August 2004

Composite panel solutions with STYROFOAM

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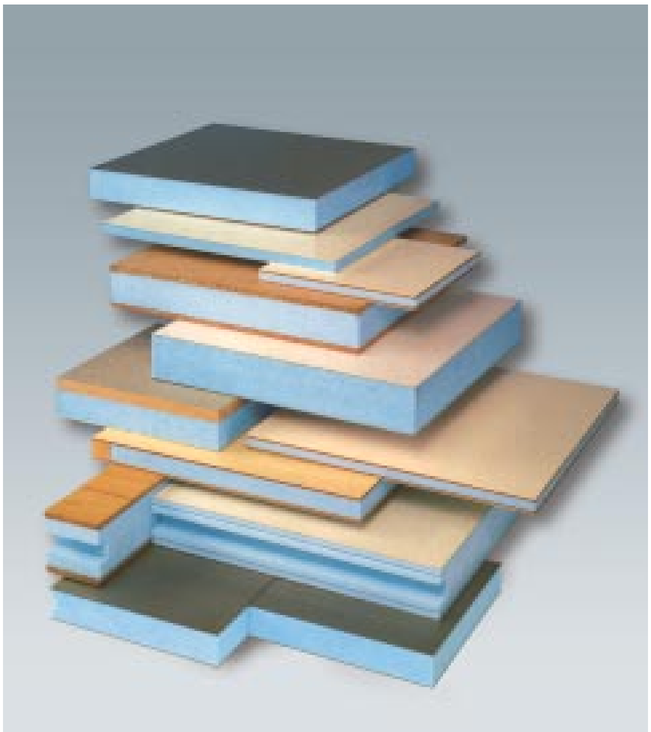


Fig. 1 **Samples of composite panels with a core of STYROFOAM material**

Fig. 2 **STYROFOAM polystyrene extruded foam**

1. Composite panels with a core of STYROFOAM

1.1 About STYROFOAM

1.1.1 STYROFOAM – from the inventor of XPS

Extruded polystyrene foam (XPS) was first developed and produced in the 1940s by Dow Chemical in the US and was used by the US navy as swimming floats. Due to its good thermal insulating properties and moisture resistance, this blue foam soon found its way into the construction of temperature controlled stores and since the early 1950s has also been used most successfully in the building industry. Constant further development of the material and of the technology associated with its production have led to today's diversified range of products – which offer innovative and efficient solutions for a vast array of applications using STYROFOAM extruded polystyrene foam.

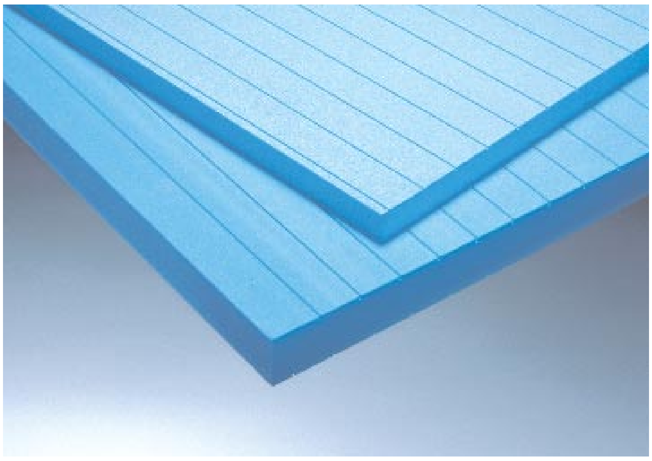


Fig. 3 **STYROFOAM RTM-X with grooved surface**

1.1.2 Product properties

STYROFOAM extruded polystyrene foam is a closed-cell material; it offers a range of properties which are very important for a core material in composite panels: they include

Good thermal insulation
STYROFOAM provides reliable and durable thermal insulation performance.

High mechanical strength
STYROFOAM has extremely high strength in compression, tension, bending and shear. Composite panels made with STYROFOAM exhibit high impact strength and resistance to dynamic loading.

High water and vapour resistance
The closed cell structure ensures that STYROFOAM retains its performance even when in permanent contact with moisture.

Chemical resistance
STYROFOAM material is resistant to most acids and salts.

Good bonding properties
STYROFOAM boards have a smooth dust free surface, which provides a very good base for lamination

Lightweight
STYROFOAM's high strenght-to-weight-ratio is particularly important in applications such as camper vans and refrigerated trucks.

Long-term performance
STYROFOAM does not rot: its thermal and mechanical properties have been proven long-term.

Easy to use
Due to its homogeneous cell structure and uniform density STYROFOAM can be cut very accurately and to very close tolerances.

With all those specific product properties, STYROFOAM products are a proven solution to the production of lightweight and highly durable composite panels.

Composite panels with a core of STYROFOAM

1.1.3 Environmental compatibility and durability

Environmental concerns increasingly focus attention on the need for sustainable constructions using materials and strucutures which offer long-term performance.

The properties and performance characteristics of STYROFOAM make it a highly efficient material for long-term use in composite panels: product quality and properties are continuously recorded and monitored by Dow's in-house laboratories and tested by independent institutes.

STYROFOAM products made with CO_2 as the blowing agent contain air in the foam cels and are identified by the suffix 'A': for example STYROFOAM IBF-A. STYROFOAM products for specific applications, requiring even lower thermal conductivity, are made using HFC as the blowing agent and are identified by the suffix 'X': for example STYROFOAM RTM-X.

1.2 Long-term experience of STYROFOAM as a core material tried-and-tested in practice

The idea of sandwich construction dates back to the 19th century, but the technique really came into its own in the 20th century, largely in response to the demands of the aerospace industry to optimise strength-to-weight-ratio. Today, automated methods of production, together with a large selection of facing materials and adhesives, permit the production of composite panels tailored to meet a vast range of requirements in very diverse fields of application. With the development of ever-larger presses, it is today possible to produce sandwich panels in excess of over 12 m long.

STYROFOAM boards have been used for more than 40 years as a core material which allows precision processing and which is highly stable in composite panels – over 20 million square metres of such panels, with their 'blue interior', have been successfully tried and tested in that time. With this long-term practical experience, Dow has built up a wealth of sound technical and technological know-how – which is particularly important for the successful development of solutions for composite panel production.

1.3 Applications

The fields of use are varied – STYROFOAM is used as a core material in the following applications:

- **Trucks for chilled and refrigerated transport**
- **Chilled stores**
- **Cold storage cells**
- **Cold store walls**
- **Façade panels**
- **Self-supporting roof panels**
- **Insulating doors**
- **Camper vans and caravans**
- **Portable cabins**
- **Internal partitions**

2. Production and structure of composite panels with STYROFOAM

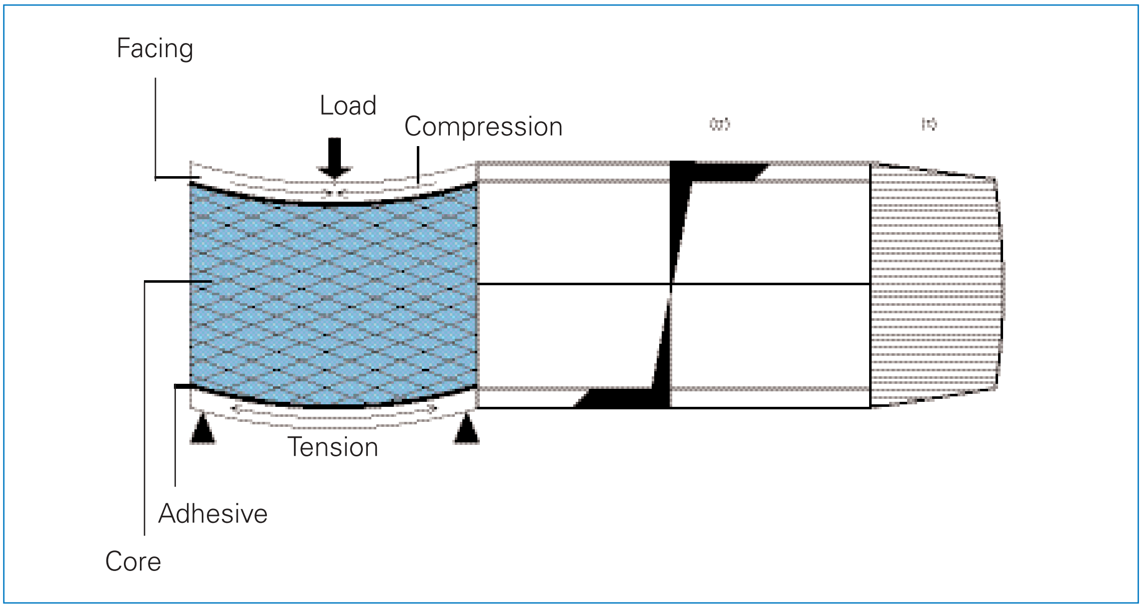


Fig. 4

A composite panel is a load-bearing, lightweight laminated structure, the performance of which can be analysed in the same way as that of a steel I beam. Bending moments, induced by loading, are resisted by tensile and compressive forces in the facings, whilst the core material absorbs the shear forces (fig. 4).

The performance and durability of a composite panel depend upon the proper harmonization of its constituent parts and the manufacturing process itself. From decades of experience in a whole range of applications, Dow has built up a vast store of know-how – both on production technologies and on the various components of the composite panel.

Fig. 5

2.1 Wide choice of facings

A wide range of sheet materials can be used as facings for lamination to STYROFOAM core material (fig. 5) including:

Wood-based sheets, aluminium, steel, PVC, GRP, gypsum plasterboard, gypsum cellulose fibre and glass.

Fig. 6
Cross-section of an aluminium-faced door panel with a STYROFOAM core

Production and structure of composite panels with STYROFOAM

2.2 Adhesives

Solvent-free adhesives such as 1 and 2-component polyurethane adhesives must be used to adhere the panel facings to the core. Reactive polyurethane, hot-melt, or epoxy adhesives are also used in specific cases and various press technologies are deployed, including vacuum and hydraulic presses and hip rollers.

The choice of adhesive and bonding technique is governed by the strength requirements of the panels to be produced, and their particular application.

Fig. 7 Placing the STYROFOAM boards

2.3 STYROFOAM core material

The core material has to absorb the shear forces which occur due to the loading and bending of the composite panel (see fig. 4).

STYROFOAM is ideally suited as a core material because:

- its high compressive strength prevents the facings from buckling.
- it increases the composite panel's resistance to deflection.
- its shear strength provides a very high shear modulus.

The high shear modulus provided by STYROFOAM allows composite panels to be designed with long self-supporting spans, enhanced rigidity and low deflection.

Fig. 8 Once the adhesive has been applied, a laminated wooden layer is installed

STYROFOAM extruded polystyrene foam boards for use in composite panels have planed surfaces and are produced to very close dimensional tolerances. Boards can be ordered with grooved surfaces which assist the bonding process by allowing air to be driven and the adhesive to spread uniformly.

Standard tolerances

Width (600 mm width) +3/–0 mm, (1200 mm width) +5/–0 mm
Length +10/–0 mm
Thickness +/–0,5 mm (custom-made product: +/–0,1 mm)

Other tolerances on request
Standard grooves:
3.5 mm deep x 1.8 mm wide at 39 mm centres.

Fig. 9 Applying facing layer (GRP in this illustration)

Production and structure of composite panels with STYROFOAM

Laboratory testing

Dow's extensive test programme includes small-scale dynamic fatigue testing, panel surface temperature measurements, testing the effects of solar exposure, testing large-scale panels to failure and a variety of customised mechanical testing. The endurance properties of the products are evaluated, by performing creep tests.

The research and development department in Rheinmünster conducts product analyses, performs material research and develops new applications.

Fig. 10 Creep testing STYROFOAM in the laboratory

Fig. 11 Shear test on STYROFOAM

Professional support for your planning

Thanks to our decades of experience and our close working relationship with our customers, we have extensive knowledge of the technical processes involved in the production of composite panels. Please do not hesitate to contact us if you have any questions relating to the calculation of composite panels – our experts will be pleased to help.

2.4 Design notes

- Deflection should be calculated in accordance with Euro-Code 1 and be limited to span/300.
- Shear stress should not exceed the maximum allowable shear stress of STYROFOAM core material.
- Tensile and compressive stresses should not exceed the maximum allowable stresses of the facing materials or their critical buckling stress.
- Stringent quality control during production is essential for attaining a consistently high level of bonding.
- Where conditions of use make thermal and/or hygroscopic bowing a possibility, this should be taken into account in the panel design.

2.5 Composite panel calculations

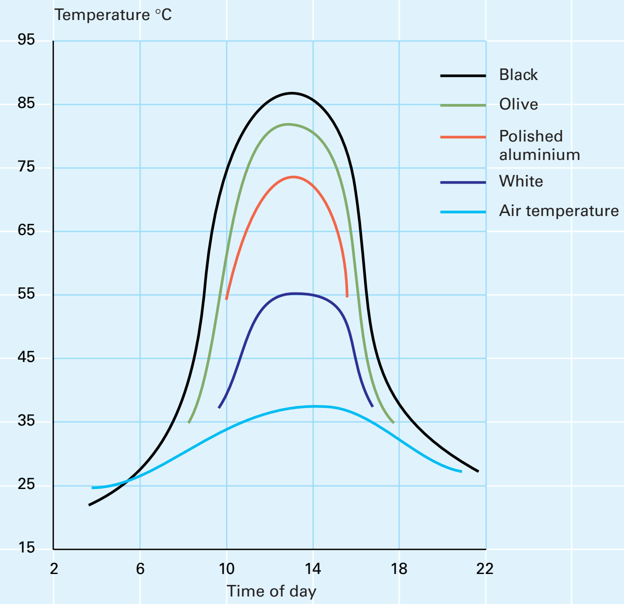
Before the following calculations can be used, it is essential to ensure continuous bonding between the various layers of the composite panel can be achieved.

For a simply supported composite panel, the deflection can be evaluated using the following equation:

$$d = k_f \frac{P \cdot \ell^3}{E \cdot I} + k_c \frac{P \cdot \ell}{G \cdot A}$$

= flexural deflection + shear deflection

d = Deflection
P = Load
ℓ = Span
E = Elastic modulus
I = Moment of inertia
G = Shear modulus
A = Area
k = specific coefficient



Panel surface temperature with solar exposure
The data refer to a 100 mm thick composite panel with STYROFOAM core and aluminium facings exposed horizontally in still air.

Fig. 12

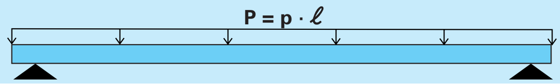
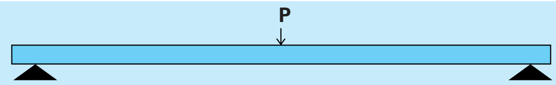
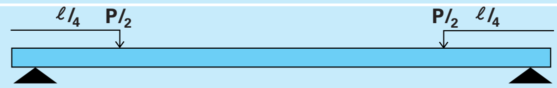
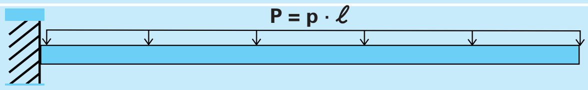
		k_f	k_c
Simply supported beam, uniformly distributed load		$\frac{5}{384}$	$\frac{1}{8}$
Simply supported beam, central point load		$\frac{1}{48}$	$\frac{1}{4}$
Simply supported beam, point loads at ℓ/4 span from the supports		$\frac{11}{768}$	$\frac{1}{8}$
Cantilever, uniformly distributed load		$\frac{1}{8}$	$\frac{3}{4}$
Cantilever, point load at free end		$\frac{1}{3}$	$\frac{6}{5}$

Fig. 13
Inserting the STYROFOAM boards into a floor panel.

3. Composite panels for refrigerated trucks

The technical requirements for refrigerated truck bodies are defined by regulations and by economic considerations, which include the resale value of a vehicle.

To be cost efficient, refrigerated truck bodies must be insulated effectively and reliably whilst also being lightweight and built with highly durable materials to last for decades. By choosing STYROFOAM as a core material it is possible to satisfy those requirements.

Panels with STYROFOAM core material have been used in the manufacture of floors, walls and roofs of refrigerated truck bodies for more than 25 years with proven success: STYROFOAM LB-X, STYROFOAM RTM-X and STYROFOAM HD 300-X are ideally suited to such applications.

Fig. 14 Well insulated and able to support loads: refrigerated truck bodies using STYROFOAM cored panels.

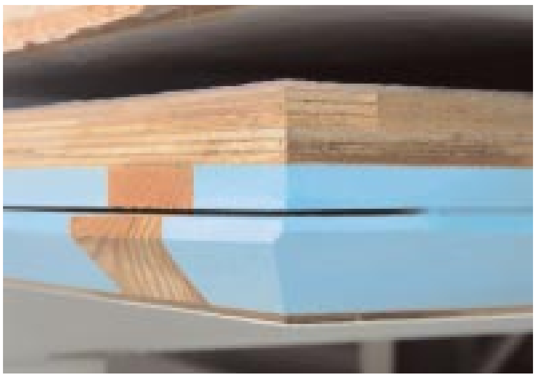


Fig. 15 Detail view of a floor structure

Our specialists will be pleased to assist you in selecting the right STYROFOAM product and calculating the required thicknesses for any application.

STYROFOAM and its characteristic properties in refrigerated trucks:

Durable thermal insulation
With a closed refrigeration chain and thermally efficient construction, the cargo space can be maintained at a controlled temperature very economically. Furthermore, because of the long-term performance of the STYROFOAM core, the cargo space will pass the second ATP test after six years of service.

High mechanical strength
When used in floor panels STYROFOAM supports heavy cargo loads and the dynamic loads of fork lift trucks. When used in walls it absorbs high dynamic loads, such as those caused by wind and vibration. When used in roof panels STYROFOAM will support high tensile loading from suspended items.

Moisture resistance
The closed cell structure means that STYROFOAM material is resistant to moisture – which is important for the long-term performance of the panel and can help to minimise costs of repair and maintenance.

Easy to use
STYROFOAM can be cut to size using conventional woodworking tools and machinery.

Fig. 16

4. Composite panels for the construction of camper vans, caravans and portable cabins

Fig. 17 Robust body consisting of floor, wall and roof panels with STYROFOAM core

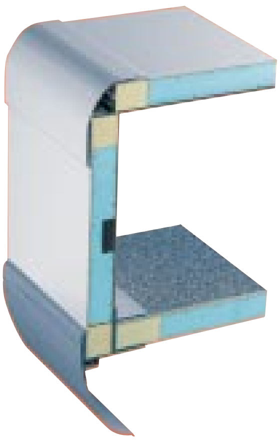


Fig. 18 Profile with GRP outer skin and STYROFOAM core material

Another field of application, in which Dow has decades of experience, is the use of STYROFOAM as a core material in composite panels used to construct camper vans and caravans. Leading manufacturers benefit from the very high strength-to-weight ratio of composite panels with STYROFOAM in the production of their vehicles.

With camper vans and portable cabins, the long-term thermal performance of STYROFOAM insulation plays a significant role.

STYROFOAM composite panels provide a high level of rigidity to withstand the vibrations and stresses in the roofs of camper vans, caravans and portable cabins.

Because of the rigidity of STYROFOAM XPS it is possible to reduce the number and cross-section of wooden inserts used in floor panels whilst maintaining the required strength.

Good thermal insulation
Important for long-term comfort at low temperatures during winter operation.

High mechanical strength
The composite panels provide good rigidity and load-carrying capability and optimise the absorption of dynamic forces and impacts throughout the life of the vehicle.

Lightweight
Improves fuel efficiency over the life of the vehicle.

5. Composite panels for cladding, windows and doors

The use of lightweight claddings has opened up a whole new perspective in architectural design within Europe – both in new buildings and in the renovation of older ones. Insulated composite cladding panels facilitate rapid construction and offer great flexibility in the choice of the facing materials and finishes.

To be suitable for this application the panel core material must offer high mechanical strength and thermal performance, properties which STYROFOAM extruded polystyrene foam possess.

Fig. 19 Cross-section of a window frame profile

Leading manufacturers of external doors and windows have chosen STYROFOAM, selecting it for its, convincing properties and performance.

Long-term thermal insulation
STYROFOAM offers highly effective long-term thermal insulating performance.

Good mechanical properties
Provides the necessary high resistance to mechanical loading and high impact strength.

Lightweight
Easy to handle in all fields of application.

Versatile finish and design options
Thanks to the wide choice of materials available as facings.

Fig. 20 Modern architecture using façade panels…

Fig. 21 ... and spandrel panels

6. Technical Data

Properties [1]	CE-Code	Standard	Unit	STYROFOAM IBF-X	STYROFOAM IBF-A	STYROFOAM LB-X	STYROFOAM LB-A
Density		DIN EN 1602	kg/m^3	30	30	32	33
Thermal conductivity @ 10 °C		DIN EN 12667/ DIN EN 12939	W/m·K	0,030	0,035	0,027	0,0335 (≤ 60 mm) 0,0345 (61 – 80 mm) 0,0355 (> 80 mm)
Thermal conductivity λ_D		DIN EN 13164	W/m·K	0,033	0,036	0,029 (20 – 70 mm) 0,030 (71 – 120 mm)	0,035 (< 80 mm) 0,036 (80 – 120 mm)
λ design value according to Z-23.15-1476		DIN 4108-4	W/m·K	0,034	0,037	0,030 (20 – 70 mm) 0,031 (71 – 120 mm)	0,035 (≤ 60 mm) 0,036 (61 – 80 mm) 0,037 (> 80 mm)
Compressive stress or compressive strength @ 10% deformation **Compressive modulus**	CS(10\Y)σ_m –	DIN EN 826 DIN EN 826	N/mm^2 [2] N/mm^2	0,25 10	0,25 10	0,30 12	0,30 12
Compressive creep (50 years) ≤ 2% deformation	CC(2/1,5/50)σ_c	DIN EN 1606	N/mm^2	0,08	0,08	0,11	0,11
Tensile strength **Tensile modulus**	TR400 TR600 TR900 –	DIN EN 1607 DIN EN 1607	N/mm^2 N/mm^2	0,45 10	0,45 10	0,50 12	0,50 12
Shear strength	–	DIN EN 12090	N/mm^2	0,2	0,2	0,25	0,25
Shear modulus	–	DIN EN 12090	N/mm^2	7	7	8	8
Water vapour diffusion resistance factor (μ)	–	DIN EN 12086	–	100	100	100	100
Long term water absorption by total immersion by total immersion	 WL(T) 1,5 WL(T) 0,7	 DIN EN 12087 DIN EN 12087	 Vol.-% Vol.-%	 ≤ 1,5 –	 ≤ 1,5 –	 ≤ 1,5 –	 ≤ 1,5 –
Dimensional stability under specified temperature and humidity	DS(TH)	DIN EN 1604	%	≤ 2	≤ 2	≤ 2	≤ 2
Deformation under specified compressive load and temperature	DLT(2)5	DIN EN 1605	%	–	–	≤ 5	≤ 5
Reaction to fire **Reaction to fire** Euroclass	– –	DIN 4102 EN 13501-1	– –	B1 E	B1 E	B1 E	B1 E
Coefficient of linear thermal expansion	–	–	mm/m·K	0,07	0,07	0,07	0,07
Temperature limits	–	–	°C	–50/+75	–50/+75	–50/+75	–50/+75
Capillarity	–	–	–	0	0	0	0
Edge profile	–	–	–	butt	butt	butt	butt
Surface finish	–	–	–	planed	planed	planed/grooved	planed/grooved
Dimensions [3] Thickness Width Length	 – – –	 DIN EN 823 DIN EN 822 DIN EN 822	 mm mm mm	 20 – 200 600/1200 2500	 20 – 120 600 2500	 20 – 120 600, 1200 2500	 20 – 120 600 2500
Tolerances [3] Thickness Thickness Width < 700 mm Width ≥ 700 mm Length	 T3 T1 – – –	 DIN EN 823 DIN EN 822 DIN EN 822 DIN EN 822	 mm mm mm mm	 –0,5/+0,5 –0/+3 –0/+5 –0/+10	 –0,5/+0,5 –0/+3 – –0/+10	 –0,5/+0,5 –0/+3 –0/+5 –0/+10	 –0,5/+0,5 –0/+3 – –0/+10
Applications [4]		DIN 4108, T 10		WAB, WAP, WI	WAB, WAP, WI	WAB, WI, DAD	DAD, WAB, WI
Governmental standard		XPS-EN13164-		T3-CS(10/Y) 250-DS(TH)	T3-CS(10/Y) 250-DS(TH)	T3-CS(10/Y)300- DS(TH)-TR400	T3-CS(10/Y)300- DS(TH)-TR400

Properties [1]	CE-Code	Standard	Unit	STYROFOAM RTM-X	STYROFOAM HD 300F-X	STYROFOAM SM-X	STYROFOAM FB-X	STYROFOAM SP-X
Density		DIN EN 1602	kg/m³	40	45	32	32	35
Thermal conductivity @ 10 °C		DIN EN 12667/ DIN EN 12939	W/m·K	0,027 (≤ 50 mm) 0,025 (> 50 mm)	0,027 (≤ 50 mm) 0,025 (> 50 mm)	0,026	0,030	0,026
Thermal conductivity λ_D		DIN EN 13164	W/m·K	0,029	0,029	0,029	0,033	0,029
λ design value according to Z-23.15-1476		DIN 4108-4	W/m·K	0,029 (20 – 70 mm) 0,030 (> 70 mm)	0,029 (40 – 70 mm) 0,030 (> 70 mm)	0,029	0,034	0,029
Compressive stress or compressive strength @ 10% deformation	CS (10\Y)σ_m	DIN EN 826	N/mm² [2]	0,4	0,7	0,25	0,20	0,3 [6]
Compressive modulus	–	DIN EN 826	N/mm²	15	25	10	8	12
Compressive creep (50 years) ≤ 2% deformation	CC(2/1,5/ 50)σ_c	DIN EN 1606	N/mm²	0,14	0,25	0,08	–	0,12
Tensile strength	TR400	DIN EN 1607	N/mm²			–	0,40	–
	TR600			0,7				
	TR900					1		
Tensile modulus	–	DIN EN 1607	N/mm²	16	25	–	–	–
Shear strength	–	DIN EN 12090	N/mm²	0,4	0,5	–	0,23	–
Shear modulus	–	DIN EN 12090	N/mm²	10	14	–	–	–
Water vapour diffusion resistance factor (μ)	–	DIN EN 12086	–	150	150	150	100	150
Long term water absorption by total immersion	WL(T) 1,5	DIN EN 12087	Vol.-%	≤ 1	–	–	≤ 1,5	–
by total immersion	WL(T) 0,7	DIN EN 12087	Vol.-%	–	≤ 0,7	≤ 0,5	–	≤ 0,5
Dimensional stability under specified temperature and humidity	DS(TH)	DIN EN 1604	%	≤ 2	≤ 2	≤ 2	≤ 2	≤ 2
Deformation under specified compressive load and temperature	DLT(2)5	DIN EN 1605	%	≤ 5	≤ 5	–	–	–
Reaction to fire	–	DIN 4102	–	B1	B1	B1	B1	B1
Reaction to fire Euroclass	–	EN 13501-1	–	E	E	E	E	E
Coefficient of linear thermal expansion	–	–	mm/m·K	0,07	0,07	0,07	0,07	0,07
Temperature limits	–	–	°C	–50/+75	–50/+75	–50/+75	–180/+75 [5]	–50/+75
Capillarity	–	–	–	0	0	0	0	0
Edge profile	–	–	–	butt	butt	butt	butt	butt
Surface finish	–	–	–	planed/grooved	planed/grooved	skin	planed	skin
Dimensions [3]								
Thickness	–	DIN EN 823	mm	20 – 120	40 – 100	40 – 100	200	50 – 100
Width	–	DIN EN 822	mm	600/1200	600	600/1200	600	600
Length	–	DIN EN 822	mm	2500	2500	2400/2500	2500	2500
Tolerances [3]								
Thickness	T3			–0,5/+0,5	–0,5/+0,5		–1/+1	
Thickness	T1	DIN EN 823	mm			–2/+3		–2/+3
Width < 700 mm	–	DIN EN 822	mm	–0/+3	–0/+3	–0/+3	–0/+3	–0/+3
Width ≥ 700 mm	–	DIN EN 822	mm	–0/+5	–	–0/+5	–	–
Length	–	DIN EN 822	mm	–0/+10	–0/+10	–0/+10	–0/+10	–0/+10
Applications [4]		DIN 4108, T 10		DAD, WAB	DAD, WAB	WAB, WZ	–	–
Governmental standard		XPS-EN13164-		T3-CS(10/Y)400-DS(TH)-TR600	T3-CS(10\Y)700-CC(2/1.5/50) 210-WL(T)0,7-DS(TH)-TR900	T1-CS(10/Y) 250-DS(TH)	T3-CS(10/Y) 200-DS(TH)	T1-CS(10/Y) 300-DS(TH)

1) The properties refer to thickness ranges mentioned in the table
2) 1 N/mm² = 10^3 kPa; 1 kPa = 10^{-3} MPa
3) Products with special dimensions or closer tolerances may be available upon request.
4) Only valid for the use of products in building applications. Details are given for potential applications, which however for the final building product need to be defined by its fabricator.
5) Temperature limit –180°C only for pipe shells
6) Compressive strength ≥ 0,35 N/mm²

7. Notes

Please note the Material Savety Data Sheets published by Dow.

STYROFOAM products contain a flame retardant additive to inhibit accidental ignition from a small fire source. The boards are, however, combustible and, if exposed to an intense fire, may burn rapidly. During shipment, storage, installation and use they should not be exposed to flames or other ignition sources. In most countries fire classifications are based on small scale tests which may not reflect the reaction of the material in its end-use state under actual fire conditions.

Polystyrene products will melt when brought into direct contact with high temperature heat sources: for Dow STYROFOAM boards the recommended maximum working temperature is 75°C.

The use of solvent-free adhesive is recommended. Advice on compatibility with polystyrene foam should be sought from the adhesive manufacturers prior to application. Solvent attack may occur if STYROFOAM boards are in direct contact with materials which contain volatile organic components eg solvents.

Protect STYROFOAM from prolonged exposure to intense sunlight to prevent degradation of the surface of the board.

STYROFOAM* boards should be stored on a clean, flat surface in an area free from flammable or volatile materials. When large quantities of the boards are stored indoors, the building should be ventilated to allow a minimum of two air changes per hour.

When stored for long periods in the open, the boards should be protected from direct sunlight to avoid degradation. Light coloured plastic sheeting is a suitable protective cover. Avoid dark materials as excessively high temperatures may develop beneath them.

Recommendations about the methods, use of materials and construction details are given as a service to designers and contractors.These are based on the experience of Dow with the use of STYROFOAM boards. Any drawings are meant only to illustrate various possible applications and should not be taken as a basis for design. Since Dow is a materials supplier and exercises no control over the installation of STYROFOAM boards, no responsibility is accepted for such drawings and recommendations.

In particular, no responsibility is accepted by Dow for the systems in which STYROFOAM is used or the method of application by which it is installed. The legal obligations of Dow in respect of any sale of STYROFOAM boards shall be determined solely by the terms of the respective sales contract.

8. Table of images

Cover picture + Fig. 7
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NL-8471 AD Wolvega

Fig. 2 Pecolit Kunststoffe GmbH & Co. KG,
Pechhüttenstr.8, D-67105 Schifferstadt

Fig. 5 + 6
Stadur Süd Dämmstoff-Produktions GmbH,
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Fig. 14 + 16
Schmitz Cargobull AG, D-48612 Horstmar

Fig. 17 + 18
Frankia Fahrzeugbau Pilote GmbH & Co. OHG,
D-95509 Marktschorgast

Fig. 19 IFN-Internorm Bauelemente GmbH & Co. KG,
A-4050 Traun

Fig. 20 + 21
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