RAVATHERM™ XPS

New generation of insulation for refrigerated trucks

Version June 2024

This document replaces all former versions and releases

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
- ››› Appropriate weight/strength ratio.

RAVATHERM™ XPS X – the new generation of insulation for refrigerated trucks composite panels offers all these features and can be used to manufacture the walls, roofs and floors of refrigerated truck bodies.

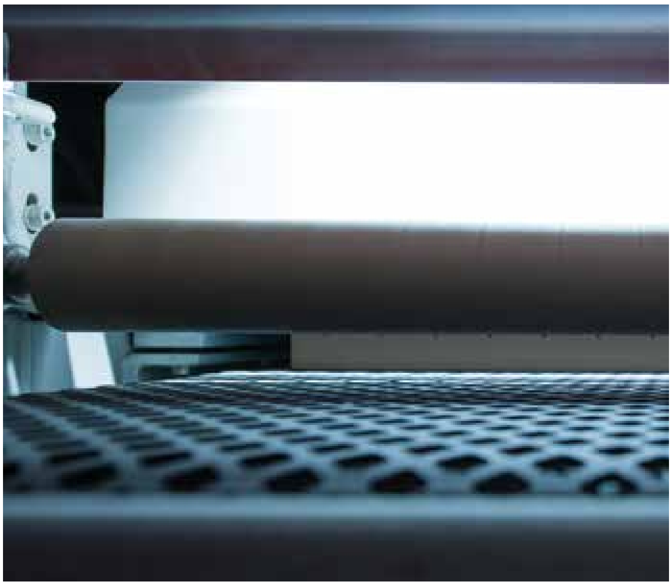


Fig. 01: RAVATHERM™ XPS X Panels go through a thorough control process, before being used for refrigerated trucks

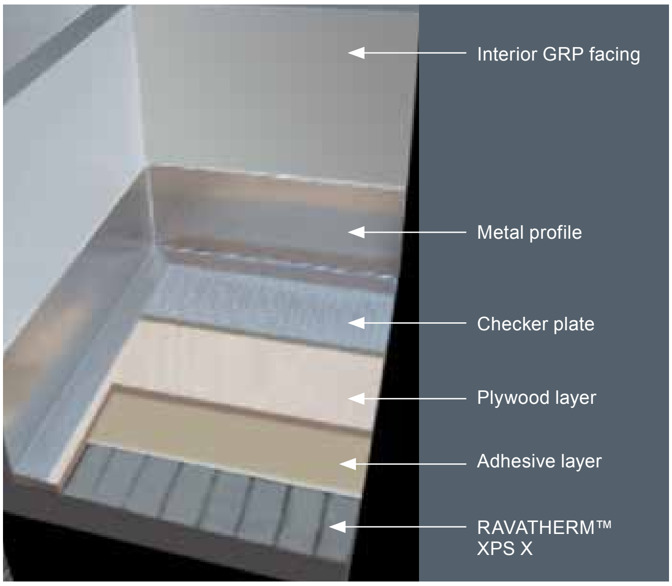


Fig. 02: Cross section of a wall/floor element

Ravago – Core Composites
Competence at our core

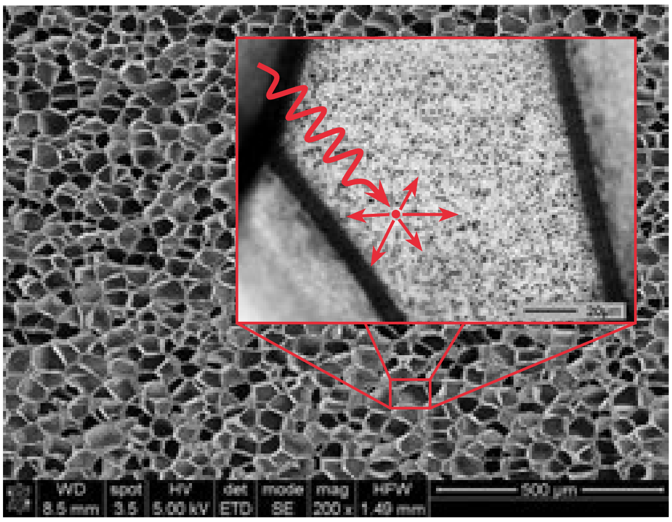


Fig. 03: RAVATHERM™ XPS X incorporates infra-red attenuator particles into the cell walls to scatter and reflect heat radiation

Fig. 04: RAVATHERM™ XPS X extruded polystyrene

RAVATHERM™ 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 RAVATHERM™ products for a wide variety of applications, like refrigerated trucks, pipe section insulation and motor-homes.

RAVATHERM™ 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 Ravago 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 enabled Ravago to take a new step forward with the development of the high-class performance insulation!

We've achieved this through using a patent-granted technology: a manufacturing process which uses a zero-ODP blowing agent system and incorporated infra-red attenuator particles to scatter and reflect heat radiation within the foam board.

Ravago Industry Solutions is a branch of the Ravago group, a fast-growing multinational company with a culture based on family values. Founded in Belgium in 1961 the company is committed to ethical and sustainable business practices and forges strong relationships with its 7,000-strong workforce and 49,000 customers.

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 governed 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 appliances.
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.

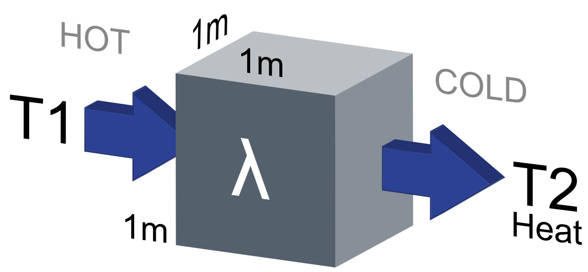


Fig. 05: Heat flow

Opting for RAVATHERM™ XPS X as the core layer material for sandwich panels in refrigerated trucks means opting for long-lasting effective thermal insulation.

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 RAVATHERM™ XPS X Ultra HD300 and RAVATHERM™ XPS X Ultra RTM, products mainly used in refrigerated truck floors. When RAVATHERM™ XPS X 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.

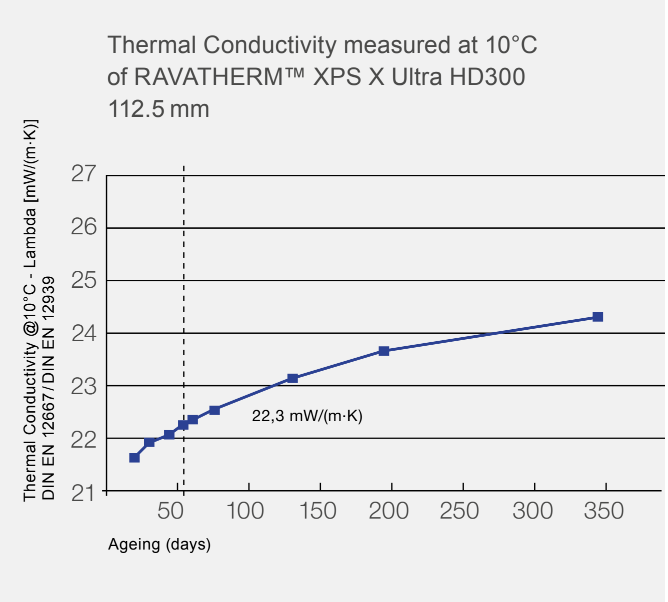


Fig. 06: Thermal conductivity over time testing

[1] TÜV-Süd, Transportkälte- und Dämmtechnik ATP, www.tuev-sued.de

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.

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

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.

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

Here is an example of calculating the R-value of a 3-layer sandwich panel:

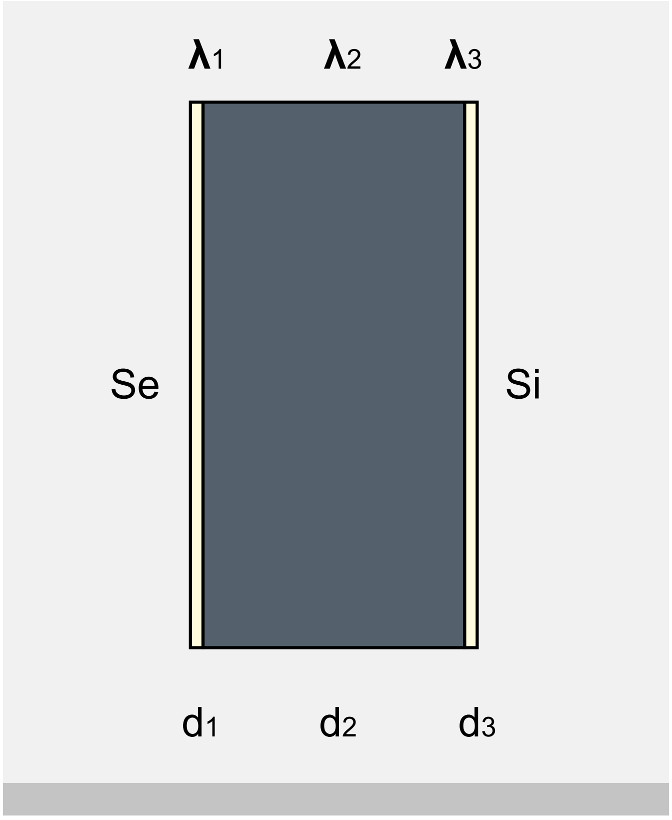


Fig. 07: Cross section of a 3-layer sandwich panel

Layer	Product name	Thickness d (mm)	λ [W/(m·K)]	R (m^2K/W)
1	GRP	1,5	0,16	0,009
2	RAVATHERM™ XPS X Ultra HD300, RAVATHERM™ XPS X Ultra RTM	60	0,023	2,609
3	GRP	1,5	0,16	0,009
TOTAL				2,63

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

Dry to the core
RAVATHERM™ XPS X'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.

RAVATHERM™ XPS X 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 an excellent product for refrigerated truck panels where long-term insulating properties are required (Fig. 08).

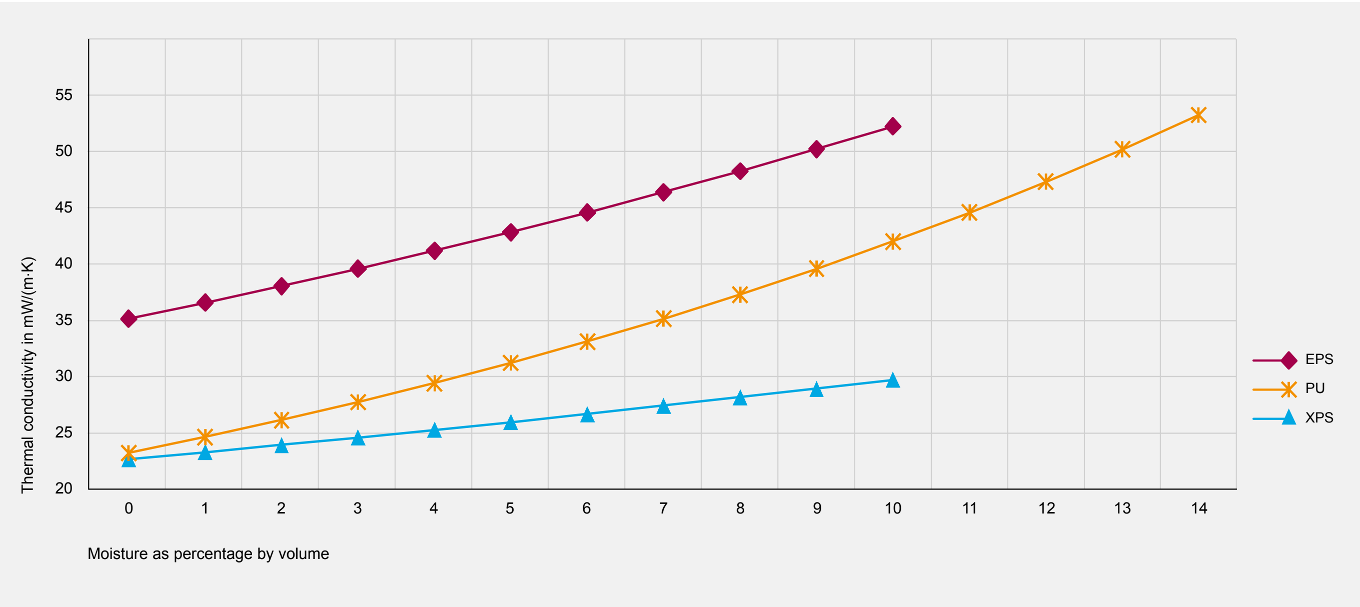


Fig. 08: Effect of moisture content on the thermal conductivity (λ) of foam core materials according to EN ISO 10456

Strength and reliability
RAVATHERM™ XPS X's mechanical performance

The specification of materials for sandwich panels involves consideration of performance parameters and results of relevant calculations.

The excellent mechanical properties of RAVATHERM™ XPS X allow the use of the grey core in highly-stressed applications. It is capable to withstand heavy cargo loads but also dynamic loads. Where the expected loads are known, the deflection of a simply supported composite panel, consisting of two facings constantly glued to a foam core, can be calculated relatively precisely with the following equationn (Fig. 09).

The important mechanical parameters of the foam core are its compression and shear resistance.
Compression forces affect the core as soon as a supported sandwich panel receives a vertical load. If the maximum compression load of the foam core is exceeded its cell structure collapses and the sandwich panel is crushed. Shear forces come into play as soon as a sandwich panel is loaded by bending.

Calculation part = facing — Calculation part: core

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

= flexural deflection + shear deflection for sandwich panels with thin facings

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

Fig. 09: Deflection calculation

Tensile forces affect the core material when, for example, heavy loads are attached to a roof or ceiling panel. If the maximum permissible force is exceeded the panel may undergo plastic deformation (no longer return to its original shape) or even tear. All of those effects of forces are simulated in the Ravago laboratory in order to determine the loading limits of the foam core and also of finished and bonded sandwich panels.

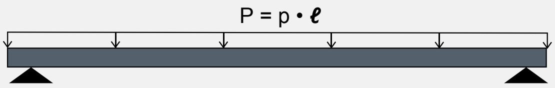
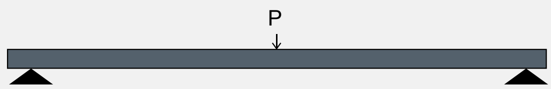
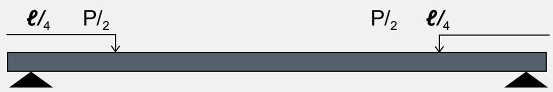
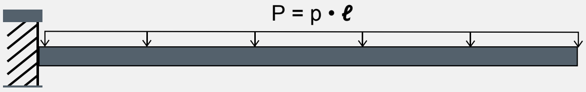
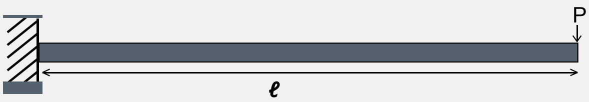
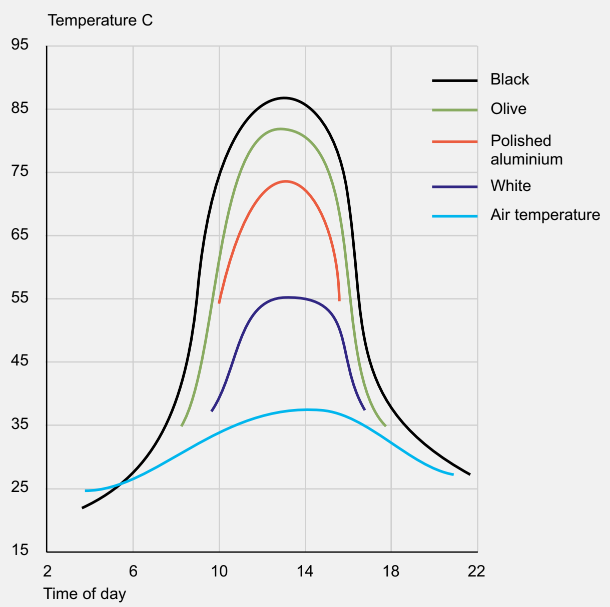
		k_f	k_c
Simply supported beam, uniformly distributed load		$\frac{5}{384}$	$\frac{1}{8}$
Simply supported beam, central point load		$\frac{1}{48}$	$\frac{1}{4}$
Simply supported beam, point loads at $\ell/_4$ span from the supports		$\frac{11}{768}$	$\frac{1}{8}$
Cantilever, uniformly distributed load		$\frac{1}{8}$	$\frac{1}{2}$
Cantilever, point load at free end		$\frac{1}{3}$	1

Fig. 10: Deflection calculation

Fig. 11: Testing creep performance in Ravago's dedicated laboratory



The data refer to a 100 mm thick composite panel with RAVATHERM™ XPS X core and aluminium facings exposed horizontally in still air.

Fig. 12: Panel surface temperature with solar exposure

In creep tests, Ravago investigates how its products behave over long periods under constant load. Ravago has its own laboratory with dedicated equipment being capable of measuring compressive creep of RAVATHERM™ XPS X products – this is unique in the industry.

RAVATHERM™ XPS X 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, RAVATHERM™ XPS X has an excellent suitability in the industry.

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. 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 RAVATHERM™ XPS X a s/n-curve was generated internally, showing the relation between the dynamic shear stress and the amount of cycles the sample has been exposed to.

Fig. 13: Dynamic test on sandwich panels with RAVATHERM™ XPS X core

According to this particular s/n-curve RAVATHERM™ XPS X resists > 600.000 load cycles when applying a dynamic load representing 50 % of the measured maximum static load according to EN 12090.

Ravago makes use of in-house fatigue testing equipment to control the fatigue behavior of RAVATHERM™ XPS X products and to work on product developments in this respect.

Tailored to fit
Production capabilities

RAVATHERM™ XPS X 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 5 mm from RAVATHERM™ XPS X blocks.

The oscillating hot-wire cutting equipment utilized by Ravago 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. Ravago 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
Standard	Standard ± 0,5 mm 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) ± 0,1mm

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 > 15 mm: 39 mm groove spacing; 3,5 mm deep, 1,8 mm wide). In addition to processing using hot-wire equipment, RAVATHERM™ XPS X panels can be simply and cleanly cut using conventional tools and machines from the timber industry.

Fig. 14: Oscillating hot-wire cutting machine

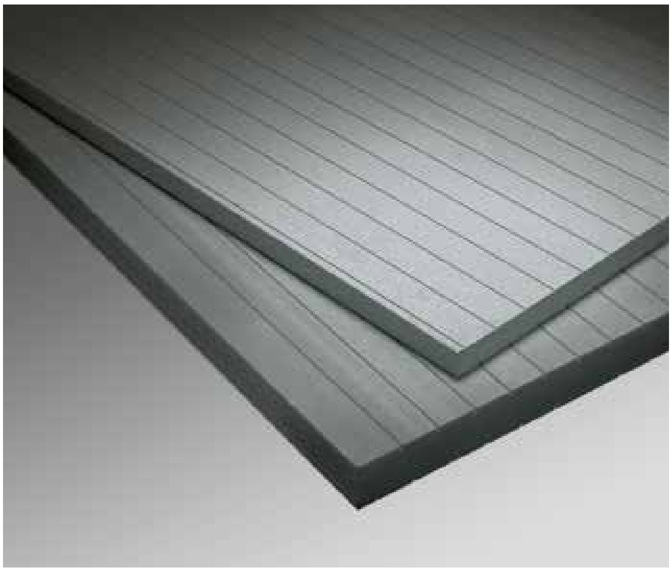


Fig. 15: Grooved RAVATHERM™ XPS X

Fig. 16: Application of a 2 component PU adhesive

Fig. 17: Vacuum Table

For bonding purpose with e.g. aluminium, wood and GRP, solvent-free adhesives are strongly recommended.
The use of polyurethane adhesives, as 1C and 2C (component) PU adhesives and also reactive hotmelt adhesives can be successfully used in combination with RAVATHERM™ XPS X. Related to the adhesion process, Ravago 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/m^2; the optimum negative pressure in each case must be determined experimentally for the cores and facings.

A quality approach
Customer focus

RAVAGO undertakes rigorous quality management during and after the production o fRAVATHERM™ XPS X 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 60 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 Ravago XPS products are CE marked.

Declaration of Performance (DoP) 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 extruded polystyrene as a core material and on modern simulation programs, Ravago'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.

Fig. 18

Technical data

Properties	Standard	Unit	RAVATHERM™ XPS X PLUS LB (GV)	RAVATHERM™ XPS X PLUS RTM (GV)	RAVATHERM™ XPS X ULTRA RTM (GV)	CE-Code
Density (mean value)	EN 1602	kg/m³	35	40	40	–
Thermal Conductivity Declared (λ_D)	EN 13164	W/(m·K)	0,029 (≤ 100 mm) 0,030 (> 100 mm)	0,029	0,028	λ_D
Thermal Conductivity for 60 days old foam – mean value at 10°C	EN 12667 EN 12939	W/(m·K)	0,027 (≥ 40 mm)	0,027 (≤ 50 mm) 0,025 (> 50 mm)	0,025 (≤ 50 mm) 0,023 (> 50 mm)	λ-mean, 60d
Compressive stress or compressive strength @ 10% deformation[1]	EN 826	kPa	300	400	400	CS(10\Y)
Tensile Strength[1]	EN 1607	kPa	600	900	900	TR
Shear Strength	EN 12090	kPa	250	400	400	SS
Moduli (typical) E-Modulus[1]	EN 826	MPa	12 (< 30 mm) 15 (30 – 79 mm) 20 (≥ 80 mm)	17 (< 30 mm) 20 (30 – 79 mm) 28 (≥ 80 mm)	17 (< 30 mm) 22 (30 – 79 mm) 28 (80 – 120 mm)	MPa
Tensile Modulus[1]	EN 1607	MPa	24 (≥ 50 mm)	28 (≥ 50 mm)	28 (50 – 120 mm)	MPa
Shear Modulus[2]	EN 12090	MPa	8	10	10	MPa
Compressive Creep max after 50 years ≤ 2% deformation under stress σ_C	EN 1606	kPa	–	140	140	CC(2/1,5/50)σ_C
Water vapour diffusion resistance factor μ (tabulated value)	EN 12086	–	150	150	150	MU
Long term water absorption by total immersion	EN 12087	%	1,5	1,5	1,5	WL(T)
Dimensional stability under specified temperature (70°C) and humidity conditions (90%rh)	EN 1604	%	< 5	< 5	< 5	DS(70,90)
Deformation under specified compressive load (40kPa) and temperature (70°C) conditions	EN 1605	%	–	< 5		DLT(2)5
Coefficient of linear thermal expansion (typical value)	–	mm/(m·K)	0,07	0,07	0,07	–
Fire Performance	EN 13501-1	–	E	E	E	–
Temperature limits	–	°C	-50/+75	-50/+75	-50/+75	–
Tolerances – Thickness	EN 823	mm	-0,5/+0,5	-0,5/+0,5	-0,5/+0,5	T3
Width	EN 822	mm	< 700 mm: 0,0/+3 > 700 mm: 0,0/+5	< 700 mm: 0,0/+3 > 700 mm: 0,0/+5	0,0/+3	T3
Length	EN 822	mm	0,0/+10	0,0/+10	0,0/+10	T3
Dimensions – Thickness	EN 823	mm	20 – 100	21 – 120	40 – 120	T3
Width	EN 822	mm	600 – 1210	529 – 1202	600	T3
Length	EN 822	mm	1400 – 3515	1200 – 3140	2000 – 3000	T3
Edge Profile	–	–	Butt Edge	Butt Edge	Butt Edge	–
Surface finish	–	–	Planed GV planed/grooved	Planed GV planed/grooved	Planed GV planed/grooved	–
DESIGNATION CODE			XPS-EN13164-T3-CS(10\Y)300 -DS(70,90)-WL(T)1.5-TR600-SS250	XPS-EN13164-T3-CS(10\Y) 400 -CC(2/1.5/50) 140-DS(70,90)-DLT(2)5-WL(T)1.5-TR900-SS400	XPS-EN13164-T3-CS(10\Y)400 -CC(2/1.5/50)140-DS(70,90)-WL(T)1.5-TR900-SS400	

1) Measured in thickness direction
2) Typical value for Shear Modulus, may vary with the inplane direction.

1 N/mm² = 10^3 kPa = 1 MPa

Technical data

Properties		Value	Unit	RAVATHERM™ XPS X PLUS HD300 (GV)	RAVATHERM™ XPS X ULTRA HD300 (GV)	CE-Code
Density (mean value)		EN 1602	kg/m³	45	45	–
Thermal Conductivity Declared (λ_D)		EN 13164	W/(m·K)	0,029	0,028	λ_D
Thermal Conductivity for 60 days old foam – mean value at 10°C		EN 12667 EN 12939	W/(m·K)	0,027 (≤ 50 mm) 0,025 (> 50 mm)	0,025 (≤ 50 mm) 0,023 (> 50 mm)	λ-mean, 60d
Compressive stress or compressive strength @ 10% deformation [1]		EN 826	kPa	700	700	CS(10\Y)
Tensile Strength [1]		EN 1607	kPa	1200	1200	TR
Shear Strength		EN 12090	kPa	500	500	SS
Moduli (typical) E-Modulus [1]		EN 826	MPa	35 (< 80 mm) 38 (≥ 80 mm)	35 (< 80 mm) 38 (≥ 80 mm)	MPa
Tensile Modulus [1]		EN 1607	MPa	31	31	MPa
Shear Modulus [2]		EN 12090	MPa	14	14	MPa
Compressive Creep max after 50 years ≤ 2% deformation under stress σ_C		EN 1606	kPa	210	210	CC(2/1,5/50)σ_C
Water vapour diffusion resistance factor μ (tabulated value)		EN 12086	–	150	150	MU
Long term water absorption by total immersion		EN 12087	%	0,7	0,7	WL(T)
Dimensional stability under specified temperature (70°C) and humidity conditions (90%rh)		EN 1604	%	< 5	< 5	DS(70,90)
Deformation under specified compressive load (40kPa) and temperature (70°C) conditions		EN 1605	%	< 5	< 5	DLT(2)5
Coefficient of linear thermal expansion (typical value)		–	mm/(m·K)	0,07	0,07	–
Fire Performance		EN 13501-1	–	E	E	–
Temperature limits		–	°C	-50/+75	-50/+75	–
Tolerances	Thickness	EN 823	mm	-0,5/+0,5	-0,5/+0,5	T3
	Width	EN 822	mm	0,0/+3	0,0/+3	T3
	Length	EN 822	mm	0,0/+10	0,0/+10	T3
Dimensions	Thickness	EN 823	mm	40 – 100	40 – 114,5	T3
Width		EN 822	mm	600	600	T3
Length		EN 822	mm	2320 – 2650	200 – 3000	T3
Edge Profile		–	–	Butt Edge	Butt Edge	–
Surface finish		–	–	GV planed/grooved	GV planed/grooved	–
DESIGNATION CODE				XPS-EN13164-T3-CS(10\Y)700 -CC(2/1.5/50)210-DS(70,90)-DLT(2)5-WL(T)0.7-TR1200-SS500	XPS-EN13164-T3-CS(10\Y)700 -CC(2/1.5/50)210-DS(70,90)-DLT(2)5-WL(T)0.7-TR1200-SS500	

1) Measured in thickness direction
2) Typical value for Shear Modulus, may vary with the inplane direction.

1 N/mm² = 10³ kPa = 1 MPa

Important information

Please follow the application guidelines issued by Ravago.

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

Should RAVATHERM™ XPS X 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 foam surface or deterioration during long periods of storage outdoors, panels should be protected from direct sunlight. White colored protective packaging should be applied in case an outside storage must be considered. Dark colored or clear film should be avoided in case of outside storage as this could lead to 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 regulations. Fire protection requirements are outlined in National regulations, which must be complied with.

Recommendations regarding methods, use of materials and structural details have been devised on the basis of Ravago'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.

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