

Sandwich elements as room-closing wall and roof components

Fire protection information for planning, construction and maintenance



The present publication is non-binding. The insurance providers can also accept other safety precautions or installation and maintenance companies at conditions set at their own discretion which do not conform to these technical specifications or guidelines

Title pictures:



www.sandwichbau.com

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1 Preliminary remarks

Sandwich elements are widely used as structural elements for the roof and external walls, in particular for industrial and commercial buildings as well as structures built for a specific purpose, such as multi-purpose arenas, since building with building designs of light and prefabricated elements can be quickly and thus efficiently realised.

Considerable risks, however, can be connected with the sandwich design. There were a series of major fires in other European countries the extent of which essentially could be attributed to the use of sandwich elements; in most cases total loss was the ultimate result. In this publication those fire hazards that result from the use of sandwich elements are described first. Moreover preventive measures are presented that can help to minimise large fires or to avoid them completely.

The following information thus provides instructions and ideas for effective protective measures within the scope of an integral fire protection concept. These notes, however, can solely have a tentative character. In isolated cases other protective measures not described in this technical specification may also be needed to reach object-specific protection objectives and to implement an integrated protection concept.

Legal and official directives are not affected.

Questions about fire protection measures in the case of specific risks should be coordinated with the responsible authorities and insurance providers.

The present publication is based on today's knowledge and will be updated if fundamental changes or new findings occur in construction and fire protection technology.

2 Scope

This publication deals with industrially prefabricated sandwich elements for the formation of room-closing components for external and internal walls as well as roof and ceiling designs. Cassette walls are not a subject of the following consideration.

The information contained in this publication concerning loss prevention generally applies to buildings being newly built with consideration of the object-specific protection requirements. The protective measures should be logically applied to existing buildings.

3 Terms

Sandwich element

Multi-layer construction elements – also referred to as “composite panel” or “insulating sandwich panel” – are designated as sandwich elements that essentially consist of two profiled metal surface layers and a thermal insulation layer arranged in the middle. These elements can be attached to steel and wood substructures.



Fig. 3.01: Basic construction of a sandwich element

Sandwich elements are considered single-leaf building elements.

Surface layer

The two external layers of a sandwich element are designated as surface layers. In the case of metal surface layers, one often speaks of covers. These can be smooth or profiled and usually consist of material that is the same on both sides. The surface layers are rigidly connected with the underlying insulation material (by foaming or adhesion). They have a static, physical structural and optical function. In addition the metal surfaces of sandwich elements can be easily cleaned, which is for example of great importance for ensuring of food hygiene.

Insulation material

The insulation material forms the core of the sandwich element. It is also frequently designated as core material or core layer. Very light materials (organic or inorganic) are used as insulating materials that assume insulation tasks (heat, cold, noise etc.).

Joint

The separation layer (longitudinal joint) between two sandwich elements is designated as a joint. The joint represents an interruption of the protective ends of the surface layer. Joints are differentiated as butt joint and overlapping joint.

Integral fire protection concept

A fire protection concept, which supplements preventive and repelling fire protection measures in terms of risk and protection objectives, is also increasingly required within the scope of building approvals for special structures. In the process the protection of persons as the primary objective of the building regulation should be in particular taken into account.

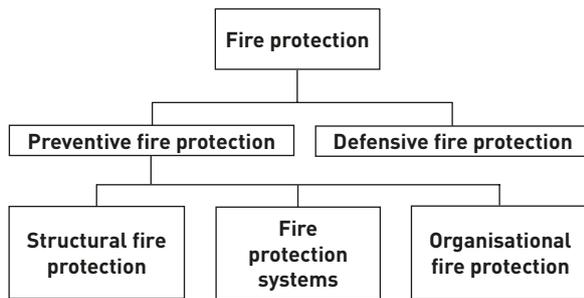


Fig. 3.02: Basic design of an integral fire protection concept.

In contrast to an officially approved fire protection concept, an integrated fire protection concept is distinguished by the fact that aspects of the protection of property and the securing of company processes, such as the limitation of the plant interruption, are also considered worthy objectives. Early consideration of all relevant protection objectives allows planners to combine measures for personal and protection of property and thus realize technically optimal and economically acceptable fire protection.

The objectives of structural fire protection includes

- prevention of fire outbreak due to material and
- prevention of the spread of fire as well as sufficient fire resistance time of the building support structure in accordance with its fire exposure and the value/significance of the building,
- and prevention of an expansive spread of fire through section partitions.

4 Responsibility for fire safety

In accordance with the legal provisions, the employer or operator must in principle ensure company fire safety. It is therefore recommended that fire protection be made into a component of company objectives and strategy (risk management).

When constructing, erecting, changing and maintaining structural installations, building manager, planner, executing company and operator must fulfil the required fire protection demands in each assigned sphere.

Note:

- *VdS 2000 Fire protection in the plant, guideline*
- *VdS 2009 Fire protection management, guideline for the responsible persons in the plant and company*

5 Overview of useable sandwich element designs

In practice, there are a large variety of designs with composite building elements. The design of these structural elements can be fundamentally differentiated as follows:

- **Firm bond:** Surface layers of these building elements are firmly bonded with the insulation material (core material). This can be achieved by foaming or applying adhesives

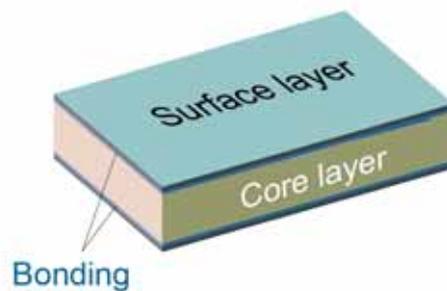


Fig. 5.01: Firm bond = Sandwich

- **Loose bond:** The core layer of these building elements is in contrast to a firm bond not bonded to the surface layer. They are therefore not sandwich elements.

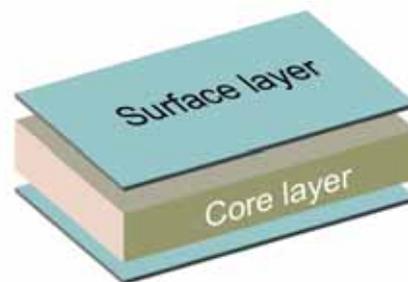


Fig. 5.02: Loose bond = no Sandwich, rather e.g. cassette element

A rigid element results due to the fixed connection between surface layers and the core layer. The load carrying capacity of the linking element is thus many times higher than the sum of the load carrying capacities of the individual components. Therefore the connection element must be evaluated as a whole – material properties of the surface layer or the insulation materials considered separately do not allow a generally valid statement to be made about the behaviour of the complete sandwich element.

Surface layers/surface shells

Surface layers include: steel, stainless steel, aluminium, copper, fibreglass reinforced plastics, chip board, plasterboard etc.

Usually, sandwich elements with metal surface layers are used for the external areas (wall fronts - roof) for static structural and optical reasons. Elements with non-metallic surface layers are frequently used for internal construction.

Insulation materials

Usually the insulation materials should be light, pressure-resistant and insulating. Many different materials are used (organic or inorganic).

Combination of materials for sandwich elements

To provide a better overview within the scope of this publication, the essential combination options are displayed in Table 5.02 and the typical parameters related to fire protection in Table 5.03.

Manufacturing process of sandwich elements

Sandwich elements are produced in a continuous (line production) or discontinuous (piece production) manufacturing process.

With the continuous process the element is produced as an endless strand and is cut to the required length. The surface layers are here usually wound on so-called coils (rolls) and are frequently profiled before gluing or foaming. This production method requires large-scale installations and is extensively automated. Sandwich elements for fronts and roofs with metal surface layers are frequently produced by this method.

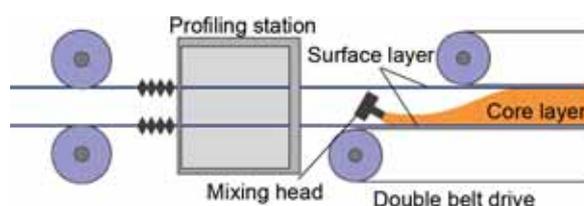


Fig. 5.03: Continuous production

With discontinuous production, the surface layers with their later end dimensions are foamed in presses or glued to the insulation material. Sandwich elements for cold storage cells and partitions are frequently produced by this method. The complexity of automation is significantly less for this type of production.

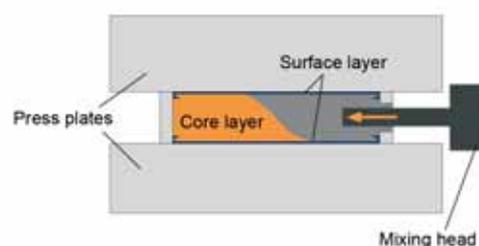


Fig. 5.04: Discontinuous production

6 Risk Characteristics

In past years in other European countries, increasing major fires in buildings with sandwich elements in the construction have been observed. In particular, food production plants, cleanrooms

	Raw density [kg/m ³]	Pressure resistance [kPa]	Rated heat conductivity [W/mK]	Material class (DIN 4102)
PUR/PIR	≥ 35	≥ 100	≥ 0,025	B 1 to B 3
EPS/XPS	≥ 15	≥ 70	≥ 0,035	B 1 to B 3
Rock wool	≥ 100	≥ 60	≥ 0,040	A 1 to A 2

PUR/PIR = Polyurethane/Polyisocyanurate, from the thermal-setting plastics series

EPS/XPS = expanded (foamed)/extruded Polystyrole, from the thermoplastics series

Table 5.01: Material properties of typical insulation materials

Surface layer	Internal insulation		
	1 – Rock wool	2 – PUR (PIR)	3 – EPS/XPS
1 – steel or stainless steel	11	12	13
2 – aluminium	21	22	23
3 – fibreglass reinforced plastics	Not available	32	33

Table 5.02: Combination indices (K-Nr.)

K-Nr.	Material class of the layers [DIN 4102]			Overall material class	Fire load (q_R) kWh/m ² ×cm	Burning droplets	Hints
	sur-face	core	sur-face				
11	A	A	A	A ⁴⁾ /B ⁴⁾	small	N.A.	Wall designs up to F 120 possible
21	A	A	A	B ⁴⁾	small	N.A.	Depending on design: Softening temperature ≥ 160 °C
12	A	B2	A	B	2,4 ¹⁾	no	Insofar as completed foamed
22	A	B2	A	B	2,4 ¹⁾	no	See 21: causes premature sandwich loss and burning of the insulation material
32	B2	B2	B2	B	52,3 ¹⁾³⁾	no	Completely decisive for the combustion
13	A	B1	A	B	2,2 ²⁾	yes	Insulation material usually in plate with easy edge burning
23	A	B1	A	B	2,2 ²⁾	yes	see 13, 21 und 22
33	B2	B1	B2	B	52,1 ²⁾³⁾	yes	Particularly critical fire behaviour, e.g. burning droplets and intensive smoke formation.
<p>1) At a raw insulation weight of 35 kg/m³</p> <p>2) At a raw weight of 20 kg/m³</p> <p>3) With a surface layer of at least 2 mm</p> <p>4) The material class of the sandwich elements in accordance with DIN 4102 must be demonstrated by fire tests. The percentage of burnable adhesives must be particularly observed. A European classification will be required after the national introduction of the harmonised classification standards.</p>							
Table 5.03: Fire protection parameters of common sandwich elements							

of the pharmaceutical industry and also buildings with other types of usage, e.g. department stores and agricultural buildings, are affected.

These damages often result in losses up to tens of millions of Euros being suffered, which in most cases were compensated for by insurance providers as total loss.

6.1 Causes of damage

The analysis of major damages shows that the cause of fire usually is not directly connected to the usage of sandwich elements. If in the course of the development of the fire the building structure is directly exposed to the fire, e.g. in the case of advanced or fully developed fire, sandwich

elements can no longer withstand the prevailing thermal effect.

Insufficient performance of maintenance and repair work on building and plant facilities and also flame operations (e.g. welding, separating, soldering, melting and roof sealing work with open flames) as well as drilling and sawing with sporadic heating on the work areas of the sandwich elements can be a cause for fire outbreak and flame development.

Additional causes are found in improper installations of all types, such as electrical installations, insertion of piping or ventilation lines, if combustible insulation materials are made more easily accessible to ignition energy by this than this contribute to fire outbreak.

Experience has shown that internal spaces/cells constructed with sandwich elements, for which no fire protection requirements from the building authorities exist and therefore materials not classified in terms of fire protection with critical fire behaviour are used, pose a particular risk.

6.2 Fire behaviour

Experience shows that the fire behaviour of sandwich elements and the damages to be expected are primarily determined by

- materials used for the surface layers
- insulation material used for the core layer
- the type of design of the bond
- design of the connection joints
- construction work

if applicable also at the construction site.

Experience shows, however, that during fire outbreak sandwich elements are hardly involved in the occurrence of fire, because when the butt joints are intact, the surface layers can protect the combustible insulation materials from direct flame effects and the inflow of oxygen. In addition, the thermal decomposition products can hardly escape. If the surface layer is damaged or destroyed, then this protection effect becomes lost.

6.2.1 Surface layer

Combustible surface layers, such as GRP, can directly take part in the occurrence of fire. Non-combustible surface layers can, in contrast, screen the combustible insulation materials from direct fire effects in the case of fire outbreak. The effectiveness of the screening is particularly dependent on material properties, e.g. melting point (steel > 1000 °C, Aluminium ca. 600 °C). The coatings are usually very thin and have like the thickness of the surface layers only an insignificant effect on the fire behaviour.

6.2.2 Insulation materials for the core layer

In terms of fire protection, combustible construction materials have the fundamental drawback that they can contribute to fire spread and flame development. Along with the combustibility further criteria for the selection of insulation materials are decisive:

- Mineral wool: inorganic material, not combustible, low smoke formation, no burning droplets. Depending on the binding agent portion class A1 or A2.

- PUR/PIR: Organic material from the thermo-setting plastic series. Carbonises during flame effect – no fire spreading, no melting, no droplets, no secondary fires.
- EPS/XPS: Organic material from the thermal plastics series. Melts at temperatures as low as 90 °C. Releases burning droplets and can create secondary fires.

6.2.3 Sandwich element

When exposed to fire, the gasifying components of the core layer on the rupturing edges burn up first and possibly the surface layer if it is combustible. In the further course of fire development, the bonding effect between surface layer and insulation layer – primarily on the side exposed to the fire – weakens and the surface layers can in part become detached and burn up (also see Figures 6.01 and 6.02).

The insulation layer exposed by this can burn up openly, in particular if manufacturing-related cavities are present and/or the burnable insulation



Fig. 6.01: A major fire experiment with sandwich elements as external components



Fig. 6.02: Sandwich elements after a fire

material can continue to burn independently.

A fire spread within the surface layers is not accessible to extinguishers and the fire brigade.

In addition, the combustible insulation materials of the core layer can create considerable smoke formation.

6.2.4 Connection joints between structural elements

Depending on the design of the connection joints, sandwich elements can influence the fire development. In the process, butt joints (see also figure 6.03), where the surface layers are edged at the border area and the individual construction elements hit dully against one another, behave less favourably in the case of fire than do overlapping joints (also see Figure 6.04), where the flames cannot have a direct effect due to the overlapping of the surface layers in the spring and groove connections.

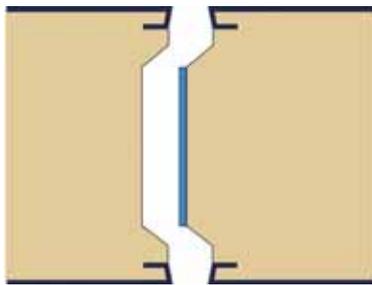


Fig. 6.03: Butt joint with a sealing strip

Sandwich elements with non-metallic surface layers almost always exhibit the butt joints which are more critical for fire protection.

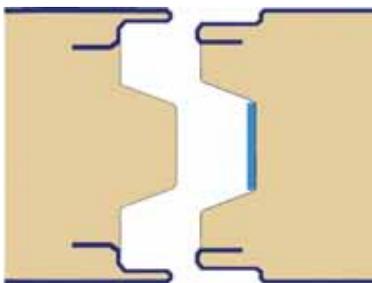


Fig. 6.04: Overlapping joint with a sealing strip

6.2.5 Substructure

Experience shows that a failure of the fixing to the substructure can lead to the loosening of sandwich elements which can both contribute to the expansion of damages and also be dangerous for rescue forces.

6.3 Construction errors and other risks

Construction errors, such as improper assembly, non-inserted or missing sealing strip at the construction site, installation of damaged or unsuitable and/or non-approved elements or improperly designed openings/inlets can negatively affect the fire behaviour of sandwich elements (see Fig. 6.05).

This work is often connected with follow-up installations of all types such as expansions of or changes to electrical installations, installation of piping or ventilation lines, with openings to be planned for later, etc.

Mechanical damages to the metal surface layers are additionally critical – caused, for example, by a forklift –, which makes the core layer locally accessible to the damage fire.



Fig. 6.05: example of an unprotected opening in a sandwich element with exposed installation material

7 Fire protection tips

The analysis of fires results from a series of hints about the manner in which sandwich elements pose a comparably lower fire risk. If these measures are taken into account in both the planning and design of components, the risk of fire and total loss can be significantly lowered.

Even when sandwich elements are currently evaluated and classified within the scope of various test procedures, significant differences in results can be achieved depending on the respective fire scenario stipulated for the test as well as the test procedure.

The usage of sandwich elements in the construction of buildings can have major effects on their risk-related evaluation. Involving the insurance provider in the early planning stages is therefore recommended.

7.1 Tips for planning

When using sandwich elements, the risks must be considered within the scope of a holistic fire protection concept. In the process, both the selection and optimized usage of the sandwich element can clearly limit the aforementioned risks



Fig. 7.01: No spread of fire inside the elements

7.1.1 Insulation material

In principle, preference should be given to non-combustible insulation materials.

Combustible insulation materials can in accordance with building laws be used for the core layer when the sandwich element as a whole is at least classified as normally inflammable. However, sandwich elements classified as normally inflammable can contain easily inflammable insulation materials which enable fast and expansive flame spread in the case of fire. Sandwich elements should therefore not contain and easily inflammable insulation materials.

Evidence of the material class is to be provided with reference to building laws.

7.1.2 Surface layer

Preference should be given to the use of steel sheets because they lose their rigidity under the influence of fire comparably later than other metal sheets, for example aluminium sheets.

Burnable surface layers should be avoided, because they contribute to fire development and allow for early spread of fire to the burnable core layer.

7.1.3 Bond and joint

Sandwich elements are to be designed without cavities between the core layer and the surface layers, because such cavities promote the spread of flame and smoke in the case of fire by way of a chimney effects.

Longitudinal joints between sandwich elements must be designed to overlap if possible (comp. Fig. 7.02), to protect the burnable core layer against direct flame effects for as long as possible. Preference should be given to seals installed at the factory. If seals are installed on site the assembly instructions of the manufacturer must be observed

7.1.4 Fixing and substructure

All sandwich element fixings to the substructure must be made with such adhesives which have been generally approved by the building authorities in terms of strength and have a melting point in accordance with DIN 4102-1 of more than 1000 °C. Other fixings can fail early in the case of fire and thus cause major building damages and jeopardise the fire fighting of the fire brigade.

It should be noted that in the case of fire-resistant wall or roof components of sandwich elements, the associated support/substructure must exhibit at least equal fire resistance.

7.1.5 Additional planning tips

Openings for the ducts of building and production service through sandwich elements must be carefully planned.

A spread of fire can also be restricted if the core layer of the effected elements consist of non-combustible insulation materials. In order to extensively prevent early fire penetration into the thermal insulation, the breakthrough must be particularly protected in terms of fire protection with sealing approved by the building authorities, which ensures protection of the exposed insulation materials by means of a heat-resistant intermediate layer.

When pipelines with increased surface temperatures are inserted, e. g. exhaust ducts or thermal oil lines, the related regulations must be complied with, e.g. fire protection code.

When planning the construction design of fire-resistant structures, one should additionally consider the arrangement of the sandwich elements

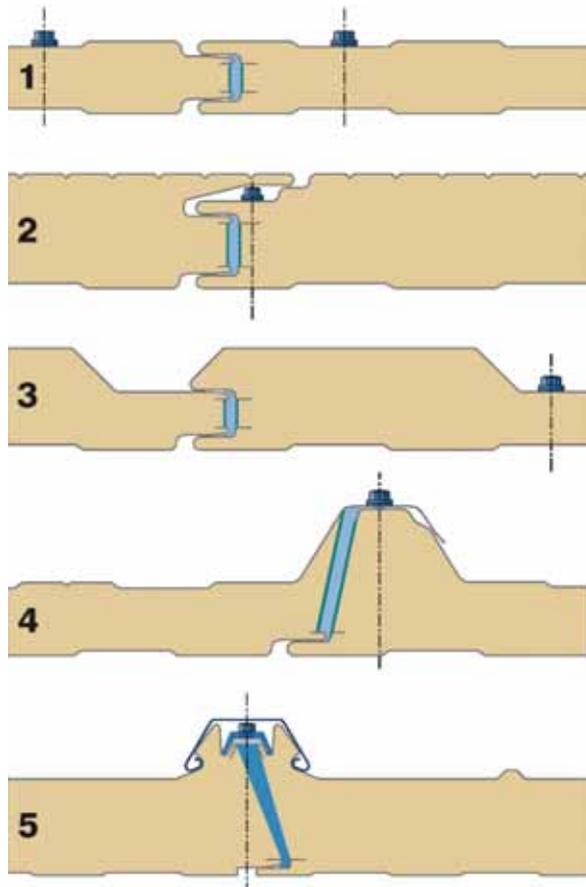


Fig. 7.02: Design examples of longitudinal joints

(horizontal/vertical, allowable span width) in accordance with the respective general test certificate of the building authorities.

If by reason of operational processes, e.g. internal transport with forklift, mechanical damage of metal surface layers can often be expected, then the endangered components must be provided with skirting protection.

7.2 Tips for the construction design

In order to ensure that building measures conform with both the public legal requirements and the setting fire protection concept, the construction design should be monitored so that construction products and types of construction, e.g. insulation materials, demonstrably and as planned exhibit the required properties. [e.g. the Mark of Conformity].

Mark of Conformity

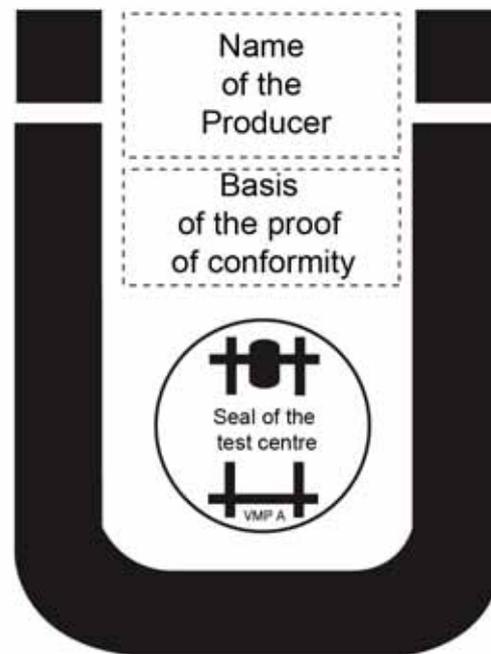


Fig. 7.03: Mark of conformity (sample)

Sandwich elements with damaged surface layers and joint areas may not be installed by reason of the then reduced fire protection function.

Before assembly of the sandwich elements, the sub-structure must be checked for dimensional accuracy and alignment.

It should always be ensured that sandwich elements be joined in such a way that they interlock and installed with the associated sealing and cover strip.

Sandwich elements should only be assembled by trained technicians.

Sandwich elements should be visibly labelled on accessible sites so that the insulation material used can also be identified in the installed condition.

In the labelling, the materials used for the surface and core layers as well as the design type of the joints and connections must be clearly visible. Among other things, these specifications are needed for evaluation in terms of fire protection within the scope of a usage change or renovation measures and must also be available after multiple changes in ownership

7.3 Tips for the plant

The demands placed on the fire protection function of the sandwich element or the construction design with sandwich elements must be permanently met. If required, details can be reviewed in the fire protection concept.

7.3.1 Maintenance

During routine plant inspection one should ensure that the surface layers of the sandwich elements are not damaged.

Damaged elements must be replaced immediately or repaired in such a way that the protection function of the surface layers and joint areas remain intact. (Hint: Particular attention should be given here if hot work must be performed).

Should elements become loose from the substructure, they must be properly reattached in accordance with the specifications of the static evidence.

7.3.2 Openings

If additional openings are added after construction, one must always ensure that suitable procedures are selected which prevent ignition of the burnable insulation materials.

Openings of all kinds must be closed in such a way, that the protective function of the surface layers is restored and the burnable core not exposed (also see Fig. 7.01).

Additional tips for the proper creation of openings can be found in the assembly instructions of the manufacturer.

8 Insurance-related tips

In principle, designs of walls, ceilings, roofs and support structures are evaluated in terms with the scope of fire insurance.

A holistic fire protection concept for the building or plant which sensibly combines the individual measures for personal and property protection is particularly important for the evaluation of sandwich elements as wall and roof components because the fulfilment of all design and operative tips from this publication present only one element of the protection concept.

Note:

VdS 2000 *Fire protection in the plant, Guidelines*
VdS 2009 *Fire protection management, guidelines for the responsible persons in the plant and company*

Moreover, additional designs for the usage of sandwich elements in buildings with specific types of usage, e.g. cold stores, are contained in the guidelines and information sheets of the insurance provider.

Note:

VdS 2032 *Fire protection for cold and freezer stores; Guidelines for planning, design and operation (in preparation)*

Appendix of Literature and Sources

Standards

DIN 4102 Fire behaviour of materials and components

- Part 1: Building materials; Terms, requirements and tests

DIN 18230 Structural fire protection in industrial construction

- Part 2: Investigation of the fire behaviour of materials in storage arranges – Values for the burn factor m

Beuth Verlag GmbH, 10722 Berlin
Internet: www.beuth.de

Publications of the Association of German Insurance Companies e. V. (GDV)

VdS 2000 Fire protection in the plant, Guidelines

VdS 2009 Fire protection management, Guidelines for those responsible in the plant and company

VdS 2032 Cold stores; Recommendations for fire protection

VdS Damage prevention, Publisher
Amsterdamer Straße 174, 50735 Köln
Internet: www.vds.de

Other literature

GALILEO
Creative Building with Sandwich; Info for planners, trades and builders
GALILEO, Deggendorf

Peter Jagdfeld
Behaviour of core-bonded facade elements in the natural fire experiment
VFDB, 1/1988 und
IFBS Info 6.0.6 Brandschutz Dezember 1997

Rolf Koschade
The Sandwich Design
Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH, Berlin

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