



STYROFOAM solutions



Composite panel solutions with STYROFOAM

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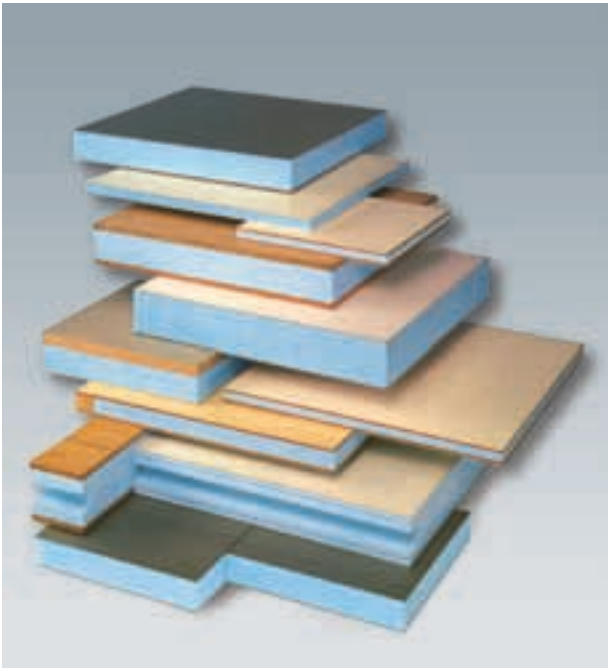


Fig. 01 » Samples of composite panels with a core of STYROFOAM™ material



Fig. 02 » 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.

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 strength-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.

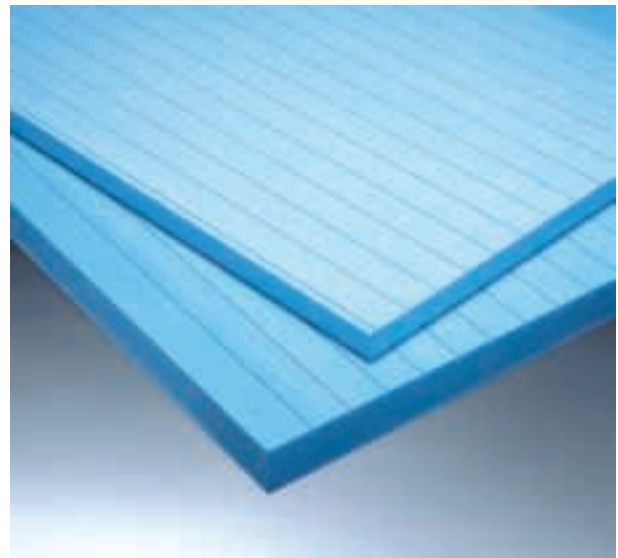


Fig. 03 >> STYROFOAM™ RTM-X with grooved surface

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

1. 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 structures 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 CO₂ as the blowing agent contain air in the foam cells 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.

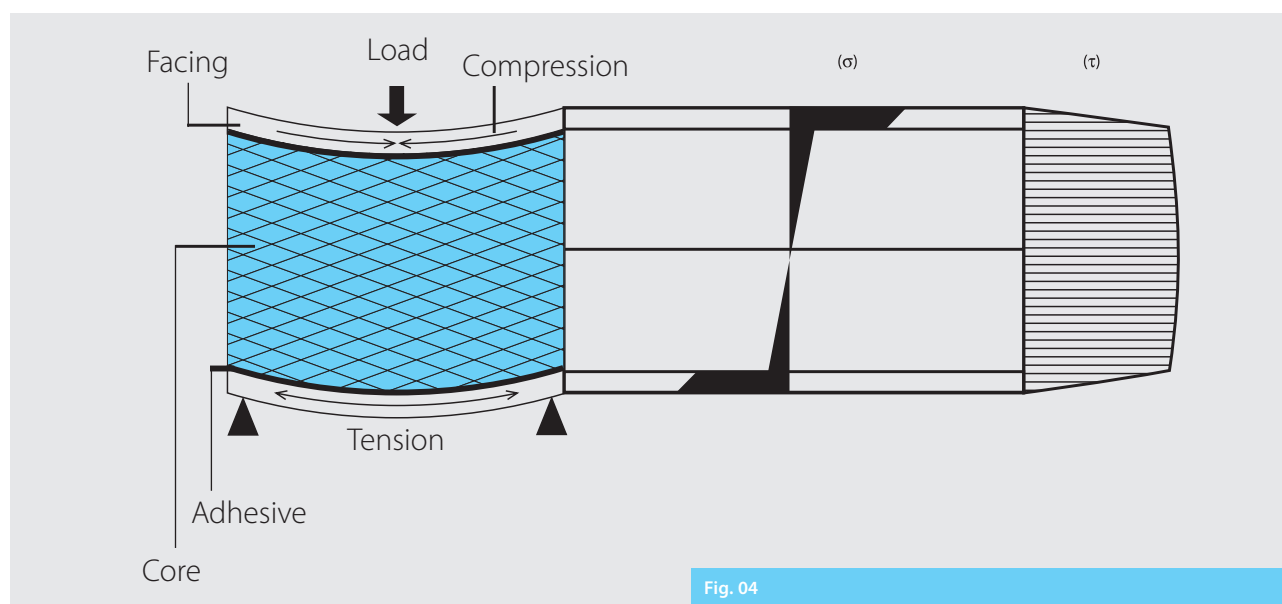
STYROFOAM™ boards have been used for more than 40 years as a core material which allows precision processing and which is highly stable in composite panels – over 20 million square metres of such panels, with their 'blue interior', have been successfully tried and tested in that time. With this long-term 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



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. 04).

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.

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. 06 ►► Cross-section of an aluminium-faced door panel with a STYROFOAM™ core

2. 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.



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. 04).

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.

STYROFOAM™ extruded polystyrene foam boards for use in composite panels have planed surfaces and are produced to close dimensional tolerances.



Fig. 08 >> Once the adhesive has been applied, a laminated wooden layer is installed

An in-house hot-wire cutting facility enables Dow to produce down to 8 mm thin layers out of STYROFOAM™ blocks. A standard thickness tolerance of ± 0.5 mm can be achieved with this equipment. On special request Dow can offer material with a special thickness tolerance of ± 0.1 mm. 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) $\pm 3/-0$ mm
	(1200 mm width) $\pm 5/-0$ mm
Length	$\pm 10/-0$ 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. 09 >> Applying facing layer (GRP in this illustration)

2. 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

2.4 Design notes

- »» Deflection should be calculated in accordance with Euro-Code 1 and be limited to $\text{span}/300$.
- »» 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.



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. Production and structure of composite panels with STYROFOAM

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
I = Span
E = Elastic modulus

I = Moment of inertia
G = Shear modulus
A = Area
k = specific coefficient

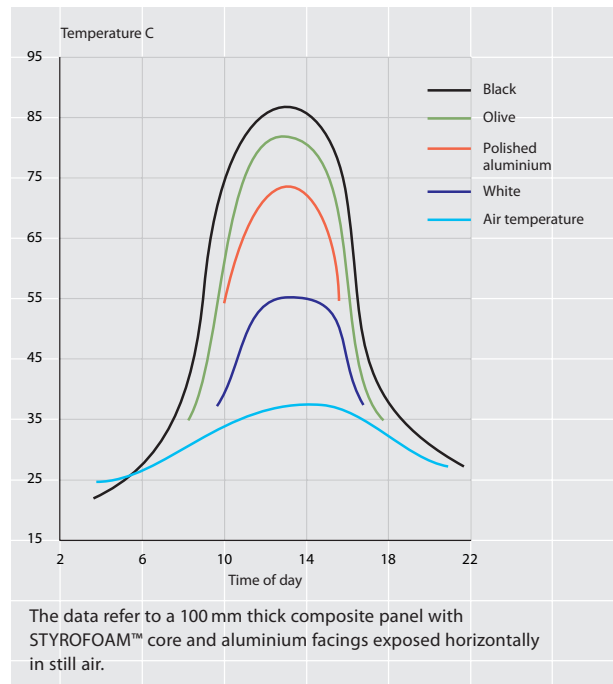


Fig. 12 >> Panel surface temperature with solar exposure

		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 $\ell/4$ 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.

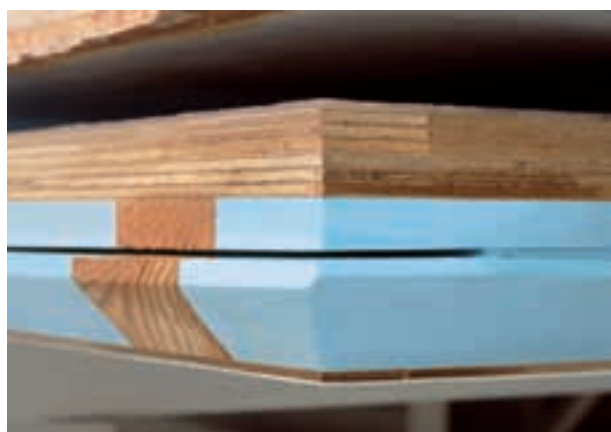


Fig. 15 » Detail view of a floor structure

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



Fig. 20 » Modern architecture using façade panels...

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. 21 » ... and spandrel panels

6. Technical Data

Properties ¹⁾	CE-Code	Standard	Unit	STYROFOAM™ IBF-A	STYROFOAM LB-A	STYROFOAM IBF-X	STYROFOAM LB-X
Density		DIN EN 1602	kg/m³	32	33	32	33
Thermal conductivity @ 10°C		DIN EN 12667/ DIN EN 12939	W/m-K	0,035	0,0335 (≤ 60 mm) 0,0345 (61 – 80 mm) 0,0355 (> 80 mm)	0,030	0,027
Thermal conductivity λ _D		DIN EN13164	W/m-K	0,035 (≤ 80 mm) 0,036 (> 80 mm)	0,035 (≤ 80 mm) 0,036 (> 80 mm)	0,033	0,029 (20 – 70 mm) 0,030 (71 – 120 mm) 0,031 (> 120 mm)
λ design value according to Z-23.15-1476		DIN 4108-4	W/m-K	0,037	0,035 (≤ 60 mm) 0,036 (61 – 80 mm) 0,037 (> 80 mm)	0,034	0,030 (20 – 70 mm) 0,031 (71 – 120 mm) 0,032 (> 120 mm)
Compressive stress or compressive strength @ 10% deformation ²⁾	CS(10/Y)σ _m	DIN EN 826	N/mm² ³⁾	0,25	0,30	0,25	0,30
Compressive modulus ²⁾	—	DIN EN 826	N/mm²	10	12	10	12
Compressive creep (50 years) ≤ 2% deformation ²⁾	CC(2/1,5/50)σ _c	DIN EN 1606	N/mm²	—	—	—	—
Tensile strength ²⁾	TR400 TR600 TR900	DIN EN 1607 DIN EN 1607 DIN EN 1607	N/mm² N/mm² N/mm²	0,45 — —	0,50 — —	0,45 — —	0,50 — —
Tensile modulus ²⁾	—	DIN EN 1607	N/mm²	10	12	10	12
Shear strength	—	DIN EN 12090	N/mm²	0,2	0,25	0,2	0,25
Shear modulus	—	DIN EN 12090	N/mm²	7	8	7	8
Water vapour diffusion resistance factor (μ)	—	DIN EN 12086	—	100	100	100	100
Long term water absorption by total immersion	WL(T)1,5	DIN EN 12087	Vol.-%	≤ 1,5	≤ 1,5	≤ 1,5	≤ 1,5
by total immersion	WL(T)0,7	DIN EN 12087	Vol.-%	—	—	—	—
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	—	DIN 4102	—	B1	B1	B1	B1
Reaction to fire Euroclasse	—	EN 13501-1	—	E	E	E	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/grooved	planed	planed/grooved
Dimensions ⁴⁾							
Thickness	—	DIN EN 823	mm	20 – 120	20 – 120	20 – 200	20 – 160
Width	—	DIN EN 822	mm	600	600	600/1200	600/1200
Length	—	DIN EN 822	mm	2500	2500	2500	2500
Tolerances ⁴⁾							
Thickness	T3			–0,5/+0,5	–0,5/+0,5	–0,5/+0,5	–0,5/+0,5
Thickness	T1	DIN EN 823	mm				
Width < 700 mm	—	DIN EN 822	mm	–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
Applications ⁵⁾		DIN 4108, T 10		WAB, WAP, WI	DAD, WAB, WI	WAB, WAP, WI	WAB, WI, DAD
Governmental standard		XPS-EN13164		T3-CS(10/Y) 250-DS(TH)	T3-CS(10/Y)300- DS(TH)-TR400	T3-CS(10/Y) 250-DS(TH)	T3-CS(10/Y)300- DS(TH)-TR400

1) The properties refer to thickness ranges mentioned in the table.

2) Measured in thickness direction

3) 1 N/mm² = 10³ kPa; 1 kPa = 10^{–3} MPa

4) Products with special dimensions or closer tolerances may be available upon request.

5) 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.

Properties ¹⁾	CE-Code	Standard	Unit	STYROFOAM™ RTM-X	STYROFOAM HD 300F-X	STYROFOAM FB-X	STYROFOAM SP-X
Density		DIN EN 1602	kg/m ³	40	45	32	35
Thermal conductivity @ 10°C		DIN EN 12667/ DIN EN 12939	W/m-K	0,025 ⁸⁾	0,025 ⁸⁾	0,030	0,026
Thermal conductivity λ_D		DIN EN 13164	W/m-K	0,029 (≤ 120 mm) 0,031 (> 120 mm)	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)	0,034	0,029
Compressive stress or compressive strength @ 10% deformation ²⁾	CS(10/Y) σ_m	DIN EN 826	N/mm ² ³⁾	0,4	0,7	0,20	0,3 ⁷⁾
Compressive modulus ²⁾	–	DIN EN 826	N/mm ²	15	25	8	12
Compressive creep (50 years) $\leq 2\%$ deformation ²⁾	CC(2/1,5/50) α_c	DIN EN 1606	N/mm ²	–	0,21	–	0,11
Tensile strength ²⁾	TR400 TR600 TR900	DIN EN 1607 DIN EN 1607 DIN EN 1607	N/mm ² N/mm ² N/mm ²	– 0,7 –	– – 1	– – –	– – –
Tensile modulus ²⁾	–	DIN EN 1607	N/mm ²	15	25	–	–
Shear strength	–	DIN EN 12090	N/mm ²	0,4	0,5	–	–
Shear modulus	–	DIN EN 12090	N/mm ²	10	14	–	–
Water vapour diffusion resistance factor (μ)	–	DIN EN 12086	–	150	150	100	150
Long term water absorption by total immersion	WL(T)1,5	DIN EN 12087	Vol.-%	≤ 1	–	$\leq 1,5$	–
by total immersion	WL(T)0,7	DIN EN 12087	Vol.-%	–	$\leq 0,7$	–	$\leq 0,5$
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	–	DIN 4102	–	B1	B1	B1	B1
Reaction to fire Euroclass	–	EN 13501-1	–	E	E	E	E
Coefficient of linear thermal expansion	–	–	mm/m-K	0,07	0,07	0,07	0,07
Temperature limits	–	–	°C	–50/+75	–50/+75	–180/+75 ⁶⁾	–50/+75
Capillarity	–	–	–	0	0	0	0
Edge profile	–	–	–	butt	butt	butt	butt
Surface finish	–	–	–	planed/grooved	planed/grooved	planed	skin
Dimensions ⁴⁾							
Thickness	–	DIN EN 823	mm	20 – 120	40 – 100	200	50 – 100
Width	–	DIN EN 822	mm	600/1200	600	600	600
Length	–	DIN EN 822	mm	2500	2500	2500	2500
Tolerances ⁴⁾							
Thickness	T3			–0,5/+0,5	–0,5/+0,5	–1/+1	
Thickness	T1	DIN EN 823	mm				–2/+3
Width < 700 mm	–	DIN EN 822	mm	–0/+3	–0/+3	–0/+3	–0/+3
Width ≥ 700 mm	–	DIN EN 822	mm	–0/+5	–	–	–
Length	–	DIN EN 822	mm	–0/+10	–0/+10	–0/+10	–0/+10
Applications ⁵⁾		DIN 4108, T 10		DAD, WAB	DAD, WAB	–	–
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	T3-CS(10/Y) 200-DS(TH)	T1-CS(10/Y)300-DS(TH) CC(2/1,5/50)110 WL(T)0,7

6) Temperature limit –180 °C only for pipe shells

7) Compressive strength $\geq 0,35$ N/mm²

8) Measured after 60 days

7. Notes

Please note the Material Safety Data Sheets published by Dow.

STYROFOAM™ boards contain a flame retardant additive to inhibit accidental ignition from a small fire source. The boards are, however, combustible and, if exposed to an intensive 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 product in its end-use state under actual fire conditions. STYROFOAM boards should, when installed, be adequately protected from direct exposure to fire as directed by national regulations. The national regulations set out the requirements for the fire performance.

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.

No freedom from any patent owned by Dow or others is to be inferred. Because use conditions and applicable laws may differ from one location to another and may change with time, Customer is responsible for determining whether products and the information in this document are appropriate for Customer's use and for ensuring that Customer's workplace and disposal practices are in compliance with applicable laws and other governmental enactments. Dow assumes no obligation or liability for the information in this document.

No warranties are given; all implied warranties of merchantability or fitness for a particular purpose are expressly excluded.

8. Table of images

Cover picture + Fig. 7

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8471 AD Wolvega, Netherlands

Fig. 2

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Pechhüttenstr. 8, 67105 Schifferstadt,
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Fig. 5 + 6

Stadur Süd Dämmstoff-Produktions GmbH,
72124 Pliezhausen, Germany

Fig. 14 + 16

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Fig. 17 + 18

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Fig. 19

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Fig. 20 + 21

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