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	07.09.78	VK-U Dl/SchS	806 4523	11.09.78

ROHACELL

Dear Mr. Erwin!

Thank you very much for your enquiry which had been sent to us by Mr. Ott of CY/RO Industries, USA.

Please find enclosed literature and samples about ROHACELL which will give you all information you asked for.

Yours faithfully

R ö h m   G m b H

i.V. [signature] i.A. [signature]

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Rohacell®

Rigid Foam

ROHACELL pressed 170 kg/m^3

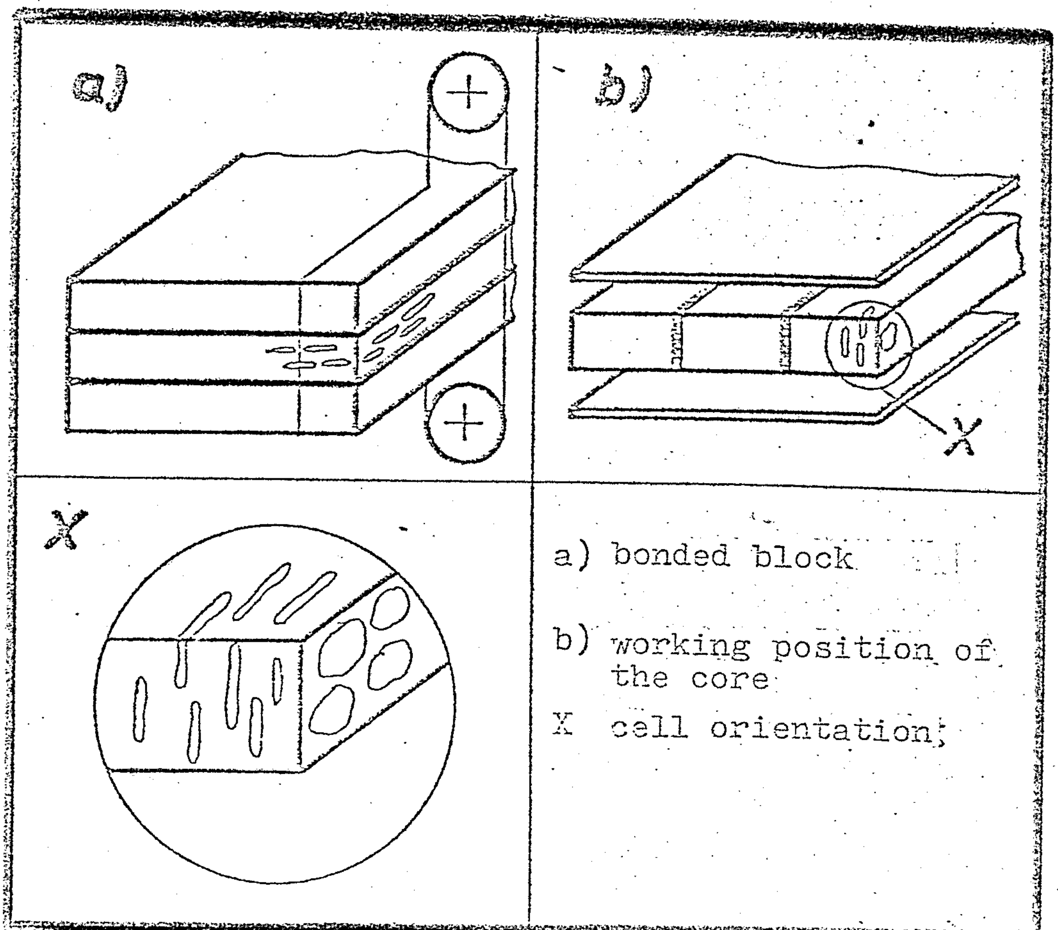
ROHACELL pressed 190 kg/m^3

In order to meet the requirement for a composite core material with very high specific strengths, stability under dynamic stress and economical processing properties, ROHACELL grades with higher densities than the 30 kg/m^3, 50 kg/m^3 und 70 kg/m^3 of the current ROHACELL range were introduced.

ROHACELL pressed is a rigid polymethacrylimide foam with an orientated cell structure whose highest strength and rigidity properties are in the plane of the board. For a number of uses in sandwich core construction it is therefore eminently reasonable to allow the direction of the principal stress to coincide with the direction of maximum material strength, i. e. to use a sandwich core with an upright cell structure.

Here is an example of this working technique. Our compressed, rigid ROHACELL foams are supplied as boards. As a rule they are bonded with two-component adhesives to give a height corresponding to the width of the required sandwich core. Cores are sawn out of the resultant block at right angles to the glue lines so that the cell structure is vertical when the core is horizontal.

This technique need not necessarily be followed in every case. When the strenghts measured in the press direction are sufficient for a specific purpose, ROHACELL boards can be used for large areas rather than by the above method.



a) bonded block

b) working position of the core

X cell orientation;

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rohacell®

lightweight **rigid** foam

Guidelines for model building

MB

rohacell®

Chemical properties

ROHACELL® is a rigid foam on the basis of polymethacrylimide. The base materials are methacrylic acid and methacrylonitrile. The copolymer formed from these constituents expands at 170 – 200 °C aided by a blowing agent. The result is a snow-white foam with a fine, closed cell structure.

Bulk densities and grades:	ROHACELL is produced in three bulk densities:
	30 kg/m³ = ROHACELL 31
	50 kg/m³ = ROHACELL 51
	70 kg/m³ = ROHACELL 71

Sales Range

Sheet thickness mm:	1	2	3	4	5	6	8	10	15	20	25	30	40	45	50	55	65
ROHACELL 31				+	+	+	+	+	+	+	+	+	+		+		+
ROHACELL 51	O	O	O	+	+	+	+	+	+	+	+	+	+			+	
ROHACELL 71				+	+	+	+	+	+	+	+	+	+	+			

Sizes: O = 1250 x 625 mm
+ = 2500 x 1250 mm
1250 x 1250 mm
1250 x 625 mm

The table shows the resistance of ROHACELL 31, 51 and 71 to various technical liquids. ROHACELL is particularly resistant to organic solvents and fuels, but it does not withstand alkaline media.

at 20 °C

Acetone	+	Methyl alcohol	–
Benzene	+	Methyl isobutyl ketone	+
Carbon tetrachloride	+	Petroleum ether	+
Dibutyl phthalate	(+)	Soda solution (5 pc)	–
Diesel oil	+	Styrene	+
Ether	+	Sulphuric acid (10 pc)	+
Ethyl acetate	+	Supergrade petrol	+
Glacial acetic acid	–	Tetrahydrofuran	–
Isopropyl alcohol	+	Toluene	+
Lacquer solvent I	+	Trichloroethylene	+
Lacquer solvent II	+		

at boiling temperature

Carbon tetrachloride	(77 °C)	+
Benzene	(80 °C)	+
Trichloroethylene	(88 °C)	+
Chlorobenzene	(132 °C)	–
Xylol	(139 °C)	+
O-dichlorobenzene	(180 °C)	–

+ = resistant, (+) = limited resistance, – = not resistant

Dimensional stability under heat is given up to about 185 °C. The maximum service temperature for short-term stressing is 180 °C; for long-term stressing, 160 °C.

Physical properties

Apart from excellent solvent resistance and high dimensional stability under heat ROHACELL also shows outstanding mechanical strength.

The most important properties of ROHACELL 31, 51 and 71 are tabulated below.

Properties	Test conditions	ROHACELL 31	ROHACELL 51	ROHACELL 71	Unit	Standard
Density	23 °C/50% r.h.	30	50	70	kg/m^3	DIN 53 420
Tensile strength	23 °C/50% r.h.	1.0	1.9	2.8	N/mm^2	DIN 53 455
Compressive strength	23 °C/50% r.h.	0.4	0.9	1.5	N/mm^2	DIN 53 421
Flexural strength	23 °C/50% r.h.	0.8	1.6	2.5	N/mm^2	DIN 53 423
Shear strength	23 °C/50% r.h.	0.4	0.8	1.3	N/mm^2	DIN 53 294
Modulus of elasticity	23 °C/50% r.h.	36	70	92	N/mm^2	DIN 53 457
Shear modulus	23 °C	14	21	30	N/mm^2	DIN 53 445
Heat distortion temperature		185	185	185	°C	DIN 53 424
Coefficient of linear thermal expansion	20 °C	$3.7 \cdot 10^{-5}$	$3.3 \cdot 10^{-5}$	$3.5 \cdot 10^{-5}$	K^{-1}	VDE 0304/1
Thermal conductivity	20 °C	0.031	0.029	0.030	W/mK	DIN 52 612
H_2O absorption (saturation)	20 °C/98% r.h.	0.59	0.88	1.1	vol. %	internal
H_2O absorption (after 50 days)	20 °C (immersed)	13	15	16	vol. %	DIN 53 428

Note: 1 N/mm^2 ≈ 10 kgf/cm^2 — 1 W/mK ≈ 0.86 kcal/mhdeg.

Machining

ROHACELL is machined without lubricants on high-speed wood and plastics working machines, employing the usual tools. Common machining methods are drilling, planing (incl. thicknessing), milling, sawing and grinding. A suitable device should be used to extract the dust which forms during machining. Thin sheets can be cut with a sharp knife. Stamping and punching are possible within certain limits.

(See Figs. 1 – 7)

Thermal treatment

In principle ROHACELL 31 and 51 can be cut with a heated filament. This working method should, however, not be used since it may result in the formation of harmful vapours.

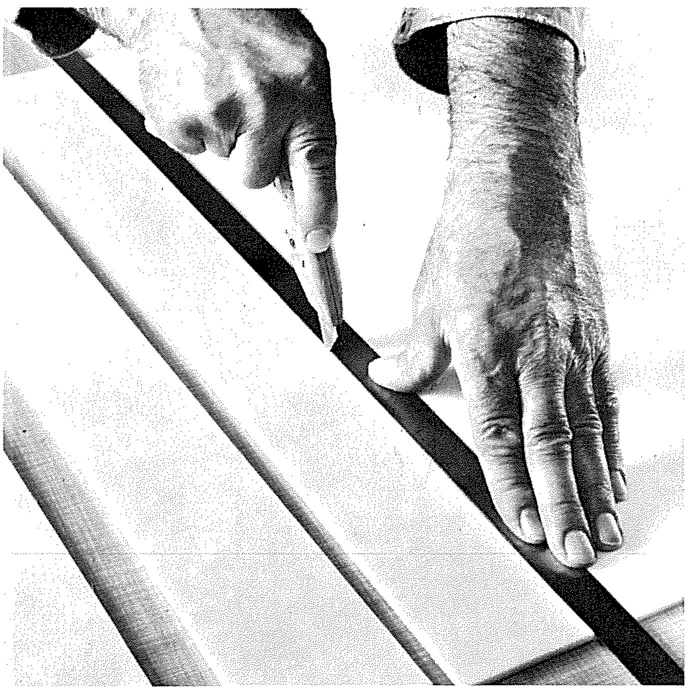

Fig. 1: Thin sheets are cut with a knife. Thicker sheets can be scored with a knife to half their depth and then broken. A particularly clean fracture is obtained by breaking the sheet at the edge of a table.

Fig. 2: For planing edges and faces one uses ordinary wood planing machines. Thicknessing machines are also suitable. Since the foam is easily dented, the profile of the draw-in rollers may show on its surface. Therefore, the cutting depth should be chosen with a view to removing such impressions.

Cold bending

ROHACELL sheets also respond to cold bending. To this end they are laminated on one side with a thin, flexible skin (e.g. aluminium sheet) and bent in such a way that the tensile forces act on this skin while the foam on the inside is merely compressed. The achievable bending radii are very small.

(See Figs. 8 and 9)

Embossing

Another way of shaping ROHACELL is cold and hot embossing. In cold embossing the desired patterns and profiles are pressed into the foam, which is then stressed beyond its maximum compressive strength and squeezed together. This results in a destruction of the cellular structure.

In hot embossing an embossing die heated to 170 – 190 °C is pressed into the foam. The compression load must be less than the maximum compressive strength at 20 °C. In this case the foam is embossed at its temperature-dependent softening rate and the cellular structure is not destroyed.

(See Fig. 10)

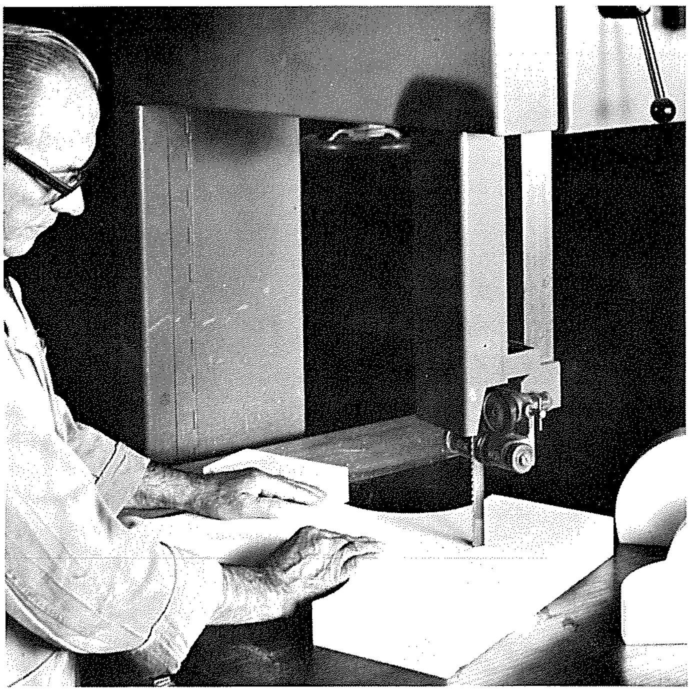

Fig. 3: Band and compass saws can be used for cutting shapes.

Fig. 4: Circular discs or cylindrical parts are produced on the turner's or wood turner's lathe. The required gripping forces are transmitted by wooden discs.

Shaping

At a temperature of 170 – 190 °C ROHACELL becomes thermoelastic and can be shaped. The required temperature depends on the degree of shaping and the density; ROHACELL 31 needs higher temperatures than ROHACELL 71.

Apart from shaping proper at a constant material strength there is the possibility of shaping by compression, during which the entire original sheet or part of it can be compressed to approx. 25 per cent of its original thickness. Shaping by compression results in higher strength values at right angles to the direction of compression due to an orientation of the cellular structure.

Compression shaping at very low temperatures damages the cellular structure. The pressure to be applied depends on the density of the ROHACELL sheet to be shaped and lies between 1 and 10 kgf/cm². Where heated press plates are available, partial compacting of the surface can be achieved by short-term application of the shaping pressure only at the start of heating. In this case the foam structure is deformed merely to the extent of heat penetration. The result is an almost closed-cell surface. Subsequent cooling to about 140 °C is necessary.

Since the foam has a low heat capacity, which corresponds to its low mass, the sheets require protection against cooling when transported from the heating cabinet to an unheated shaping fixture. This can be done with sheets of silicone rubber or cotton glove cloth, between which the foam is heated and also shaped. The function of these sheets is to maintain the required temperature just long enough for complete shaping. Partial heating of the foam is also possible with a heated shaping tool or a radiator. The long-term heat distortion temperature of shaped sheets is about 140 °C. The foam must be cooled to below this temperature before it is removed from the shaping jig. The smallest achievable bending radius is about twice the sheet thickness.

Moreover, sheets of ROHACELL can be shaped after immersion in water of 90 °C for about 1 to 2 min., dependent on their thickness. A sheet shaped in this way must, however, be subsequently annealed in a mould, about 30 mins. at 130 – 160 °C, to fix its shape and to extract the water. The part must remain in the mould until it has cooled down. The use of this technique is restricted to shaping about one axis.

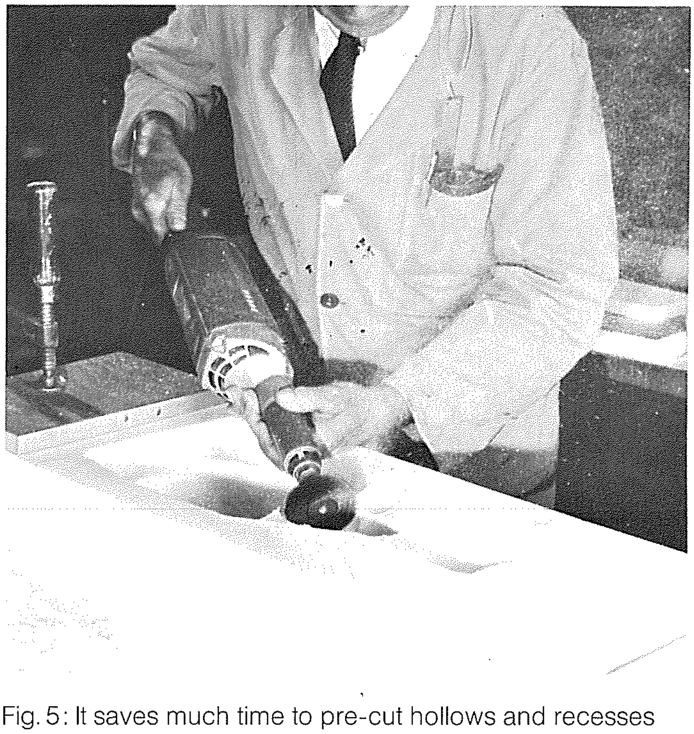

Fig. 5: It saves much time to pre-cut hollows and recesses with a portable grinder or drill with wire brush insert. Finishing and surface smoothing is then done by hand with abrasive paper.

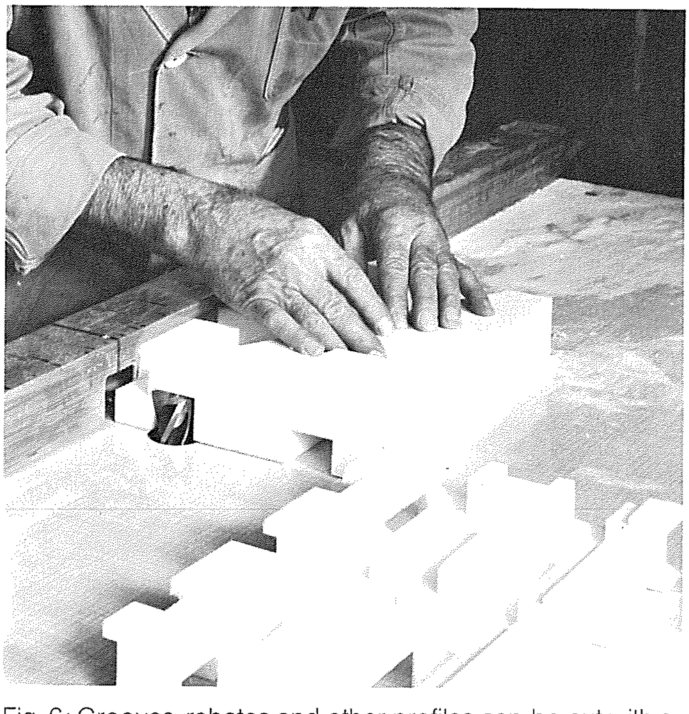

Fig. 6: Grooves, rebates and other profiles can be cut with a routing cutter. If due care is taken, the material can be routed to web widths of 2 mm.

Bonding

In view of the large number of suitable adhesives and the multitude of materials which can be bonded to ROHACELL, it is impossible to recommend a general working method or to specify the amounts to be applied and the drying and curing times to be observed. We shall, however, always be glad to seek feasible solutions to special problems in co-operation with the adhesives manufacturers. For all bonding problems ROHACELL offers the inestimable advantage of solvent resistance and the thermal stability required for hot setting (epoxy resins up to 160 °C).

As a result, practically all commercial adhesives can be used. Mechanical anchoring in the cut cells adds considerably to the strength of the bond between adhesive and ROHACELL. According to their availability adhesives are divided into three categories:

1. solvent-containing adhesives,
2. adhesive dispersions,
3. solvent-free adhesive systems.

Since ROHACELL is highly impervious to solvent diffusion, the adherends in large-area bonds between ROHACELL and ROHACELL or ROHACELL and other diffusion-tight materials to which adhesives of group 1 and 2 have been applied must be well aired before they are joined under pressure. Bonds produced with these (normally rubber-based) systems usually stay somewhat elastic and show good peel strength. If the joint can be heat-sealed, a bond of much better quality will be achieved.

Heat sealing requires good heat transmission and therefore it can only be reasonably used for the bonding of thin layers to ROHACELL, e.g. for laminating with sheet metal or decorative paper.

To this end the adhesive-covered adherends are aired until they are non-blocking, are then placed on top of each other and bonded under pressure at a temperature of 80 - 120 °C. The pressure may be up to 50 per cent of the maximum compressive strength of the foam at 20 °C and should be maintained for 1 – 5 minutes. The bonded material should be removed at a temperature below 80 °C.

For special applications it is sufficient to apply the adhesive to one adherend only, viz. to the laminate skin – but then in somewhat thicker layers – and to heat-seal the latter with the

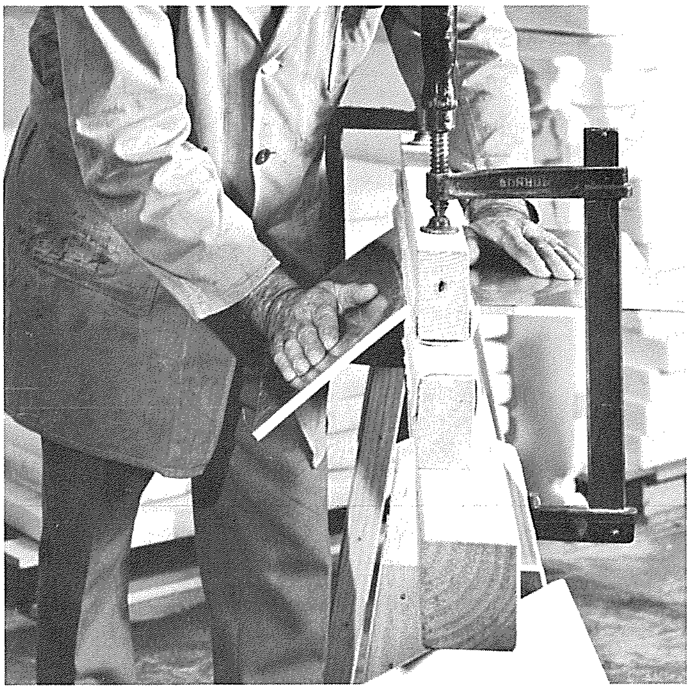

Fig. 7: Sheets bonded to metal or plastics on one side only can be cold bent towards the foam side. In this case the metal sheet absorbs the harmful tensile forces while the foam is merely compressed.

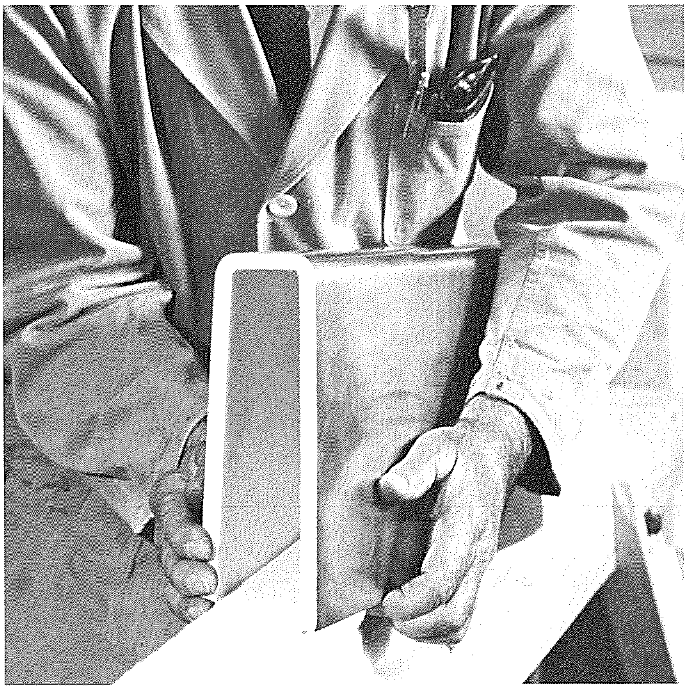

Fig. 8: If another metal or plastics sheet is subsequently bonded to the inside, a strong and rigid sandwich unit is obtained.

foam after allowing sufficient time for block-free airing as described above. If a heatable press is not available, the laminate skins can be adequately heated with pre-heated packing sheets of slightly thicker sheet metal or fibreboard. In the case of small joint areas and very thin cover layers a hot iron will give a satisfactory bond.

The solvent-free systems include thermoplastic adhesives, two-component adhesives and adhesive films. To ensure that the foam cells are well filled, two-component adhesives like epoxy, polyester or methacrylate casting resins should be cured under sufficient pressure (1 – 3 kgf/cm²), or they should be applied at a very low viscosity. Heating (up to 160 °C) accelerates the curing process. The joints become very hard and rigid.

Adhesive films and thermoplastic adhesives require heat for bonding and are thus normally suitable for heat sealing. The adhesive films must be thick enough (100 – 200 g/cm²) to be firmly anchored in the cut cells of ROHACELL.

The adhesive used for bonding ROHACELL to other materials can normally be selected with a view to its suitability for these materials. For metals and laminated plastics it may be an epoxy resin or rubber adhesive, for example; for acrylic glass, a methacrylate resin; for wood and paper, a polyvinyl acetate dispersion; or for glassfibre-polyester sheet, a polyester resin.

If the ROHACELL surface is treated with a needle roller prior to application of the adhesive, the strength of the bond will satisfy very high demands.

Needle roller:	needle spacing along and around the roller about 2.5 mm, staggered arrangement, approx. needle length 3 – 4 mm, butt diameter ca. 1 mm, pointed tip.
Available from:	Christoph Burckhardt & Co. Pfarrgasse 11
	CH-4019 Basle

Where bonds in ROHACELL must be worked, the most suitable adhesives are those which give less rigid joints.

Fig. 9: The foam sheet can be shaped by sanding, using a steel template fixed to the sheet. Sanding is either done with an abrasive belt or by hand on a wheel stand. For large parts one uses a board covered with abrasive paper, which is drawn across the template by hand. Where a large number of articles must be shaped by sanding this template would wear excessively. In this case one uses a frame above the belt to which undersized templates are attached and guided towards the belt.

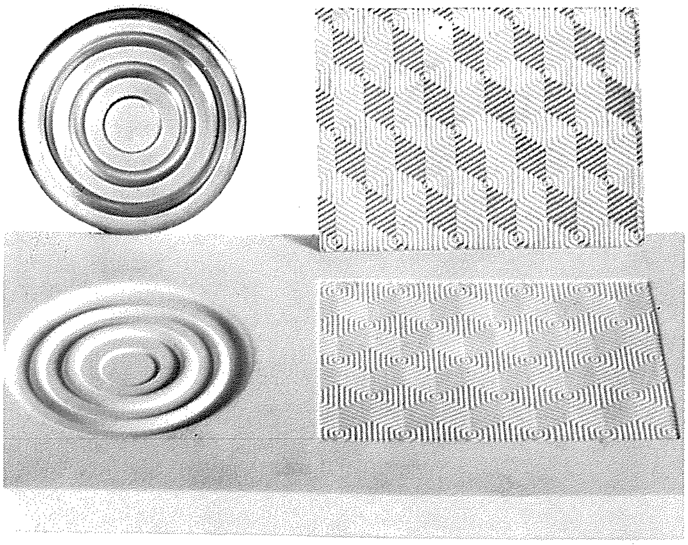

Fig. 10: Hot embossing gives an almost closed surface. In this process thin polyethylene or PVC films can be sealed direct to the surface without the use of an adhesive.

Painting, coating and laminating

ROHACELL can be sprayed or coated with most commercial paints and varnishes (including nitrocellulose lacquers). Emulsion paints, as they are used in building construction, for example, are usually basified and thus unsuitable for ROHACELL since it is not resistant to alkaline media. To produce smooth and glossy surfaces the foam is first filled and sanded. Spraying with polyester fillers, for example, is also possible. For grain-effect lacquering spray-filled surfaces need not be sanded prior to application of the lacquer coat.

Where joints or damaged areas in ROHACELL must be filled and then smoothed, the filler should show a sanding behaviour similar to that of the ROHACELL grade used in order to ensure smooth transitions from the filled area to the adjoining foam. You can prepare this filler yourself according to the following formulae:

Fig. 11: Curvatures are produced by thermoforming. Due to the high thermoforming temperature of 170 – 190 °C the foam would cool down very quickly after removal from the heating cabinet and cracking would occur. Therefore it is packed between cotton glove cloth or silicone rubber sheets, which prevent fast cooling.

Formula 1: 90 pbw surfacer
20 pbw thinner
15 pbw microballoons

The microballoon quantity depends on the ROHACELL grade to be filled. The more microballoons you add, the better will be the sanding behaviour. The thinner serves to vary the consistence of the surfacer so that it spreads evenly.

Formula 2: 100 pbw filler
25 pbw microballoons

Again the microballoon quantity depends on the ROHACELL grade to be smoothed.

For better adhesion the ROHACELL area to be filled is coated once with filler before the surfacer is applied.

Filling increases the compressibility of the foam surface to a considerable extent. Particularly decorative and resistant surfaces are obtained by metal flame spraying, using, for example, aluminium, bronze, copper or iron.

Another possibility of providing ROHACELL with a very light, decorative and smooth surface is laminating with films of thermoplastic synthetic resins. Suitable are elastic films which can be ironed on and other films from PVC, polyethylene, etc., which are applied at 160 – 190 °C under gentle pressure. This includes low-pressure pre-preg films of GRP, which cure on the foam under pressure and heat and become firmly anchored with it.

A favourite coating material for ROHACELL is glass-reinforced polyester resin, which can be applied by hand or compression. For hand lay-up resins of low viscosity should be used to ensure a thorough penetration of the cells. The entire resin quantity is carefully spread on the foam surface and pervades the laid up glass mat from below.

Adhesives in use for bonding ROHACELL to various materials

Adhesives in use for bonding ROHACELL to various materials

Adhesives	Basis	Trade name*	Manufacturer	Materials	Notes
solvent-containing contact adhesives	rubber/ synthetic rubber	®TECHNICOLL ®TEROKAL-KLEBER ®KÖ-KLEBER ®ISARPLAST/ ULTRAFLEX ®BOSTIK ®UHU ®PATTEX	Beiersdorf, Hamburg Teroson, Heidelberg Kömmerling, Pirmasens Isar-Rakoll, München Bostik, Oberursel Uhu-Werk, Bühl/Baden Henkel, Düsseldorf	metals, wood, various plastics, decorative papers, laminated plastics sheets, rubber, ROHACELL to ROHACELL	Adequate airing is important; contact adhesives are usually suitable for heat sealing
Adhesive dispersions	PVac (white glue)	®RAKOLL-EXPRESS SR ®KEIMFIX	Isar-Rakoll, München Keim-Leim, Köln	wood, wood veneer	Suitable for non-diffusion-tight materials; use only plywood veneers
Two-component adhesives (solvent-free)	epoxy resins	TECHNICOLL TEROKAL KÖ-KLEBER ®RAKOLIT ®ARALDIT UHU-PLUS	Beiersdorf, Hamburg Teroson, Heidelberg Kömmerling, Pirmasens Isar-Rakoll, München Ciba-Geigy, Wehr/Baden Uhu-Werk, Bühl/Baden	metals, glass-reinforced epoxy resin, laminated plastics sheets, plastics, ROHACELL to ROHACELL	The curing time can be considerably reduced by heating (up to 160 °C).
	polyester	®PALATAL ®LEGUVAL	BASF, Ludwigshafen Bayer, Leverkusen	glass-reinforced polyester, ROHACELL to ROHACELL	Highly reactive laminating resins can normally be used
	poly-urethane	®IBOLAR	Isar-Rakoll, München	metals, GRP, various plastics, rubber	
	PMMA	®ACRIFIX, ®PLEXIT	Röhm GmbH, Darmstadt	acrylic glass, ROHACELL to ROHACELL	
permanently elastic pressure-sensitive adhesives	varying	TECHNICOLL UHU	Beiersdorf, Hamburg Uhu-Werk, Bühl/Baden	paper, plastics films	

*) Under these trade names adhesives manufacturers usually supply a wide range of adhesives with different properties and working conditions. They should not be selected for their suitability and working conditions alone, but economic aspects should also be considered. The manufacturers' instructions for use must be observed.

Auxiliaries

Auxiliaries	Trade name	Available from
Surfacers	e.g. Resolan model surfacer	Esslinger Farben + Firnis Fabrik Dr. Carl Resau Gutenbergstraße 11 7301 Deizisau W. Germany
Thinners	diluents for cellulose lacquers	specialised dealers
Fillers	e.g. Clou Hartgrund 400	specialised dealers
Microballoons		Bakelite UK Ltd. Redfern Road Tyseley Birmingham B11 2BJ

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® = registered trade mark

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rohacell®

lightweight **rigid** foam

Technical information

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This is ROHACELL

ROHACELL is a rigid plastics foam for lightweight constructions. Its natural colour is white, the cells are uniformly fine and over 95% of them are closed.

ROHACELL is a rigid, polymethacrylimide plastics foam. It is produced by thermally expanding sheets made from a methacrylic copolymer which reacts to give a polymethacrylimide during foaming. The blowing agent is the carbon monoxide liberated during the process.

Form and availability of ROHACELL

Grades that can be supplied

ROHACELL is supplied in different densities

Grade	Gross density kg/m^3	Description
ROHACELL 31	30	For foam plastics these grades have the optimum relationship between the specific gravity and strength so that they cover a wide range of industrial uses
ROHACELL 51	50	
ROHACELL 71	70	
ROHACELL 110	110	New, special grade which closes the gap in properties between low density ROHACELL and the post-compacted grades with a higher density
ROHACELL P 170	170	Postcompacted grades with an oriented cell structure and the highest strength and rigidity in the plane of the sheet
ROHACELL P 190	190	

Physical form

ROHACELL is only supplied in the form of sheets, i. e.

ROHACELL 31, 51, 71

with a thickness and size conforming to the standard sales range; thicknesses other than those in the sales range can also be produced on request

ROHACELL 110

blocks of a thickness and size conforming to the standard sales range

ROHACELL P 170 and P 190

blocks of a thickness and size conforming to the standard sales range

Sales range

Sheet thickness (mm)	1	2	3	4	5	6	8	10	15	20	25	30	40	45	50	55	65
ROHACELL 31				+	+	+	+	+	+	+	+	+	+		+		+
ROHACELL 51	O	O	O	+	+	+	+	+	+	+	+	+	+			+	
ROHACELL 71				+	+	+	+	+	+	+	+	+		+			

Sizes: O = 1250 x 625 mm
+ = 2500 x 1250 mm
1250 x 1250 mm
1250 x 625 mm

Sheet thickness (mm)	48
ROHACELL 110	+

Size: 2160 x 550 mm

Sheet thickness (mm)	23	28
ROHACELL P 170		+
ROHACELL P 190	+	

Size: 2500 x 600 mm

Properties of ROHACELL

General properties

ROHACELL is a hard, brittle plastics foam with excellent mechanical properties, high heat and solvent resistance and very low thermal conductivity, especially at low temperatures. The strengths and the moduli of elasticity and shear are currently unsurpassed by any other foam plastics material of the same bulk density.

Physical properties

ROHACELL 31, 51, 71

Mechanical properties

Table 1: Mechanical properties of ROHACELL 31, 51, 71

Properties[1]	Units[2]	ROHACELL 31	ROHACELL 51	ROHACELL 71	Standard
Gross density	kg/m³	30	50	70	DIN 53420
Tensile strength	N/mm²	1.0	1.9	2.8	DIN 53455
Compressive strength	N/mm²	0.4	0.9	1.5	DIN 53421
Flexural strength	N/mm²	0.8	1.6	2.5	DIN 53423
Shear strength	N/mm²	0.4	0.8	1.3	DIN 53294
Modulus of elasticity	N/mm²	36	70	92	DIN 53457
Shear modulus	N/mm²	14	21	30	DIN 53445
Shear modulus	N/mm²	13	19	29	DIN 53294
Elongation at break	%	3,5	4	4.5	DIN 53455

1) Test conditions: 23 °C and 50% relative humidity
2) 1 N/mm² ≈ 10 kp/cm²

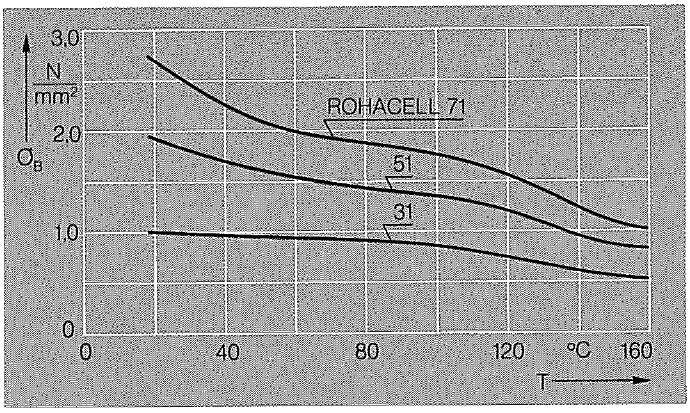

Fig. 1: Tensile strength (DIN 53 455) as a function of the temperature

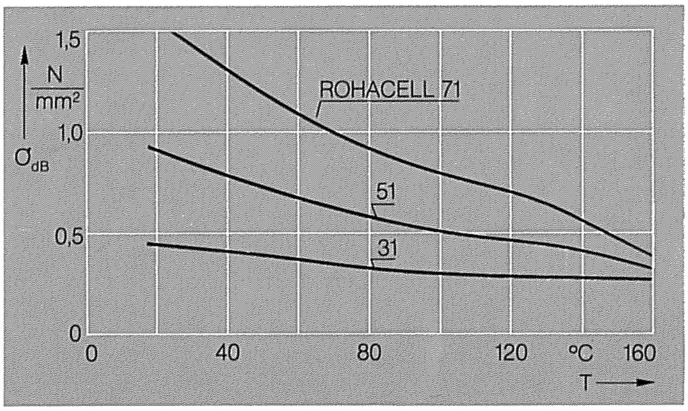

Fig. 2: Compressive strength (DIN 53 421) as a function of the temperature

Material behaviour at elevated temperatures

Figs. 1 to 5 show the tensile, compressive and flexural strength and the moduli of elasticity and shear of ROHACELL as a function of the temperature. The illustrations demonstrate that mechanically stressed ROHACELL can be used up to 160 °C.

In the absence of mechanical stress ROHACELL can be employed up to 180 °C and for brief periods even up to 200 °C.

When ROHACELL is statically stressed for long periods, the creep (time-dependent deformation under a static load), which is so prominent when plastics are used near the second order transition temperature, must be borne in mind.

The long-term behaviour of dynamically stressed ROHACELL is excellent. No time-dependent decrease in the yield stress has been observed for periods up to 10^7 load reversals.

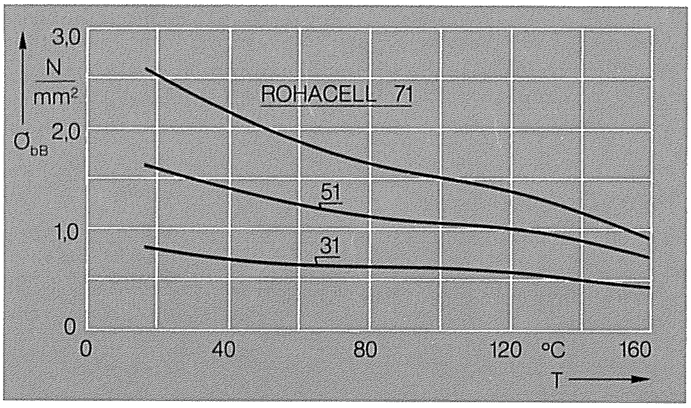

Fig. 3: Flexural strength (DIN 53 423) as a function of the temperature

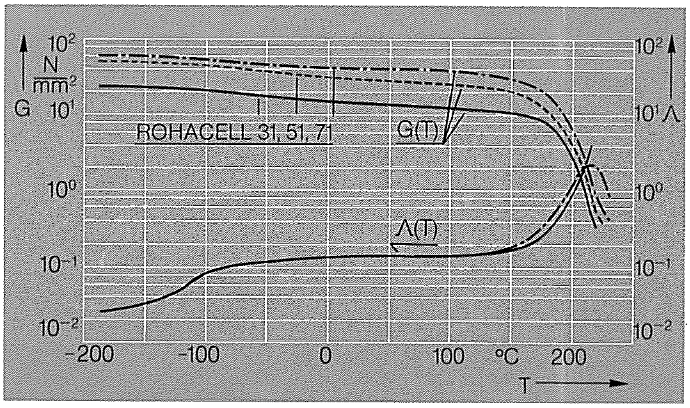

Fig. 5: Shear modulus G and mechanical damping Δ (DIN 53 455) as a function of the temperature

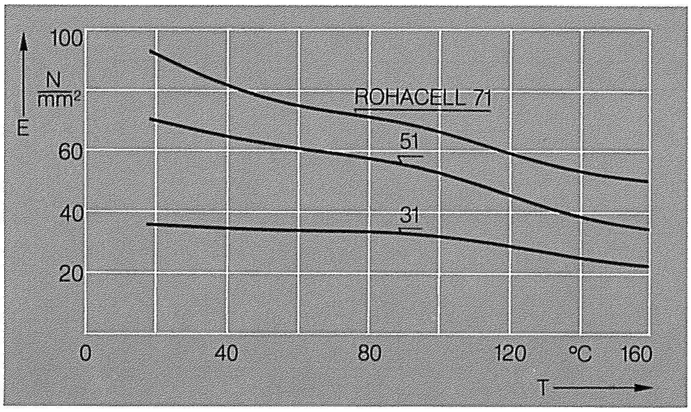

Fig. 4: Modulus of elasticity (DIN 53 457) as a function of the temperature

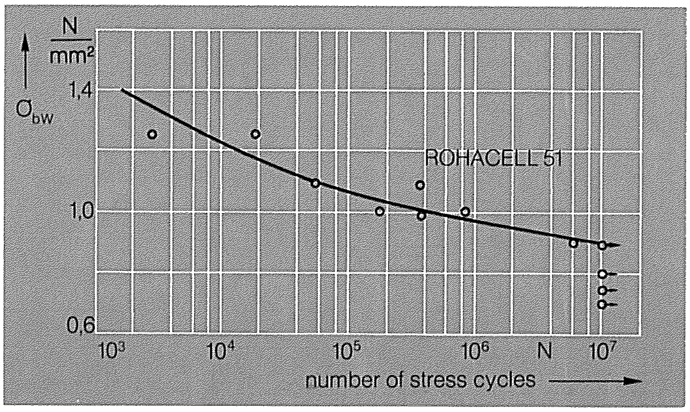

Fig. 6: Resistance of ROHACELL 51 to periodic stressing at about 10 Hz stress cycles

Thermal properties

Table 2: Thermal properties of ROHACELL 31, 51, 71

		ROHACELL			
Properties	Units	31	51	71	Standard
Deflection temperature under load	°C	185	185	185	DIN 53424
Linear coefficient of thermal expansion[1]	K^{-1}	3,7 $x10^{-5}$	3,3 $x10^{-5}$	3,5 $x10^{-5}$	VDE 0304/1
Coefficient of thermal conductivity[1]	W/mK[2])	0.031	0.029	0.030	DIN 52 612

[1]) Tested at 20 °C
[2]) 1 W/mK ≅ 0.86 kcal/m h deg

Deflection temperature under load

As a rule the "deflection temperature under load" of a given product is adequately described by the concrete requirements for strength, constant weight and dimensional stability. Tables 3 and 4 therefore show how the weight, volume and linear dimensions of ROHACELL test specimens change when they are kept for thirty days in air at different temperatures.

Table 3: Weight and dimensional changes of ROHACELL 31, 51, 71 kept at different temperatures for thirty days

		ROHACELL 31			ROHACELL 51			ROHACELL 71		
Storage temp.	°C	100	120	160	100	120	160	100	120	160
Change in weight	%	-3.3	-4.4	-5.2	-4.0	-5.1	-3.9	-3.7	-4.2	-6.0
Change in length	%	-0.8	-1.0	-1.6	-1.0	-1.4	-1.8	-0.8	-1.0	-1.9
Change in volume	%	-1.7	-3.2	-4.2	-2.3	-3.9	-4.8	-2.3	-3.0	-3.3

Table 4: Weight and dimensional changes of ROHACELL 31, 51, 71 after heat conditioning as in Table 3 and then keeping the specimens under standard heat and temperature conditions

		ROHACELL 31			ROHACELL 51			ROHACELL 71		
Storage temp.	°C	100	120	160	100	120	160	100	120	160
Change in weight	%	0	-0.2	-1.6	-0.2	-0.6	-2.5	-0.3	-0.9	-2.9
Change in length	%	0	-0.2	-1.2	-0	-0.4	-1.3	-0.2	-0.4	-1.5
Change in volume	%	-0.1	-0.2	-2.7	-0.1	-1.1	-3.7	-0.5	-1.3	-2.0

Linear thermal expansion

For a plastics material the termal expansion of ROHACELL is extremely low.

Table 5: Coefficient of linear thermal expansion of ROHACELL 31, 51, 71 at different temperatures

Temperature °C	ROHACELL 31 $\frac{1}{K} \cdot 10^{-5}$	ROHACELL 51 $\frac{1}{K} \cdot 10^{-5}$	ROHACELL 71 $\frac{1}{K} \cdot 10^{-5}$
− 150	2.5	2.4	3.0
− 100	2.5	2.4	3.0
− 50	2.8	2.7	3.0
0	3.0	3.0	3.2
+ 20	3.7	3.3	3.5

The coefficients of expansion are distinctly less than those of other rigid foam plastics. At very low temperatures the values are similar to those which are only reached by metals. This results in a very good stress-deformation behaviour for composite systems.

Thermal conductivity

The thermal conductivity of the various ROHACELL grades differs only slightly; it is within the regions given for various temperatures in Table 6. These values were determined with aged specimens whose cells were essentially full of air and contained no gaseous blowing agent. They are therefore stable, ultimate values which no longer increase under normal circumstances. The arithmetical values of the coefficient of thermal conductivity according to DIN 4108 are 0.041 W/mK or 0.035 kcal/mhdeg for all three grades.

Table 6: Coefficients of thermal conductivity of ROHACELL 31, 51, 71 at various temperatures

Temperature °C	ROHACELL 31, 51, 71 W/mK *)
− 160	0.015 – 0.019
− 100	0.019 – 0.021
− 40	0.023 – 0.028
+ 20	0.028 – 0.034
+ 80	0.035 – 0.041
+ 140	0.042 – 0.048

*) 1 W/mK ≅ 0.86 kcal/m h deg

Water vapour diffusion

Table 7: H_2O diffusion resistance factor of ROHACELL 31, 51, 71

		ROHACELL			
Property*)	Unit	31	51	71	Standard
H_2O diffusion resistance factor	1	400	650	900	DIN 53122

*) Test conditions: 20 °C and 0 – 85% relative humidity

The values given in Table 7 are surprisingly high. Measurements have shown that above 65% relative humidity the water vapour diffusion of ROHACELL increases with the humidity reading. The values according to DIN 53122 should therefore not be used for calculations involving the physics of buildings when the relative humidity is liable to rise above 80% (Fig. 7).

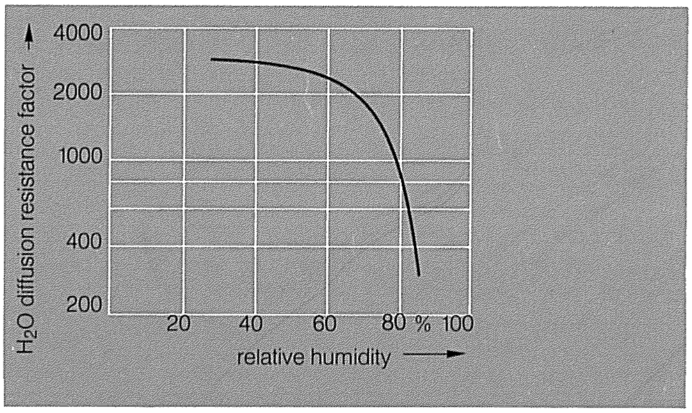

Fig. 7: H_2O diffusion resistance factor as a function of the relative humidity of ROHACELL 31.

Water absorption

Polymethacrylimide, rather like the polyamides, absorbs relatively much water. Table 8 lists the sorption equilibria (equilibrium water content per unit weight of the dry specimens) of ROHACELL in humid air. Table 9 gives the increase in weight and the volume change of specimens immersed in water for 50 days. These values show that despite the relatively high water absorption the dimensional stability is satisfactory. A shrinkage of the samples is only observed after prolonged immersion in water at temperatures above 50 °C.

Table 8: Sorption equilibria of ROHACELL 31, 51, 71 as a function of the atmospheric humidity

Atm. humidity	Equilibrium water content in %		
% R.H.	ROHACELL 31	ROHACELL 51	ROHACELL 71
15	1.5	1.3	1.2
30	2.9	2.6	2.4
50	4.7	4.2	3.6
65	6.0	5.0	4.3
98	19.5	17.5	15.5

Table 9: Water absorption and volume change of ROHACELL 31, 51, 71 after 50 days water immersion

		ROHACELL			
Property	Unit	31	51	71	Standard
H_2O absorption at 20 °C	vol. %	13	15	16	DIN 53428
50 °C		18	23	26	
Vol. increase on water immersion 20 °C	vol. %	<1	<2	<3	
50 °C	vol. %	<2	<2	<3	

Fig. 8 shows that the compressive strength of ROHACELL reaches a constant level irrespective of the period of water immersion.

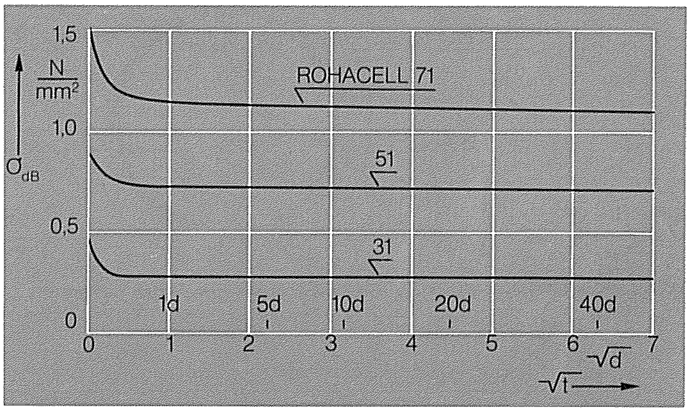

Fig. 8: Compressive strength of water immersed ROHACELL as a function of time

Electrical properties

Table 10: Electrical properties of ROHACELL 31, 51, 71

			ROHACELL		
Property	Test condtns.	Units	31	51	71
Dielectric constant	20 °C / 2.8 GHz	1	1.04	1.07	1.10
Dissipation factor	20 °C / 2.8 GHz	1	6×10^{-4}	8×10^{-4}	10×10^{-4}
Surface resistance	23 °C / 50% R.H.	Ohm	2×10^{13}	9×10^{12}	5.5×10^{12}

ROHACELL 110

Table 11: Physical properties of ROHACELL 110

Properties[1]	Unit[2]	ROHACELL 110	Standard
Gross density	kg/m^3	110	DIN 53420
Tensile strength	N/mm^2	3.5	DIN 53 455
Compressive strength	N/mm^2	3.0	DIN 53421
Flexural strength	N/mm^2	4.5	DIN 53423
Shear strength	N/mm^2	2.4	DIN 53294
Modulus of elasticity	N/mm^2	160	DIN 53457
Shear modulus	N/mm^2	58	DIN 53445
Shear modulus	N/mm^2	50	DIN 53294
Elongation at break	%	4.5	DIN 53 455
Deflection temperature under load	°C	180	DIN 53424

1) Test conditions: 23 °C and 50% relative humidity
2) 1 $N/mm^2 \approx 10$ kgf/cm^2

ROHACELL P 170, P 190

These ROHACELL grades have very high specific strength values. The cell structure has been orientated by a special process which results in different strengths in the plane of the sheet and at right angles to it. This enables sandwich structures to be optimised by suitably arranging the position of the ROHACELL sheets.

For a number of uses of sandwich structures it is therefore reasonable to allow the direction of the principal stress to coincide with the direction of maximum material strength, i. e. to use the core with a vertical cell structure.

Table 12: Physical properties of ROHACELL P 170, P 190

		ROHACELL		
Properties[1]	Unit[2]	P 170	P 190	Standard
Gross density	kg/m^3	170	190	DIN 53420
Tensile strength	N/mm^2	7.5	8.5	DIN 53455
Compressive strength	N/mm^2	6.5 (2.8)[3]	7.8 (3.2)[3]	DIN 53421
Flexural strength	N/mm^2	10.5 (10.0)[3]	12.5 (12.0)[3]	DIN 53423
Shear strength	N/mm^2	4.5 (3)[3]	5.5 (3)[3]	DIN 53294
Modulus of elasticity	N/mm^2	320	380	DIN 53457
Shear modulus	N/mm^2	120	185	DIN 53 445
Shear modulus	N/mm^2	88	100	DIN 53294
Elongation at break	%	5	6	DIN 53455
Deflection temperature under load	°C	130[4]	130[4]	DIN 53424

1) Test conditions: 23 °C and 50% relative humidity
2) 1 $N/mm^2 \approx 10$ kgf/cm^2
3) measured normally to the plane of the sheet
4) At elevated temperatures the cell structure begins to lose its orientation

$54,9 \times 10^3$ psi
Al = 10^7 psi

Chemical resistance

The outstanding characteristics of ROHACELL include its resistance to organic solvents. This is as true for benzene, xylene and monostyrene as for common paint and adhesive solvents, components of motor fuels and most other industrial solvents (see Table 13). However, ROHACELL is unstable in alkaline media.

Table 13: Resistance Table for ROHACELL 31, 51, 71, 110

At 20 °C			
Acetone	+	Paint solvent I	+
Benzene	+	Paint solvent II	+
Carbon tetrachloride	+	Petrol ether	+
Dibutyl phthalate	(+)	Soda solution (5%)	–
Diesel fuel	+	Sulphuric acid (10%)	+
Ether	+	Super petrol	+
Ethyl acetate	+	Styrene	+
Glacial acetic acid	–	Tetrahydrofuran	–
Isopropyl alcohol	+	Toluene	+
Methyl alcohol	–	Trichloroethylene	+
Methyl isobutyl ketone	+		

At the boiling point		
Benzene	(80 °C)	+
Carbon tetrachloride	(77 °C)	+
Chlorobenzene	(132 °C)	–
O-Dichlorobenzene	(180 °C)	–
Trichloroethylene	(88 °C)	+
Xylene	(139 °C)	+

+ resistant (+) limited resistance – not resistant

Bearing in mind the special behaviour when hot, Table 13 also holds for ROHACELL P170 and P190.

Fire behaviour

ROHACELL develops a small amount of smoke as it burns. The fumes contain no corrosive decomposition products.

The toxicity of the fumes was determined according to DIN 53 436 E, i. e. by the mortality of rats which had inhaled the thermal decomposition products of ROHACELL for ½ hour. In the temperature range up to 600 °C the ROHACELL decomposition products proved to be less toxic than those of pinewood.

From a material thickness of 10 mm upwards grades ROHACELL 31, 51 and 71 are "normally flammable" (German class B 2) within the meaning of DIN 4102 and are regarded as dripping off without burning. According to ASTM D-1692-59 T they are classified as "Burning by this Test". The burning behaviour differs from grade to grade and depends on the thickness of the material. For ROHACELL 51, 10 mm thick, it amounts, for example, to 2.4 cm/min.

Finishing ROHACELL

Machining

ROHACELL can be machined with all high-speed wood and plastics working machines. Naturally all special machines for rigid foam plastics, e. g. horizontal and vertical band saws (no knives) with maximum band speed are also suitable.
In principle there is no need for lubricants. A suitable device should be used to extract the dust which forms during machining.

Cutting with a heated filament

In principle ROHACELL 31 and 51 can be cut with a heated filament. This working method should, however, not be used since it may result in the formation of harmful vapours.

Thermoforming

ROHACELL 31, 51 and 71 sheets are readily thermoformed at temperatures of 170 to 190 °C. Because the heat capacity of the material is low it is, however, vitally necessary to see that the ROHACELL surfaces do not cool down before thermoforming has finished. In addition to simple folding, and shaping with a die and cavity block, ROHACELL mouldings can also be produced by vacuum thermoforming, blow moulding and suitable composite methods. These processes can only be used to a limited extent for ROHACELL 110 and not at all for ROHACELL P 170 and P 190.

Bonding

Most commercial adhesives can be used:

+ Polyester and epoxy resins at casting, brushing or spraying viscosity are suitable for firm, rigid bonds. The cure should take place under sufficient pressure (1 – 3 bar) to ensure that the cells are properly filled with the bonding resin.
+ Synthetic rubber based solvent adhesives have also performed well. However, they must be allowed to flash off thoroughly after application to both sides, after which the adherend surfaces are united under pressure because ROHACELL is very fast to solvent diffusion.
+ For bonding ROHACELL to other materials, e. g. for sandwich structures, it is normally possible to use adhesives suitable for the given foreign material, e. g. for

Metals:	Epoxy resins, rubber or polyurethane adhesives
Acrylic glass:	Methacrylic resins
GRP sheets:	Polyester or epoxy resins, polyurethane adhesives

+ Heat activated adhesive films might be used to make heat resistant bonds with metallic surface layers.

Painting and varnishing

ROHACELL can be sprayed or brushed with all commercial paints, varnishes and lacquers (incl. nitrocellulose lacquers). For smooth, glossy surfaces the surface of the plastics foam is first filled and rubbed down. Spray fillers, e. g. polyester fillers, are also suitable. The high heat resistance of ROHACELL enables it to be coated with sprayed metal, too.

Application of GRP laminates

The usual laminating methods like hand lay-up, fibre sprays and moulding methods can be employed. Minimum pressures of 1 bar are desirable to obtain good peel strength. Heat curing is advisable; ROHACELL tolerates temperatures up to 160 °C! Because it resists styrene there is no need to seal the surface of the foam when polyester resins are used.

More information

Two addresses for more information

- For commercial enquiries and requests for samples and literature

  ROHACELL Sales, direct dialling 06151/8064523

- For technical enquiries and requests for advice from the Customer Service department

  ROHACELL Customer Service, direct dialling 06151/8064818

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