



STYROFOAM

Core material for refrigerated trucks

PROVEN PERFORMANCE

Industry know-how

A number of factors come into play when designing refrigerated truck bodies:

- »» As the vehicles are designed to transport easily-perishable food, they must be insulated effectively.
- »» The good thermal performance of a refrigerated truck should be maintained during the overall lifetime of the vehicle, requiring that the body elements don't pick up moisture.
- »» Refrigerated trucks must be capable of withstanding high mechanical forces experienced when loaded with heavy cargo loads, during service on the road or during loading and unloading.
- »» To keep fuel costs down the refrigerated truck body should be of low weight.

The industry has addressed these requirements by producing refrigerated truck bodies from sandwich panels containing an insulating core material. Such core materials must provide these properties over the whole lifetime:

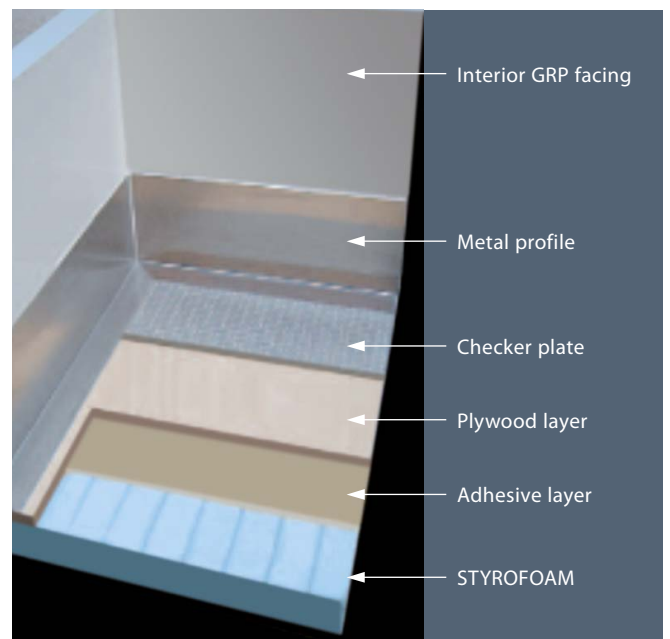
- »» Good thermal insulation
- »» Low moisture pick-up
- »» High mechanical strength and an appropriate weight/strength ratio.

STYROFOAM™, the famous blue extruded polystyrene foam (XPS), offers all these features and has been used to manufacture the walls, roofs and floors of refrigerated truck bodies for many years and is applied in the vehicles of some of the industry biggest names.

Figure 01: STYROFOAM panels have been used in refrigerated truck bodies over a quarter of a century



Figure 02: Cross section of a wall/floor element



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DOW CORE COMPOSITES

Competence at our core

STYROFOAM was developed by Dow in the USA in the 1940s and has been used for more than 40 years as a sustainable core material. Continuous progress in the product and production technology has resulted in a broad range of STYROFOAM products for a wide variety of applications, like refrigerated trucks, pipe section insulation and motor-homes.

STYROFOAM panels have repeatedly proved successful in extremely demanding applications, and are highly sought after by manufacturers of branded products worldwide - as well as by their customers.

This practical long-term experience has provided Dow with well-founded technical and technological know-how; an important pre-requisite for the successful development of intelligent and innovative solutions for composite production. It is this wealth of expertise and the ability to innovate that make Dow the leading manufacturers of core materials made from extruded polystyrene foam today.

Dow combines the power of science and technology with the "Human Element" to passionately innovate what is essential to human progress.

The Company connects chemistry and innovation with the principles of sustainability to help address many of the world's most challenging problems such as the need for clean water, renewable energy generation and conservation, and increasing agricultural productivity. Dow's diversified industry-leading portfolio of specialty chemical, advanced materials, agrosiences and plastics businesses delivers a broad range of technology-based products and solutions to customers in approximately 160 countries and in high growth sectors such as electronics, water, energy, coatings and agriculture. In 2009, Dow had annual sales of \$45 billion and employed approximately 52,000 people worldwide. The Company's more than 5,000 products are manufactured at 214 sites in 37 countries across the globe.

Figure 03: STYROFOAM extruded polystyrene



COOL CUSTOMER

Thermal insulation

Perishable or temperature-sensitive goods whether they be foodstuff, pharmaceutical products, fine chemicals or electronic components, are transported in refrigerated vehicles, the bodies and floors of which consist of sandwich panels with plastic foam core materials.

"The ATP agreement is an agreement on the international carriage of perishable foodstuffs and on the special equipment to be used for such carriage.

The key subjects covered by the ATP agreement include the grouping of transport units into classes according to their suitability and equipment, the technical requirements regarding thermal insulation and fitting of refrigeration units, methods and procedures to check insulation performance and the efficiency of cooling or heating equipment.

All vehicles used for international carriage of perishable foodstuff must have an ATP certificate. The majority of refrigerated vehicle body structures are ATP certified with the "FRC" group of letters meaning that easily perishable foodstuffs may be transported in vehicle bodies of this kind without restriction"⁽¹⁾.

Initial ATP certification is granted for 6 years by an ATP center based on measurements performed on a truck representative of a production series. If performance is maintained over time, prolongation of certification can be awarded. Opting for STYROFOAM as the core layer material for sandwich panels in refrigerated trucks means opting for long-lasting effective thermal insulation.

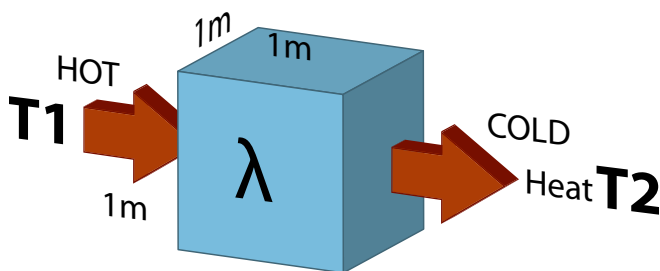


Figure 04: Heat flow

A measure of the thermal insulation value of a material is the thermal conductivity " λ ". Heat conduction is the transport of heat from particle to particle under a temperature gradient. The thermal conductivity is a measure for the heat conduction in a defined building material at a temperature difference of 1°K (equivalent 1°C).

Below chart shows the long-term thermal conductivity of STYROFOAM HD300F-X, a product that is mainly used in refrigerated truck floors. When STYROFOAM is laminated on both sides with diffusion-tight facings as defined per EN 13164, the thermal conductivity of the foam at the time of lamination can be considered.

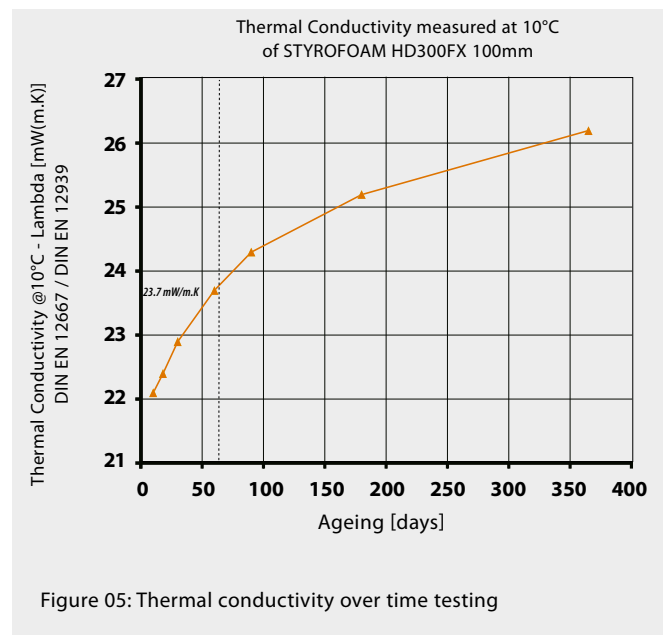


Figure 05: Thermal conductivity over time testing

(1) TÜV-Süd, Refrigeration and insulation equipment in line with ATP test standards, www.tuev-sued.de

COOL CUSTOMER

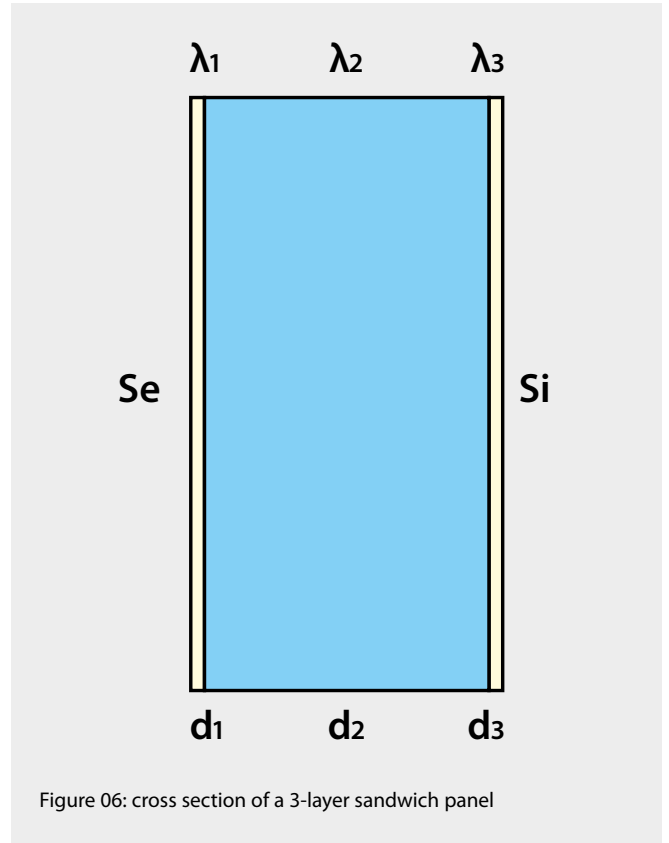
Thermal insulation

The thermal resistance R (in m² K/W) of a layer of material is calculated by dividing the thickness of the layer, d, by the thermal conductivity, λ. With a sandwich panel comprising three or more layers, the total thermal resistance is the sum of the thermal resistance of the individual layers.

$$R = \frac{d_1}{\lambda_1} + \frac{d_2}{\lambda_2} + \frac{d_3}{\lambda_3} + \dots + \frac{d_n}{\lambda_n}$$

The thermal transmittance “U” (in W/m²K) is the reciprocal value of R under consideration of the internal and external surface resistance, that depend on the final application of the element. Following formula needs to be used when calculating the U-Value of a sandwich panel.

$$U = \frac{1}{R_{si} + R + R_{se}}$$



	Product name	Thickness d (mm)	λ (W/mK)	R (m ² K/W)
LAYER 1	GRP	1.5	0.16	0.009
LAYER 2	STYROFOAM RTM-X	60	0.025	2.400
LAYER 3	GRP	1.5	0.16	0.009
TOTAL		63		2.418

Table 01: R-value calculation for a 3-layer sandwich panel

DRY TO THE CORE

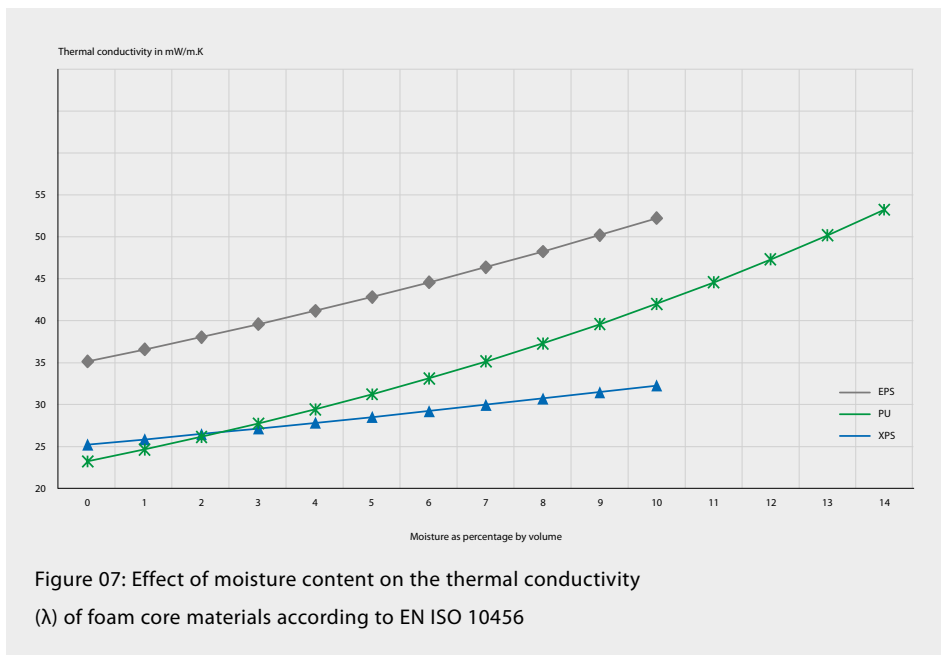
STYROFOAM's resistance to moisture

The moisture resistance of the core layer material can have a significant impact on long term insulation performance of truck panels. This is of particular concern after damages to the exterior or interior that may occur during on- or off-loading and daily service. Damages in sandwich panels and poorly maintained joints in a refrigerated truck body might allow water diffusion into the wall, floor or roof structure. Liquid water conducts 25 times more heat than air. If the material is in a freezing environment, ice trapped in it would conduct even 100 times more heat than air. Therefore water in its different phases has a drastic impact on the insulation performance of core materials.

Two tests are of importance when it comes to moisture pick-up determination:

- »» Water absorption during long-term immersion
- »» Moisture pick-up by diffusion - this test is particularly meaningful if composite panels are used in refrigerated vehicle construction.

STYROFOAM is an insulation material insensitive to moisture, which is characterized by its high resistance to water vapor diffusion. This is one of the reasons why it is a preferred product for refrigerated truck panels where long-term insulating properties are required (**figure 07**).



STRENGTH AND RELIABILITY

STYROFOAM's mechanical performance



Figure10: Testing creep performance in Dow's dedicated laboratory

In creep tests, Dow investigates how its products behave over long periods under constant load.

Dow has its own laboratory with dedicated equipment being capable of measuring compressive creep of STYROFOAM products - this is unique in the industry.

STYROFOAM has excellent creep behavior: it is measured according to EN 1606 allowing a maximum deformation of 2% after 50 years of constant loading with 30% of the static compressive load measured according to EN 826. The test duration of 50 years can be reduced to 2 years by making use of an extrapolation.

In addition to mechanical loads, the constructor must also consider thermal and other stresses occurring during use. When exposed to high summer temperatures and intense sunshine, the outside of a dark-painted truck body becomes significantly hotter than ambient temperature. With black facings temperatures close to or above 90°C can be reached.

With light-colored facings, the energy consumption of the cooling unit and the thermal stresses in the sandwich panels are expected to be lower than with dark colored facings, since the temperature gradient through the panel is reduced. With such light-colored facings and service temperatures below +75°C, STYROFOAM has demonstrated excellent suitability in the industry.

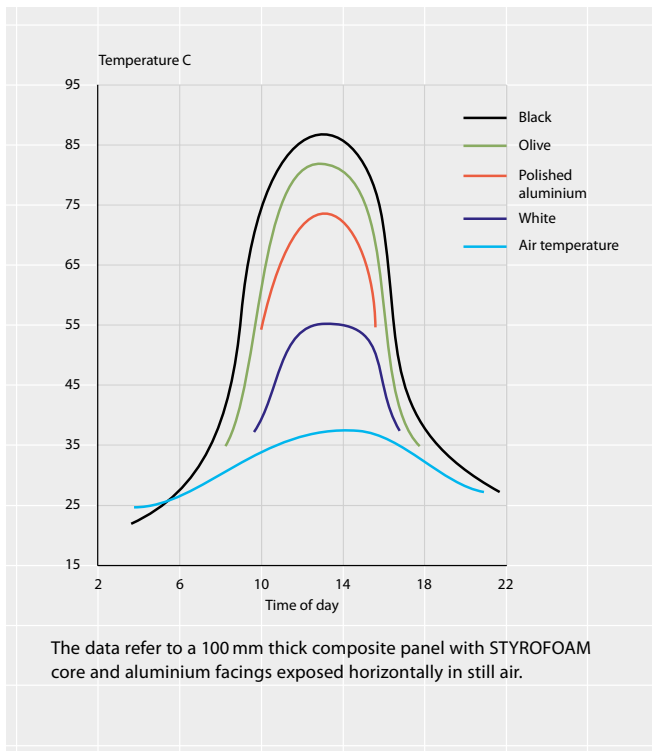


Figure 11: Panel surface temperature with solar exposure

STRENGTH AND RELIABILITY

STYROFOAM's mechanical performance

Tests and structural calculations make it possible to take mechanical load cases as well as thermal and other stresses into consideration in the design of a sandwich panel. The results of construction calculations may require another material or material thickness to be chosen or require the construction to be modified. Calculations should be verified by testing.

A very important load case in a truck body is the dynamic load event. Dynamic load events are initiated in trucks through the general service on the road and loading and unloading, often involving forklifts. Empty and fully loaded forklifts moving on the floor construction result in significant load exposed both to the floor and may also impact the entire body.

Such events are too complex to be defined in a single, static test, but dynamic laboratory test can provide some conclusion on fracture behavior - which in turn helps manufacturers to select appropriate materials that are equipped to deal with the various stresses they are likely to undergo during a truck's lifetime.

Assuming a truck is in service an average of eight years (250 days a year in service), test have to be run with more than 500.000 load cycles.

Independent studies on fatigue behavior of Dow materials, carried out by an authorized body in Sweden (Royal Institute of Technology), found that STYROFOAM shows an excellent fatigue behavior. The applied test is called 4-point bending test and has been carried out in accordance to ASTM C393.

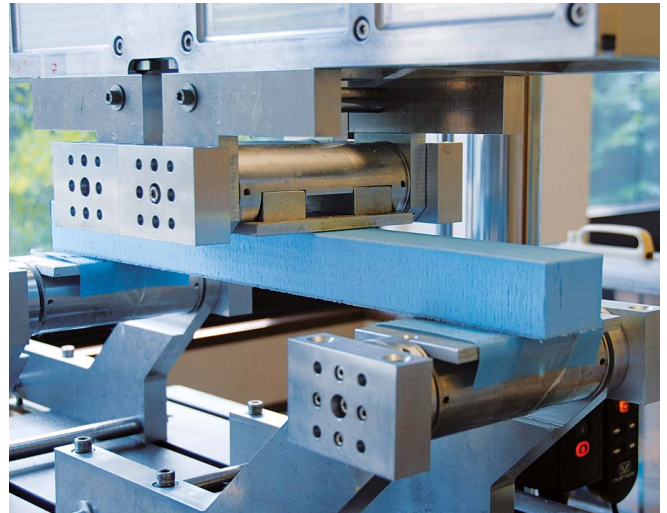


Figure 12: Dynamic test on sandwich panels with STYROFOAM core

To fully cope with the assumption that a truck is in service an average of eight years (250 days a year in service), tests have been run with >500.000 load cycles.

For STYROFOAM HD300F-X a s/n-curve was generated, showing the relation between the dynamic shear stress and the amount of cycles the sample has been exposed to. According to this particular s/n-curve STYROFOAM HD300F-X resists > 600.000 load cycles when applying a dynamic load representing 50% of the measured maximum static load according to ASTM C393. Dow makes use of in-house fatigue testing equipment to control the fatigue behavior of STYROFOAM products and to work on product developments in this respect.

TAILORED TO FIT

Production capabilities

STYROFOAM extruded polystyrene foam panels are produced with a flat, dust-free surface and tight tolerances. Hot-wire foam cutting equipment allows to cut core layers of as thin as 5mm from STYROFOAM blocks.

The oscillating hot-wire cutting equipment utilized by Dow can achieve a standard thickness tolerance of ± 0.5 mm, but there is also the option of manufacturing products as custom-made items with a thickness tolerance as little as ± 0.1 mm using a sander. Dow is capable of manufacturing tailor-made product-requests for specific dimensions or particular tolerances, these could be arranged with the responsible engineer.

Production type	Thickness tolerance
Online Standard	0.5 mm
Online close tolerance (CT)	0.3 mm
Hot-wire cut (OF)	(<15 mm) 0.5 mm (≥ 15 mm) 0.3 mm
Quick sanded (QS)	(≥ 10 mm) 0.3 mm
Sanded (SA)	(≥ 10 mm) 0.1 mm

Panels with grooves can also be produced on request. Grooves may assist the bonding process by enabling an easier air release and facilitating the even distribution of adhesive. (Standard grooves for product thickness >15mm: 39 mm groove spacing; 3.5 mm deep, 1.8 mm wide). In addition to processing using hot-wire equipment, STYROFOAM panels can be simply and cleanly cut using conventional tools and machines from the timber industry.



Figure 13: grooved STYROFOAM RTM

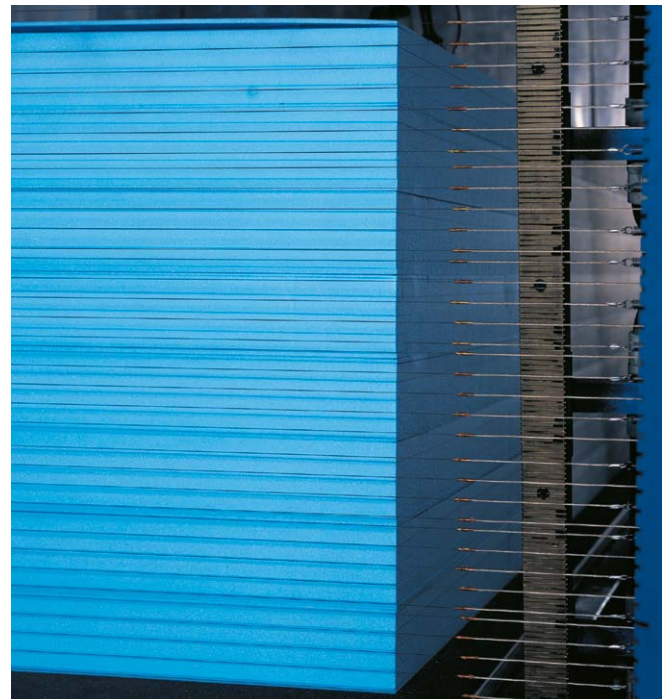


Figure 14: Oscillating hot-wire cutting machine

TAILORED TO FIT

Production options



Figure 15: Application of a 2 component PU adhesive



Figure 16: Vacuum Table

For bonding purpose with e.g. aluminium, wood and GRP, solvent-free adhesives are strongly recommended. The use of polyurethane adhesives, as 1- and 2-component PU adhesives and also reactive hotmelt adhesives have successfully been used in combination with STYROFOAM for decades. Related to the adhesion process, Dow offers different grooving and surface qualities.

Where hydraulic, pneumatic or roller presses are used, the assembly of the sandwich panel takes place at a separate production station; with a vacuum table, all production stages are carried out directly on the table itself. Vacuum tables are generally used in vehicle construction with the negative pressure helping to press the sandwich panel together. In this way, the adhesive is evenly distributed to produce a sandwich panel of a constant thickness and with an optically flawless surface. A vacuum pump produces a negative pressure of approximately 150 to 600 mbar. This corresponds to a surface pressure of approx. 15 to 60 kN/m²; the optimum negative pressure in each case must be determined experimentally for the cores and facings.

A QUALITY APPROACH

Customer focus

Dow undertakes rigorous quality management during and after the production of STYROFOAM in order to manufacture consistently high quality products.

On a regular basis samples of the production runs are taken to check key properties such as dimensions, density, fresh lambda, compressive strength and others.

Selective product analyses are also conducted in the central Research and Development Department's laboratories.

This is where application-specific properties, including shear strength, tensile strength, lambda after 90 days and water pick-up are regularly checked. Data are captured in a database, shared and constantly monitored in all plants.

Regular external inspections of our products are conducted by certified European testing and inspection organizations.

The majority of STYROFOAM products are CE marked.

Declarations of conformity (DoCs) are available on demand and quality systems are based on the ISO 9000 standard.

Laboratory and test benches also support material research and the development of new application solutions.

Customers are frequently involved in work on specific solutions for composite production - for example, when it comes to stringent requirements in terms of surface finishes or the development of specific testing methods.

Based on decades of experience in the use of STYROFOAM as a core material and on modern simulation programs, Dow's experts regularly assist customers with the structural design and development of their products and the development team of the Core Composites business is willing to help establish the suitable product for each specific application.



TECHNICAL DATA

Properties ¹⁾	CE-Code	Standard	Unit	STYROFOAM RTM-X	STYROFOAM HD300F-X	
Cell content				HFC	HFC	
Density	-	EN 1602	kg/m ³	40	45	
Thermal conductivity @ 10°C ²⁾	-	EN 12667/ EN 12939	W/m·K	0.025	0.025	
Compressive stress or compressive strength @ 10% deformation ³⁾	CS(10\Y)sm	EN 826	N/mm ² 4)	0.4	0.7	
E-Modulus (typical) ³⁾	-	EN 826	N/mm ²	17 (≤30mm) 22 (31-80mm) 28 (>80mm)	33 (30-80mm) 38 (>80mm)	
Compressive creep (50 years) ≤ 2% deformation ³⁾	CC(2/1.5/50) σc	EN 1606	N/mm ²	-	0.21	
Tensile strength ³⁾	TR600	EN 1607	N/mm ²	0.7	1	
	TR900					
Tensile Modulus (typical) ³⁾	-	EN 1607	N/mm ²	28 (≥50mm)	31 (≥50mm)	
Shear strength	-	EN 12090	N/mm ²	0.4	0.5	
Shear Modulus (typical)	-	EN 12090	N/mm ²	13	17	
Water vapour diffusion resistance factor μ	-	EN 12086	-	150	150	
Long term water absorption by total immersion	WL(T)1.5	EN 12087	Vol-%	≤1		
Long term water absorption by total immersion	WL(T)0.7	EN 12087	Vol-%		≤0.7	
Capillarity	-	-	-	0		
Coefficient of linear thermal expansion	-	-	mm/m·K	0.07		
Reaction to fire Euroclass	-	EN 13501-1	-	E		
Temperature limits	-	-	°C	-50/+75		
Dimensions ⁵⁾	Thickness	-	EN 823	mm	20-140	40-110
	Width	-	EN 822	mm	600/1200	600
	Length	-	EN 822	mm	2000/2500/3000	
Tolerances	Thickness	T3	EN 823		-/+0.5	
	Width <700 mm	-	EN 822	mm	-0/+3	
	Width ≥700 mm	-	EN 822	mm	-0/+5	
	Length	-	EN 822	mm	-0/+10	
Edge Profile	-	-	-	butt edge		
Surface Finish	-	-	-	planed or planed & grooved		

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

²⁾ λ 90/90, ≤ 60 days

³⁾ Measured in thickness direction

⁴⁾ 1 N/mm² = 10³ kPa; 1 kPa = 10⁻³ Mpa

⁵⁾ Products with special dimensions or closer tolerances may be available upon request.

IMPORTANT INFORMATION

Please follow the application guidelines issued by Dow. STYROFOAM panels melt at high temperatures. The recommended maximum temperature for continuous use is 75 °C. Please note that on hot summer days STYROFOAM panels should not be covered with dark coatings/coverings (sealants, fleece, matting), otherwise the insulation panels may become distorted. When bonding STYROFOAM panels with colored outer layers, temperature changes on the surface of the outer layers should be monitored. Avoid using dark outer layers.

Should STYROFOAM panels come into contact with materials, which contain volatile substances, solvent damage could occur. When choosing an adhesive, please follow the manufacturer's instructions regarding usability for bonding polystyrene foam.

To prevent weathering of the surface during long periods of storage outdoors, panels should be protected from direct sunlight. Light colored plastic film is ideal for this. Dark colored or clear film should be avoided as this could encourage a build-up of heat.

Panels should be stored on a clean, level surface, away from flammable materials. Panels contain a flame-retardant additive, which should prevent accidental ignition by a small naked flame. However, panels are flammable and could ignite if they are not professionally processed or used incorrectly. Therefore, during shipping and storage as well as during and after installation, these materials should not come into contact with naked flames or other ignition sources/flammable substances.

All flammability classifications are based on laboratory tests and do not necessarily reflect the behavior of the material in the final application under actual fire conditions. After processing, panels should be suitably protected against direct exposure to fire in accordance with National building regulations. Fire protection requirements are outlined in National building regulations, which must be complied with.

Recommendations regarding methods, use of materials and structural details have been devised on the basis of Dow's experience. These recommendations are only provided as a service.

The corresponding diagrams/drawings are designed to only provide information on possible types of uses and are not intended to be used as construction documents.

TABLE OF IMAGES

Fig. 01, 03

PECOLIT Kunststoffe GmbH & Co. KG
Pechhüttenstraße 8
D-67105 Schifferstadt, Germany

Fig. 02

SIKA Deutschland, Stuttgart

Fig. 15

Concorde Reisemobile GmbH
Concorde-Strasse 2-4
Schlüsselfeld, Aschbach
Germany

Fig. 16

JDK de Keersmaecker, Londerzeel, Belgium

Cover Picture, Fig. page 12

Schmitz Cargobull AG, 48612 Horstmar
Germany



Note:

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DOW EUROPE GmbH

Dow Building Solutions

Bachtobelstrasse 3

CH-8810 Horgen,

Switzerland

internet: www.dowrefrigeratedtrucks.com