in the event of fire according to a model of natural fire progression or for deviations from the general recommendations according to EKS Section C 1991-1-2.

2 The design process

General recommendations:

Analytical design should include a description of what shall be analysed, how it shall occur and what is regarded as adequate fire safety.

The following steps should form part of the analytical design of buildings' fire protection:

- Identification of the verification requirements

- Verification of adequate fire safety

- Control of verification

- Documentation of the fire protection design

2.1 Identifying verification requirements

It follows from BBR Section 5:112 that all regulations that are not satisfied with simplified design in accordance with the general recommendations in BBR 5:2-5:7 shall be verified with analytical design.

General recommendations:

For identification of the verification requirement, deviations from simplified design should be clarified to indicate which parts of the building’s fire protection are affected by the change. Table 1 can be used as an aid. Deviations from the general recommendations in Section 5:2 should be taken into account by linking them to the relevant requirements in 5:3-5:7.

For load-bearing capacity in the event of fire, deviations from the general recommendations in EKS Section C 1991-1-2 should be identified.

Table 1 Matrix to identify deviations from simplified design (SD).

Part of the fire protection		Deviations from simplified design							
		Deviation				Addendum			
		1	2	3	4	1	2	3	4
5:2	Fire resistance classes and other preconditions								
5:3	Possibilities for evacuation in the event of fire								
5:4	Protection against the occurrence of fire								
5:5	Protection against fire and smoke spread within the building								
5:6	Protection against fire spread between buildings								
5:7	The possibility of rescue operations								
EKS Section C 1991-1-2	Load-bearing capacity in the event of fire								

2.2 Verification

Verification refers to all work intended to demonstrate that the building complies with society’s requirements for fire protection when an analytical design is used. This means that the analyses carried out in a satisfactory manner constitute a basis which shows that the goal of fire protection has been satisfied.

The verification usually starts with the identification of scenarios based on the building's conditions and risks. For some simple cases of verification with qualitative assessment, however, the step of identifying scenarios may be omitted. The identified scenarios are used to test that the fire protection is adequate. The scenarios referred to in the general recommendations can, for example, be seen as different locations within a building where a fire that could represent a stress on the building could occur. At these locations, the so-called required fire scenarios can then form a quantitative description of these fires.

The simplest method of verification is the qualitative assessment, which means that the fire protection can be verified only by using logical reasoning or other evidence. Qualitative assessment can only be applied if the choice of design only deviates to a limited extent from a simplified design, or if the fire protection comfortably meets the requirements by a good margin. If the deviations are greater or if, for other reasons, there is a need for a more comprehensive verification, scenario analysis or quantitative risk analysis may be applied.

If several technical changes are implemented simultaneously, a separate assessment of robustness will be required. An example of when this is required could be when a technical system is added to the fire protection at the same time as several departures are made simultaneously.

Verification methods other than those indicated in the general recommendations may be used. Models have different areas of validity and particular caution should be exercised when employing a combination of different methods.

General recommendations:

The verification should include a risk identification in order to identify relevant scenarios that represent a stress on the building's fire protection. These scenarios should be chosen based on the risk level for each scenario, i.e. the likelihood and the consequences of this scenario occurring.

For each regulation, the developer should demonstrate how the requirement is satisfied on the basis of its intended use. The verification should pay particular attention to how the requirement can be maintained throughout the economically viable lifetime of the building.

For example, if several technical replacements are implemented simultaneously, a special appraisal of the robustness of the building's overall fire protection should be conducted. In the appraisal of the building's overall fire protection, therefore, further scenarios in addition to those listed in each section should be considered in order to test the robustness. The appraisal can form part of the sensitivity analysis.

2.2.1 Verification with qualitative assessment

Verification with qualitative assessment may only be applied if the deviations from the simplified design are limited. This applies even if the effect of the design on fire safety is well known, and if the design comfortably conforms to the requirements, then verification with qualitative assessment can also be applied.

The qualitative verification is also covered by the general recommendations on documentation and verification as provided in Section 6.

General recommendations:

Limited deviations means that the impact on fire safety is small and that the uncertainties of the chosen design are small. The point of departure for qualitative

assessment should be the risk identification that forms the basis for the analytical design.

Verification with qualitative assessment can be based on logical reasoning, statistics, proven solutions, testing, item-specific trials, basic calculations, etc. Verification on the basis of past experience should be checked with regard to whether the risks and preconditions have changed over time.

2.2.2 Verification with scenario analysis

A scenario analysis assumes that the building's fire protection is subjected to stresses described as a series of scenarios that are derived from the risk identification. These consist of various combinations of required fire scenarios and other possible preconditions in the building. The verification demonstrates that the acceptable exposures are not exceeded in any of the design scenarios. Examples of preconditions that may be included in the development of scenarios are blocked escape routes in an analysis of opportunities to escape, or the effects of wind in an analysis of fire spread between buildings.

There are different types of required fire scenarios depending on the type of problem to be verified. Depending on the design of the building, it may also be the case that not all required fire scenarios are relevant, and there may be other scenarios that are considered more relevant than those specified in the general recommendations. Such scenarios may also occur as a result of several technical changes being implemented simultaneously.

General recommendations:

Verification with scenario analysis should assume that the building's fire protection is exposed to one or more scenarios. The selection of the scenarios should be based on the risk identification, given that the preconditions and the stress itself may vary. Required fire scenarios should be identified and justified so that they form a plausible worst-case stress. The exposure should be acceptable for all design scenarios. Verification with scenario analysis can be based on the methods and the levels for acceptable exposure as specified in Sections 3-5 or equivalent.

Verification with scenario analysis should include a sensitivity analysis to identify variables that have a major impact on safety levels. Such variables should be treated conservatively. Examples of variables that could be included in the sensitivity analysis are heat release rate, flame temperature, the walking speed of persons being evacuated and people's distribution between different escape routes. The variables for which values are provided in the general recommendation in Sections 3-5 do not normally have to be analysed for sensitivity.

The results of the sensitivity analysis should be included in an assessment to determine whether the proposed fire protection solution is satisfactory.

2.2.3 Verification with quantitative risk analysis

A quantitative risk analysis proceeds on the assumption that the scenarios identified in the risk identification are collectively included in the analysis. The likelihood and consequences of various possible outcomes are considered for each scenario.

General recommendations:

Verification using quantitative risk analysis should be based on the distributions of input variables. The distributions for the variables should reflect the conditions that can be expected during the economically viable lifetime of the building.

Verification with quantitative risk analysis should include a sensitivity analysis to identify the variables that have a major impact on safety levels. Such variables should be treated conservatively. An uncertainty analysis can complement the sensitivity analysis to specifically examine such variables.

The results of the sensitivity analysis should be included in an assessment to determine whether the proposed fire protection solution is satisfactory. Examples of variables that could be included in the sensitivity analysis are heat release rate, the reliability of the technical systems, people's walking speed and the distribution of people being evacuated between different escape routes.

The results of a quantitative risk analysis can be presented with measures that, for example, indicate individual risk or societal risk.

2.3 Satisfactory fire safety

2.3.1 Generally

According to BBR 5:1, the purpose of a building's fire protection is to provide adequate fire safety.

General recommendations:

Fire protection can be verified through a comparison with the protection afforded by a simplified design for a reference building. Alternatively, fire protection can be verified against the criteria set out in these general recommendations.

The reference building should be a similar building for which a simplified design is applied, e.g. regarding building class, activity class, fire load, number of levels and number of persons who may be present in the building.

For a qualitative assessment, a comparison with a reference building according to a simplified design should represent the level for adequate fire protection.

For scenario analysis, the criteria set out in these general recommendations should represent the level for satisfactory fire protection.

For quantitative risk analysis, the level of adequate fire protection should be determined by comparison with a reference building according to a simplified design or with the criteria set out in these general recommendations.

2.3.2 Building Class Br0

Only analytical design is applicable for buildings designed in building class Br0. The regulations in BBR require an assessment of whether the fire protection is adequate.

General recommendations:

The building's design shall be verified against the functional requirements in the BBR. Fire protection for buildings should be assessed as part of an overall assessment of the building's risk profile.

For buildings in building class Br0, the general recommendations in BBR Section 5 may only be used as a reference system to a limited extent. A limited extent here means, for example, protection that is only related to the design of individual rooms, fire compartments or components. The design of the fire protection should at least correspond to what applies for similar building classes, such as building class Br1 for

buildings with three or more floors, or building class Br2 for buildings on one floor with assembly halls in activity class 2B or 2C.

The criteria provided in these general recommendations may represent the level of what is considered adequate fire safety.

Special consideration should be given to the following aspects:

- **if exterior fire-fighting efforts cannot be implemented,**
- **if internal rescue operations may be complicated,**
- **if the feared consequences are very great,**
- **if the evacuation process may be associated with major difficulties.**

3 Possibilities for evacuation in the event of fire

3.1 Generally

This section describes how the possibility of escape in the event of fire can be verified (the relevant parts of BBR 5:3).

3.2 Analysis model

A verification with scenario analysis of the possibility of escaping in the event of a fire shall show that the evacuation is completed before people are exposed to critical conditions. Several fire and evacuation scenarios shall be examined in the verification.

General recommendations:

The possibility of escape in case of fire should be based on a comparison between the time for the evacuation and the time until critical impact occurs. The time for evacuation should include times for perception, preparation and movement. When selecting the conditions for the analyses, people's behavioural patterns for the particular activity and scenarios in the risk identification should be included. The risk identification can thus be used to identify various so-called evacuation scenarios.

The risk identification is assumed to include that fires can occur at different locations on a single premises, although not necessarily simultaneously. Furthermore, various possible preconditions for the evacuation should be considered, such as if a large proportion of the people are persons with impaired orientation or movement capacity, or children.

The effect on the evacuation sequence of the preconditions in the progress of the fire should be included in the analysis. As an example, the evacuation process should be affected by lack of technical systems in required fire scenario 3, and that the fire's location could mean that people's distribution amongst the different exits may vary.

In the analysis of the evacuation possibilities from buildings, the time available for evacuation should be longer than the evacuation time for all relevant scenarios.

Consideration should be given to the behaviour patterns that can be expected for the activity in question.

Walking distance to the nearest escape route should not exceed 80 m.

3.3 Evacuation sequence

3.3.1 Maximum number of people

Escape routes should be designed for the largest number of people expected to be on the premises. The number of people for which the premises are designed will then constitute a restriction on the use of the premises.

General recommendations:

Verification of the possibilities of escape in case of fire should be based on the maximum number of people that can be expected to be on the premises. Table 5:333 in the BBR can be used to estimate the maximum number of people in a building, unless otherwise indicated. For premises which are also intended to be used for activities other than the principal activity, this should be considered in the selection of the maximum number of people.

When assessing the evacuation time, it should be taken into account that some persons may have impaired mobility or orientation capacity. Public buildings should be designed such that 1% of the people in the building can be persons with reduced mobility.

3.3.2 Perception

Perception time refers to the time period from when the fire starts until the person in question becomes aware that a fire has occurred. This means that the time period can vary between different people in a building, as they can have different preconditions for detecting the fire. People close to the fire are more likely to detect it early, while those further away from the fire may not notice the danger until an evacuation alarm starts.

General recommendations:

Perception time for people who see a fire should not be less than 30 seconds. If the building is equipped with an evacuation alarm, the perception time for people who do not see the fire can be determined from the time when the evacuation alarm starts.

If alarm storage is used, it is assumed that the building has access to appropriately trained staff. The time for alarm storage should be included in the perception time unless it can be demonstrated otherwise.

3.3.3 Preparation time

Preparation time refers to the time period taken for people to interpret the situation and prepare to move. This can entail searching for more information, talking to other people nearby, listening to an evacuation message, fighting the fire or otherwise preparing to handle the situation. The preparation time includes the time between the moment the person becomes aware that a fire has occurred and that the physical movement begins.

General recommendations:

Table 2 Suggested preparation times for some activities.

Activity	**Person sees the fire**	**Preparation time**
Public areas, schools, offices, department stores, shops	**Yes**	**1 minute**
Department store, no alarm	**No**	**4 minutes**

Department store, alarm bell	**No**	**3.5 minutes**
Department store, simple spoken message	**No**	**2 minutes**
Department store, detailed spoken message	**No**	**1 minute**
Smaller premises with alarms in the relevant area, small cinema, shop, church	**No**	**1 minute**
Hospital[1], staff, alarm bell	**No**	**2 minutes**
Hospital[1], staff, sound signal and text messages	**No**	**1 minute**
Nightclub, staff[2]	**No**	**1 - 1.5 minutes**
Nightclub, guests[2]	**No**	**3 - 5 minutes**

1) Refers to nursing wards with good overview (single corridor).

2) Depending on the type of alarm and organisation.

Table 2 uses the concepts of a simple spoken message and a detailed message. A simple spoken message refers, for example, to "A technical error has occurred on the premises. Please leave the building". A detailed message should contain information which means that people in the building are informed about what has happened and what they are expected to do.

3.3.4 Evacuation time

The evacuation time is the time it takes to evacuate the relevant area or the entire building and will consider both walking times and queuing times, for example at doors, stairs and ramps.

General recommendations:

An analysis of the possibility for evacuation should include an estimate of how the people are distributed in the building and amongst the various exits.

People's walking speeds under different conditions can be selected from Table 3 or 4. People with reduced mobility can be assumed to move with a speed and flow corresponding to the values in Tables 3 and 4 multiplied by ⅔.

Table 3 Walking speed and people flow for people who move independently of other people.

Route	**Walking speed along the inclined plane**	**Minimum width[1]**	**People flow**
Horizontal	**1.5 m/s**	**0.9 m**	
Up the stairs	**0.6 m/s**	**0.9 m**	
Down the stairs[2]	**0.75 m/s**	**0.9 m**	
Door	**-**	**0.8 m**	[3]

Table 4 Walking speed and people flow with high densities of people for people moving in groups with other people. High densities of people means a maximum of two persons per m².

Route	Walking speed along the inclined plane	Minimum width[1]	People flow
Horizontal	**0.6 m/s**	**0.9 m**	**1.2 p/sm**
Up the stairs	**0.5 m/s**	**0.9 m**	
Down the stairs[2]	**0.5 m/s**	**0.9 m**	**1 p/sm**
Door	**-**	**0.8 m**	[3]

1) **Escape routes serving more than 150 people should have a minimum clear width of 1.20 m.**

2) **The flow is calculated on the effective width of the stairs, i.e. the staircase's entire width reduced by 0.3 m. The indicated value refers to stairs that slope in the range of 26° -32°.**

3) **For doors that people being evacuated can be expected to know, the flow can be assumed to be 1.1 p/sm. In other cases, 0.75 p/sm shall apply.**

Evacuation time(s) from a premises can be calculated using the following equation.

$$t_{förf} = \frac{l}{v} + \frac{n}{b \cdot f}$$

where l is the longest walking distance (m), v is the current walking speed (m/s), n is the number of people passing a door, b is the width of the door (m) and f is the flow of people through the door (p/sm).

In premises where the time available for evacuation is long, difficulty with evacuation may occur due to extensive queue formations. Queuing time primarily refers to the time that people stand waiting in front of a door before they have a chance to pass through it. The door referred to is usually the first door that a person passes through during an evacuation.

General recommendations:

Short queuing time should be sought where there is a risk of high densities of people, which may be relevant for premises in, for example, activity classes 2B and 2C. The queuing time should be limited so that it does not exceed eight minutes. In assessing the maximum permitted queuing time, factors that affect the risk of injury should be taken into account.

3.4 Required fire scenarios

Three required fire scenarios that are generally applicable to the majority of evacuation analyses are specified for evacuation analyses. The scenarios are selected so that they represent a reasonable stress on the building's fire protection. Scenario 3 is intended to separately assess the fire protection when technological systems do not work and should not be confused with a sensitivity analysis under Section 2.2.2.

General recommendations:

The scenarios may have to be repeated for different locations of the fire if the building is complex and it is not possible to predict which is the most unfavourable location for the fire. An example of when this may be appropriate is in buildings containing rooms with different ceiling heights, buildings that are open on several floors and buildings

underground with few openings to the outside. A risk identification can be an aid in carrying out this work.

3.4.1 Required fire scenario 1

General recommendations:

Fire scenario 1 is characterised by a serious fire with rapid development and a high heat release rate, a probable worst case. The installed technical protection systems can be assumed to function as intended and the impact of these may be included.

The fire spread should be modelled on the basis of the following preconditions and specifications:

- Fire progression (growth rate, maximum heat release rate development and production of combustion products) shall be selected according to Tables 5 and 6.

- An automatic fire extinguishing system may affect the fire behaviour in accordance with Section 3.4.5.

3.4.2 Required fire scenario 2

General recommendations:

If the building is not equipped with a comprehensive automatic fire and evacuation alarm, the analysis should include fire scenario 2.

Fire scenario 2 is characterised by a fire in an area where there are normally no people, but which is adjacent to an area that has a large number of people. The technical protection systems can be assumed to function as intended and the impact of these may be included.

The fire spread should be modelled on the basis of the following preconditions and specifications:

- Fire progression (growth rate, maximum heat release rate development and production of combustion products) shall be selected according to Tables 5 and 6.

- An automatic fire extinguishing system may affect the fire behaviour in accordance with Section 3.4.5.

3.4.3 Required fire scenario 3

General recommendations:

Fire scenario 3 is characterised by a fire progression that can be seen as having a smaller stress effect on the building's fire protection, but which develops at the same time as individual technical systems are not functioning as intended. The technical systems that should all be separately made inaccessible for required fire scenario 3 are as follows:

- Automatic fire and emergency alarm.

- Automatic fire extinguishing system.

- Automatic smoke ventilation or other systems for the control of fire and smoke spread.

- Elevators used for evacuation.

- Secondary failures should be considered if the error means that several systems could be knocked out by an event, such as the power supply failing if control signals are missed.

The fire spread should be modelled on the basis of the following preconditions and specifications:

- Fire progression (growth rate, maximum heat release rate, development and production of combustion products) shall be selected according to Tables 5 and 6.

- Automatic fire extinguishing systems may affect fire behaviour according to Section 3.4.5, except when the extinguishing system is disabled.

3.4.4 Fire progression

The fire progression can be assumed to follow a simplified course unless other information can be shown to be more accurate. The term 'early fire development' means the stage before flashover occurs. Afterwards, the fire behaviour is described as fully developed.

General recommendations:

The heat release rate (kW) should be calculated according to the following equation and can, in the area of the fire, be limited by the available air flow. The transport of the unburned gases should be considered.

$Brandeffekt = \alpha t^2$ **(Brandeffekt = heat release rate)**

α - growth rate, kW/s^2

t - time, s

Design values in the fire scenarios should not be less than what is shown in Table 5 for the early fire development.

Table 5 The design growth rate, heat release development, heat of combustion in the early stage of the fire.

Activity	Growth rate, kW/s^2	Heat release, MW	Combustion heat, MJ/kg
Offices and schools	**0.012**	**5.0**	**16**
Homes, hotels and healthcare facilities	**0.047**	**5.0**	**20**
Assembly halls	**0.047**	**10.0**	**20**
All activities for required fire scenario 3	**According to rows 1-3**	**2.0**	**20**

Design values for the fire scenarios should not be less than what is shown in Table 6 for the early stage of the fire. The values will apply if well-ventilated combustion can be assumed.

Table 6 The design values for the production of soot and smoke in the early stage of the fire.

Activity	Soot production	CO-production	CO_2-production

Fire scenarios 1 and 2	**0.10 g/g**	**0.10 g/g**	**2.5 g/g**
Fire scenario no. 3	**0.06 g/g**	**0.06 g/g**	**2.5 g/g**

The values in Table 6 indicated for required scenario 3 can also be used for required scenarios 1 and 2 if there is no automatic water sprinkler system in the room.

If combustion occurs under ventilation-controlled conditions, this should be considered when selecting the production terms for soot, CO and CO_2.

3.4.5 The impact of an automatic fire suppression system

General recommendations:

The effect of an automatic fire suppression system can be considered as indicated below. For other types of extinguishing systems not listed below, a specific assessment should be carried out.

If the heat release development upon activation of an automatic water sprinkler system or residential sprinklers is no more than 5.0 MW, heat release can be reduced as follows:

- After the sprinkler activation, heat release is kept constant for 1 minute.

- Then the heat release reduces to 1/3 of the release at the time of activation. This reduction occurs during the ensuing minute.

- Heat release is then kept constant at this level.

If the fire's heat release at sprinkler activation is greater than 5.0 MW, the heat release should be assumed to be constant after sprinkler activation.

Gas extinguishing systems, designed in accordance with current standards, can be assumed to reduce the heat release rate immediately after the design concentration of the extinguishing agent is achieved.

3.5 Acceptable exposure during evacuation

To determine the time available for evacuation, a maximum acceptable exposure of people to the impact that the fire generates in the relevant location, which is called critical impact, must be determined.

General recommendations:

Table 7 shows the acceptable levels for the critical impact of fire for the verification of evacuation safety. To meet the acceptable level, criterion 1 or criterion 2 and criteria 3-6 should be satisfied. This means that in some cases, evacuation through smoke can be accepted. Visibility should be calculated against the indicative markers, walls or the equivalent.

Table 7 Level of critical impact in the analysis of evacuation safety

Criterion	**Level**
1. Smoke layer level above floor	**Lowest 1.6+0.1 × room height**
2. Visibility, 2.0 m above floor	**10.0 m in areas > 100 m^2**
	5.0 m in areas ≤ 100 m^2 The criterion can

	also be applied to situations where queue formation occurs at an early stage at the location where the queue develops.
3. Heat dose	**max. 60 kJ/m^2 above energy from a radiation level of 1 kW/m^2**
4. Temperature	**max. 80°C**
5. Heat radiation	**max. 2.5 kW/m^2 or**
6. Toxicity, 2.0 m above floor	**Carbon monoxide concentration (CO) < 2000 ppm** **Carbon dioxide concentration (CO_2) < 5 %** **Oxygen concentration (O_2) > 15 %**

3.6 Specific situations

3.6.1 Evacuation elevator

An evacuation elevator can increase the possibility of evacuation for people with reduced mobility.

General recommendations:

If an evacuation elevator is installed in a building, the design of the possibility for evacuation and the elevator's design should be verified by analytical design.

Evacuation elevators should be regarded as complementary to the stairs that are used for evacuation. In order to replace a stairway with escape via the elevators, the analysis should include factors such as extended total evacuation time and the evacuation capacity.

Indicative markings should be adapted to the intended use of the elevator.

The following questions and factors should be investigated separately:

- the building's evacuation strategy and the time for evacuation (alternative evacuation routes and any sequentially controlled evacuation);

- control system, measures relating to maintenance and that the system's operation is maintained during the reasonable economic lifetime of the building,

- how the elevator's operation is assured during the time necessary for evacuation,

- accessibility requirements,

- redundancy of vital systems for the functioning of the elevator (such as power supply and incoming signals),

- protection against fire and smoke for those evacuating who are waiting for the elevator, in the elevator and on the route from the elevator to the open air,

- protection against fire impact for the elevator machinery,

- the impact of any water penetration into the elevator shaft,

- the risk of smoke and heat impact on sensitive components,

- the possible impact of cold air temperature on sensitive components,

- control sequences in the detection,

- communication facilities (such as alarm buttons and emergency telephones),

- waiting times for those evacuating,

- possible measures by those evacuating or others in the building that lead to delayed evacuation or unnecessary risk-taking,

- the possibility of activating and controlling the elevator’s function and how the activation and control is achieved.

4 Protection against fire and smoke spread within the building

4.1 Generally

This section describes how protection against fire and smoke spread within the building can be verified (the relevant parts of BBR 5:5).

4.2 Analysis models

The spread of fire within a building can take place by convection, conduction and by radiation. If analytical design is used to verify protection against fire and smoke spread within a building, it may be relevant to consider the spread of fire and smoke through, for example, ventilation systems, fire compartment boundary structures and through windows and other openings. The choice of the analytical model is assumed to take account of the above methods for heat conduction. A verification of protection against fire and smoke spread in the building can assume that a number of fire scenarios and analytical models will need to be used.

4.3 Verification of the separation ability of fire compartments

This section (4.3) deals with verification of the separation ability between fire compartments, with particular focus on the analysis of fire separating structures and building components according to BBR Section 5:2. This includes, for example, walls, windows and penetrations in fire compartment boundaries. Technical ventilation fire protection is described in Section 4.4.

4.3.1 Analysis model

In order to verify the separation ability between fire compartments using analytical methods, it is primarily temperature increase and radiation levels on the side not exposed to fire that are relevant to analyse. Verification can be done by using proven solutions, testing, object-specific experiments or calculations.

General recommendations:

For the analysis of the separation ability of building components, the maximum temperature and the maximum radiation levels used on the side not exposed to the fire (opposite side) should not exceed acceptable levels for all relevant scenarios.

4.3.2 Required fire scenarios

For a verification of the separation ability between fire compartments, the risk identification can be a starting point for the fire scenarios included in the further analysis.

General recommendations:

Required fire scenarios should be identified and justified so that they form a plausible worst-case stress for the building’s fire protection. Consideration should be given to the size of fire compartments, their openings, penetrations and the like.

4.3.2.1 Fire progression

The fire progression can be assumed to follow a simplified course unless other information can be shown to be more accurate. The choice of values that describe the course of the fire for each scenario is assumed to reflect the conditions in the relevant area.

General recommendations:

The separation capacity for structural components separating fire compartments can be verified using a model of natural fire progression in accordance with EN 1991-1-2, Annex A. Design should be for a fully developed fire, unless it can be demonstrated otherwise. Refer also to EKS, section C 1991-1-2. The design fire load should be determined using the Swedish National Board of Housing, Building and Planning’s report on fire load.

For separating structures that under a simplified design are produced in class EI 60 or higher, the separation ability should be determined using a complete fire progression, including the cooling phase. For a lower fire class, parts of the complete fire progression apply for the time period indicated in the class designation, excluding the cooling phase. For building components which, according to a simplified design, are produced in class EI 90 or higher, the design fire load should be increased by 50%.

4.3.2.2 The impact of an automatic fire suppression system

If there is an automatic extinguishing system, the fire load in the relevant fire compartment can be reduced.

General recommendations:

Consideration can be given to the impact of an automatic fire suppression system according to BBR 5:252 by the design fire load being reduced to 60% of its original value.

4.3.3 Acceptable stress

Acceptable stress on the building components exposed to fire can be assessed in accordance with the following general recommendations.

General recommendations:

For the design of separating structures with the model of natural fire progression, the temperature on the side of the building components not exposed to fire should not exceed 200°C on average and 240°C at isolated points.

The air-tightness (I) of separating structures should be designed in the same way as for the corresponding fire resistance class according to BBR. In assessing the air-tightness, special consideration should be given to whether building components may be deformed or damaged by fire.

Fire resistance class EI can be exchanged for Class E if the safety for evacuation is good and the probability of fire spread does not increase. The requirement can be regarded as satisfied if doors, walls, etc. are arranged so that the distance to evacuating people or

flammable material is so far that the radiation level does not exceed 2.5 kW/m^2. Higher levels of radiation may be acceptable if the timeframe for evacuation and ignition is considered.

4.4 Ventilation-related fire protection (4.4)

This section addresses the verification of ventilation-related fire protection according to BBR 5:533 for analytical design.

4.4.1 Analysis model

General recommendations:

Analytical design of a building's ventilation-related fire protection can be implemented using the following methods.

- Ensured flow control in the event of fire, so-called fan in operation, where fans or fans, in conjunction with other safety solutions, are used to limit the amount of smoke that is spread to other fire compartments in the building.

- Pressure-relief of the fire compartment, which is activated at an early stage with, for example, an automatic fire alarm. Activation should ensure that the fire compartment is depressurised so that the risk of spread of fire and smoke to other fire compartments is limited.

- Pressure-relief of the ventilation ducts, which is activated at an early stage with, for example, an automatic fire alarm. Activation should ensure that the ventilation ducts are depressurised so that the risk of spread of fire and smoke to other fire compartments is limited. Pressure relief of ventilation ducts should not be applied to areas with protection level 1.

Designs with the methods above require verification based on calculations or testing. Consideration should be given to the relevant pressure decrease and thermal path forces in vertical channels as a result of smoke with high temperature.

4.4.2 Required fire scenarios

For verification of a building's ventilation-related fire protection, a risk identification can be used to identify the relevant fire scenarios that may be included in the subsequent analysis.

General recommendations:

Required fire scenarios should be identified and justified so that they form a plausible worst-case stress for the building's fire protection at various times in the course of a fire. Required fire scenarios should include various configurations of open and closed windows in the building's climate envelope and the possible interaction between air flows through different parts of the ventilation system, such as kitchen hoods.

4.4.2.1 Fire progression

For an analysis of a building's ventilation-related fire protection, the design fire sequence can be divided into two phases, the early phase and the late phase of the course of the fire. The early stage of the fire is characterised by a high pressure build-up and a moderate smoke temperature. In the late stage of the fire, there is normally pressure relief through broken windows. The later phase is characterised by a low pressure build-up and a high smoke temperature. The design fire progression can be expressed in a so-called fire-flow, which is a function of the volume of the studied area and the fire's growth rate.

General recommendations:

In determining the fire progression and the fire flow, consideration should be given to fire growth, the geometry of the fire area and the ventilation conditions.

- **The fire's growth rate should, in the early course of the fire, correspond to a growth rate of 0.047 kW/s^2, unless otherwise demonstrated.**
- **The fire flow may be limited by a maximum pressure build-up, which can be assumed to be 1500 Pa, unless otherwise demonstrated.**
- **In the early course of the fire, the design smoke temperature can be assumed to be max. 350^{o}C.**
- **The smoke temperature in the late course of the fire, i.e. when flashover has occurred, can be determined with a model for natural fire progression according to SS-EN 1991-1-2, Annex A or equivalent. The design fire load should be determined using the Swedish National Board of Housing, Building and Planning's report on fire load.**

4.4.2.2 The impact of an automatic fire suppression system

If there is an automatic fire suppression system, this can be taken into account.

General recommendations:

If the fire compartment studied is equipped with an automatic sprinkler system or residential sprinklers, the temperature of the smoke can be assumed to be limited to the temperature that applies at the time of sprinkler activation.

4.4.3 Other prerequisites

Leakage in a surrounding structure can have a major impact on smoke spread and pressure changes in a building in the event of fire. It follows from BBR 5:533 that air treatment installations shall be designed for the fire and temperature effects they are likely to be exposed to.

General recommendations:

Fans should be designed to deliver the required flow at the relevant pressure differences and smoke temperatures. Leakage through structures, installations within the building and the climate envelope should be taken into account.

Consideration should be given to the pressure differences created by the ventilation system and which may affect the possibility of opening doors for evacuation. This can also apply to individual rooms within a fire compartment. Rules for doors can be found in BBR Section 5:335.

4.4.4 Acceptable exposure for smoke spread in the ventilation system

It follows from BBR 5:533 that protection against smoke spread through the ventilation system shall be maintained for a period corresponding to the fire compartment separation capacity. Acceptable exposure to smoke spread in the ventilation system can be determined from classification according to protection level 1 or 2.

General recommendations:

Fire compartments containing escape routes or sleeping people, e.g. Vk3, Vk4, Vk5B and Vk5C, should be assigned to protection level 1. Other fire compartments can be assigned to protection level 2.

For compartments in protection level 1, the acceptable limit for smoke spread should be 1% of the volume of the receiving fire compartment.

For compartments in protection level 2, the acceptable limit for smoke spread should be 5% of the volume of the receiving fire compartment.

4.5 Specific situations

4.5.1 Pressurisation of spaces (4.3)

Section 5:257 establishes requirements for pressurisation of spaces.

General recommendations:

Pressurisation can be used to provide protection against fire and smoke spread to areas. SS EN 12101-6 can be applied for verification of the pressurisation of staircases. Alternatively, an equivalent method can be used to verify that the pressurisation of a fire-lock or other space provides adequate protection.

5 Protection against fire spread between buildings

This section describes how protection against fire spread between buildings can be verified (BBR 5.61).

5.1 Analysis model

Fire spread between buildings may occur by conduction, convection and by radiation. The fire protection can be designed as a combination of distance and separating structures, only distance or only separating structures. Fire spread by convection can occur primarily by spot fires to adjacent, combustible roof structures. This section primarily discusses protection against fire spread between buildings by radiation. The choice of the analytical model is assumed to take into account the radiation between adjacent buildings. A verification of protection against fire spread between buildings can assume that a number of fire scenarios and analytical models will need to be used.

General recommendations:

Limiting the risk of fire spread between buildings can be achieved, for example, by:

- buildings being erected at a suitable distance from each other,

- restricting the size of unprotected building components,

- restricting the fire susceptibility of exposed surfaces, or

- restricting the extent of the fire with fire safety installations such as an automatic fire suppression system.

For analysis of fire spread between buildings, the maximum radiation levels on the exposed building should not exceed acceptable levels for all relevant scenarios.

5.2 Required fire scenarios

For verification of protection against fire spread between buildings, a risk identification can be used to identify the relevant fire scenarios that may be included in the subsequent analysis.

General recommendations:

Required fire scenarios should be identified and justified so that they form a plausible worst-case stress for the building's fire protection. Consideration should be given to the size of fire compartments, openings and the placing of adjacent buildings.

Emitted radiation should be calculated for the complete course of a fire in the fire compartment that has the greatest risk of fire spread to nearby buildings.

5.2.1 Fire progression

The indicated heat radiation can be assumed to follow a simplified course unless other information can be shown to be more accurate.

General recommendations:

The design radiation levels from window surfaces can be based on a simplified model with constant heat radiation from the window surfaces according to Table 8. The table applies under the assumption that the facade material is designed in the lowest class A2, s1-d0, and is not expected to emit any radiation.

Table 8 Radiation levels for protection against fire spread between buildings.

Activity	Radiation level, kW/m^2
Homes, offices, meeting rooms, open parking garage	**84**
Shops, factories, warehouses	**168**

As an alternative to a simplified model, a more detailed analysis can be used to pay more careful attention to the temperature and size of the flames when they come out through the compartment openings. The choice of values that describe the course of the fire for each scenario is assumed to reflect the conditions in the relevant area.

General recommendations:

To determine the fire development and characteristics of the flames that come out through windows, SS-EN 1991-1-2 Annex B can be applied. The design fire load should be determined using the Swedish National Board of Housing, Building and Planning's report on fire load.

To determine the emitted radiation, consideration should be given to whether the facade can be expected to remain intact during the design fire progression. Surfaces that should be included in the analysis are, for example, combustible facades, windows and other surfaces that can be expected to emit radiation.

5.2.2 The impact of an automatic fire suppression system

If there is an automatic extinguishing system, the fire stress can be reduced.

General recommendations:

If the fire compartment is equipped with an automatic water sprinkler system or residential sprinklers, the following reduction of the fire impact can be applied.

- Outgoing radiation in Table 8 can be reduced by 50%, or

- When applying SS-EN 1991-1-2, the design fire load can be reduced to 60% of its original value.

5.3 Acceptable exposure to the adjacent building

Acceptable exposure to the adjacent building may be valued based on estimated levels of radiation.

General recommendations:

Buildings should be designed so that the radiation level to nearby buildings is less than 15 kW/m^2 for at least 30 minutes. Alternative radiation levels can be determined based on the facade surfaces' design and materials.

6 Documentation and verification

6.1 Documentation

This section describes how analytical design can be documented according to BBR 5:12 and BBR 5:812.

General recommendations:

A description of buildings that are wholly or partly designed according to analytical design should be fully reported as part of the fire protection documentation.

The documentation should include the following elements, as a minimum:

- what is different in comparison with a simplified design,

- risk identification carried out,

- design preconditions and assumptions on which the verification is based,

- plans for operation and maintenance,

- description and justification for the methods and models employed,

- account of performed calculations to such an extent that the calculation process can be followed,

- deviations from the general recommendations in this statute and the reason for the deviations, and

- conclusions based on the analytical verification.

6.2 Control of verification

General recommendations:

The verification plan according to Chapter 10, Articles 6-8 of the PBA should contain the following verification points:

- **That all deviations from the simplified design are verified.**
- **That design verification is completed.**
- **That the design preconditions are correct.**

If calculations are used as input for scenario analysis or quantitative risk analysis, the accuracy of the calculations shall be demonstrated through the design verification. Design verification means verification of the design assumptions, construction documents and calculations. This verification should be performed by a person who has not previously been involved in the project.