Technical Manual

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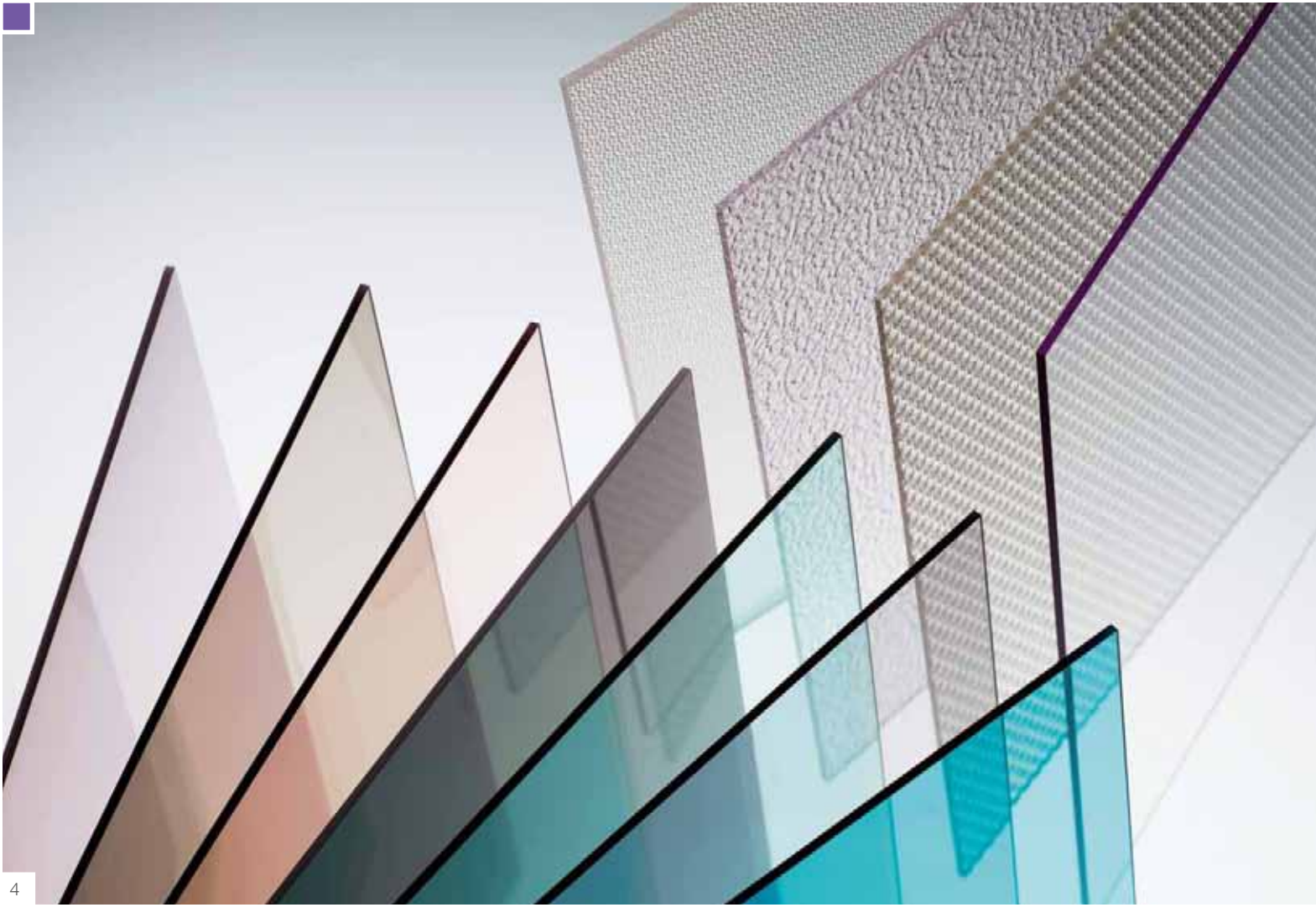
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1. THE SOLID POLYCARBONATE SHEET

1.1 At a glance technical specification

Each grade designation shows the type, colour, light transmission and additional properties of Makrolon® sheets. **Example: Makrolon® UV white 2130** can be read as follows …

Makrolon®	UV	white	2	1	30

Brand name	Type	Colour	Properties	Colour	Reference number
Makrolon®	GP: general purpose UV: UV-protected AR: abrasion resistant NR: non-reflective FR: flame retardant FG: food grade DX: Diffusion eXcellence SX: Scattering eXcellence VP: Visual Protection CC: Climate Control	clear white bronze grey green blue	–: no special treatment 2: 2-sides UV-protected 7: 1 side abrasion resistant 8: 2 sides abrasion resistant	0: clear 1: white 2: orange 3: red 4: violet 5: blue 6: green 7: grey 8: brown/bronze 9: black	



1.2 Grades

Makrolon® GP – general purpose
Makrolon® GP is the standard grade of the Makrolon® polycarbonate solid sheet range.

Makrolon® GP sheets are extremely break-resistant. Their impact resistance, which is 250 times higher than glass, provides perfect protection for people and objects.

The material is resistant to extreme temperatures, and can be used under the most demanding conditions (from – 100 °C to +120 °C). Its high transparency combined with the smooth surface makes it an attractive material for a wide variety of applications.

Makrolon® GP sheets obtain good fire classifications in accordance with most European standards.

Makrolon® UV – UV-protected
Makrolon® UV sheets are extremely weather-resistant because the sheets are produced with a coextruded UV-protective layer. This layer is also made from polycarbonate and is homogeneously fused with the sheet material. No delamination of the layer is possible, even after years of exposure to the elements or if the sheets are cold bent.

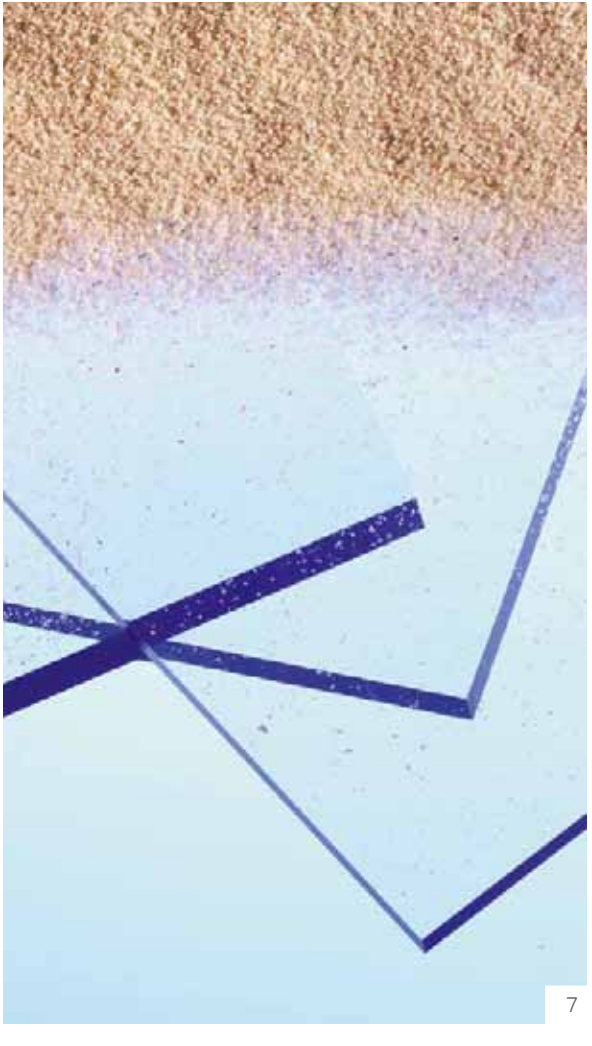
This system has been extensively tested both in artificial weathering tests as well as in natural weathering under extreme climatic conditions. It provides Makrolon® UV with high weather resistance and superior durability. Makrolon® UV sheets therefore come with a 10-year guarantee on weather resistance. For detailed information on the warranty, please check our warranty statement. This document is available from our distributors and on our website: www.sheets.covestro.com

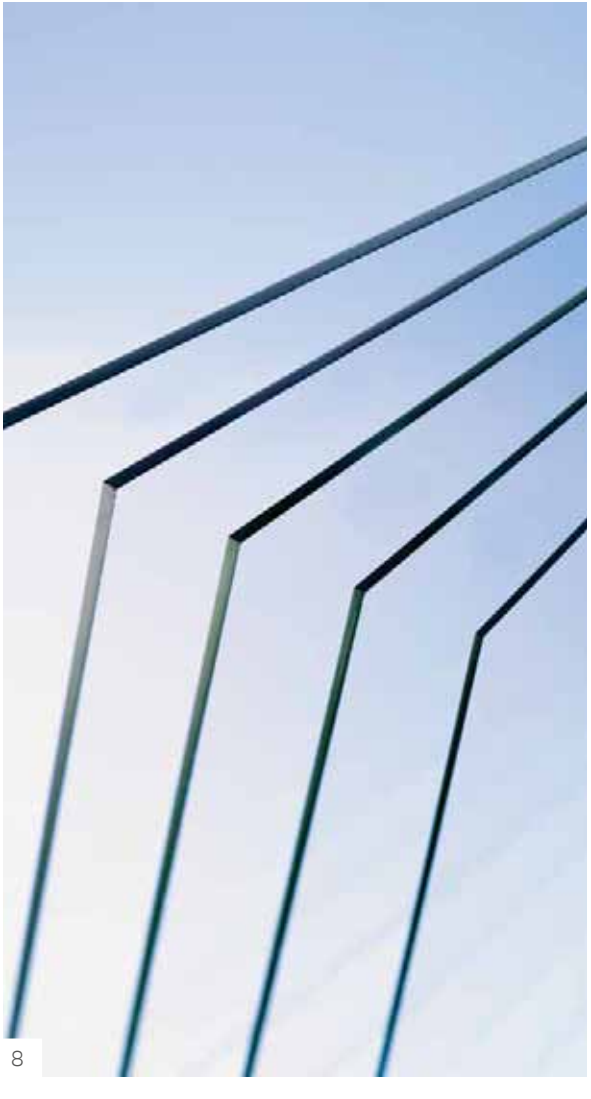
Makrolon® AR – abrasion resistant

Makrolon® AR stands for hardcoated sheets made from polycarbonate. Makrolon® AR offers comparable surface quality to glass and the outstanding impact strength of polycarbonate. The sheets are highly scratch-resistant due to their polysiloxane coating. Pronounced soiling, such as graffiti, can be removed effectively by means of suitable graffiti removing products. Makrolon® AR also offers excellent UV resistance and shows superior resistance to chemicals.

Their high scratch resistance and impact strength make Makrolon® AR sheets the ideal choice for transparent noise barriers, glazing in schools, hospitals, prisons and psychiatric units, as well as for safety glazing in vehicle construction, to name just a few examples. Their chemical resistance means they are ideal as windows in machine guards.

The high resistance to scratches and abrasion on both sides gives Makrolon® AR a long service life. We give you a 10-year guarantee against breakage and light transmission decrease and a 5-year guarantee against delamination. For detailed information on the warranty, please check our warranty statement. This document is available from our distributors and on our website: www.sheets.covestro.com





Makrolon® NR – non-reflective
Makrolon® NR is a transparent sheet with a matt finish and improved UV resistance on one side. These sheets are ideal in signage applications and poster glazing.

Makrolon® FR – flame retardant
Makrolon® FR sheets are flame retardant sheets which have classifications according to UL-94 V0, FAR 25.853 and EN 45545.

Makrolon® for LED lighting
A full range of Makrolon® sheets is available to fulfil all requirements in lighting technology. Makrolon® DX (Diffusion eXcellence) sheets provide a unique combination of high light diffusion and high light transmission. They are based on the most up-to-date scattering technology, offering high luminance uniformity and a high light output at the same time.

Opaque **Makrolon® RX** (Reflection eXcellence) sheets offer extremely high light reflectance, reducing light losses when used as reflector material.

Makrolon® SX (Shaping eXcellence) microprismatic sheets have a microlense surface pattern, which combines excellent optical efficiency with light diffusion.

Makrolon® UV Adlight
Makrolon® UV Adlight is the perfect material for backlit signs, compatible with LED-lighting technology, available with a matt or glossy surface with UV-protection for long lasting outdoor life. It minimises breakage losses, eliminates LED hot-spots and allows for shallow channel letter designs.

Makrolon® patterned
Makrolon® patterned are clear transparent polycarbonate sheets with a patterned surface. Several patterns are available, some with special light scattering properties for lighting applications, others with double-sided patterns for semi-transparent wall dividers. More specific information is available on the website.

Makrolon® Titan
Makrolon® Titan sheets in 18 and 20 mm thickness offer effective protection, incorporating high safety standards, for machine guards. They combine glass-like transparency with a C3 classification in accordance with ISO 23125.

Makrolon® ColorLine
Enjoy colourful design flexibility with Makrolon® Colorline, available in 20 colours in a sheet thickness range of 2–8 mm and with a minimum order quantity of 250 kg.

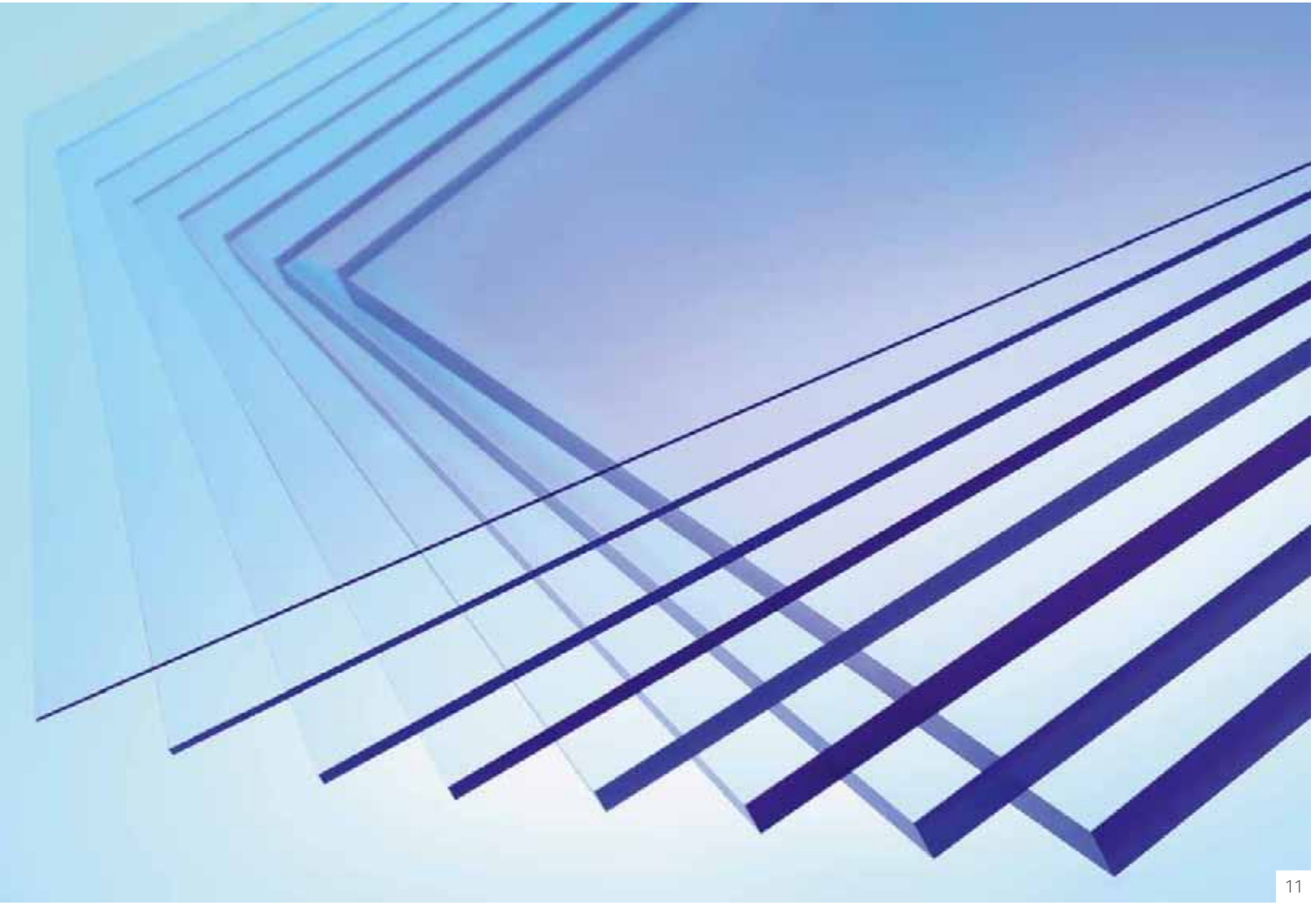


Makrolon® SilentSound
Makrolon® SilentSound is the transparent solution for noise protection along roads and railways. It offers noise reduction levels up to 37 dB (R_w) and meets all requirements for road safety, stability and structural durability. They are also available with bird strike protection and anti-graffiti, and are suited for noise barriers in accordance with EN 14388 or ZTV-LSW 06.

Makrolon® FG – food grade
Makrolon® FG sheets are produced from resins which are suitable for food contact applications. The material complies with the European directives and the American FDA regulations.

Makrolon® VP
Makrolon® VP (Visual Protection) is a range of materials offering high level protection in specific industrial applications, such as for welding, electrical arcs and laser.







2. MATERIAL PROPERTIES

Makrolon® is synonymous with first-class sheets. The sheets are made from polycarbonate and are available in solid and multi-wall format. Their versatility is such that they can be used in many applications and can withstand a wide temperature range.

Makrolon® sheets are renowned for good transparency, extremely high break resistance and impact strength, high dimensional behaviour stability and good electric insulation. They also obtain excellent fire ratings (see the specific data sheets for more detailed information).

Their consistency is thanks to outstanding raw materials from Covestro, the Covestro Sheet Europe extrusion know-how, our comprehensive quality management system and production processes certified according to DIN ISO 9001.



Properties			Typical value[1]	Unit	Test method
Mechanical					
Density			1.20	g/cm³	ISO 1183-1
Tensile stress at yield		50 mm/min	> 60	MPa	ISO 527-1,-2
Elongation at yield		50 mm/min	6	%	ISO 527-1,-2
Tensile strength at break		50 mm/min	> 60	MPa	ISO 527-1,-2
Elongation at break		50 mm/min	> 50	%	ISO ISO 527-1,-2
Tensile modulus		50 mm/min	2350	MPa	ISO ISO 527-1,-2
Limiting flexural stress		2 mm/min	ca. 90	MPa	ISO 178
Impact strength	Charpy at 23 °C	unnotched (3 mm)	no break	kJ/m²	ISO 179/1eU
		notched (3 mm)	ca. 11	kJ/m²	b.o. ISO 179/1eA[2]
	Izod at 23 °C	notched (3 mm)	ca. 70P	kJ/m²	b.o. ISO 180/A[2]
Ball indentation hardness H 358/30			113	MPa	ISO 2039-1
Poisson's ratio			0.40	—	—

(1) These values are measured on injection molded samples, and are not intended for specification purposes.
(2) b.o.: based on

Properties		Typical value	Unit	Test method
Optical				
Light transmission in relation to thickness	3 mm (clear)	87–88	%	DIN 5036
	5 mm (clear)	86–87	%	DIN 5036
	10 mm (clear)	82–83	%	DIN 5036
	15 mm (clear)	79–80	%	DIN 5036
Reflection loss in the visible range (for glossy surface)		ca. 5	%	—
Total energy transmission (g) in relation to thickness	3 mm (clear)	ca. 83	%	EN 410
	10 mm (clear)	ca. 79	%	EN 410
Absorption in the visible range in relation to thickness	3 mm (clear)	ca. 4	%	—
Refractive index		1.586	—	ISO 489
Thermal				
Thermal coeff. of linear thermal expansion		0.065	mm/m °C	ISO 11359-1,-2
Thermal conductivity		0.20	W/m °C	ISO 8302
Heat transfer coefficient (Ug) in relation to thickness	1 mm	5.8	W/m² K	DIN 4701
	3 mm	5.5	W/m² K	DIN 4701
	5 mm	5.2	W/m² K	DIN 4701
	10 mm	4.6	W/m² K	DIN 4701

Properties		Typical value	Unit	Test method
Thermal				
Specific heat capacity		1.3	J/g K	—
Calorific value		31	MJ/kg	ISO 1928
Thermoforming temperature		190–210	°C	—
Maximum surface temperature (IR radiator)		ca. 220	°C	—
Max. permanent service temperature without load		ca. 120	°C	—
Min. permanent service temperature without load		ca. –100	°C	—
Ignition temperature		550	°C	DIN 51794
Vicat softening temperature	Method B50	148	°C	ISO 306
Heat deflection temperature under load	Method A: 1.80 MPa	127	°C	ISO 75-2
	Method B: 0.45 MPa	139	°C	ISO 75-2
Electrical				
Electrical strength	1 mm	34	kV/mm	IEC 60243-1
Volume resistivity		1E14	Ohm.m	IEC 60093
Surface resistivity		1E16	Ohm	IEC 60093
Relative permittivity	100 Hz	3.1	—	IEC 60 250
	1 MHz	3.0	—	IEC 60 250
Dissipation factor	100 Hz	5	10^{-4}	IEC 60 250
	1 MHz	95	10^{-4}	IEC 60 250

Properties		Typical value	Unit	Test method
Acoustic				
Weighted sound reduction index R_w in relation to thickness	4 mm	26	dB	DIN EN ISO 140-3
	8 mm	30	dB	DIN EN ISO 140-3
	10 mm	32	dB	DIN EN ISO 140-3
	12 mm	36	dB	DIN EN ISO 140-3
	15 mm	36	dB	DIN EN ISO 140-3
	18 mm	37	dB	DIN EN ISO 140-3
	20 mm	37	dB	DIN EN ISO 140-3
Behaviour towards water and air				
Moisture absorption	water absorption saturation, 23 °C	0.30	%	ISO 62-4
	water absorption equilibrium, 23 °C	0.12	%	ISO 62-1
Permeability, measured on 10-micron film	water vapour, 23 °C, 85 % RH	15	g cm/(m².24h)	ISO 15106-1
	N_2	120	cm³/(m²·24h·bar)	b.o. ISO 2556(1)
	O_2	650	cm³/(m²·24h·bar)	b.o. ISO 2556(1)
	CO_2	3800	cm³/(m²·24h·bar)	b.o. ISO 2556(1)

(1) b.o.: based on


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3. CHARACTERISTICS

3.1 Impact strength

Makrolon® outperforms most other transparent materials on impact strength. It is almost unbreakable. Makrolon® solid sheets are up to 250 times more impact resistant than glass, and they have been tested in accordance with several standards, complying with the most stringent regulations.

Makrolon® AR in 3 to 12 mm can reach Class B (ABG) and VIII/B/M (ECE R43) (regulations for vehicle glazing).

Some typical results are listed in the tables below.

Standard	Material	Thickness	Classification
Safety glazing			
EN 356 (security glazing, resistance to manual attack)	Makrolon® GP Makrolon® UV Makrolon® AR	≥ 4 mm	EN356-P5A
EN 12600	Makrolon® UV, patterned	5 mm	class 3
		6 mm	class 2
		8 mm	class 1
		10 mm	class 1
		12 mm	class 1

Standard	Material	Thickness	Classification
Machine guards			
ISO 23125, formerly EN 12415	Makrolon® GP Makrolon® AR	6 mm	A1, A2, B1
		8 mm	A1, A2, B1, C1
		10 mm	A1, A2, A3, B1, B2, C1, C2
		12 mm	A1, A2, A3, B1, B2, B3, C1, C2
	Makrolon® Titan	18 mm	A1, A2, A3, B1, B2, B3, C1, C2, C3
		20 mm	A1, A2, A3, B1, B2, B3, C1, C2, C3
EN 12417	Makrolon® GP Makrolon® AR	6 mm	Ec = 478 Nm, 117 m/s
		8 mm	Ec = 680 Nm, 143 m/s
		10 mm	Ec = 1020 Nm, 150 m/s
		12 mm	Ec = 1125 Nm, 150 m/s
	Makrolon® Titan	18 mm	EC = 1423 Nm, 168 m/s
		20 mm	EC = 1423 Nm, 168 m/s

3.2 Light transmission

Makrolon® sheets have a light transmission value of up to 90 %, depending on the colour and thickness of the sheets (check the individual data sheets for more details). Coloured and/or translucent sheets reduce light intensity and heat, which results in pleasant room temperature and ambience. Our opal white sheets offer improved light diffusion, resulting in a more diffuse but brighter light, ideal for working environments.

Makrolon® UV sheets absorb dangerous UV radiation. These sheets are therefore ideal as skylights or in situations where protective glazing is needed to shelter materials sensitive to UV-light in factory units, museums or shopping centres.

3.3 Temperature resistance

Makrolon® sheets can be used at temperatures between – 100 °C up to +115 °C. The stability of the sheets remains at a high level within this temperature range, which means they can be used where other transparent plastics will fail. In normal circumstances, the temperatures to which the sheets are exposed will be in the range of – 15 °C up to +60 °C, which is well within the material's capabilities.





3.4 Fire behaviour

Makrolon® sheets meet stringent requirements set by the European Union for fire safety. Although the material is not classified as fire-resistant, it significantly hinders flame propagation in comparison with other transparent, thermoplastic materials.

When used as sky dome or roofing, the heat of the flame will cause the sheet to melt and form an opening in case of fire. Smoke and heat dissipate through the opening, thus leading to a drastic temperature reduction in the room and, more importantly, reduced load on the supporting structure. In effect, the sheet acts as a heat extractor, which can relieve the thermal load on a building of 300 °C or more in a fully developed and growing fire.

The harmonized European standard EN 13501-1 defines the fire classification of construction products and building elements, and overrules former national standards like DIN 4102, NF-F 16-101 etc.

Typical classifications of Makrolon® sheets according to EN 13501-1 are B-s1-d0 or B-s2-d0, depending on thickness and colour.

Makrolon® Polycarbonate sheets may change their fire behaviour due to ageing and weathering. For details, please check with the Technical Service Department.

3.5 Noise insulation

Excessive noise and continuous, disturbing noise are harmful. That is why the effect of noise needs to be kept down to a minimum. Sound pressure levels and sound reduction indexes are expressed in decibels (abbreviated as dB).

Makrolon® sheets reduce sound levels mainly by reflecting sound waves.

R_w
For practical assessment of sound reduction, the "weighted sound reduction index", R_w is used.

Sound reduction index of single-sheet glazing

Makrolon® in mm	R_w in dB Acc. to DIN EN ISO 140-3
4	26
8	30
10	32
12	36
15	36
18	37
20	37





Sound reduction index of double-sheet glazing
A significant sound reduction can be obtained with two or more Makrolon® solid sheets sandwiching an air layer.

Makrolon® GP in mm	Air space in mm	Makrolon® GP in mm	R_w in dB (1)
4	50	4	31
4	150	4	39
6	30	6	32
10	30	10	40
10	60	10	45

(1) Indicative data

Makrolon® SilentSound is the perfect solution for transparent noise barriers along the highway, with an extended warranty against weathering. Our Makrolon® SilentSound range complies with the European EN 14388 and the German ZTV-LSW 06 guidelines for noise protection by sound barriers. It offers noise reduction levels up to 37 dB (R_w), and is fully certified on other characteristics such as fire resistance, impact of stones and danger from falling debris. Check our website for more information.

3.6 Chemical resistance

The chemical resistance of Makrolon® against other substances depends on the concentration of these products, the temperature, the duration of contact and the internal tension level of the polycarbonate sheet. Internal tension is mostly caused by processing (drilling, milling, bending, mounting,...). Several types of damage can arise, sometimes more than one at the same time.

Dissolving/Swelling
Low-molecular, aromatic or halogenated and polar components can migrate into the plastic. The damage can range from a sticky surface to complete dissolving.

Stress cracking
Some chemicals migrate into the surface, causing relaxation of tensions in the material. This results in microscopic stress cracking. These small cracks act as notches and have a negative influence on the mechanical properties.

Molecular reduction
Some properties of materials are determined by the molecular weight. If a substance initiates a molecular reduction through a chemical reaction, the impact resistance and elastic properties of the material will be influenced. Electrical properties are rarely influenced, while thermal properties are only slightly influenced by the molecular weight.





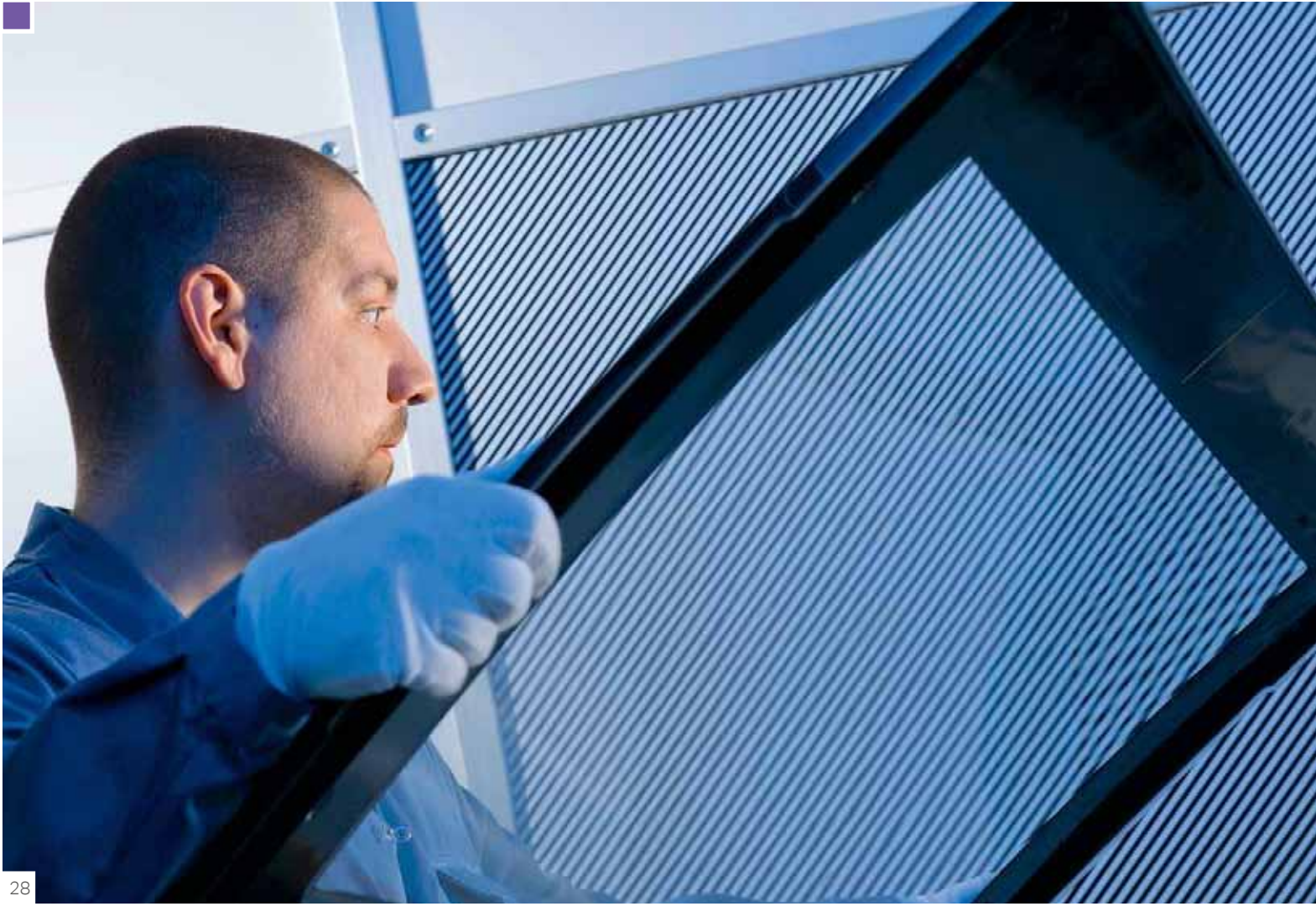
As a general guideline on the chemical resistance of Makrolon®, we can state the following:

Polycarbonate resists:
- mineral acids up to the highest concentrations
- neutral and acidic salt solutions
- oxidising and reducing agents
- saturated, aliphatic hydrocarbons and alcohol with the exception of methanol (methyl alcohol)
- many oils, fats and waxes

It is damaged by:
- alkali
- ammonia and amines, as well as their solutions
- aromatic or halogenated solvents
- aldehydes, ketones and esters
- methyl alcohol

More detailed information on chemical resistance is available upon request.





4. MACHINING

4.1 General remarks

Tools
Makrolon® sheets can be machined using the standard tools commonly used for metal. We recommend carbide-tipped tools. Above all, it is important to use sharp cutting tools with the right geometry.

Cooling
No cooling is required during the normal machining of Makrolon® sheets. In the event of local overheating during machining – e. g. when drilling through very thick materials – we recommend cooling with water or oil-free compressed air. Oil emulsions and cutting oils must not be used when machining Makrolon® as these may contain additives to which Makrolon® is not resistant, resulting in stress crack formation.

Dimensional accuracy
The coefficient of linear expansion of Makrolon®, at 0.065 mm/m °C, is significantly higher than for metal or glass. For this reason, dimensions should always be checked at room temperature. For a summer-winter temperature change from –10 °C to +35 °C, one metre of sheets will change 3 mm in length.

Shrinkage of approx. 3 to 6 % depending on thickness occurs when the material is heated above the glass transition temperature (approx. 145 °C) for the first time.





Protective masking
Makrolon® sheets are provided with a polyethylene-based masking film for protection against damage during transport, fabrication and installation. This means that the film should be left on the sheet during machining.

The masking has a shelf life of 6 months. It should be removed immediately after the installation of the sheets. Solar radiation and weathering may influence the properties of the film and make it very difficult to remove later on (possible formation of adhesive residues).

Take care not to store the sheets in contact with sunlight.

Our standard protective masking film is not suitable for exposure to thermal loads or thermoforming. The film should therefore be removed from the sheets before processes such as drying, hot line bending and/or thermoforming.

We have specially manufactured, unprinted grades of film that allow the sheets to be thermoformed with the protective masking left on. These are available on request.

Marking
Marking out of drill holes or edges to be cut should be done on the protective film, using either a soft pencil or felt-tip pen. Sharp marking tools should not be used as the tracing mark has a notching effect, and a higher load at this point may cause the sheet to crack.

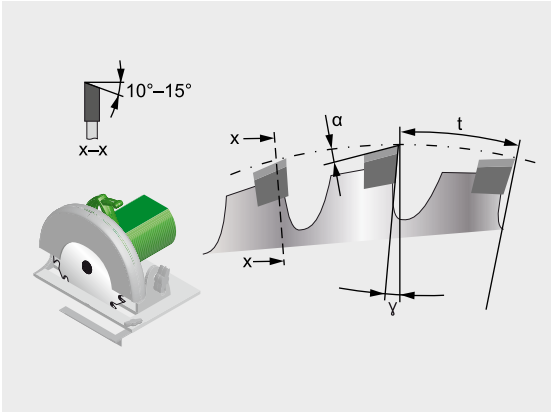
4.2 Sawing

Hand saws
Standard hand saws may be used to cut Makrolon® sheets. A saw with fine spacing between the teeth is recommended.

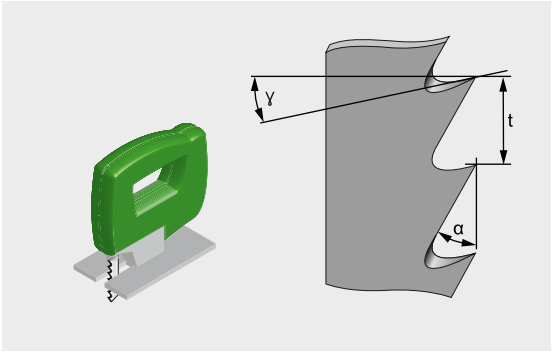
Circular saws
Using a circular saw is the easiest way to cut Makrolon® sheets. Experience has shown that carbide-tipped circular saw blades produce the cleanest cuts. The spacing varies from fine for thin sheets to coarse for thicker materials. Ensure that no shavings are left on the cutting surface as these could damage the protective film and scratch the Makrolon® sheets. When handling sheets less than 1.5 mm thick use a thick underlay board or a pair of shears instead of a circular saw.

Ribbon saws
Ribbon saws are ideal for curved cutting of formed parts or irregular shapes. To achieve a clean-cut edge, it is important to work on a solid cutting surface. A wide spacing is required when working with thick materials. For higher quality cut edges, circular saws or milling cutters achieve a better result than ribbon saws.





Circular saw blade



Ribbon saw

Troubleshooting

Fused cut edge:

- Check tool sharpness
- Check cutting speed and reduce if necessary
- Check rate of advance and reduce if necessary
- Cool if necessary

Notched cut edge:

- Check tool sharpness
- Check tool geometry
- Improve cutting surface (use an underlay if necessary)

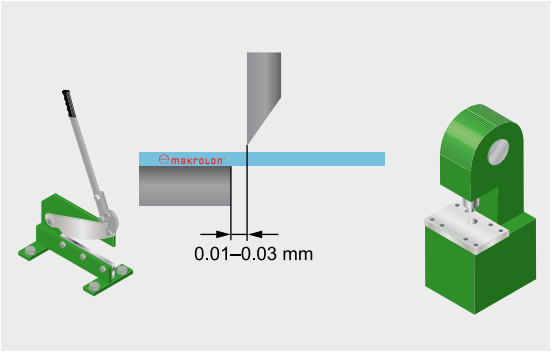
Recommended angles for sawing	Ribbon saw	Circular saw
Clearance angle α	20 – 40°	10 – 30°
Rake angle γ	0 – 5°	5 – 15°
Cutting speed v (m/sec)	10 – 17	17 – 50
Spacing t (mm)	1.5 – 3.5	2 – 10

4.3 Cutting and punching

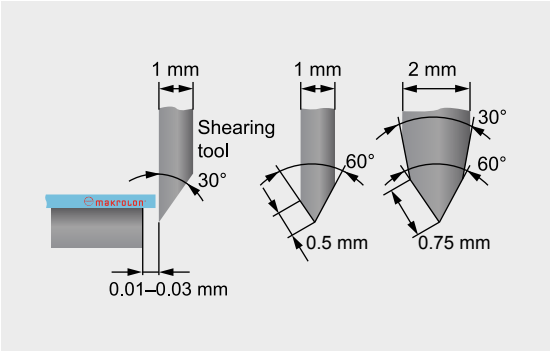
Makrolon® sheets up to 3 mm thick are easy to cut and punch, producing a good cut result. The thicker the sheet, the poorer the quality of the cut is likely to be, and the greater the risk of cracking. Good results can be obtained using a sharp shearing tool with a wedge angle of max. 45°, with clearance between the tool and the cutting surface of 0.01 to 0.03 mm. If you require smooth cut edges, Makrolon® sheets with a thickness of 1.5 mm or more should be sawn or milled.

When punching close-tolerance holes, allowance must be made for shrinkage if machining is to be followed by heat treatment of over 145 °C. This means that the hole should be measured approx. 5 % larger than actually required. The bigger the hole and the thicker the sheet, the lower the tendency for the sheet to shrink. Good results are obtained using symmetrically ground shearing tools.

For punching/cutting Makrolon® sheets that are more than 1.5 mm thick, we recommend asymmetrically ground blades. To achieve right angles, blades ground on one side with a wedge angle of 30° should be used. Make sure that the base plate (polyamide or polyethylene HDPE with a high molecular weight) remains in place and is properly centred with the punching tool to ensure clean cut edges.

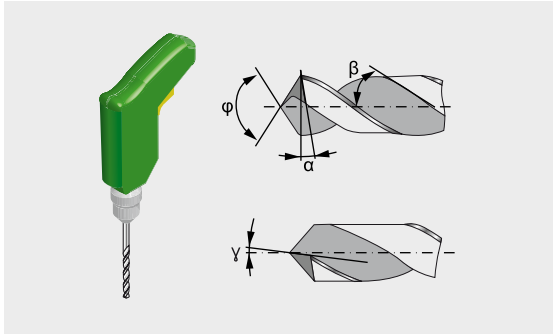


Clean cut edges – clearance between blade and supporting surface: 0.01–0.03 mm



Depending on sheet thickness, various different types of cutter are recommended for punching





Drills for Makrolon® sheets

4.4 Drilling

Standard drills used for metalworking are perfectly suitable for machining Makrolon® sheets. Make sure that the cutters on the drill are sharp. Cooling during drilling is generally not necessary.

When working with relatively large drilling depths we recommend using water or compressed air and/or regularly withdrawing the drill from the hole to reduce heat and remove shavings. Oil/water emulsions or cutting oils should not be used when drilling through Makrolon® sheets. Standard circle-cutting equipment (e. g. circle cutters or compass saws) is suitable for large-scale drilling. The drill holes should be smooth and as free as possible of notches or rough areas to ensure secure fastening.

Recommended angles for drilling	
Clearance angle α	5–15°
Rake angle γ	0–5°
Point angle	110–130°
Helix angle β	19–40°
Cutting speed	15–30 m/min
Feed	0.1–0.3 mm/rev

4.5 Milling and routing

Makrolon® sheets are easy to process using milling machines. The choice of milling machine depends on the type of machining required. Ensure that your tool has good chip clearance and sharp cutters.

Routing can also be used to cut curved shapes. A sharp tool with a rotating speed of 20,000 rpm is recommended. Use straight carbide-tipped or high-speed steel router bits, preferably with a 6 to 10 mm diameter.

Recommended angles for milling	
Clearance angle α	5 – 10°
Rake angle γ	0 – 10°
Cutting speed	100 – 500 m/min
Feed	0.1 – 0.5 mm/rev

4.6 Laser cutting

Various types of laser can be used for the thermal cutting of Makrolon® sheets – with or without film. Lasers are particularly suitable for cutting complex contours. To achieve a bubble-free cut edge, the Makrolon® sheets need to be pre-dried after which it is recommended that they be conditioned.





Laser beam cutting of Makrolon® sheets that are more than 2 mm thick leads to brownish colouring at the edges.

Ensure good ventilation because hydrocarbon-based gases can form during laser cutting.

4.7 Grinding and polishing

Grinding
Makrolon® sheets can be ground either dry or wet using industrial abrasives in preparation for polishing. The contact pressure between the grinding tool and the sheet should be kept low to avoid melting because of friction.

When grinding it is recommended that you use different grits in succession (e.g. in the sequence 150, 240 and 400).

Polishing
Medium-density polishing wheels with a peripheral velocity of 20 to 30 m/s can be used to polish Makrolon® sheets with mild alkali-free polishing pastes.

A clean polishing wheel without polishing paste is then used to complete the polishing process.

Large-surface polishing should be avoided.




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5. FORMING

5.1 Cold forming

Cold bending
All Makrolon® sheets (with the exception of Makrolon® AR) can be subjected to cold bending as long as the sheet radius is not less than 150 times the sheet thickness.

Minimum radius = 150 x sheet thickness

Thermoforming is recommended for smaller radii.

Cold folding
Makrolon® sheets can be cold folded. To achieve good results, the following guide values should not be exceeded:

Sheet thickness in mm	Bending radius in mm	Maximum folding angle
1 to 2.5	2	90°
3 and 4	3	90°
5 and 6	4	60°

The relaxation immediately following the cold folding process means that the sheet has to be overstretched by approximately 25°. The internal and external stress levels take a few days to become balanced, with the parts only then assuming their final shape.





Folding parameters can vary from machine to machine, depending on the pressure, bending knife angle etc. Some trial and error may be needed to find the correct settings.

Bear in mind that cold folding creates high stress in areas at the edge of the material.

Avoid the use of aggressive chemicals, particularly with cold folded and cold bent parts.

Cold folding should be restricted to thin Makrolon® sheets.

5.2 Thermoforming

Protective masking
Makrolon® sheets are provided with a polyethylene-based masking film to protect the smooth surfaces from damage during transport and processing.

Our standard protective masking film is not suitable for exposure to thermal loads or thermoforming, and should be removed from the sheets before processes such as drying, hot line bending and/or thermoforming.

We have specially manufactured, unprinted grades of film that allow the sheets to be thermoformed with the protective masking left on. These films are available on request.

Pre-drying
Makrolon® sheets can absorb moisture from the air. Therefore, we recommend drying the sheets prior to forming. Insufficient pre-drying leads to the formation of bubbles during the heating process, which has a bad influence on the optical quality of the finished part.

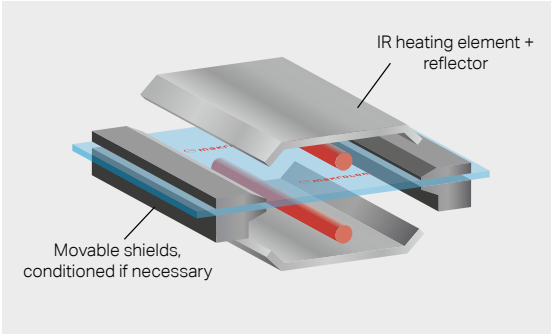
A circulating air oven should be set at a temperature of 120 to 125 °C to ensure thorough pre-drying. The drying times vary according to the thickness of the Makrolon® sheets.

Sheet thickness in mm	Drying time at 125 °C in hours
1	1.5
2	4
3	7
4	12
5	18
6	22
8	30

The sheets can be hung up in the oven or laid in a frame. Make sure that the protective film has been removed and that the sheets are spaced 20 to 30 mm apart to allow the air to circulate freely.







Hot folding

To reduce heating time and save energy when using the thermoforming machine, pre-dried Makrolon® sheets should be kept in the drying oven until processing. Makrolon® sheets that are cooled to room temperature after the drying process should be processed within a maximum of ten hours (depending on ambient conditions) unless re-dried. When cutting the sheets, it is important to remember that there will be one-off shrinkage upon initial heating to above the glass transition temperature of 145 °C. Shrinkage values of max. 6 % for sheets up to 3 mm thick and of max. 3 % for thicker sheets can be expected.

Prior to thermoforming, Makrolon® sheets should be thoroughly cleaned using an anti-static detergent or ionised compressed air thus avoiding surface defects e.g. embedded particles of dust on the finished part.

To avoid pre-drying we can supply the sheets in aluminium packaging straight from production. This special packaging protects the sheets better against moisture and can help to avoid pre-drying if the material is thermoformed within a short time after delivery. This packaging is available on request.

Hot folding

Hot folding is a relatively easy forming process for the production of uniaxially formed parts. The Makrolon® sheet simply requires local heating to 150 to 160 °C so that pre-drying is generally not required.

The Makrolon® sheet is heated using linear IR heaters or heating elements. As soon as the desired temperature is reached, the sheet is removed from the heating element, folded, placed in the mold and clamped into position. The desired shape should be fixed until the material becomes stiff.

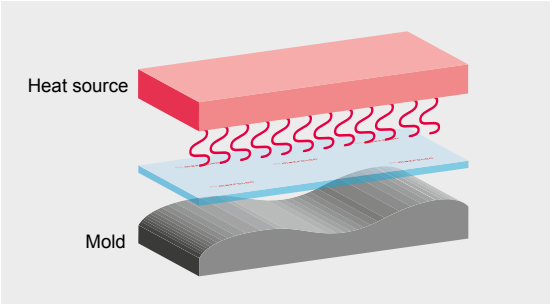
If using one-sided heating, the Makrolon® sheet must be turned over several times to guarantee even heating on both sides. With a sheet thickness of 3 mm or more and when producing large numbers of units, we recommend simultaneous heating of both sides using a sandwich heating appliance. By adjusting the heating width using the shields, various different bending radii can be achieved. However, do not fall below a minimum bending radius of three times the sheet thickness.

Local heating creates stresses in the finished part. Care should be taken when using chemicals with bent formed parts.

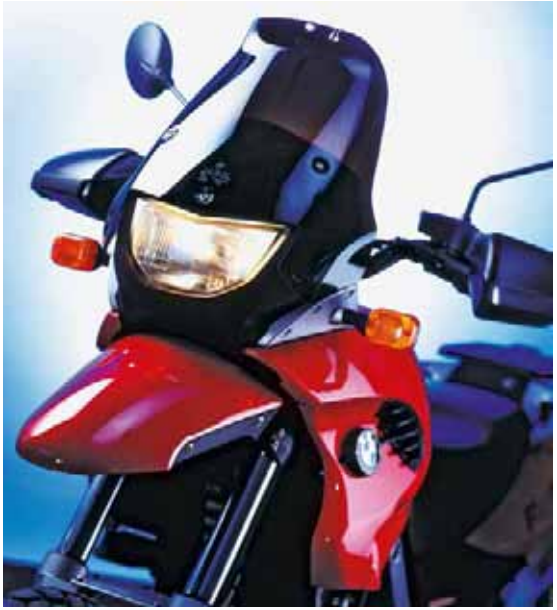
Drape forming
Simple, two-dimensionally formed parts with large radii of curvature can be drape formed. The Makrolon® sheets are heated to the right temperature in a circulating air oven and quickly transported to a tool heated to between 80 and 100 °C. The sheet's own weight or light pressure applied with gloves or cloth is enough to form the sheet over the male tool.

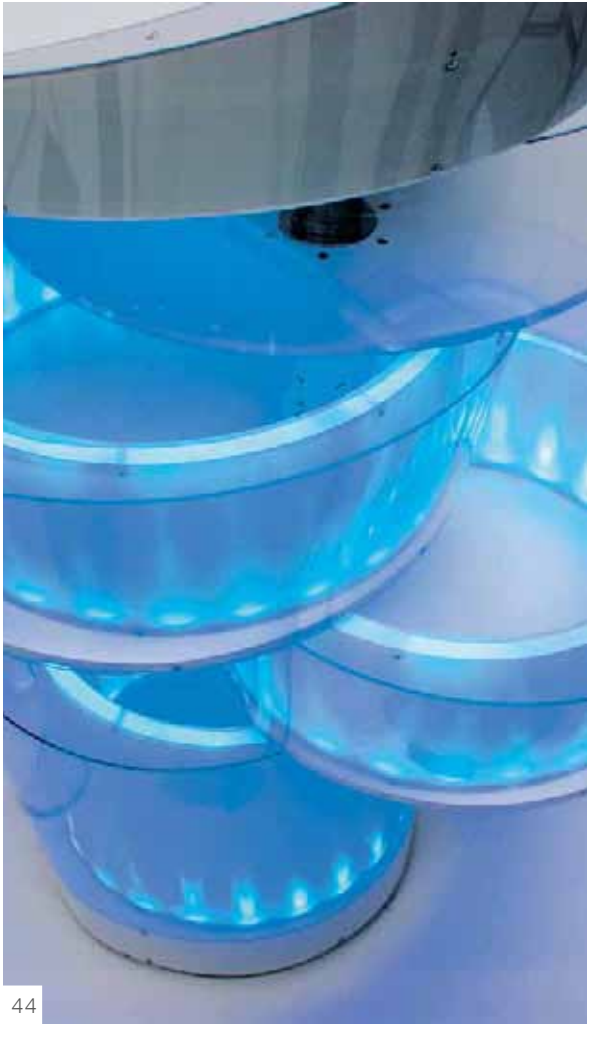
The sheets then need to be cooled in fresh air. Make sure there are no draughts, which can cause distortions or stresses in the formed part.

We recommend removing the protective film before heating the sheets in an oven.



Drape forming





Thermoforming
To achieve formed parts of good quality, the Makrolon® sheets should be heated evenly as part of a controlled process to a temperature of 170 to 205 °C. The best forming precision of the parts is achieved at the upper end of the forming temperature range. Given that the forming temperature is very high and Makrolon® sheets cool quickly, it is better in practice to heat the sheets directly on the forming machine and not – as is frequently done with other thermoplastics – in separate circulating air ovens.

For heating the Makrolon® sheets we recommend two-sided IR heating systems, which can be heated up relatively quickly. The advantage of two-sided heating lies in more even and quicker heating of the material. This enables shorter cycle times and is more economical. The heating time increases in linear proportion to the thickness of the Makrolon® sheets and should be calculated by means of trials on the forming machine.

To avoid any significant loss of heat at the sheet edges during the heating process or uneven cooling, which could create internal stresses and warping, we recommend that the clamping device be conditioned. To improve the thickness flow, the sheets may be hot formed with mechanical pre-stretching.

Cooling the finished part
Makrolon® sheets cool quickly, so that short cooling cycles can be achieved. As soon as the formed part is dimensionally stable (at approx. 135 °C) it can be removed from the tool.

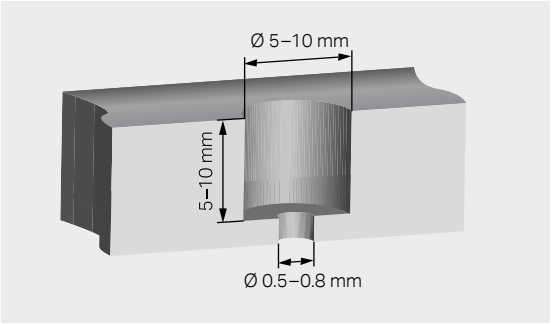
Thermoforming tools
To produce large numbers of units and/or to achieve optimum surface quality, use should be made of conditioned (120 to 130 °C) aluminium or steel molds with silk-matt surfaces. A mold angle of between 4 and 6° will facilitate the release process.

When constructing forming molds, allowance should be made for shrinkage of 0.8 to 1 %. Provision should be made for sufficient and correctly placed vents with a diameter of no more than 0.5 to 0.8 mm to avoid impressions on the molded part. To improve ventilation, the hole may be back-drilled with a larger drill.

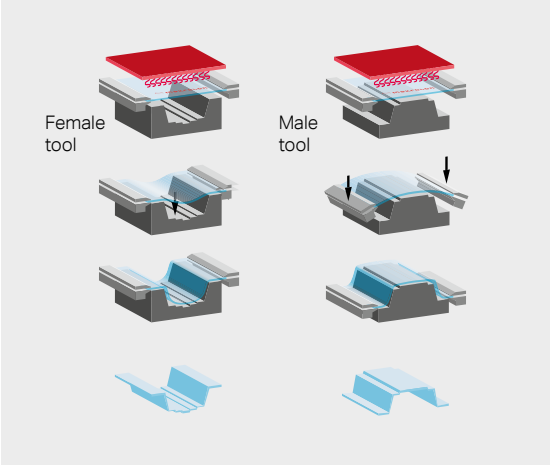
The radii should be measured as generously as possible and at least correspond to the wall thickness of the Makrolon® sheet to attain a higher level of stiffness and to avoid any dilution or wrinkle formation during forming.

Male and female tools
The decision on whether to use a male or female tool depends on the application. To achieve a better surface quality on the outer side of the finished part, and to attain greater detail, use of a female tool is recommended.

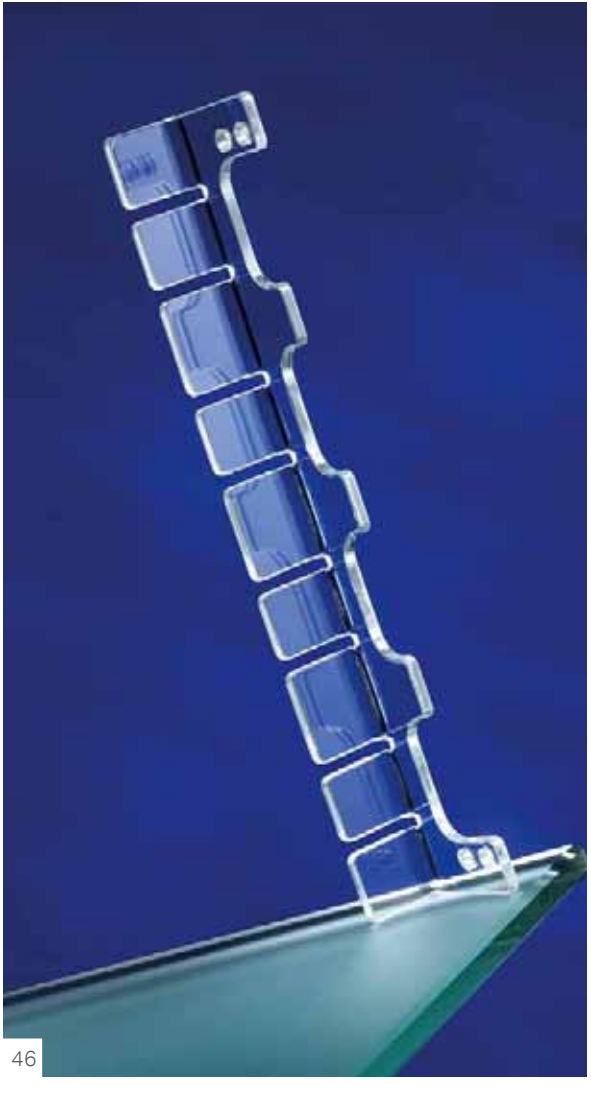
Blowing or thermoforming without countermold
This technique is used to form domes. Blowing without a countermold involves working with air pressure whilst the thermoforming process without a counter-mold is carried out in a vacuum. To produce perfect moldings, the sheets should be evenly heated. Avoid any draughts in the workshop that could lead to uneven heating. At a sheet temperature of approx. 135 °C, the part retains its desired shape and can be removed.



Sketch of vents during thermoforming



Sketch of vents during thermoforming



High-pressure forming
Compressed air is used to increase the atmospheric air pressure in a closed mold, stretching the softened sheet across the mold. This results in precise reproduction of detail and sharp edges.

Twin-sheet forming
Two heated sheets are placed between two female tools. Using compressed air, blow moldings are produced with a high degree of structural stiffness and lightweight construction. This method can be used to form and join two sheets during one process.

Conditioning
Makrolon® sheets should be processed under optimum conditions as far as possible to avoid high internal stress in the sheets, which could result in a need for subsequent heat treatment. Conditioning means heating parts, keeping them at their temperature and then slowly cooling them again.

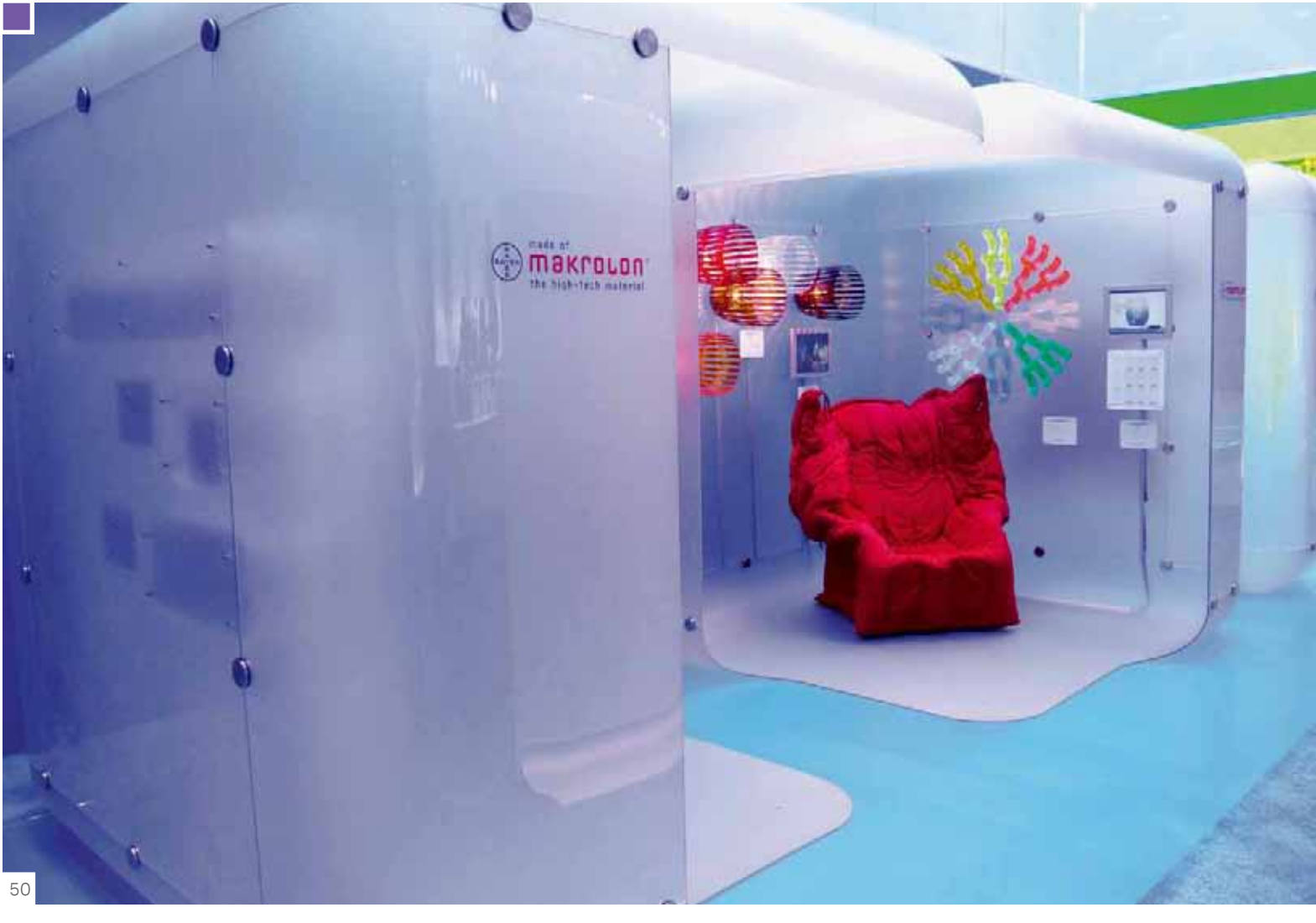
Internal stresses in Makrolon® sheets can be largely removed by conditioning in a hot cabinet. The parts are evenly heated to 120 to 125 °C and kept at this temperature on the basis of 1 hour per 3 mm of thickness. It is important that the parts are then cooled slowly without any extreme temperature fluctuations, preferably in an oven.

Tips for thermoforming

Problems	Possible causes	Solution	Hot bending	Stretch forming	Thermo-forming	Blowing/ Thermoform-ing without countermold
Bubbles in the sheet	Moisture	Pre-drying	■	■	■	■
	Excess heating	Reduce heating	■		■	■
Badly formed parts	Sheet too hot	Reduce heating			■	■
	Tool too cold	Raise tool temperature			■	
	Part not released soon enough	Shorten cooling cycle			■	
	Vacuum too fast	Limit vacuum			■	
	Sharp edges	Round off edges			■	
	Sheet surface too small	Use larger sheets			■	
Wave formation	Uneven heating	Monitor hot areas and shadow areas			■	
	Too small a distance between molds	Min. distance = 2 × thickness			■	
	Vacuum too fast	Limit vacuum			■	
	Sheet surface too large	Distance between clamp & tool < 50 mm			■	

Problems	Possible causes	Solution	Hot bending	Stretch forming	Thermo-forming	Blowing/ Thermoform-ing without countermold
Reduced or incomplete details	Insufficient vacuum	Check for lack of tightness or add vents			■	
	Sheet temperature too low	Increase heating			■	
Molding sticks to mold	Tool too hot	Reduce tool temperature			■	
	Part not released soon enough	Release sooner			■	
	Release angle too small	Release angle > 4 to 6°			■	
Impressions	Mold surface too smooth	Slightly matt tool			■	
	Sheet temperature too high	Reduce heating time	■	■		
	Vents badly positioned	Re-evaluate vent positioning			■	
Surface defects	Dust on sheet or mold	Clean with ionised compressed air		■	■	
	Vents badly positioned	Re-evaluate vent positioning			■	
Uneven finished parts	Tool/clamp too cold	Increase pre-heating			■	
	Heating/cooling	Check for draughts; check heating	■	■	■	■
	Release too late	Release sooner			■	




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the high-tech material

6. FASTENING & BONDING

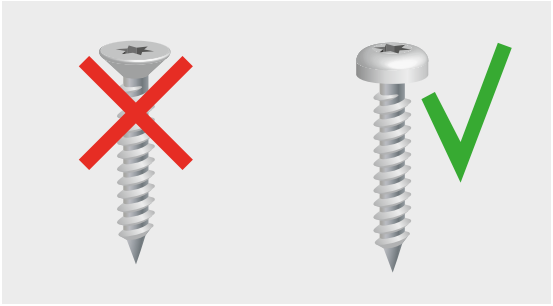
6.1 Mechanical fastening

Holes drilled in Makrolon® sheets impair the strength of the sheets. Bearing in mind the relatively high linear thermal expansion coefficient of Makrolon® compared with metal or glass, structural measures should be taken to ensure the Makrolon® part can move freely under temperature fluctuations.

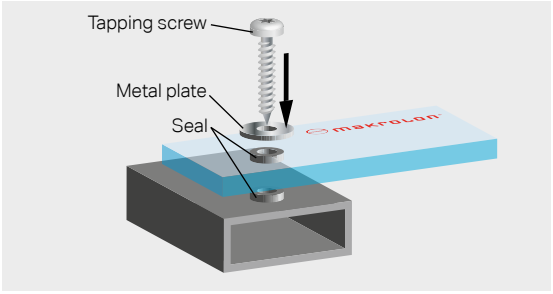
Example:
For a temperature difference of 45 °C (– 10 °C to +35 °C) the length and width of a polycarbonate sheet changes by approx. 3 mm/m. The table below shows the expansion of a sheet measuring 1 m in length under such a temperature difference in comparison to other materials.

Material	Linear thermal expansion coefficient in mm/mK	Expansion at 45 °C temperature difference in mm
Makrolon®	0.065	2.93
Aluminium	0.024	1.08
Steel	0.012	0.54
Glass	0.008	0.36

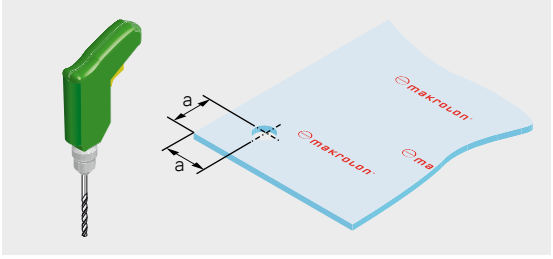




Avoid screws with bevelled heads, which can cause cracking



Mechanical fastening



Mechanical fastening: Distance a: 2 × ø drilled hole, but >6 mm

During fastening work make sure that the Makrolon® sheet is not excessively stressed by local pressure forces. Avoid the use of screws with bevelled heads, which can cause cracking. Washers or profiled rubber/foam strips should be used to distribute the pressure. Do not use PVC-based materials in direct contact with the sheet.

Fastening holes should always be drilled allowing for expansion and shrinkage. The allowance should be based on the sheet dimensions and the expected temperature fluctuations. With very large sheets it may even be necessary to drill oblong holes. The diameter of the hole must be 6 mm larger than the screw diameter for sheets up to 2 m length; for longer sheets add 3 mm per additional metres long sheet length.

The distance between the mid-point of the holes and the outer edge of the sheet must be at least twice the diameter of the hole and a minimum of 6 mm. The screws should only be tightened to a position that enables the Makrolon® sheet to expand or shrink freely when exposed to temperature stress.

Industrial screw taps may be used for thread-cutting in Makrolon®, but are not recommended. There is a risk of cracking due to the notching effect. We advise only opting for this type of fastening if no other form – e. g. bonding, clamping or screwing through a clearance hole – is possible. Cutting oil must not under any circumstances be used on Makrolon®.

Metal threaded inserts can be sunk into Makrolon® and fastened using ultrasonic welding. Protective plates for machinery may also be clamped into rubber profiles made from EPDM. Thin sheets may also be nailed, tacked or riveted, though these forms of fastening should only be used in exceptional cases.

6.2 Welding

Makrolon® sheets may be joined to each other using ultrasonic welding. Detailed information on ultrasonic welding equipment and the welding conditions should be requested from the relevant equipment manufacturer.

6.3 Solvent-based adhesives

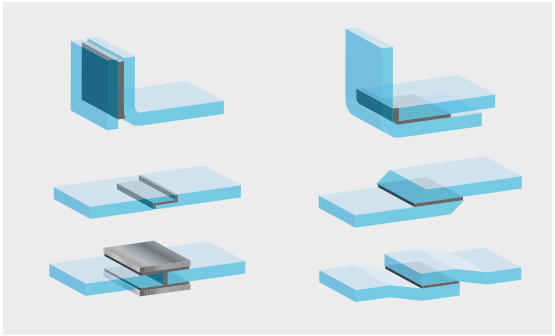
Warning! Solvents may be toxic or contain carcinogens. Always ensure good ventilation when working with solvents and follow the information contained in the safety data sheets provided by the manufacturer.

When bonding Makrolon® sheets, the load should be evenly distributed across the entire bonded surface. Please note that the join should not be subject to peel stress but only to shear or tension stress.

Solvent-based adhesives are the easiest and most economical way of bonding Makrolon® parts. The addition of 8 % Makrolon® shavings gives an adhesive with lower evaporation speed and higher viscosity, which makes it easier to apply.

A further advantage of this more viscous adhesive is that the surfaces being bonded do not need to fit together perfectly well (gap filling) as when using an easier flowing pure solvent-based adhesive.





Different bonded joints



Important:

- The surfaces to be bonded should be thoroughly cleaned with a soft cloth soaked in isopropyl alcohol to remove grease, dirt and other foreign bodies.
- The solvent-based adhesive should be applied as a thin layer to one of the surfaces to be bonded (any excess of adhesive will result in a weak join).
- The surfaces should be laid on top of each other immediately and briefly pressed together to ensure a good join.
- The adhered parts may be moved after just a few minutes, although – at normal room temperature – maximum bonding strength is only achieved after a few days (slow release of adhesive from the adherent).

Do not use any solvent-based adhesives for flat joints on Makrolon® AR. The inert, chemical and scratch-resistant surface prevents the adhesive from bonding properly.

Solvent-based adhesives can also be used to bond Makrolon® to other thermoplastic materials with dissolvable surfaces. These joins generally have a lower level of strength depending on the combined materials. If this is the case, it is better to use adhesive bonding agents.

6.4 Adhesive bonding agents

Please follow the general safety measures recommended by the manufacturer. Makrolon® parts may be bonded together or to other materials using industrial adhesive bonding agents that are compatible with Makrolon®. In selecting a bonding agent it is important to consider the following parameters: heat resistance, elasticity, appearance of adhesive coating, ease of processing etc.

Important:
- The surfaces to be bonded must be roughened and thoroughly cleaned to improve adhesion.
- Adhesives that contain solvents or catalysts that are not compatible with Makrolon® should not be used.
- Instructions provided by the manufacturer must be observed.

If using an adhesive bonding agent with Makrolon® AR, we advise conducting some tests first, as the material is not easily bonded. In most cases, a special primer is needed.

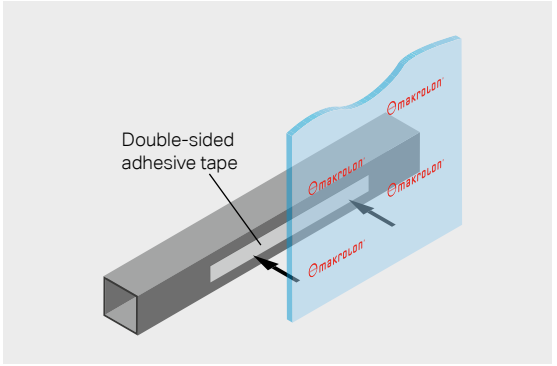
6.5 Adhesive tape

Transparent, double-sided adhesive tape (acrylic-based) may be used for rapid bonding. Do not use PVC-based tape, because most plasticizers are not compatible with polycarbonate.

Acrylic-based tapes are elastic and adhere well to Makrolon®. They are particularly suitable for bonding thin Makrolon® sheets to other plastics, glass or metal.

Tips for good bonding:
- Fold the sheet so that it is slightly wider than the adhesive tape.
- Clean the bonding area with isopropyl alcohol.
- Carefully apply the adhesive tape.
- Use a roller to apply even pressure to remove any air bubbles and improve adhesion.





Bonding with adhesive tape



7. FINISHING

Decorating
Before treating Makrolon® sheets – e.g. by coating, screen printing or thermoforming – we recommend removing any loose particles of dirt or dust adhering to the surface using ionised air (see section 8 "Cleaning").

Self-adhesive films can be used on Makrolon®. Contact your adhesive film supplier for a moisture-permeable PVC-free film type to avoid bubble formation.

Coating and printing
Once cleaned, Makrolon® may be coated and printed without any other pre-treatment.

Care should be taken to ensure that the coatings and printing inks are chemically compatible with Makrolon®, otherwise the properties of Makrolon® may be impaired. Various manufacturers can provide suitable ink systems. The manufacturer's instructions should be followed at all times.

The low surface adhesion of Makrolon® AR sheets makes printing very difficult and mostly require a primer. The matt side of Makrolon® NR is not suitable for printing.





8. CLEANING

Makrolon® has a pore-free surface to which it is difficult for dirt to adhere. Dusty parts can be wiped with water, a soft cloth or a sponge but should never be rubbed when dry!

For thorough cleaning, we recommend a non-abrasive detergent. Razor blades or other sharp tools, abrasive or strongly alkaline detergents, solvents and products which contain amines should not be used. The best way is to use a microfibre cloth that is simply dampened with water. In the case of a greater build-up of dirt or greasy stains in particular, benzene-free pure petroleum spirit (cleaner's naphtha or light gasoline) may be applied.

Splashes of dye, grease or residual sealant etc. may be removed using a soft cloth soaked in ethyl alcohol, isopropyl alcohol or petroleum ether (boiling point 65 °C) and gentle rubbing prior to curing. Rust marks can be removed with a 10 % solution of oxalic acid.

Mechanical systems involving e.g. rotating bristles, strippers etc. are not suitable for use with Makrolon® – even if generous quantities of water are added to the brushes, the sheet surface may become scratched, with the exception of Makrolon® AR. It may be possible to remove or disguise minor scuffs that are not too deep using hot air polishing. This does not apply, however, to Makrolon® AR.

Makrolon® has good electrical insulation properties resulting in electrostatic charging and the attraction of dust particles. Before treating Makrolon® sheets we recommend removing any loose particles of dirt or dust on the surface by blowing with ionized air. The particles cannot be removed using a normal compressed air gun or a cloth due to static charges.



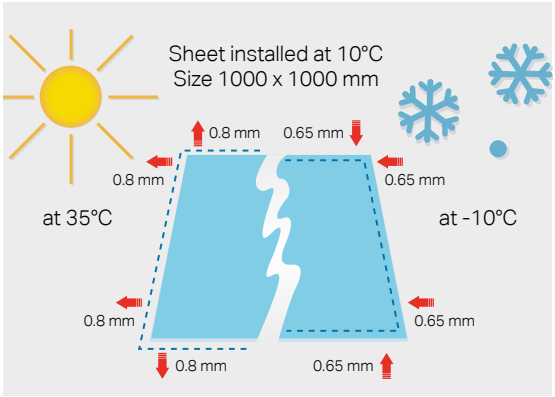


9. INSTALLATION

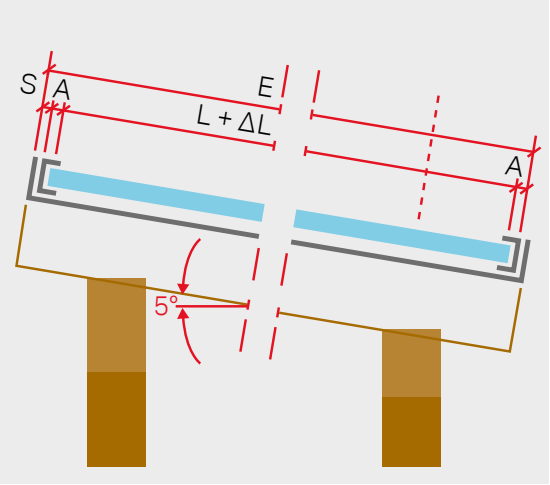
9.1 Thermal expansion

Makrolon® sheets expand when heated and contract when cooling. As with most polymers, the thermal expansion coefficient is much higher than other materials (about 8 times higher than glass, 6 times higher than steel and 4 times higher than aluminium). For this reason, all fastening and clamping devices must allow sufficient room for expansion and shrinkage.

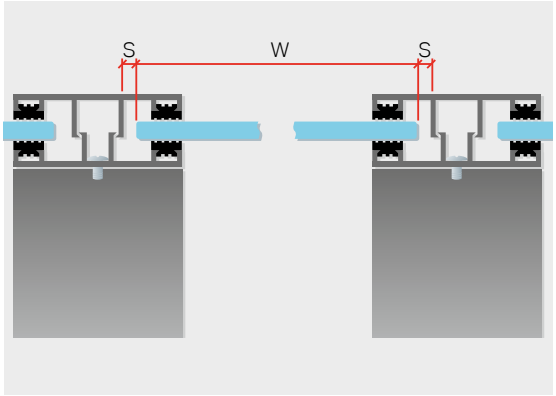
- If the sheet edge touches the inner part of the profile and the temperature increases, the sheet will not be able to expand. The sheet will distort or, in extreme cases, get damaged.
- If the sheet is installed with the edge too close to the outer extremity of the profile, the sheet could slip out of the support frame when it shrinks during cold winter weather. This effect can be reinforced by other factors such as snow load.
- The design of rubber joints must allow for significant expansion and shrinkage to prevent the joints coming out of the profiles or damaging the sheet.



Thermal expansion



Allowance for expansion in length



Allowance for expansion in width

The linear thermal expansion coefficient of polycarbonate is 0.065 mm/m °C.
Calculation example:
Sheet size: 1000 x 3000 mm (1 x 3 m)
Expected highest temperature: 35 °C
Expected lowest temperature: –10 °C
Temperature difference ΔT: 45 °C
Expansion in width: α . ΔT . W = 0.065 mm/mK . 45 °C . 1 m = 2.92 mm
Expansion in length: α . ΔT . L = 0.065 mm/mK . 45 °C . 3 m = 8.77 mm

We recommend allowing for expansion of 3 mm/m.

9.2 Rabbet depth

For a proper installation of Makrolon® sheets the clamping profiles must have a correct rabbet depth design. There are various aspects to be considered:

- The difference in thermal expansion between the sheets and the profiles must be taken into account (see previous chapter).
- As Makrolon® is a plastic material, it will flex slightly when subjected to pressure from external loads. Even though the sheets are rigid, this causes a virtual shortening of the dimensions of the sheet. When the rabbet depth on both sides of the sheets is calculated according to the expected temperature variations (with a minimum rabbet depth of 20 mm) and the calculation example in the previous paragraph is used to determine the sheet dimensions, you do not need to make any further calculations to account for the virtual shortening.

9.3 Profiles

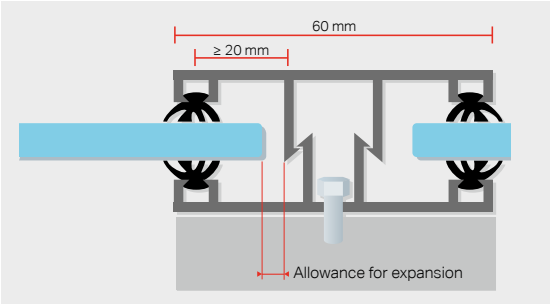
The recommended method of installation is clamping all sheet edges with the same type of profiles that are used to install glass panels. These profiles should permit the sheet to move because of elongation or contraction due to temperature changes, and at the same time provide air- and watertightness.

Many different profiles are available, from single profiles to fully modular mounting systems. Aluminium profiles with EPDM rubbers are most commonly used with polycarbonate sheets. In practice, every classical construction is possible as long as the specific characteristics of polycarbonate are respected.

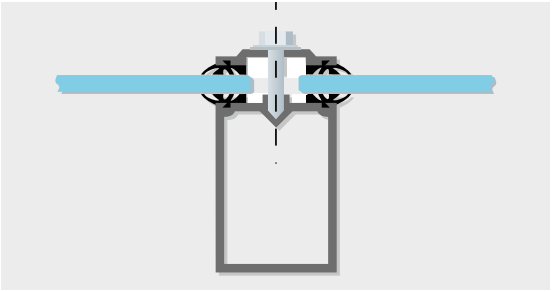
To fulfil the requirements for optimum load characteristics it is important that all the edges are properly clamped with a rabbet depth of at least 20 mm.

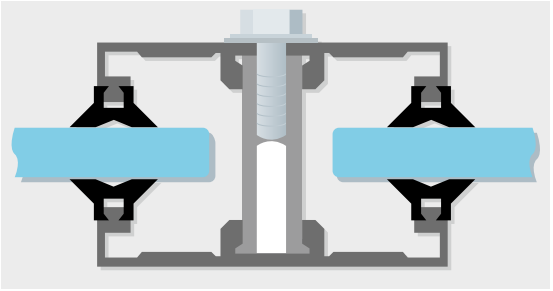
Any gaskets used must be chemically compatible with polycarbonate (see also next paragraph) and care must be taken not to stress the sheets during the construction. In all glazing systems with Makrolon®, the contact pressure exerted on the sheet by the glazing bead or clamping plate is important. This pressure is transmitted to the sheet via the glazing gasket or seal. The pressure must be regulated and uniform to ensure an adequate weather seal. Excessive contact pressure will adversely affect the glazing gasket or seal. Since the glazing gasket is the softest part in the glazing system, excessive contact pressure will cause it to bulge, or even be displaced from the glazing system which will then no longer be watertight.

We recommend using a distance ring or a profile system in which the clamping pressure is preset by the design.



Rabbet depth design


Profile system with preset clamping pressure


Distance ring



9.4 Gasket and seals

For Makrolon® sheets to remain waterproof, the gasket used in the glazing system must be resilient yet still allow for the predicted expansion and contraction of the sheet. To achieve weather tightness the gasket must be the right shape and be made of the right material.

The material from which the gasket is manufactured must be compatible with Makrolon®. The following materials are likely to be compatible:

- EPDM
- Polychloroprene
- Polyethylene (PE)
- PTFE
- Neoprene
- Silicone
- EPT

The following materials are usually not compatible:

- PVC
- PVC/Nitrile

In general, gaskets must be tested for compatibility before being incorporated into glazing systems for use with Makrolon®.

Because of sheet movement caused by expansion and contraction, gaskets must be mechanically secured to the glazing system or they will become dislodged. Securing by adhesion is not adequate.

9.5 Additional support systems

In some constructions the sheets will not only be clamped at the edges, but they will have an additional support. For instance, if a 6-m roof is required and the calculations advise a maximum unsupported span of 3 m, it is possible to either install 2 sheets of 3 m or 1 sheet of 6 m with an additional support structure in the middle.

Be aware that loads on the sheet can act in both directions: a snow load typically exerts a vertical downward force. Wind can create a downward or upward force (suction).

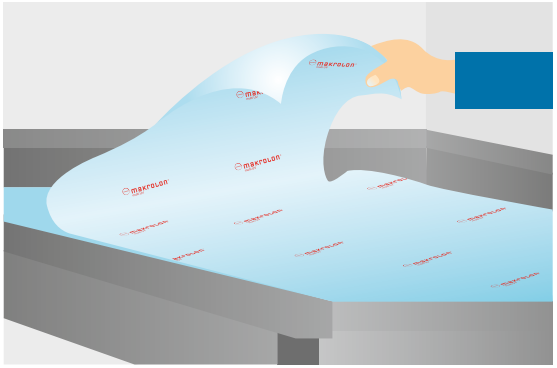
Additional support structures must be effective for both force directions: just placing an additional profile under the sheet will not be sufficient.

Holes drilled in Makrolon® sheets impair the strength of the sheets. Bear in mind that the sheet needs to be able to contract and expand. To achieve this, make sure that the Makrolon® sheet is not excessively stressed by local pressure forces. Washers or profiled rubber/foam strips with the correct rubber type should be used to distribute the pressure.

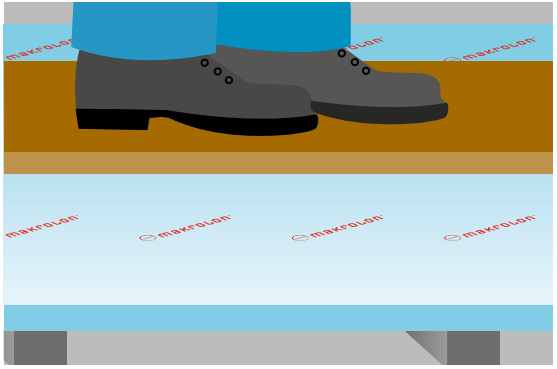
Also make sure to oversize the hole in the sheet: the hole should be 6 mm larger than the diameter of the screw for a sheet length up to 2 metres and thereafter an additional 3 mm per metre. With very large sheets it may even be necessary to drill oblong holes.

See also section 6.1 “Mechanical fastening”.





Remove the masking immediately after installation



Never walk directly on the sheets

9.6 Removing the masking

The surfaces of Makrolon® sheets are protected during transportation, storage and installation by self-adhesive PE masking film.

In general, all films should be removed straight after installation especially if the sheets are exposed to weathering, otherwise the films risk becoming brittle or more adhesive. If this happens, the film cannot be removed correctly and damage to the sheets can no longer be ruled out.

9.7 Safety

Roofs covered with Makrolon® cannot be walked on.

Always use supports to walk on the roof. Never walk on structures which incorporate Makrolon® sheets without such supports!

Tip: For your own safety use planks, rigid board or similar items when installing and cleaning the roof and abide by the appropriate safety regulations. Be careful not to damage the sheets and the sheet surface during the process.





10. CURVED GLAZING

Makrolon® sheets are ideal for arched structures such as barrel vaults. The sheets can be cold curved, which increases the rigidity of the sheet. The sheet must be clamped on four sides, but allowance must be made for linear expansion.

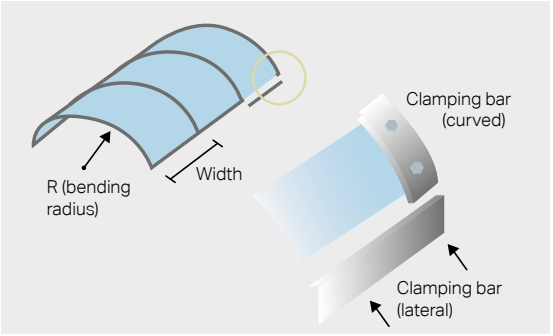
The minimum radius to which Makrolon® UV sheet can be cold bended is 150 times the sheet thickness. In order to avoid excessive stress, lower values must be avoided.

From the diagrams on the next pages you can determine the optimum thickness of Makrolon® UV solid sheet for curved glazing as a function of the radius (R), load (q) and width (b). This data can be applied on tunnel vaults where the angle contained is greater than 30° and with a uniform distributed load. These calculations include a safety factor of 1.5.

The load (usually wind load or snow load) has to be determined according to local or national planning regulations and the height of the installed glazing. This is usually done by the architect.

The calculations are valid if the sheet is clamped on all four sides, and if the recommended rabbet depth as mentioned is respected. Furthermore, sufficient clearance should be allowed for expansion of the Makrolon® sheet after installation.

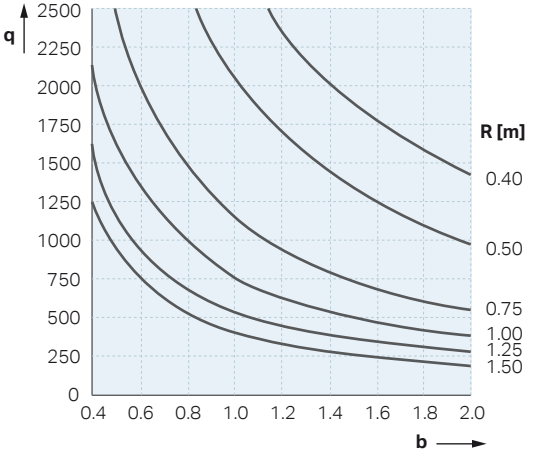
In case of doubt or queries about criteria or schematization, it is advisable to contact us.



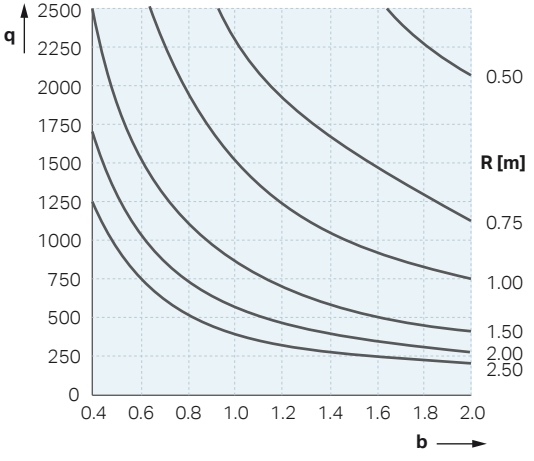
Curved glazing



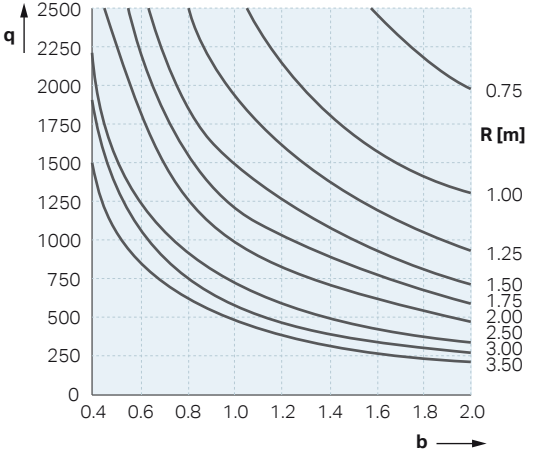
3 mm



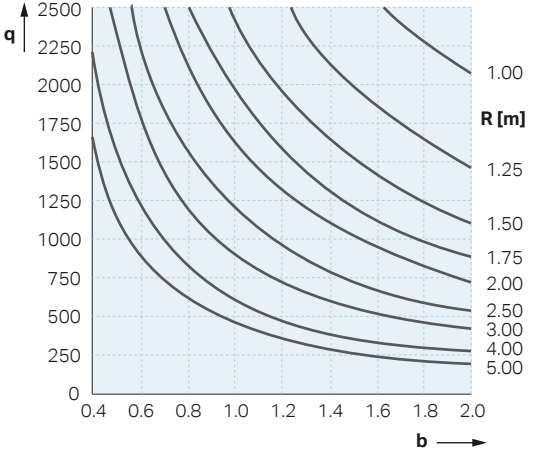
4 mm



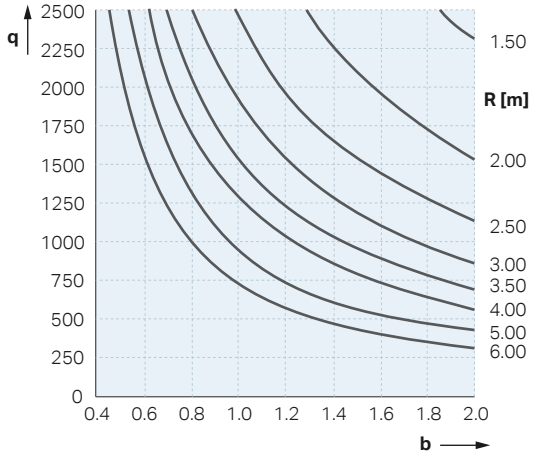
5 mm



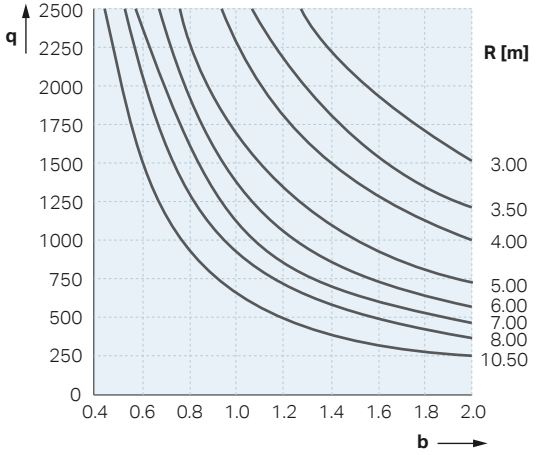
6 mm



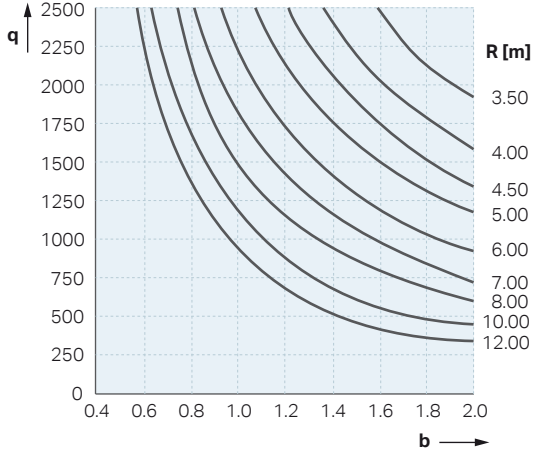
8 mm



10 mm



12 mm



q: wind load
b: sheet width
R: bending radius



11. FLAT GLAZING

The required sheet thickness of Makrolon® sheets depends on the area size of the sheet and of the load to which it may be subjected.

The dimensions are normally determined by the architect/designer.

The load (usually wind load or snow load) has to be determined to comply with local or national planning regulations and depending on the height of the installed glazing. This is usually done by the architect.

The following table is valid if the recommended rabbet depth is respected. Furthermore, sufficient clearance should be allowed for expansion of the Makrolon® sheet after installation.

In the calculations it is assumed the sheet is supported on four sides by standard aluminium glazing profiles; the edges of the sheet have been schematized as 40 % fully clamped (edge's rotation not allowed) and 60 % simply supported (free rotating edges).

The calculation has been limited according to the following criteria (a limit is also represented by each single criterion):

- maximum allowed deflection equal to 5 % of the sheet's shortest side
- maximum allowed deflection 50 mm
- maximum stress 15N/mm².

The calculations are valid for vertical and horizontal glazing. For horizontal glazing, the slope must be a minimum of 15°.

In case of doubt or queries about criteria or schematization, it is advisable to contact us.



Width in mm	Length in mm	load in kN/m²								
		0.25	0.5	0.75	1	1.25	1.5	2	3	4
500	1000	3	3	3	3	3	3	4	5	6
	2000	3	4	4	4	5	5	5	6	6
	3000	3	4	4	4	5	5	6	6	8
	4000	3	4	4	5	5	5	6	8	8
	5000	3	4	4	5	5	5	6	8	—
	6000	3	4	4	5	5	5	6	8	—
750	1000	3	3	4	4	4	4	4	5	6
	2000	4	4	5	5	6	6	8	10	10
	3000	5	5	6	6	8	8	8	10	—
	4000	5	6	6	8	8	8	8	10	—
	5000	5	6	6	8	8	8	10	—	—
	6000	5	6	6	8	8	8	10	—	—
1000	1000	4	4	4	4	4	4	5	6	8
	2000	4	4	5	6	6	8	8	10	12
	3000	5	6	8	8	8	10	10	12	15
	4000	6	8	8	8	10	10	12	15	15
	5000	6	8	10	10	10	12	12	15	15
	6000	6	8	10	10	10	12	15	—	—

Width in mm	Length in mm	load in kN/m²								
		0.25	0.5	0.75	1	1.25	1.5	2	3	4
1250	2000	4	5	6	8	8	8	10	12	15
	3000	6	8	10	10	10	12	15	15	—
	4000	8	10	10	12	12	15	15	—	—
	5000	8	10	12	12	15	15	15	—	—
	6000	8	10	12	12	15	15	—	—	—
1500	2000	4	6	8	8	10	10	12	15	—
	3000	8	10	12	12	15	15	15	—	—
	4000	10	12	12	15	15	15	—	—	—
	5000	10	15	15	15	15	—	—	—	—
	6000	10	15	15	15	—	—	—	—	—
2000	2000	8	8	10	12	12	15	15	—	—
	3000	10	12	15	15	15	15	—	—	—
	4000	15	15	15	15	—	—	—	—	—
	5000	15	15	15	—	—	—	—	—	—
	6000	15	15	—	—	—	—	—	—	—

MF0261 – July 2017

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