Fire Safe Construction with EPS

EUMEPS

EPS: expanding into a sustainable future

EPS: 98% AIR

EUMEPS

Introduction

Fire is a disaster for those involved. A major concern is the high damage potential and increasing insurance premiums from fires. In this document we address the role of insulating material in the fire safety of buildings, with a special focus on EPS. We will show that in a properly designed and constructed building, insulation material plays only a minor role in fire safety. On the other hand, insulating material contributes enormously to energy savings for the heating and cooling of buildings. This is not only a financial saving but also a contribution to the mitigation of carbon dioxide emissions and the prevention of global warming. The unique properties of EPS make it the ideal, sustainable insulating material for many applications.

The purpose of this document is to clarify the fire performance of expanded polystyrene foam (EPS) when used as insulation material. It provides an overview of the facts on fire safe constructions using EPS building products. It is targeted as a reference to all interested parties, such as: building owners, architects, constructors, firemen, insurers, risk managers and risk engineers. For the members of EUMEPS, the central issue is understanding and addressing the interests of the people involved, whether this is the owner who wants to have a comfortable, healthy, safe and affordable home; or a construction worker who wants to have a reliable, sound and fail-safe product; or a fireman who wants to limit the risks he faces when he helps people in case of emergency.

Why is EPS the preferred insulation material?

Technical advantages:
- Low weight, high compression strength, excellent walkability
- High insulation value, constant over time (without ageing effects, for example from decreasing content of blowing agents and/or increasing moisture content)
- Easy, clean and safe to work with
- Freedom to design practically any shape by molding or cutting
- Closed cell foam, inert, biologically neutral
- Available in fire safe FR quality

Health and safety aspects:
- No irritation to skin, eyes or lungs from released fibers or dust
- No personal protective equipment or clothing needed

Environmentally friendly
- Durable, because it doesn't degenerate by moisture, rotting, mould, UV exposure or compact by vibration
- Low environmental impact during production
- Easily and completely recyclable
- Free from formaldehyde, (H)CFC's and other ozone depleting blowing agents

Competitive price
- The most cost-effective insulation

1 Fire: effects and prevention

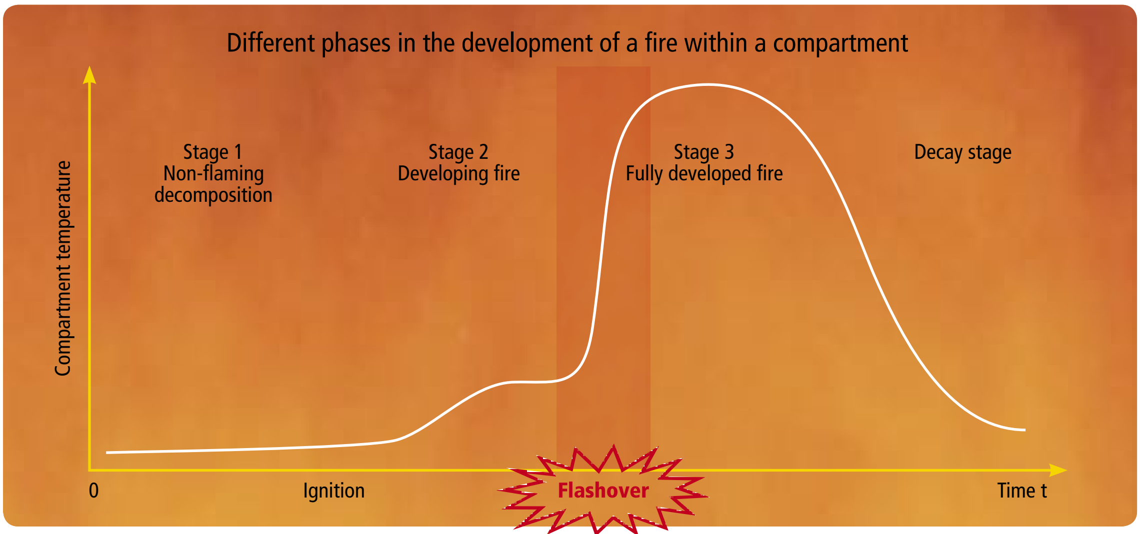
A fire can only start and continue to burn if three essential factors are present. These three factors, comprising the fire triangle, are the availability of combustible material, oxygen and ignition energy. Normally, combustible material and oxygen are always available. The third factor, ignition energy, can be provided intentionally or unintentionally, e.g. by a flame, a spark, a cigarette or by a short circuit.

1.1 Stages of a building fire

When a building is in every day use at normal temperatures there is a natural balance between flammable material and oxygen. However, when flammable material comes into contact with a sufficient amount of energy this balance is distorted. A fire can ignite and pass through a number of phases: ignition, growth/development, fully developed and decay.

Solid materials do not burn directly but give off combustible gases when heated. It is the gases that burn. In the first phase of a fire, combustible gases develop and build up while the temperature is still relatively low. After some time there can be a rapid development of the fire: the flash over. An increasing number of elements reach their ignition temperature; temperature then rises quickly from about 100°C to 750°C. The accumulated gases ignite and the fire spreads through the whole room. For humans, temperatures above 45°C are uncomfortable; a prolonged stay in a temperature above 65°C can cause damage to the lungs and people cannot survive for long if temperatures are higher. After the occurrence of a flash over, the fire reaches its full size and further development is limited by the availability of oxygen through ventilation. After flash over the chances of saving people or the content of a room are minimal because of the temperature, lack of oxygen and damage to materials by heat and soot. Left to burn, a fire will eventually decay due to the lack of flammable material.

EPS starts to soften at a temperature of about 100°C, a temperature at which people have minimal chance to survive. At this phase of a fire there is hardly any oxygen left and the air is toxic because of high levels of carbon dioxide and carbon monoxide. During the phase of rapid fire development, the flash over, wood will self ignite at a temperature of about 340°C and EPS at a temperature of about



ISO TR 9122-1 [ref 1]

	Netherlands	New Zealand	Western-Europe	USA	Denmark
Casualties (per million inhabitants)	6,4	9,6	13,3	25,0	14,6
Damage (in % GNP)	0,20	0,11	0,27	0,35	0,39
Prevention costs (% GNP)	0,30	0,18	n.a.	0,39	0,49

Overview of casualties and damage per region. [ref 2, 3]

450°C. So the time to save people and material is limited to the first stage of a fire and this is independent of the insulation material. After a flash over people inside cannot be saved and the material value of the compartment will probably be a total loss. From flash over damage control only can be achieved by isolating the possible fire. EPS has a limited role in the design of fire resistant constructions used to compartmentalise buildings. EPS should only be applied in such constructions in combination with other fire resistant materials which perform the fire resistant role.

1.2 Consequences of fire: casualties and material damage

It is not possible to prevent fire totally. Society is always in search of the optimal balance between the costs of preventive measures and the consequences of fire. Building regulation is a reflection of this process. Modern building regulation has a tendency to move towards performance based regulation. This is acknowledged in the European Union by the adoption of the Construction Product Directive (CPD), initiated in 1988, in which performance based criteria play a central role. Some older regulation still makes descriptive statements. An example of this could be requirements for non-combustibility of insulation material. The performance based alternative is to have fire performance criteria for building elements like the floor, the wall, the ceiling or the roof. The performance based approach tends to result in improved fire safety at lower cost. This can be illustrated in the Netherlands and New Zealand where regulation is mainly performance based. The death rate caused by fire in the Netherlands is now 6,4 per million inhabitants and 9,6 in New Zealand, compared to 13,3 per million in Europe and as high as 25,0 in the USA, which has mainly descriptive based regulation.

In addition, statistics indicate that performance based regulation is an effective approach for limiting fire damage.Damage caused by fire in the Netherlands is 0,2% of GNP and as low as 0,11% GNP in New Zealand compared to the European average of 0,27%. The costs of prevention in the Netherlands amount to 0,3% of the GNP and 0,18% in New Zealand. A country like Denmark, with a mainly descriptive based fire regulation, spends 60% more on fire prevention but has 95% more damage and 128% more deaths from fires than the Netherlands, with its performance based approach. [ref 2 and 3]

Reasons for high amounts of damage

- Insufficient fire prevention measures
- Increase in business continuity damage caused by a concentration of production facilities and supplies
- More expensive, yet vulnerable, production facilities
- Lighter but at the same time bigger and more complex buildings
- Larger fire compartments
- Failing fire compartmentalisation measures and fire doors
- High fire load
- Insurance and claim behavior: lower own risk and wider coverage
- Non-compliance of regulations in force

1.3 General fire prevention principles

The biggest part of the financial cost from fires around the world is caused by a few large fires with extensive damage. This is due to a number of reasons.

Considering possible fire prevention measures, this list of reasons could give some guidance to help reduce the damage:

• Make compartments!

Take into account the size of the compartment as well as the value of the contents of the compartment and the importance of it for business continuity. An example of this could be to divide the production from the storage of goods. Regularly check if compartmentalisation measures are functional. The risk is that openings will be made in compartment walls (e.g. for ventilation pipes or electricity cable gutters) or that fire doors won't close anymore.

• Professional workmanship

Good design and detailing is a first step, but professional workmanship is needed to ensure performance. Bad preparation, incorrect materials and poor execution of the work is the source of many problems.

• Reduce the fire load!

The fire load of a building is made up of two components: the static and the variable fire load. The fire load of the building products used for the construction is called the static fire load. Normally, the most important factor is the variable fire load, consisting of the building contents. To reduce the fire load the first two items to review are the contents of a building and the surface materials within a room. Insulating materials are normally covered by surface materials like gypsum, stone or steel and will only contribute to the fire after this surface material fails. By the time of this failure flash over has occurred and the compartment is a total loss.

• Make use of active fire prevention measures!

A high percentage of fires is caused by arson, so not only smoke alarms and sprinklers but also burglar alarms, fencing and entrance protection systems need to be considered.

Insulation material type is not the most important factor, e.g. 2008 fire at a Gamma DIY store (NL) with non-combustible insulation.

Details are important! Unless warnings from the roofing constructor they choose the cheaper detail. Result; the wooden substructure caught fire.

• Prevent failure of fire doors!

According to research by the global insurance company Factory Mutual, failing fire doors play a negative role in two-thirds of all fire damages. Compartmentalisation fails because fire doors are open, e.g. by wedges keeping the heavy doors open.

• Other preventive measures

- Maintenance of the electrical installation. Short circuits cause many fires and can effectively be detected by regular infrared thermographic checks.
- Maintain a policy of "hot work permits". These permits normally include measures such as the availability of hand fire extinguishers, the availability of a mobile phone and checking of the area for signs of fire after one hour.
- Prevent the storage of combustible goods against the outer walls of a building. These stored goods often are subject of arson and can cause the whole building to be destroyed by fire.

1.4 Fire prevention measures related to insulation

Although normally not the first material affected in case of fire, some guidelines could be taken into account for the use of insulation material.

• Always use a covering material.

Not only to protect insulation material from fire but also to protect it from mechanical damage, moisture and mould problems or smoldering fire. It is important for all insulating materials to be durable whilst performing their insulating role.

• Details

The quality of a construction is highly influenced by the quality of the details as designed by the architect. The solutions for the details, the places where different building elements meet, are essential for the quality of the construction, not only in respect to fire properties but for many other essential construction properties as well.

• Fire retarded EPS

Most of the EPS insulation products being sold in Europe are made of a fire retarded quality. The main purpose of this is to fulfill the regulatory and market requirements. Fire retarded EPS shrinks away from the heat when exposed to ignition energy. When ignited by the heat source it self extinguishes as soon as the heat source is taken away. Therefore fire retarded EPS does not provide the route by which fire will spread through a building.

1.5 CE-marking

Since May 2003 CE-marking of insulation products is mandatory under the Construction Products Directive (CPD). CE-marking can be seen as the 'passport' for the free trade of building products within the European Union. Part of the CE-mark is the declaration of the reaction to fire classification of the product. This classification applies to the naked product as placed on the market. For naked EPS this classification is Euroclass D or E in case of fire retarded material and Euroclass F in case of non-fire retarded material (which is often used for packaging). In fact, this classification tells little about the fire performance of the building element in which the insulation product is used.

Regulatory demands vary from country to country but in many cases the reaction to fire performance of the naked product is just a formal mandatory criterion. Where regulation is dominantly performance based, as intended by the CPD, requirements are based on building or construction elements. Recent European developments address this point of view and make it possible to perform reaction to fire tests on standardised build-ups, simulating end use applications. Producers can then declare the classification on the reaction to fire, simulating end use applications, on the product labels just outside the formal CE-box. Research by EUMEPS points out that the classification for reaction to fire for EPS in the standardised build-up behind gypsum is Euroclass B-s_1d_0. The same classification results for EPS behind profiled steel, which uses a standardised build-up simulating the end use of EPS in a flat roof construction with profiled steel. In both cases, this results in the same classification as the identical construction with mineral wool or PIR insulation.

Characteristics of	EPS-FR Temperature	EPS non-FR Temperature
Softening, shrinking, melting	from 100°C	from 100°C
Ignition temperature		
With pilot flame	370°C	350°C
Self ignition temperature	500°C	450°C

2 Fire behaviour of EPS insulation products

The fire behaviour of naked EPS insulation material is not very relevant. The material is generally covered by other material which determines the fire behaviour. The insulation material is only affected by fire after the covering material fails and by this time the building or the compartment cannot be saved from total loss. Nevertheless, many negative misconceptions exist about the role of insulation material in the case of fire, the fire behaviour of EPS, the production of smoke and its toxicity. Facts show quite a different picture!

2.1 Fire behaviour of fire retarded EPS insulation products

Like most organic materials, polystyrene foam is combustible. However, in practice, its fire behaviour depends upon the conditions under which it is used, as well as the inherent properties of the material. The inherent properties depend on whether or not the foam is made of fire retarded material or not. Most EPS insulation products have been made of fire retarded quality for decades. This is achieved by adding a very small quantity (<1%) of a fire retardant agent to the material. The fire retardant is polymerised into the molecular structure and is insoluble in water, which ensures no fire retardant leaches from the material into the environment. Research shows that the fire retardancy remains effective for decades [ref 10].

The fire behaviour of fire retarded EPS is significantly different from non fire retarded EPS. Exposed to heat, fire retarded EPS shrinks away from the heat source. The probability of ignition of the material is significantly reduced and welding sparks or cigarettes normally will not ignite it. Another effect of the fire retardant is that its decomposition products cause flame quenching: as soon as the heat source is taken away the flame extinguishes. The effect is clearly illustrated by a demonstration in which a hole is burned into a big block of EPS using a torch. As soon as the torch is taken away the fire extinguishes.

The reaction to fire behaviour should be evaluated not on the material or product, but on the building element or construction element level (also called works). A basic design rule with EPS and other insulating materials is never to use the material uncovered. Because EPS never should be the material facing the fire, reaction to fire classification of the material or naked EPS product is only of formal importance. The layer really determining the reaction to fire behaviour is the surface layer of the construction, which faces the fire and covers the EPS insulation material. Using a combination of EPS insulation and specific cover layers it is always possible to design a construction which fulfils the fire requirements. Correctly applied and installed EPS is not of influence to the occurrence and the development of fire in a building.

The excellent behaviour of EPS in constructions has been confirmed by recent studies by EUMEPS. Tested according to EN 13501-1 for the standardised build-ups of EPS covered with gypsum and steel resulted in a B-s_1d_0 classification. The smoke part of this classification, the s_1, is the best possible classification for a construction, which means there is little or no contribution to the production of smoke.

2.3 Toxicity of smoke from combustion of EPS

The contribution of EPS to the production of smoke and toxic gases depends upon on the amount of available insulation material and the density of the material. The relative importance of this contribution is determined by the share of EPS to the total fire load. As mentioned previously, the share of EPS and other insulation materials to the total fire load is generally very low, e.g. about 3% in a case study for a warehouse [ref 6].

Furthermore EPS insulation is normally covered by surface materials like gypsum, stone, wood or steel which protect the EPS during the first phase of a fire. Initially, the surface of the construction heats up after a fire starts. Subsequently, the heat flows through the construction. If the heat penetrates to the EPS within this construction, the material is not ignited but shrinks away from the heat and eventually melts. Only if the surface material is fully burnt through and the molten EPS is directly exposed to the flames will EPS contribute to the fire and produce smoke and combustion gases. Normally the fire consumes only part of the molten EPS material leaving the rest as a solidified resin after the fire.

The toxicity of the smoke of combustion of EPS was investigated by TNO in 1980. The results proved EPS to produce considerably less toxic fumes than natural materials like wood, wool or cork [ref 13]. EPS is a pure hydrocarbon $(C_8H_8)n$ which decomposes ultimately into CO, CO_2 and H_2O.
The influence of the fire retardant used in EPS is very small since the desired effect is achieved at a load content of only 0,5% to 1,0 %, whereas for some other materials a content up to 30% fire retardant is needed. The influence of the fire retardant on toxicity is therefore minimal for EPS.

2.2 Heat of combustion

The heat produced by burning material is one of the factors determining how a fire develops. That is why the fire load is often one of the criteria in regulation and must be calculated at the design stage. The calorific value of EPS per kilogram is 40 MJ/kg, e.g. two times higher than timber products with about 20 MJ/kg. However, 98% of the volume of EPS consists of air at a typical use density of 15-20 kg/m^3, which results in a low contribution to the overall fire load. EPS is also favourable compared to other insulating materials [ref 4]. The contribution of EPS to the fire load of the most common flat roof construction with a bituminous roof felt is about 10% [ref 4]. A case study showed that in a warehouse for a grocery store chain, the contribution of EPS flat roof insulation to the overall fire load was 3% [ref 6 and ref. 12]. Exchanging EPS with other insulating materials makes no difference at all to the fire load.

In the table below Prager [ref 8] shows that there is little difference in the contribution to the fire load from the various insulation materials if compared at an equal insulation value.

Material	Thermal conductivity λ (W/mK)	Density ρ (kg/m^3)	Heat of combustion H (MJ/kg)	Fire load/m^3 Q_V (MJ/m^3)	Fire load/m^2 Identical R-value Q (MJ/m^2)
EPS	0,035	20	39,6	792	92
XPS	0,040	32	39,6	1.267	169
MW	0,045	170	4,2	714	107

In [ref 8] Prager shows the contribution to the fire load for a number of common insulation materials.

The toxicity of smoke fumes from EPS and various 'natural' materials.					
Sample		Emitted fractions (v/v) in ppm at different temperatures			
	Smoke gases in a Fire	300°C	400°C	500°C	600°C
EPS (standard grade)	Carbon monoxide Monostyrene Other aromatic compounds Hydrogen bromide	50* 200 fractions 0	200* 300 10 0	400* 500 30 0	1,000** 50 10 0
EPS-SE (fire retardant grade)	Carbon monoxide Monostyrene Other aromatic compounds Hydrogen bromide	10* 50 fractions 10	50* 100 20 15	500* 500 20 13	1,000* 50 10 11
Deal	Carbon monoxide Aromatic compounds	400* -	6,000** -	12,000** -	15,000** 300
Chip board	Carbon monoxide Aromatic compounds	14,000** fractions	24,000** 300	59,000** 300	69,000* 1,000
Expanded cork	Carbon monoxide Aromatic compounds	1,000* fractions	3,000** 200	15,000** 1,000	29,000** 1,000

Remarks: Test conditions specified in DIN 53 436; air flow rate 100 1/h; 300mm x 15mm 20mm test specimens compared at normal end-use conditions. * smouldering/glowing ** as a flame - not detected

APME research according to DIN-53436.

Extensive research by APME, performed according to DIN-53436, at temperatures from 330°C to 600°C also proved that fire retarded EPS produces less toxic fumes than natural materials, producing no gases such as chlorine or cyanide [ref 11]. EPS combustion is relatively clean.

2.4 Obscuration by smoke

Toxicity is one effect of smoke, obscuration is another. Obscuration makes it difficult to escape from a room on fire. Smoke production is of particular importance for building materials used in escape routes. For standard buildings the evacuation time is about half an hour. The behaviour of the construction with respect to smoke production after this time is generally of no importance. In its normal end use EPS is covered by surface materials like gypsum, stone, wood or steel. These materials protect the EPS during this phase of a fire. Tested according to EN 13501-1 many applications will achieve a B-s_1d_0 classification. The s_1 classification for smoke production is the best possible classification. When directly exposed EPS burns it produces a considerable amount of heavy, black smoke, which is proportional to the consumed mass.

Hence, when used correctly in recommended applications, EPS does not contribute to the spread of fire and produces little smoke and toxic gases. The choice of the insulation material has little influence on the amount of toxic gases and smoke produced during a fire.

3 Fire safety of EPS insulation products and insurance

Some insurance companies vary the insurance premium of a building depending upon the insulation materials used. There is no statistical foundation for this practice. We should expect insurance companies to base their judgment on facts and solid evidence. The facts speak for themselves.

3.1 Analysis of large fires (greater than 1 million Euro damage)

In case of small and large fires there is often a lot of speculation about the cause. This is subjective and dependent on the perception, expertise or business interest of the people involved.

Dutch scientific research into the causes of big fires led to the following conclusions:

• Type of building

Most fires occurred in schools, industrial and public meeting buildings. Modern buildings built under recent regulation tend to be marginally less vulnerable to fire than old buildings. More than half of the buildings had not been inspected by the fire brigades during the past three years, although advice for improvement was given in 87% of the cases from the buildings that were inspected.

• Compartments

All buildings contained some kind of fire compartments, but only in 62% of the cases was this known to the fire fighters, who could then adapt their firefighting tactics accordingly. In 30% of the cases the compartmentalisation failed, 50% of which was due to failure of the self-closing fire doors.

• Time of the start of the fire

Most fires started outside the normal opening hours of the building: between 18.00 hrs and 09.00 hrs.

• Extinguishing of the fire

The fire fighters arrived at the fire within the acceptable time span after the fire was reported. In about 5% of the cases there was a problem to reach the fire and in 5% of the cases there was a problem with the availability of water to extinguish the fire. In 13% of the cases the fire fighters were not able to prevent the spread of fire to the neighbouring location. The fire fighters initially tried to fight the fire from the inside of the building in two thirds of the cases.

• Cause of fire

Many fires were caused by malfunctioning or misused equipment (26%) or arson (23%). In reality the percentages of both causes are probably much higher, because the cause remains unknown for 40% of the fires.

3.2 Role of insulation in fire

Objective analysis shows that the influence of insulating material on the occurrence and development of fire is marginal, if existent at all. Independent work, validated by KPMG, has been carried out by the well known Dutch institutes TNO and BDA on the role of the insulation material into the cause and development of more than 40 large industrial fires in the Netherlands (ref. 15, 16, 17, 18). This was initiated in 2002 and continues to the present day. The conclusion is that EPS does not contribute to the start or the development of these fires. It has been demonstrated that there is no proven relationship between the type of insulation material used and the fire damage. Contributory factors have been identified, amongst which are: carelessness with hot work, absent extinguishing means and the fire properties of the building content.

The fire at the Berlin Philharmonic in 2008 illustrates how carelessness with hot work can cause fire independent of the type of insulation material used. (See photos right and detail bottom)

4 FIRE SAFETY OF EPS PER APPLICATION

In this section a number of fire safe applications of EPS are described. If applied correctly, the use of EPS is of no influence to the start or development of fire in a building. Covered by a surface material EPS is never the material facing the fire and determining the fire behaviour of the construction. It's nearly always possible to design a construction with EPS fulfilling all requirements, including fire requirements.

4.1 Fire safe floors and foundations using EPS

EPS is frequently used as insulation beneath concrete ground floors or as a lost mould for foundation. EPS insulation under higher floors, e.g. when the ground floor is used as parking deck, is not recommended if the EPS is uncovered. Uncovered use is acceptable for a crawl space.

4.2 Fire safe walls using EPS

Wall constructions are the perfect example of why requirements should be performance based on a building element and not descriptive for a product or material alone. EPS is excellent for insulation to the inner side of a wall, for cavity insulation boards, for loose fill insulation, for external thermal insulation systems (ETICS) or for prefabricated composite panels, such as structural insulating panels (SIPS) or steel sandwich panels.

In all of these examples the EPS insulation is covered by an inorganic or metal surface layer. These layers make it possible to fulfill all requirements for reaction and resistance to fire dependent on the surface material applied. Tests commissioned by EUMEPS illustrate that a wall construction with only 9 mm gypsum has a classification of B-s_1d_0 [ref 21]. Normally, no tests are required for a cavity wall construction with an inner wall made out of stone [ref 20].

Tests performed by Austrian testing institutes as well as the firepolice and the Austrian fire fighters of Graz proved that EPS for ETICS also performs excellently. ETICS can achieve a reaction to fire classification of B-s_1d_0 and a full scale tests confirm these results [ref 25]. Extensive statistical research on 175 fires by the Polish fire fighter organisation pointed out that the occurrence of fires with ETICS using EPS was proportional to the market share of EPS and similarly for mineral wool [ref 26].

4.3 Fire safe EPS steel sandwich panels

Extensive research has been carried out on the reaction to fire classification for steel sandwich panels [ref 9 and ref .20]. This clarifies that it is not the core materials which determine the classification but the coating that is applied on the outsides of the steel. This coating protects the steel from corrosion and gives colour to the building. If, for example, this coating is a thin 50 micron polyester coating (giving little protection to the metal sheet) the classification will probably be Euroclass B. If a thicker and better protecting 200 micron plastisol coating is used, the classification will probably be a Euroclass C.
The results of these outcomes are confirmed by “Free standing room corner tests” (analog to ISO 13784). The tests showed that no flash over occurs for EPS cored steel sandwich panels with a well designed joint detail [ref 23].

A report by the Association of British Insurers (ABI) acknowledges that in the case of buildings for the food industry or coldstores, foam plastic cores are to be preferred to other solutions due to hygienic reasons. They also comment that "sandwich panels do not start a fire on their own" and, with appropriate fire safety management, risks associated with the food industry can be controlled acceptably. Around hot work areas (frying pans, etc.) special measures are needed and precautions should be taken where electric cables go through these panels, because the metal skins can cut through the electrical insulation of the cables (independent of the type of insulation!).

The key conclusions for the fire behaviour of EPS steel sandwich panels are:

- Independent of the core material, all steel sandwich panels with a plastisol coating will have the same Euroclass: B.
- Comparative research shows the results of the SBI tests are fully in line with the larger and therefore more expensive room corner test, ISO 9705 [ref 19].
- The differences in the test results of steel sandwich panels with an EPS core are minimal when compared to other core materials.
- The joint detail and the mounting and fixing details of the sandwich panel are very important to the result of the fire tests.

4.4 Fire safe steel decks insulated with EPS

Hot works on roofs are responsible for a considerable number of roof fires. Analysis of these roof fires lead to the conclusion that they mainly occur when open fire torches are used around details. At the connection between the flat roof and the vertical wall the roofing contractor has no clear knowledge the materials used in the wall. During renovation the collected dirt can ignite easily. Details around water drains or ventilation channels are also notorious for causing fires. Many developments are continuing to reduce the number of fires. Insurers increasingly require hot work permits and strict procedures connected to this kind of work. Recommendations are also being developed by considering details and the use of self adhesive membranes instead of torch applied membranes, where there is a considerable risk of fire [ref 27]. Hence, it is not the insulation material that is the main concern but the hot work combined with the risk of details. Both can and will be solved by the industry to make the flat roof a safer place.

The European classification system for external fire, EN 13501-5, refers to four different methods mentioned in the ENV 1187. For each of these methods it is easily possible to design a construction with EPS insulation which fulfils the requirements. Normally, there is a layer of glass fleece included somewhere in the build up. The testing for the roof construction is usually commissioned by the producer of the roofing felt. Nearly all current waterproofing felts have been tested in combination with EPS because the roofing felt producer wants to make use of the superior qualities of EPS as a flat roof insulation material regarding durability, walkability, ageing and price.

Many modern industrial buildings are made of a light weight steel construction. Sometimes the fire safety of this kind of building is a subject of discussion and the insulation material becomes part of the debate. In reality, the objective is for as large a building for as little money as possible and so cost as opposed to fire safety is the driving factor. A steel construction without any protective coating fulfills this criterion. If a fire starts in a compartment of such a building and can grow into a developed fire, then this part of the building is a total loss. Within 10 to 20 minutes the steel construction can collapse and fire fighters will not be able to enter the building. What is the role of the insulation material in this scenario? The true answer is that it has a fairly unimportant role.

Research has been commissioned by the EPS industry to find out the behaviour of different insulating materials in such a light weight steel construction [ref 12]. The conclusion of this research is that for EPS the time until a fire spreads from within the building to the surface of the roof is about 20 minutes. For other insulating materials this time could possibly be extended by another 10 to 20 minutes. It is questionable whether this is relevant if the construction fails normally between 10-20 minutes, before the fire spreads through the roof. Furthermore if a roof is not fully designed according to proven fire resistance, not all details will be fire resistant. Practical experience shows that fire will not spread to the roof through the construction but by details such as a roof light, a water drain, a ventilation pipe, a window in the wall, etc. Once the fire is on the roof fire incident reports show that the fire canwspread with a speed of up to 4 m/min depending on the weather conditions.

The fact that EPS insulation is thermoplastic has positive side effects in case of fire. The EPS shrinks away from the heat, returning to its original solid granular form and by doing so it loses its insulating properties. Therefore, part of the heat produced by the fire gets out through the roof. Because of this, the time to flash over is longer and the time before the steel structure collapses is extended. Hence, the firefighters will have more time to protect neighbouring compartments [ref 12].

A factor often not included in the analysis of fire behavior of constructions is the influence of moisture barriers and anti-corrosive coatings. Bituminous moisture barriers are still often recommended because they are the most effective and reliable moisture barriers. Other light weight moisture barriers such as PE film can easily blow away and tear. Unreliable moisture barriers can lead to severe problems in flat roofs such as loss of insulation value by moisture saturation, loss of compressive strength and leaking due to the heads of the mechanical fasteners puncturing the roof when it is walked upon. Moisture barriers as well as anti-corrosive coatings heavily influence the reaction to fire behavior of the roof.

Finally, a factor often overlooked is that a thermoplastic insulation material may shrink away and become useless after a severe fire, but other insulating materials have to be fully replaced as well. Why? - because you cannot eliminate the impregnated smell of the smoke. You can ventilate for ages but it won't help!

So, in conclusion, the insulating material does not play a decisive role in the development of a fire in a lightweight building with a steel deck. If a fire starts within a compartment of such a building, this compartment is generally a total loss, if not for the fire then for the smoke and the lingering acrid smell.

Building design is important in order to find the right balance between the advantages and disadvantages of big compartments. On the one hand bigger compartments are cheaper to build with logistic advantages, but they have higher risks and higher insurance premiums. On the other hand smaller compartments are more inconvenient and the costs of prevention higher . Compartmentisation is key to management of the fire risk. Proven constructions and details need to be used, to maximise fire and smoke resistance. Design is important but attention is also needed for the construction and the maintenance phase.

Recent research commissioned by EUMEPS, carried out by TNO/Efectis and by Warrington Fire Gent, concerned the reaction to fire of EPS on a steeldeck according to EN 13501-1. This resulted in a Euroclass B-s_1d_0 classification. Despite this d_0 classification, which is the best possible classification as regards the forming of burning droplets, questions still arise as to the possibility of molten EPS droplets falling down through the joints of a steel deck during a fire. Could such drops lead to the further spread of fire? If fire retarded EPS is exposed to fire it will shrink away. If further heated it will melt and droplets can fall down. However, these droplets extinguish as soon as they touch the ground and cool down. Tests prove that even tissue paper will not ignite by these droplets. If the droplets fall into an area already on fire they will not cool down and they will burn. The chance that a fire fighter or another person is hurt by EPS droplets is small.

5 Conclusion

Fire safety is one of the essential requirements when designing a building. It cannot be compromised.The role of insulation in respect to fire safety is often overrated. This document shows that it is perfectly possible to design a building using EPS as insulation material and fulfill all insulation requirements including fire safety.

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