Technical guidelines to use STYROFOAM™ in composites structures for motorhome and caravan

Version August 2017

THE HEART OF THE MATTER

Using STYROFOAM in composite components

With a vast range of information available at the touch of a button, today's consumer is more knowledgeable and more demanding than ever before. When it comes to motorhomes and caravans buyers have a wide range of models to choose from, and, for people making such large investment decisions, the details matter.
Manufacturers of motorhomes and caravans know they must provide a product which can withstand the increased scrutiny of dealerships and the customers that buy from them, and therefore need utmost confidence in the materials they choose.

Those who construct vehicles using composite components need high standards of performance against a number of criteria, particularly with regard the core layer material:

- mechanical properties, as composite components have a key structural role and must be capable of supporting a variety of loads;
- ability to insulate, which is key to the comfort of inhabitants;
- moisture resistance, to support long term durability and maintain performance;
- surface finish and processing to support specific manufacturing requirements.

In many countries STYROFOAM™ extruded polystyrene foam (XPS) has been used for decades as the core layer for composite components such as ceilings, walls and floors in motorhomes and caravans.

Many manufacturers have come to rely on the benefits the material brings to their production processes as well as the quality and durability of the final product.
There is also potential to save costs when manufacturing ceilings, walls and floors with composite components made with STYROFOAM™ as a core layer.

Fig. 01: Motorhome cross-section (simplified illustration to clearly explain the use of STYROFOAM™)

EXPERIENCE AT OUR CORE

Dow and the evolution of STYROFOAM

The Dow Chemical Company has a diversified industry-leading portfolio of specialty chemical, advanced materials, agrosciences and plastics businesses, which deliver a broad range of technology-based products and solutions to customers in approximately 160 countries. In 2012, Dow had annual sales of $57 billion and employed approximately 54,000 people worldwide. The Company's more than 5,000 products are manufactured at 188 sites in 36 countries across the globe.

Dow aims to connect 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. Its products are used in a wide variety of industries and applications including automotive, construction, food, pharmaceuticals, paints and packaging amongst many others.

STYROFOAM™ was invented by Dow in the 1940s and has been used for decades as a core material for composite components. The blue foam has a closed cell chemical structure which gives it excellent insulating properties, long-term resistance against moisture and high mechanical strength.

Continuous progress in the production technology behind the famous blue extruded polystyrene foam has resulted in a broad range of products for a wide variety of applications, like refrigerated vehicles, pipe section insulation, motor caravans besides others.

STYROFOAM™ composite components with the immediately recognizable blue interior have repeatedly proved successful in a variety of extremely demanding applications, and are highly sought after by manufacturers of a range of products around the world.

This practical long-term experience has created a wealth of expertise in using STYROFOAM™ for composite components. This, partnered with a desire to continue innovating of behalf of its customers, makes Dow one of the leading manufacturers of core layer materials made from extruded polystyrene foam today.

Fig. 02: STYROFOAM™ extruded polystyrene foam

A TOUGH PERFORMER

The mechanical properties of STYROFOAM

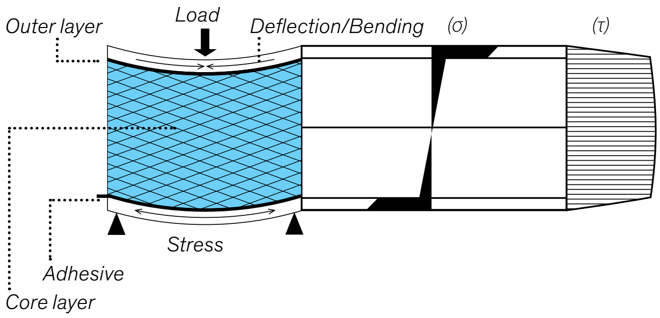


Fig. 03: Behaviour of a composite component under load

A composite panel is a lightweight, laminated component with load-bearing properties, developed on the basis of traditional T-BEAM technology.

Whilst outer layers of such panels absorb compressive and tensile forces, it is the core layer that must perform adequately in terms of shear and dynamic forces:

- ››› Shear forces impact on the core material when a panel is subjected to bending **(demonstrated in Figure 03),** a loading condition which specifically affects the floor of motorhomes or caravans.
- ››› Dynamic forces – created by wind, vibration and torsional stress – affect the walls during journeys.

The high compressive strength of the core layer material has a stabilizing effect on a composite component, reducing the risk of outer layers buckling when subjected to compression.

STYROFOAM™ is a highly resilient core layer material that enables manufacturers of motorhomes and caravans to improve the load capacity and rigidity of their vehicles whilst at the same time reducing need for extra reinforcement which may otherwise be required.

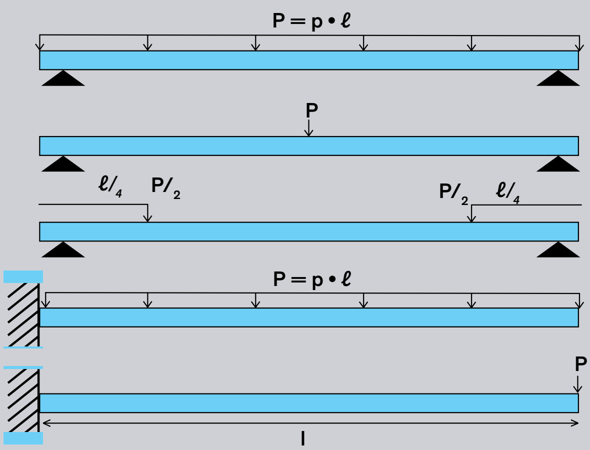
COMPOSITE PANEL DESIGN

A continuous bond between the component's layers is a pre-requisite for applying composite theory and subsequent design calculations.
For a single-span composite beam the deflection/bend can be calculated simply using the following equation:

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

= Bending ratio + Shear ratio

d = Deflection/bend
P = Load
ℓ = Span
E = Modulus of elasticity
I = Inertia
G = Modulus of rigidity
A = Area
k = Specific coefficient



	k_f	k_c
Single-span beam, area load	$\frac{5}{384}$	$\frac{1}{8}$
Single-span beam, concentrated load	$\frac{1}{48}$	$\frac{1}{4}$
Single-span beam, concentrated load at a distance of l/4 from the supports	$\frac{11}{768}$	$\frac{1}{8}$
Cantilever, cantilever area load,	$\frac{1}{8}$	$\frac{3}{4}$
Point load at the unattached end	$\frac{1}{3}$	$\frac{6}{5}$

Fig. 04: Calculation table for the specific coefficients for various loading conditions

THE STRENGTH/WEIGHT RATIO

Manufacturers using composite panels in construction of motorhomes or caravans are looking for components with the lowest possible weight combined with the greatest possible strength. The excellent strength/weight ratio of STYROFOAM™ makes it the core material of choice for many manufacturers.

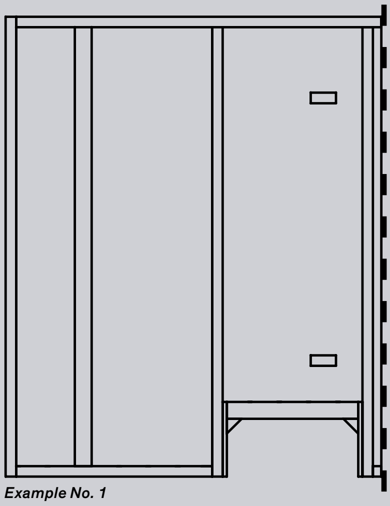
The unique closed cell structure of STYROFOAM™ means it has a high density – bringing with it specific mechanical properties much in demand by producers of composite components for motorhome and caravans – as well as low weight.

MECHANICAL PROPERTIES OF STYROFOAM™:

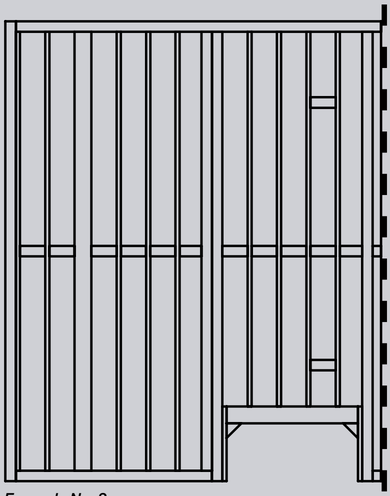
- excellent bending stiffness
- high shear strength
- excellent tensile strength
- high compressive strength.

Using a core layer material with a high rigidity such as STYROFOAM™ makes it possible to design larger span composite panels with little bending and high stiffness, as shown in **Figure 05.**

STYROFOAM™'s high shear strength and bending stiffness also allows manufacturers to create simplified structures with fewer wood inserts than would be possible with some alternative, less rigid core layer material.



Example No. 1



Example No. 2

Fig. 05: Example No.1 Modified floor structure using STYROFOAM™ XPS (STYROFOAM™ RTM-X with an apparent density of 40 kg/m³, compressive strength of 400 kPa in accordance with EN 826 and thermal conductivity of 0.025 W/(m•k) in accordance with EN 12667/12939). In comparison with Example No. 2 a floor structure with a core layer material with a lower apparent density of 15 kg/m³, compressive strength of 70 kPa and thermal conductivity of 0.038 W/(m·K).

N.B. The design is only an example and does not represent a design model for an actual structure. This example does not act as a substitute for an individual design of a floor structure in a motorhome.

This brings a number of potential benefits:

- reduction of working hours thanks to the reduced number of cuts demanded
- simpler assembly of floor panels, potentially reducing production costs
- fewer thermal bridges (junctions interrupting insulation and causing heat loss), thanks to fewer wood inserts required – bringing improvements in terms of insulation performance, minimizing heat loss and therefore on-board comfort.

LOOKING TO THE FUTURE

Energy efficiency and thermal insulation

The phrase 'energy efficiency' is now common currency. Many consumers are increasingly questioning the energy efficiency of the goods they buy, the houses they live in – and even the vehicles they drive.

Forward-thinking manufacturers of motorhomes and caravans are also embracing this trend and turning to products such as STYROFOAM™ to help insulate their vehicles, reduce thermal bridging and make life on board more comfortable – for the long-term.

Opting for composite components using STYROFOAM™ as the core layer material also means making a choice for long-lasting and effective thermal insulation, thanks the product's moisture resistant properties.

When using STYROFOAM™ in composite components produced for motorhomes and caravans, manufacturers typically use either STYROFOAM LB and/or STYROFOAM RTM in thicknesses of between 20 and 40 mm.

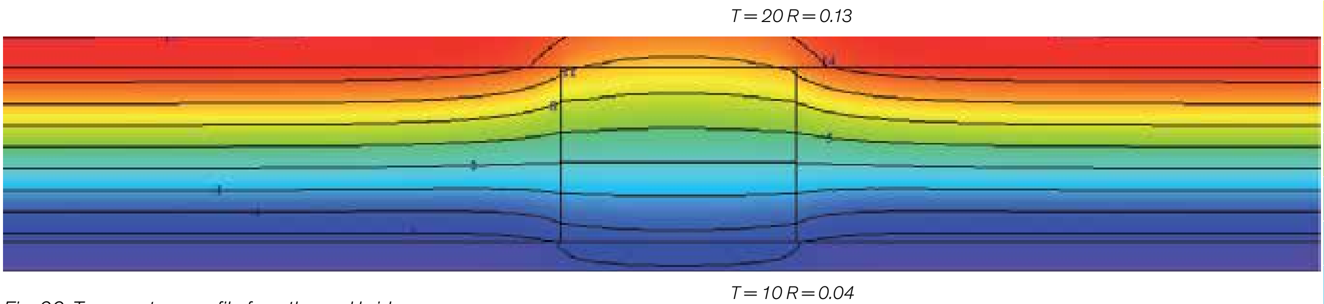


Fig. 06: Temperature profile for a thermal bridge

The thermal conductivity of these products is between 0.025 W/(m·K) and 0.033 W/(m·K) when measured in accordance with DIN EN 12667. This performance range makes it possible to choose a product that meets specific thermal requirements (see "Technical Data").

A crucial factor in assessing the thermal insulation properties of a composite component and/or an entire structure is the U-value (thermal transmittance value). U-values measure the heat flow passing through a square metre of material when the temperature is different on either side of it.
The lower the heat flow the lower the resulting thermal transmittance value, or U-value. The lower the U-value of a structure, the better its thermal insulation properties.

In theory, an improvement of around 20 % in the U-value could be achieved by using STYROFOAM™ RTM-X in the previous example provided of a typical floor structure. This is thanks to the low thermal conductivity of STYROFOAM in combination with the ability to reduce the number of thermal bridges in the form of wood inserts that could otherwise be needed for strength.

DRY TO THE CORE

STYROFOAM's resistance to moisture

The longevity of a motorhome or caravan built using composite components is influenced by the durability of the core layer material in those panels – and this in turn is directly affected by its moisture resistant properties.

Water vapour from showers, cooking, drying laundry, people and pets can all increase moisture levels in the air. Without regular ventilation, this moisture can condense on the surfaces of structural components causing odour and mould or – worse – diffuse in the form of water vapour within the composite panels and condense there, affecting their performance. The problem can be worse if outer layers have been damaged.

Insulation materials which absorb moisture readily will not perform as well: damp insulation material (with water absorption of 10 %) can lose up to 45 % of its insulation capability, because trapped moisture conducts 25 times more heat than air.

DIN EN 12087 is used to determine the water absorption levels of thermal insulation materials. The test involves samples being immersed in water for 28 days and their water content subsequently measured. The accompanying graph shows the water absorption values for STYROFOAM™, EPS (15 kg/m³) and PU, taken from relevant publications. The graphic also shows the resulting change in thermal conductivity.

Using this graph, it is easy to see that, thanks to its closed cell structure, STYROFOAM™ absorbs very little water. This results in very little change in its thermal conductivity following water absorption by immersion in comparison to thermal conductivity in a dry condition.

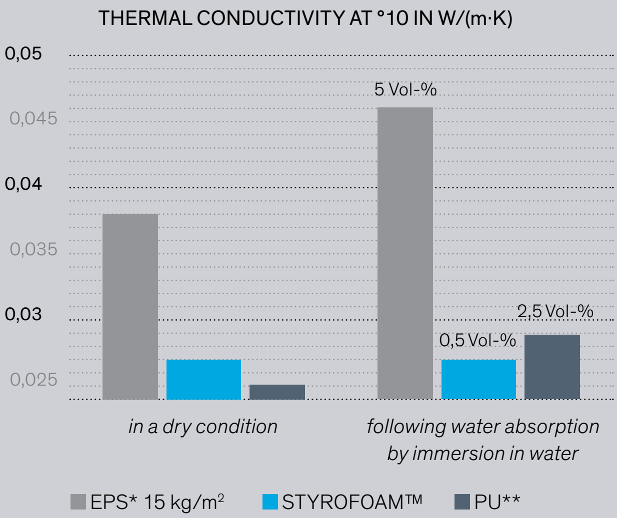


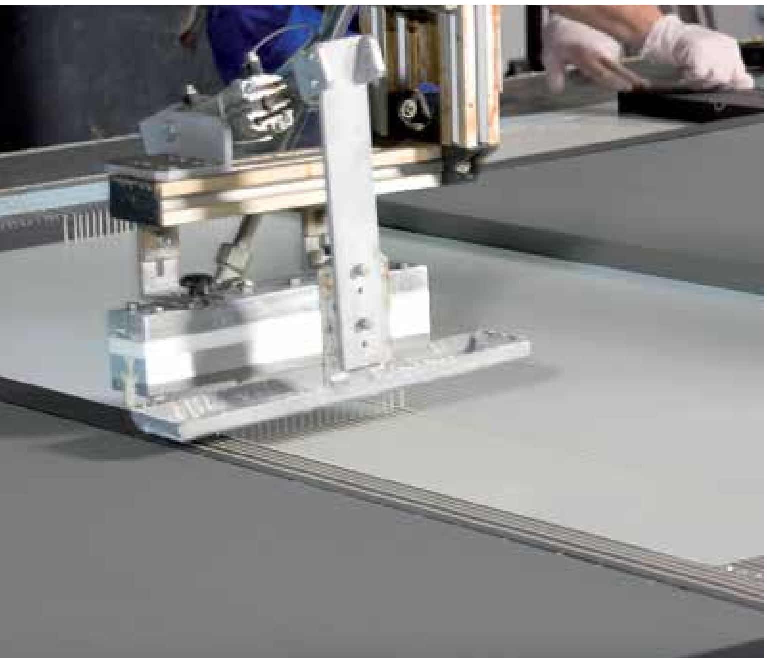
Fig. 07: Thermal conductivity depending on water absorption in accordance with EN ISO 10456.

Source: * EPS value - losBouw EPS, technical information (2005)
**PU value - IVPU, PUR for high performance insulation material (2005)

TAILORED SOLUTIONS

Surface finish and processing

Fig. 08: Oscillating hot wire foam cutting machine for heavy cutting



STYROFOAM™ extruded polystyrene foam panels are produced with a flat, dust-free surface and narrow tolerances. Using hot-wire foam cutting equipment it is possible to produce core layers as thin as 5 mm from STYROFOAM blocks.

Hot-wire equipment can achieve a standard thickness tolerance of ±0.5 mm. However, products can be manufactured as custom-made items with a thickness tolerance of ±0.1 mm. Requests for specific dimensions or particular tolerances can be discussed with your Dow contact.

Width	(600 mm wide) +3/–0 mm, (1,200 mm wide) +5/–0 mm
Length	+10/–0 mm
Thickness	±0.5 mm (custom-made items: ±0.1 mm)

Other tolerances can be available on request.

Standard grooves: 39 mm groove spacing; 3.5 mm deep; 1.8 mm wide

Panels with grooves can be produced on request. Grooves may assist the bonding process by facilitating the expulsion of air and the even distribution of adhesive.

Solvent-free adhesives are ideal for bonding a STYROFOAM™ core with outer layers made from aluminium, glass fibre, reinforced plastic and wood, including common polyurethane adhesives (one component/two component adhesives as well as reactive hot melt adhesives). Various surface finishes are available to suit the particular bonding process.

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.

Fig. 09: Grooved STYROFOAM™ panels during the bonding process

Fig. 10: Aligning STYROFOAM™ panels

Fig. 11: Adhesive being applied to STYROFOAM™ core layer material

Fig. 12: Applying the glass fibre reinforced plastic outer layer

Fig. 13: Adding markings

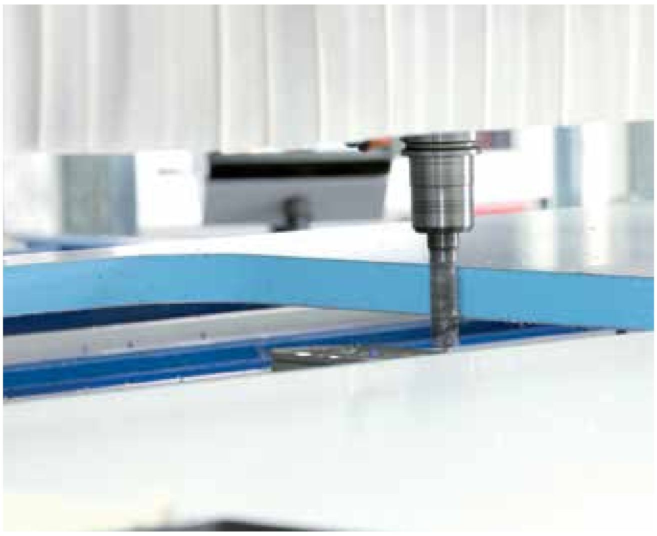


Fig. 14: Machining outside wall openings

Fig. 15: The finished side wall

OUR COMMITMENT TO YOU

Quality assurance and 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.

Dow undertakes rigorous quality management procedures during and after the production of STYROFOAM™ to support manufacture of consistently high quality products.

Selective product analyses are conducted in the laboratories of Dow's Research and Development Department in Rheinmünster, Germany. This is where application-specific properties, including thermal conductivity, water absorption by immersion or diffusion, fatigue, creep rupture behaviour as well as shear and tensile strength are regularly checked. Test pieces are also exposed to various loading conditions, in order to determine the maximum loads that both the STYROFOAM™ core layer material and manufactured composite panels can be subjected to.

Fig. 16: Testing creep rupture behaviour under a compressive load in accordance with DIN EN 1606

Fig. 17: Dynamic testing of composite test pieces with STYROFOAM™ core layer material

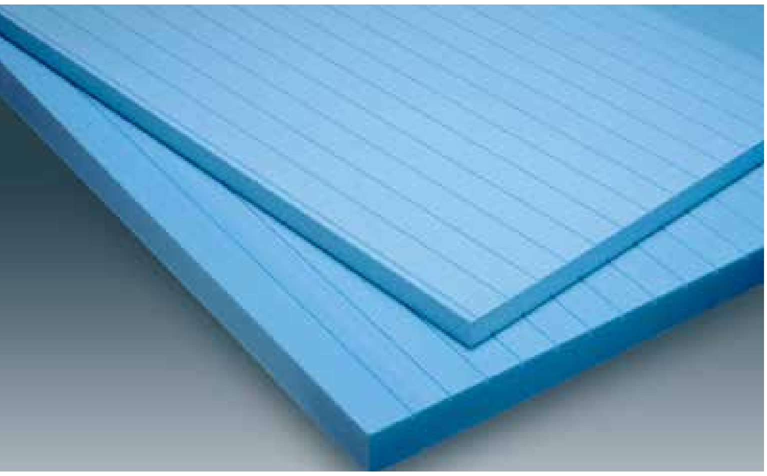


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Fig. 18: Grooved STYROFOAM™ panels

TECHNICAL DETAILS OF STYROFOAM™ PRODUCTS

Properties [1]		CE-Code	Standard	Unit	STYROFOAM™ LB-XP	STYROFOAM™ LB-AP/LBH-XP	STYROFOAM™ RTM-XP
Cell contents					HFC	Air/HFC	HFC
Density, typical		–	EN 1602	kg/m³	33	33	40
Thermal conductivity for 60 days old foam – mean value at 10°C		λ-mean, 60d	EN 12667 / EN 12939	W/(m·K)	0,027	≤ 0,033	0,025
Thermal conductivity declared (λ_D)		λ_D	EN 13164	W/(m·K)	0,029 (≤100mm)	0,033 (≤ 80mm)	0,029
Compressive stress or compressive strength @ 10% deformation [2]		CS(10\Y) σ_m	EN 826	N/mm² [2,3]	0,3		0,4
E-Modulus (typical) [2]		–	EN 826	N/mm²	12 (≤ 30 mm) 15 (31–80 mm)	9 (≤ 30 mm) 12 (31–80 mm)	17 (≤ 30 mm) 22 (31–80 mm)
Tensile strength [2]		TR600	EN 1607	N/mm²	0,6		
		TR900					0,9
Tensile Modulus (typical) [2]		–	EN 1607	N/mm²	24 (≥ 50mm)		28 (≥ 50mm)
Shear strength		SS250	EN 12090	N/mm²	0,25		
		SS400					0,4
Shear Modulus (typical)		–	EN 12090	N/mm²	8	7	10
Water vapour diffusion resistance factor μ (typical)		–	EN 12086	–	150		150
Long term water absorption by total immersion		WL(T)1,5	EN 12087	Vol-%	≤1,5		≤1
Capilliarity		–	–	–	0		
Coefficient of linear thermal expansion		–	–	mm/mK	0,07		
Reaction to fire Euroclass		–	EN 13501-01	–	E		
Temperature limits		–	–	°C	-50/+75		
Dimension [4]	Thickness	–	EN 823	mm	20-200	20-140	20-140
	Width		EN 822		600/1200		
	Length		EN 822		2000/2500/3000		
Tolerances [4]	Thickness CT "Close Tolerance"				-/+0,3		
	Thickness	T3	EN 823		-/+0,5		
	Width < 700 mm	–	EN 822		-0/+3		
	Width ≥ 700 mm	–	EN 822		-0/+5		
	Length	–	EN 822		-0/+10		
Edge Profile		–	–	–	butt edge		
Surface Finish		–	–	–	planed & grooved or planed & non-grooved		

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

2) Measured in the thickness direction.

3) 1 N/mm² = 10³ kPa; 1 kPa = 10⁻³ kN/m².

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

Dow (NYSE: DOW) combines the power of science and technology to passionately innovate what is essential to human progress. The Company is driving innovations that extract value from material, polymer, chemical and biological science to help address many of the world's most challenging problems, such as the need for fresh food, safer and more sustainable transportation, clean water, energy efficiency, more durable infrastructure, and increasing agricultural productivity. Dow's integrated, market-driven portfolio delivers a broad range of technology-based products and solutions to customers in 175 countries and in high-growth sectors such as packaging, infrastructure, transportation, consumer care, electronics, and agriculture. In 2016, Dow had annual sales of $48 billion and employed approximately 56,000 people worldwide. The Company's more than 7,000 product families are manufactured at 189 sites in 34 countries across the globe.

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