

1 General

These application guidelines are specifically intended for the fastening of EURO PANELS OVERSEAS NV sheets as a tunnel wall lining onto a sufficiently corrosion resistant steel supporting structure that is fitted to the tunnel wall. A number of basic principles are given that must be adhered to. Please contact EURO PANELS OVERSEAS NV for further information, variations or additional advice.

2 Lining material

Wall lining with tunnel liner sheets on a steel supporting structure is possible with the following EURO PANELS OVERSEAS NV tunnel liner sheets:

• GLASAL T	8 mm for straight application or radius > 15.0 m
• GLASAL T	5 mm for straight application or radius > 15.0 m
• GLASAL TR (Reinforced) ¹	5 mm for curved application ($5.0 \text{ m} \leq \text{Radius} \leq 15.0 \text{ m}$)

For product data and the details of the processing of the various panels reference is made to the product information sheet, the general instructions for use and the cleaning advice of tunnel panels, available from EURO PANELS OVERSEAS NV.

3 Advantages

GLASAL-T has the following benefits as a tunnel lining:

SAFETY

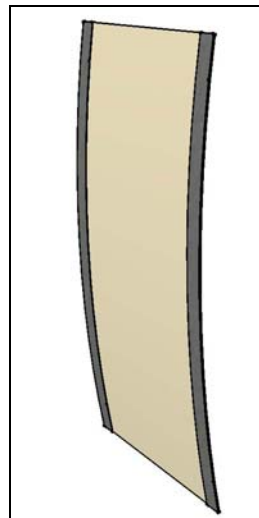
- optical guidance of the traffic thanks to its clear but diffuse reflection of light
- fire-safe (non-flammable and not flame propagating)

DURABILITY

- high scratch resistance
- high colour stability
- not susceptible to corrosion
- high resistance to dynamic loads (fatigue)
- damp proof
- frost proof
- long life expectancy

ECONOMIC

- fast installation
- low power consumption for lighting of the tunnel
- low maintenance cost
- easy to clean



¹ Panels are reinforced with metal strips at the rear along the vertical edges.

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4 Area of application

These guidelines apply to tunnels designed for normal car and truck traffic.

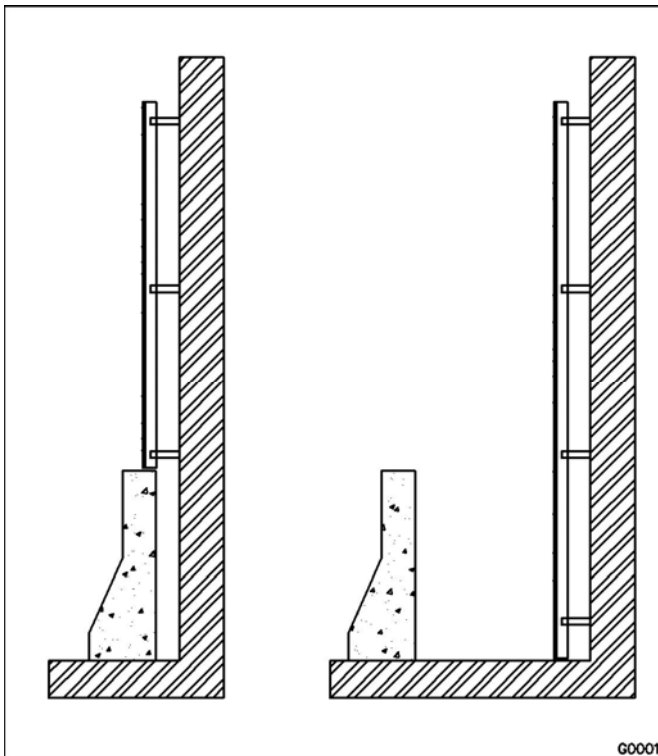
The dynamic and static pressure and low-pressure load to be expected must be determined on the basis of the valid national standards and directives.

Further load forms must be taken into account, for example :

- Pressure exerted by the brushes of cleaning machines.
- Specific pressure loads (e.g. wind load) at the entrance and exit of the tunnel.

Hereafter in this guideline the maximum real pressure load per fastening system will be indicated. This must be lower than the wind load to be expected according to the standard.

To avoid damages of the tunnel lining by traffic, the lower part of the tunnel lining has to be protected by other means (e.g. New Jersey lining, crash barriers).



In this leaflet only the tunnel lining (sub-construction and Glasal-T sheets) is treated. The static aspects and water infiltration management has to be achieved prior to the installation of the tunnel lining.


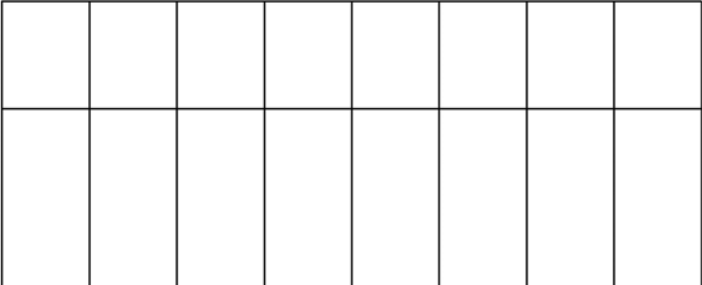

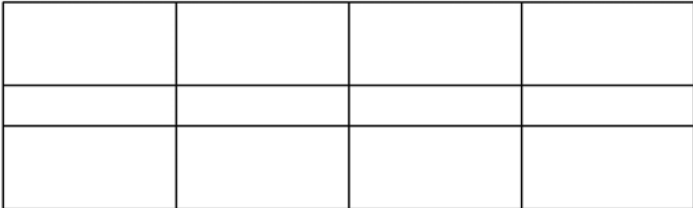
For use of Glasal-T on a tunnel ceiling directly above the traffic, please contact EURO PANELS OVERSEAS NV technical services for more specific guidelines.

During the selection of metal supporting structures (thickness, material quality, ...) for tunnel panels, aggressive environments that can affect the metal must be taken into account. The aggressiveness of the environment in a tunnel through rocks differs, for example, from that in a city tunnel with concrete walls.

5 Patterns

Pattern examples for tunnel panels.

For technical and aesthetic reasons, only use rectified panels.

 <p style="text-align: right;">G0002</p>	<p>vertical orientation height = full size sheet 2.50 or 3.00m or pre-cut sheet straight or curved</p>
 <p style="text-align: right;">G0003</p>	<p>vertical orientation height > full size sheet use full size sheet + pre-cut sheet straight or curved</p>
 <p style="text-align: right;">G0004</p>	<p>horizontal orientation height ± 2.45 metres use 2 full size sheets straight</p>
 <p style="text-align: right;">G0005</p>	<p>horizontal orientation height > 2.45 metres use 2 full size sheets + pre-cut sheet straight</p>

6 Corrosion resistant steel supporting structure

6.1. General

The design, dimensioning and calculation of the metal supporting structure as a function of the load is subject to the metal supporting structure supplier's responsibility and warranty conditions. In this document general principles will be described as examples.

The supporting structure must be designed:

- to absorb the exerted static and dynamic pressure and low or under pressure loads
- to absorb the compression forces of the brushes of cleaning machines
- to support the load of the deadweight (unless this deadweight is transferred to the tunnel floor)
- to align the profiles to obtain a completely flat lining
- to prevent tensions in the lining sheets.

- maximum bending resulting from load : $\leq \text{span}/300$
- safety factor for strength calculation : 3

The supporting structure consists of:

- the profiles to support the sheet
- the sub-frame between the profiles and the tunnel wall
- the anchorage to the tunnel wall

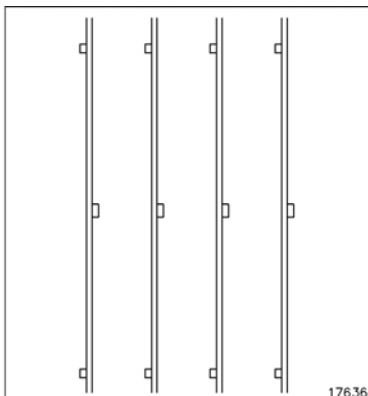
All parts of the supporting structure have to be manufactured of sufficiently corrosion resistant steel.

6.2. Orientation of the profiles

The support profiles can be orientated either vertically or horizontally, according to the following examples.

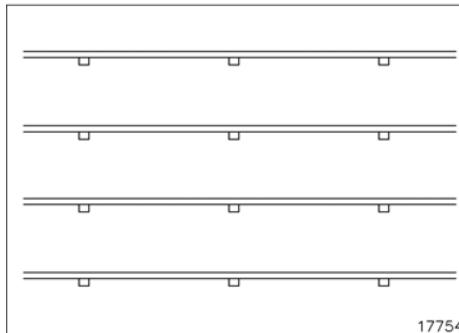
Vertical orientation

Fixed on support brackets which are fitted alternately to the left and the right of the profiles.

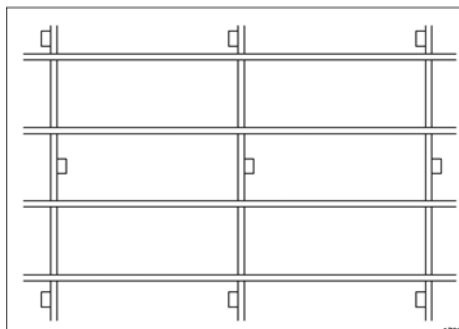


Horizontal orientation

1. Fixed on support brackets which are fitted underneath the profiles.



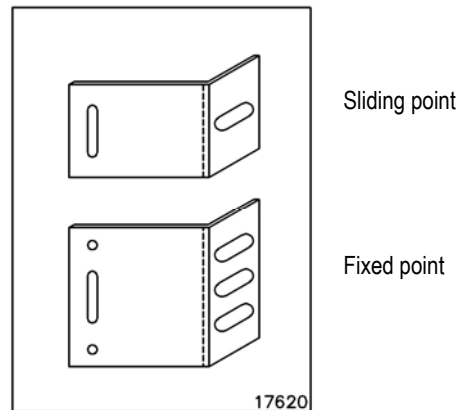
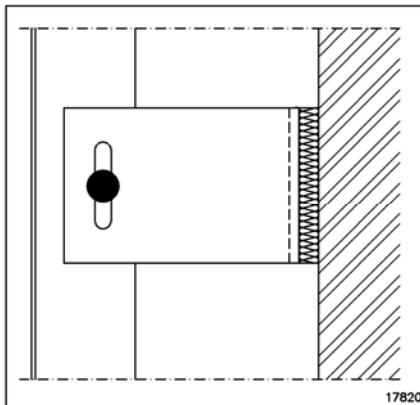
2. Fixed on vertical cross profiles which are fitted on support brackets.



6.3. Fastening of the profiles to the tunnel wall

Fastening of the profiles on the tunnel wall is carried out with corrosion resistant steel brackets. These allow compensating the tolerance between the tunnel wall and the supporting structure. In this way the irregularities of the tunnel wall can be masked or the lining can be aligned with respect to the tunnel shape.

There are various types of support bracket depending on the supplier of the support structure. In this document the support brackets are schematically shown in the following way.



The support brackets must be strong enough to withstand the occurring load.

The distance between the support brackets is determined by the occurring loads, the strength characteristics of the steel profiles and the pull-out resistance of the anchorage of the support brackets to the tunnel wall.

The anchorage of the support brackets to the tunnel wall is determined separately for each project as a function of the nature and the state of the wall to be lined. If necessary, an on-site pull-out test must be carried out by the anchorage supplier.

For concrete and rock walls a stainless steel anchor bolt with a threaded end and a nut is typically used. The nuts must be professionally locked onto the threaded end. For other substrates, such as sludge walls, special fixing means must be used to absorb the occurring loads.

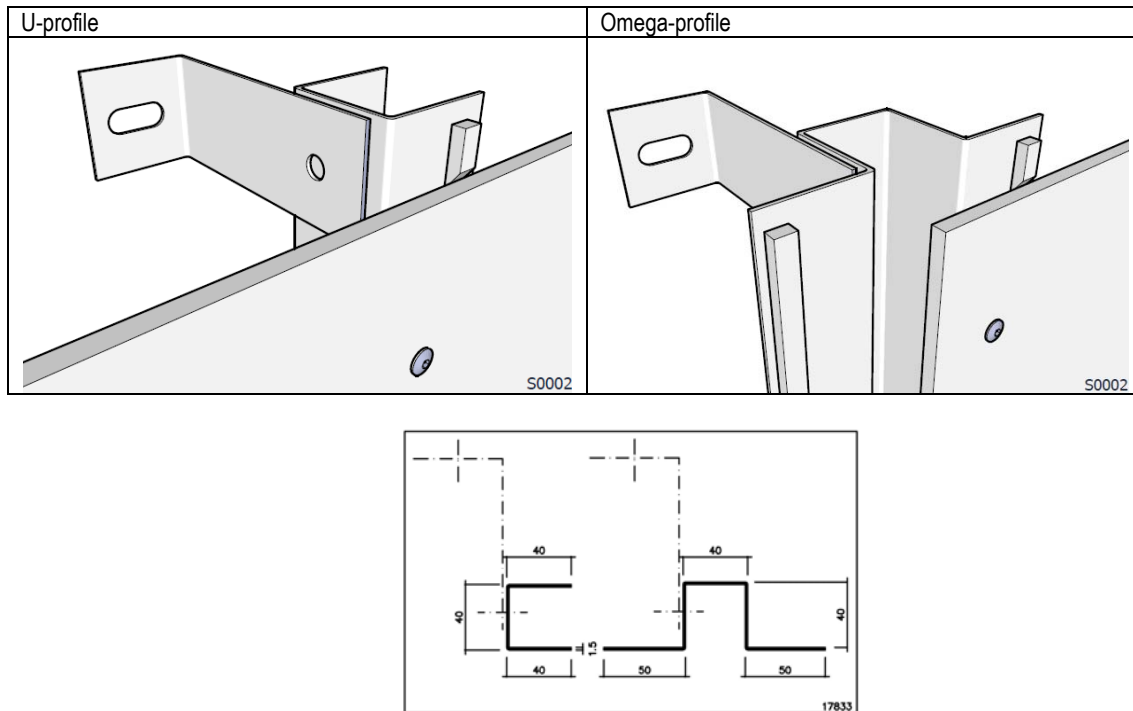
Between the support bracket and the tunnel wall an insulation block can be fitted in order to avoid galvanic corrosion.

The supporting structure has to be designed and installed to deal with the dilation of the profiles.

6.4. Vertical supporting profiles

Examples of the steel profiles are schematically shown in the following drawings.

- Omega-Profile: at the vertical joints between the tunnel panels
- U-Profile: central support



The vertical steel profiles and the plane that they form must be sufficiently even.

- Maximum unevenness : $\leq L/1000$

The steel profiles must be sufficiently wide for correct fitting of the fixing means.

- Minimum width central support (U-profile) : 40 mm
- Minimum width Ω -profile at vertical joint : 120 mm

Depending on the shape of the profiles and the spans (to be indicated by the supplier of the steel supporting structure) the steel profiles must be thick enough to withstand the occurring loads and to enable a sufficiently strong hold of the fixing means.

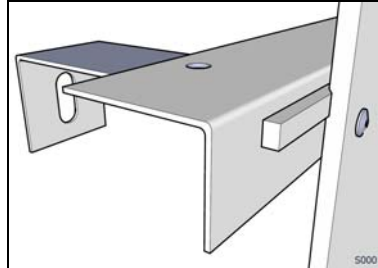
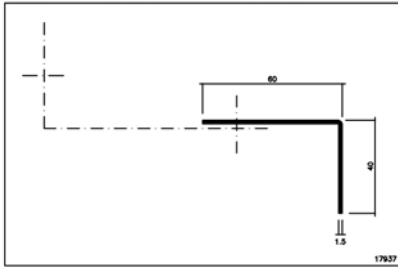
- Minimum thickness galvanized steel profile : 1,5 mm
- Minimum thickness stainless steel profile : 1,0 mm

Between the vertical steel profiles dilatation joints must be provided (provide a support bracket at both sides of the joint).

- Minimum joint width between steel profiles : 5 mm

6.5. Horizontal supporting profiles on brackets

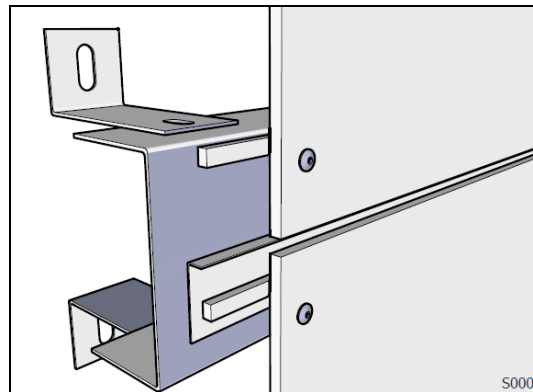
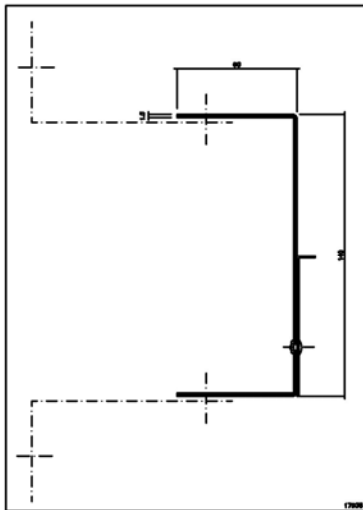
In the event of a tunnel with a curved section it is best to use horizontal profiles fixed directly with brackets. The profiles can be aligned according to a particular curve. Examples of the steel profiles are schematically shown in the following drawings.

- central supporting profile

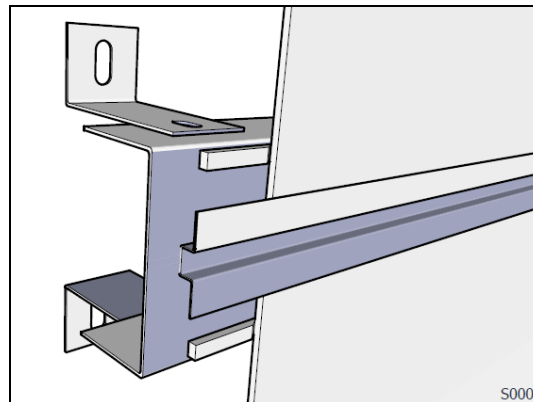
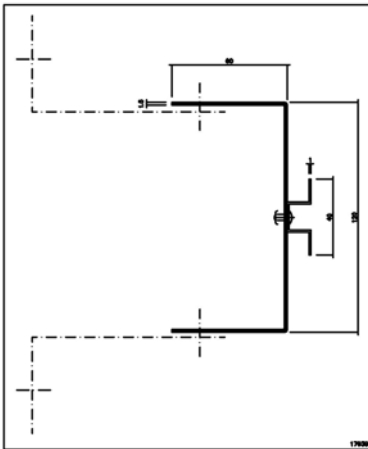
- bracket
- profile
- foam strip
- Glasal-T sheet
- rivet

- profile at the horizontal joints

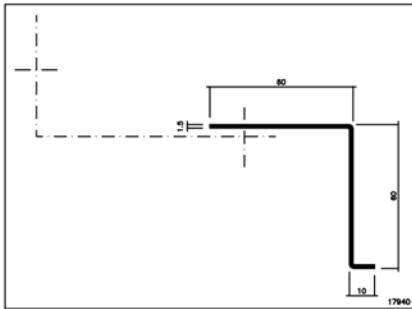
Straight application



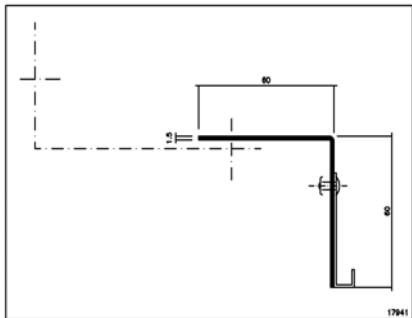
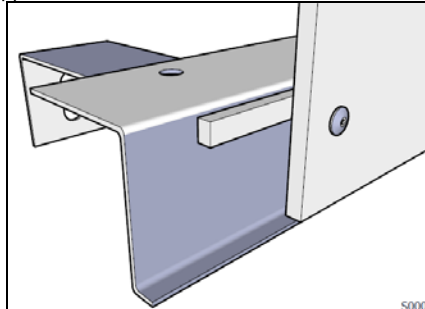
Curved application



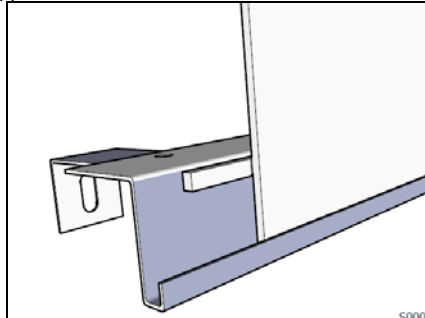
- profile at the bottom side



Straight application



Curved application



The horizontal steel profiles and the plane that they form must be sufficiently even.

- Maximum unevenness : $\leq L/1000$

The steel profiles must be sufficiently wide for correct fitting of the fixing means.

For rivet fixing

- Minimum width central support (L-profile) : 40 mm
- Minimum width profile at horizontal joint : 120 mm
- Minimum width bottom profile : 60 mm

For fixing with joint profile

- Minimum width profile at horizontal joint : 100 mm
- Minimum width bottom profile : 60 mm

Depending on the shape of the profiles and the spans (to be indicated by the supplier of the steel supporting structure) the steel profiles must be thick enough to withstand the occurring loads and to enable a sufficiently strong hold of the fixing means.

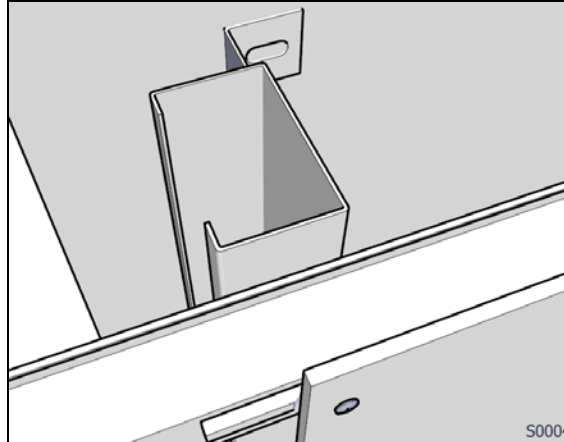
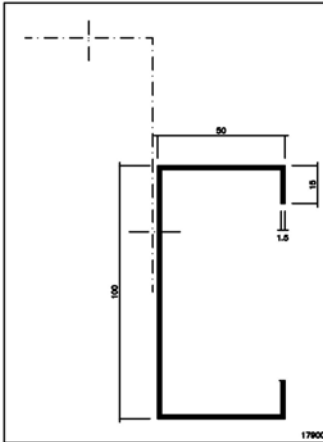
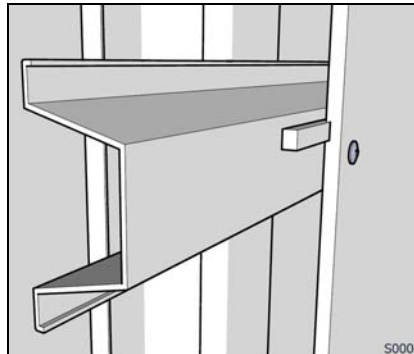
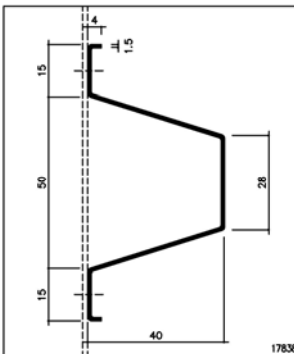
- Minimum thickness galvanized steel profile : 1,5 mm
- Minimum thickness stainless steel profile : 1,0 mm

Between the horizontal steel profiles dilatation joints must be provided (provide a support bracket at both sides of the joint).

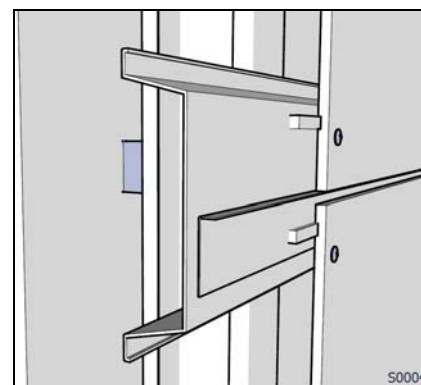
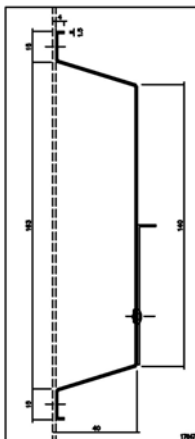
- Minimum joint width between steel profiles : 5 mm

6.6. Horizontal supporting profiles on vertical cross profiles

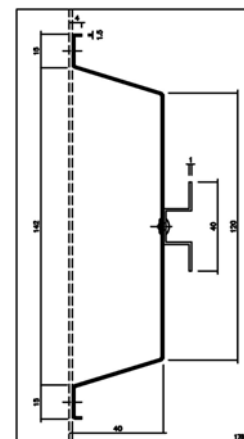
For flat tunnel lining, it can be desired to fix the horizontal supporting profiles on vertical cross profiles which are fixed to the tunnel wall with brackets. Examples of the steel profiles are schematically shown in the following drawings.

- vertical supporting profile- central horizontal supporting profile- profile at the horizontal joints

Straight application

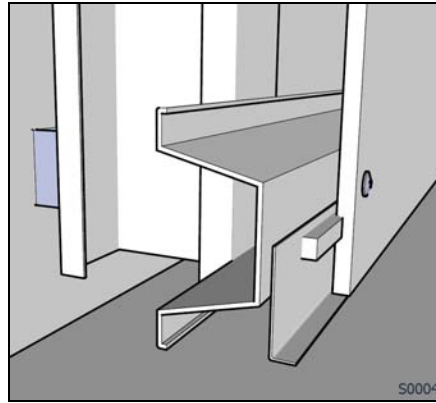
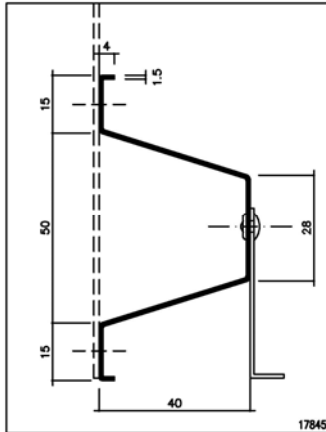


Curved application

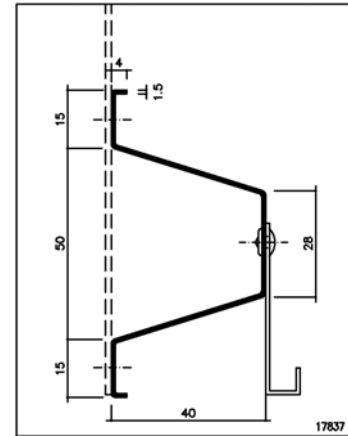


- profile at the bottom side

Straight application



Curved application



The horizontal galvanised steel profiles and the plane that they form must be sufficiently even.

- maximum unevenness : $\leq L/1000$

The horizontal steel profiles must be sufficiently wide for correct fitting of the fixing means.

For rivet fixing

- Minimum width central support (L-profile) : 40 mm
- Minimum width profile at horizontal joint : 120 mm
- Minimum width bottom profile : 40 mm

For fixing with joint profile

- Minimum width profile at horizontal joint : 100 mm
- Minimum width bottom profile : 40 mm

Depending on the shape of the profiles and the spans (to be indicated by the supplier of the steel supporting structure) the steel profiles must be thick enough to withstand the occurring loads. The steel profiles must also be thick enough to enable a sufficiently strong hold of the fixing means.

- Minimum thickness galvanised steel profile : 1,5 mm
- Minimum thickness stainless steel profile : 1,0 mm

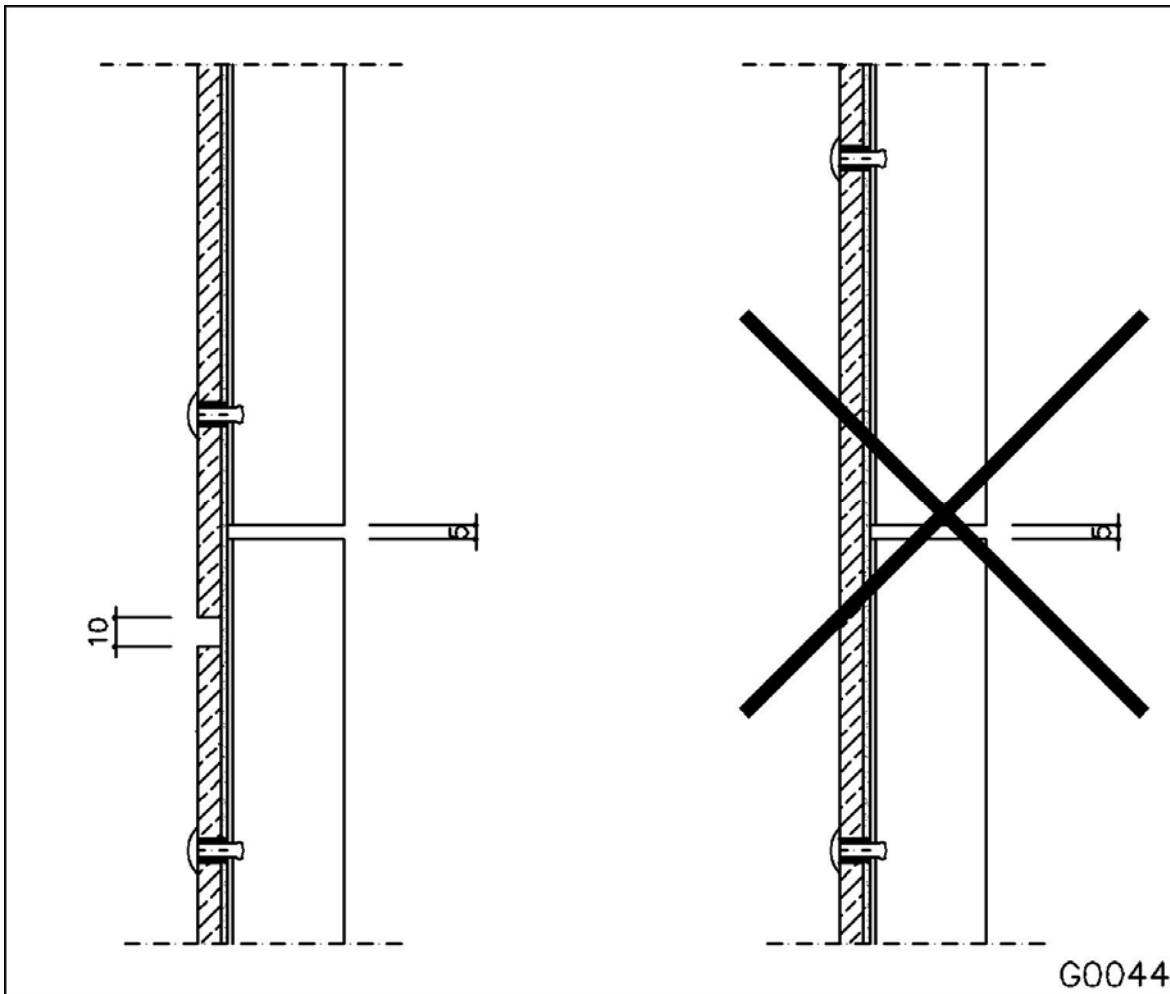
Between the horizontal steel profiles dilatation joints must be provided (provide a support bracket at both sides of the joint).

- Minimum joint width between steel profiles : 5 mm

6.7. Interaction supporting structure and tunnel lining

During the design of the supporting structure for the tunnel lining it is very important to make sure that movements of the steel profiles can be absorbed by the tunnel lining system and do not lead to stress in the tunnel lining sheets.

A joint between the steel profiles must always correspond with a joint between the sheets. Preferably the joint is continued at the same height.



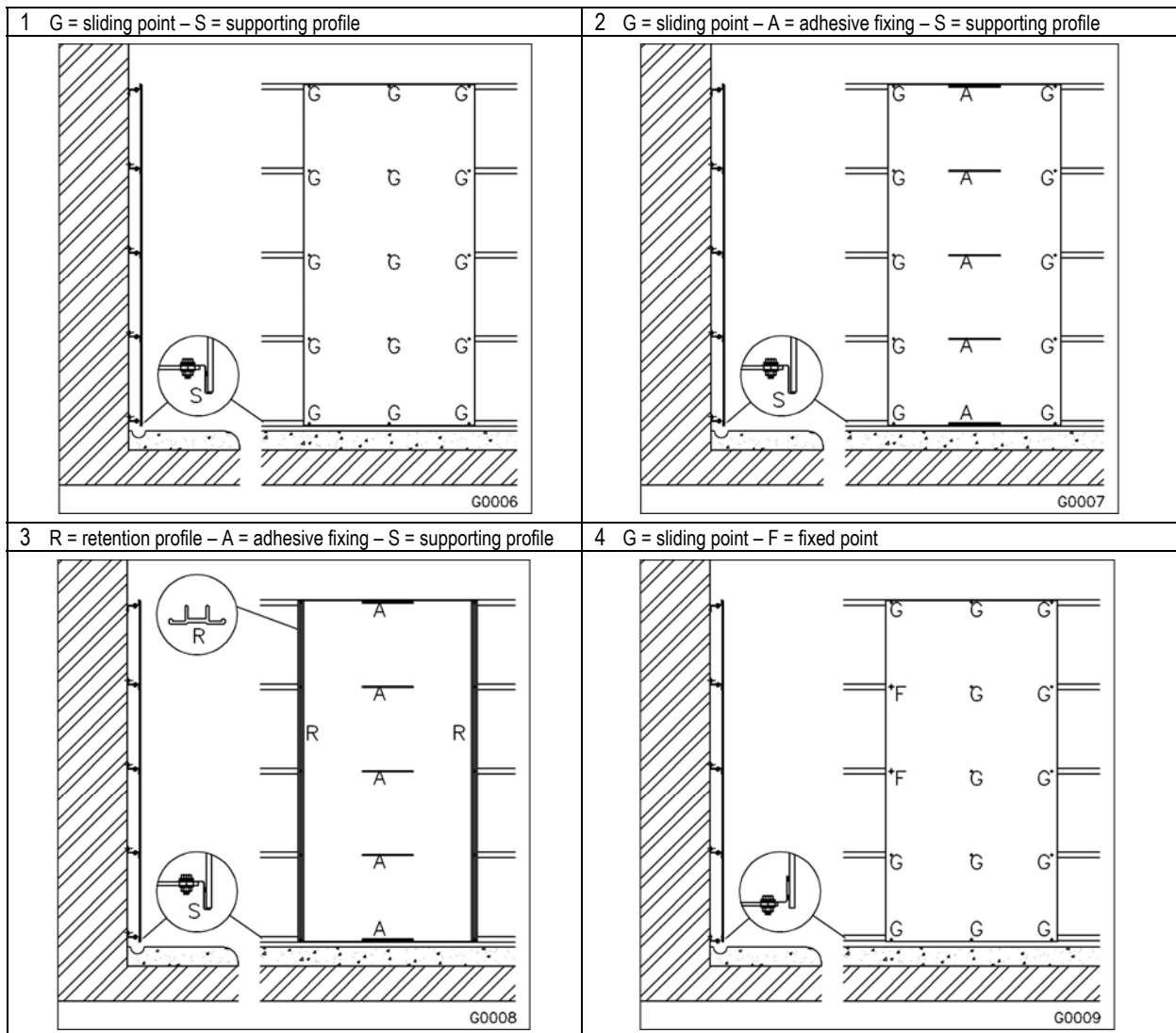
7 Fixing method of the tunnel lining sheet

Flat application (including curved application with radius >15 m)

The sheets are fixed to the supporting profile. The sheets can be fixed according to the following table.

		Center fixation	Edge fixation	Bottom fixation
1	GLASAL T	Rivet : sliding points ¹	Rivet : sliding points ¹	Support profile at bottom
2	GLASAL T	Glue ²	Rivet : sliding points ¹	Support profile at bottom
3	GLASAL T	Glue ²	Edge retention profile	Support profile at bottom
4	GLASAL T	Rivet: fixed/sliding points ³	Rivet: fixed /sliding points ³	-

Example:



¹ Sliding points are necessary to guarantee the free movement of the board.

² For the amount of glue: verify with glue supplier.

³ When no bottom support profile is used, 2 fixing points have to be fixed points; other points are sliding points.

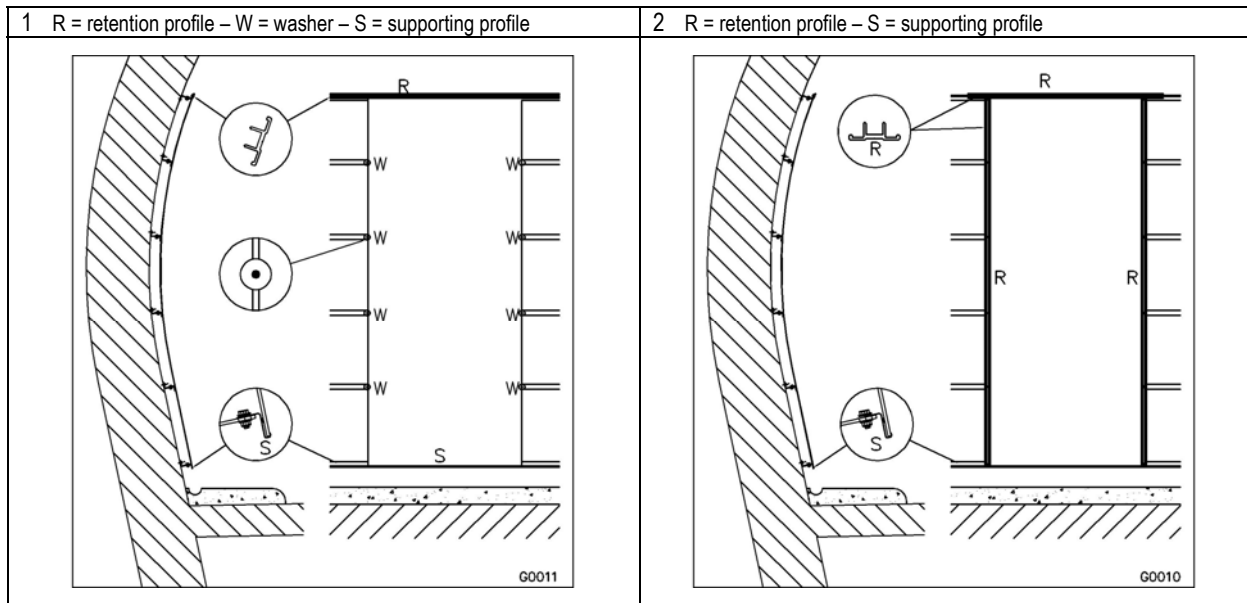
Curved application (radius <15 m)

GLASAL-TR sheets has to be bent on site. In the factory GLASAL-TR has been fitted with a metal strip (aluminium-zinc or stainless steel; width 100 mm) at the rear along the vertical edges. The sheets are often delivered flat and installed on site up against the support, which has been aligned in a bow shape. The sheets are placed into a horizontal carrier with an F-shape. Subsequently they are carefully bent and secured along the vertical edges by means of profiled joint strips or washers. Depending on wind loads it will not be necessary to use a vertical middle fixing¹.

The sheets can be fixed according to the following table.

		Center fixation	Edge fixation	Top fixation
1	GLASAL TR	-	Washer	Edge retention profile
2	GLASAL TR	-	Edge retention profile	Edge retention profile

Example:



¹ For center-to-center distances see page 15 of this document.

7.1. Fixing distances / bending radius

The following tables show the maximum real pressure load for various fixing distances, including a safety factor on strength and maximum bending conditions.

FLAT LINING GLASAL-T 8 mm R > 15m		Distance between fixing means on the same support profile (mm)		
		600	500	400
		Maximum real pressure load (N/m ²)		
Distance between fixing means on different support profile (mm)	600	663	850	1080
	500	850	1146	1463
	400	1080	1463	1875

FLAT LINING GLASAL-T 5 mm R > 15m		Distance between fixing means on the same support profile (mm)		
		600	500	400
		Maximum real pressure load (N/m ²)		
Distance between fixing means on different support profile (mm)	600	-	-	320
	500	-	339	457
	400	-	457	663

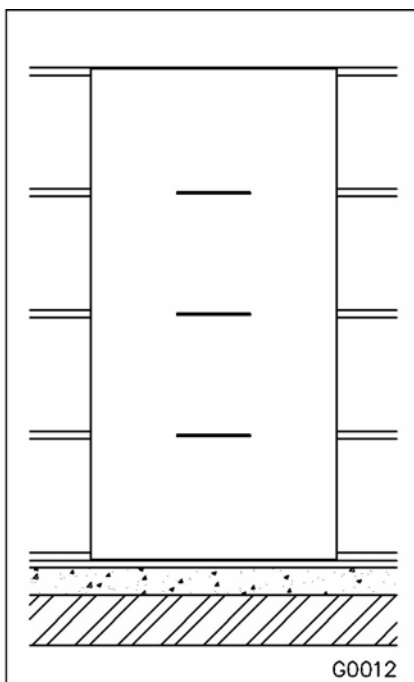
CURVED LINING	
GLASAL-TR 5 mm	5m ≤ R ≤ 15m
	Maximum real pressure load (N/m ²) to be assessed case by case

7.2 Invisible fixing through structural bonding (for flat application only)

Gluing must always be carried out in accordance with the instructions of the adhesive system's supplier and under his supervision and warranty conditions.

The steel profiles must be roughened and pre-treated with a degreasing agent and an adhesive primer. The tunnel-lining sheet must be cleaned and, if necessary, be pre-treated with an adhesive primer. A double-sided adhesive strip is applied as a support for the lining sheet during the setting period of the glue, and also serves to adjust the distance between the lining sheet and the steel profiles. The right amount of glue must be metered.

Gluing is only allowed as an alternative fixing for the visible centre fixation of the sheet. On the horizontal profiles the glue is applied according to the drawing below. For the amount of glue (number and length of glue) we refer to the last page of this document.



More information about bonding of Glasal-T can be obtained at EURO PANELS OVERSEAS NV's technical service.

7.3. Visible fixing with rivets

Fixing system with rivets

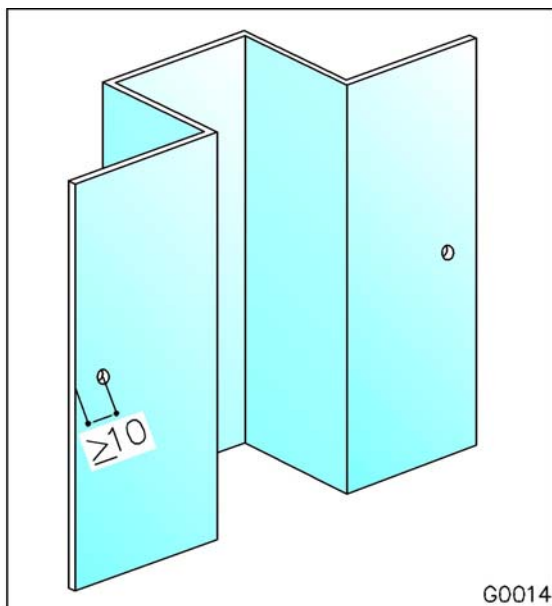
The tunnel panel is fixed with blind rivets with coloured heads. The blind rivets are inserted using an electric riveter.

Drilling through the steel profile must be done perpendicular to the panel and centralised to the panel perforations. For the pre-drilling of the steel profile a special centralising drill has to be used.

The blind rivets must be inserted perpendicular to the panel surface. The mouthpiece of the blind rivet machine may not damage the blind rivets.

The distance of the drilled hole to the edge of the steel profile may not be too small.

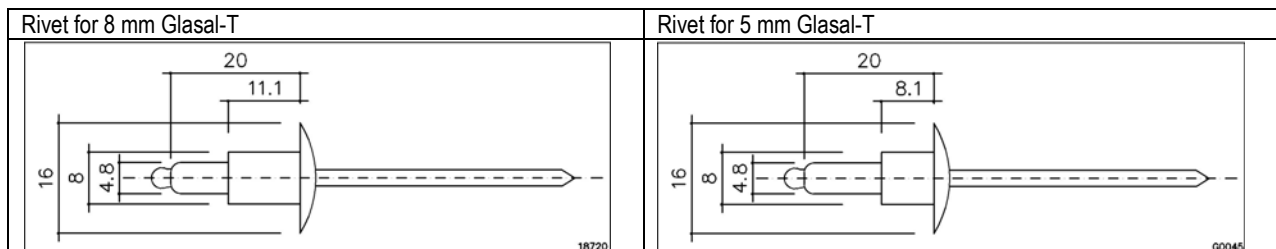
- minimum edge distance of drilled hole : 10 mm



Drilling shavings must be removed from the drilled hole so that they do not become stuck between the panel and the section. For the same reason, the bottom blind rivets are only fixed after all drilling shavings have been removed by gently knocking the panel.

The tunnel panel is fixed to the steel profile by means of stainless steel (quality A2, AISI 304) ASTRO blind rivets with colored head and a fixed (spot-welded) cylinder that prevent the blind rivet exercising too much tension on the panel. As a result, the free expansion of the panel is guaranteed.

The following design of the ASTRO blind rivet with cylinder must be respected.



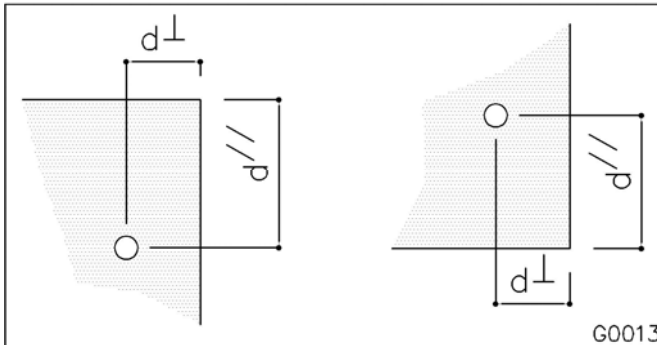
Depending on the supporting structure the panels are fixed with fixed point (F) and sliding points (G) to allow the free movement of the panel.

Holes diameters and edge distances

Holes for fixing points are pre-drilled in the panel.

- diameter of fixed fastening point : 8.3 mm
- diameter of sliding fastening point : 11 mm

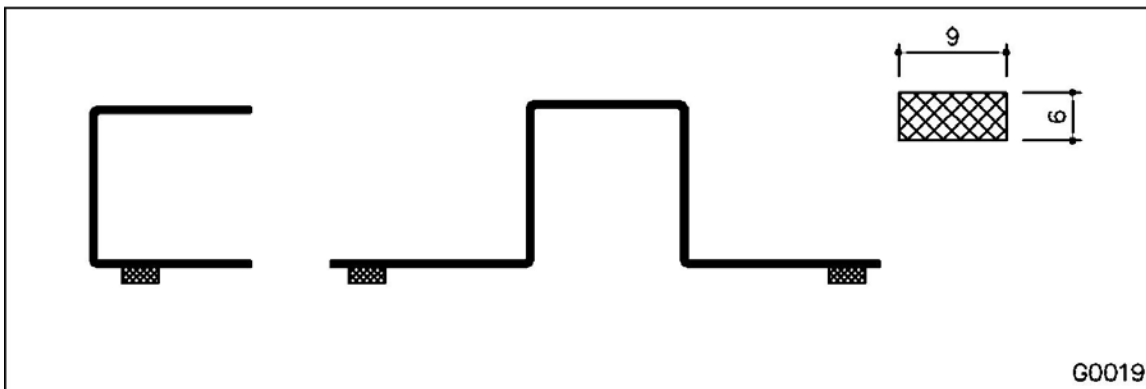
The following minimum and maximum edge distances in the panel must be respected. For the drilling of the holes a template should be used.



d^{\perp} : \perp to supporting profile	40-150
d^{\parallel} : \parallel to supporting profile	70-150

Self-adhesive foam strip

After mounting the steel supporting structure, self-adhesive foam strips are applied continuously on the steel profiles according to the diagram below. The foam strips can be compressed and serve in preventing panel vibration. The foam strips are applied to the edges of the profile to guide infiltrating rainwater downwards.

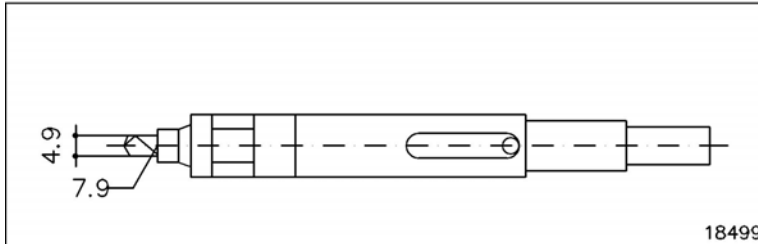


	Thickness foam strip	Foam strip compressable to
GLASAL-T 8 mm	6 mm	1 mm
GLASAL-T 5 mm	6 mm	1 mm

Centralising drill

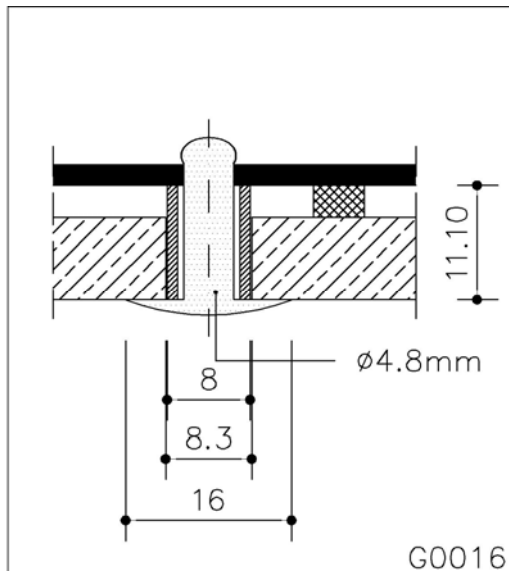
Once the panel is correctly positioned, the fixed points (F) are predrilled in the underlying steel profile using a special centralising drill.

- diameter for predrilling galvanised steel section : 4.9 mm

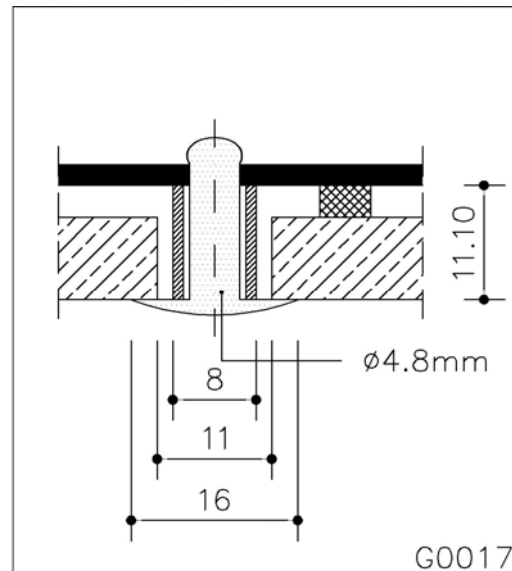


The tunnel panel is then fastened at the fixed points (F) with the ASTRO blind rivets with cylinder with the help of an electric riveter. Then the steel supporting structure is pre-drilled at the sliding points (G) with the same centralising drill. The tunnel panel is then further fixed using the ASTRO blind rivets with cylinder.

Fixed fastening point (F)



Sliding fastening point (G)



7.4. Fastening with joint fasteners

The lining sheet can also be fastened with joint fasteners on the supporting profiles behind the joints.

7.4.1. Omega-profiled joint strip

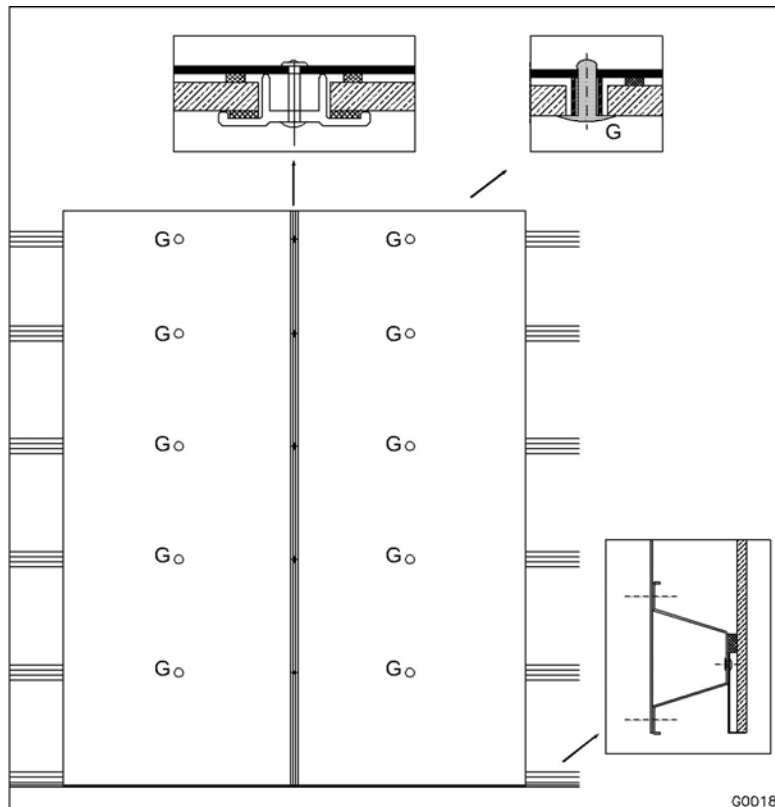
The lining sheet is fastened with vertical and/or horizontal joint profiles on the supporting profiles.

The lining sheet is supported by means of a bottom support profile.

An omega-profiled strip must be dimensioned in such a way that the sheets will not come under stress during their tightening or fastening. The foam strips at the back must also be used in the event of fastening by means of omega-profiled strips. The omega-profiled strip must be strong enough to hold the sheet during wind suction force and to deal with the span to which it is fastened.

The omega-profiled strip may not touch the surface of the lining sheet.

The omega-profiled strip depth is depending on the thickness of the lining sheet (5 mm or 8 mm)



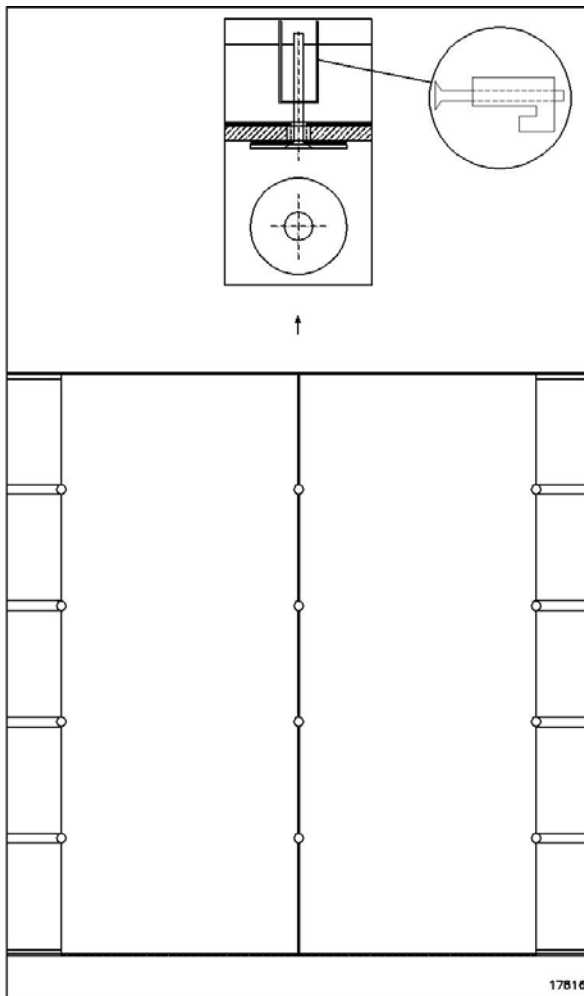
GLASAL-T 8 mm		GLASAL-T 5 mm	

7.4.2. Joint fastening with washers

The lining sheet is fastened with washers which are fixed on the supporting profiles in the joints between the panels.

This solution is only used in the event of a curved lining with GLASAL-TR.

GLASAL-T and GLASAL-TR

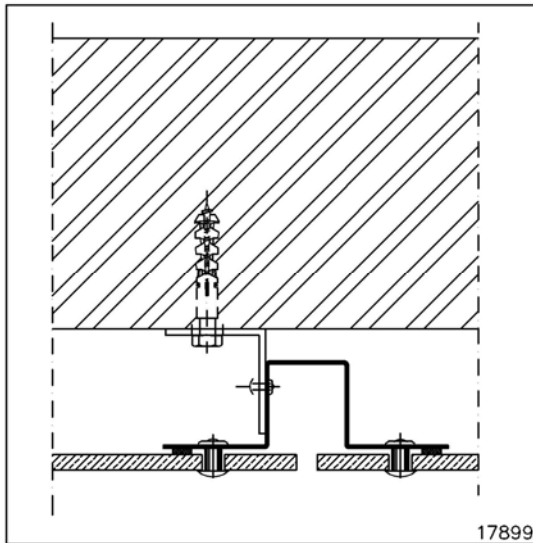


8 Joint finishing

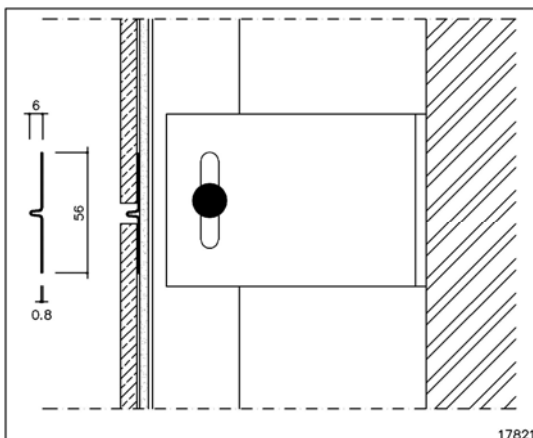
The tunnel sheets are fixed with open joints to allow the free movement of the panel.

- joint width (horizontally / vertically) : 10 mm
- maximum thickness of profiled joint strips behind sheets : 1 mm

The vertical joints at the supporting profiles can be blackened using black self-adhesive tape or a weather-resistant black coating. The joints without a profile lying behind can be left open.



If desired the horizontal joints can be finished by means of a black aluminium profiled joint strip. The part of the aluminium profiled joint strip behind the sheet must not be too thick, in order to avoid material stress. Should this be the case, the wings of the profiled joint strip must be so wide that the fastening of the sheet is realized through the profiled joint strip. The profiled joint strip is as long as the sheet. The vertical joints may not be interrupted so that infiltrating rainwater is guided downwards.



9 Accessories and tools

EURO PANELS OVERSEAS NV supplies the following accessories and tools.

ACCESSORIES		
Blind rivet with coloured head and ASTRO cylinder 11,1 mm (spacer)	RVS	4.8x20-K16
ASTRO self-adhesive foam strip for sealing	PE	6 x 9 mm
Profiled joint strip with rib for horizontal joint	aluminium black	2.5m
TOOLS		
Centralising drill 8,3/11mm		
Drill 8,3 mm		
Drill 11 mm		
Cutting blade Leitz Ø160 mm		
Cutting blade Leitz Ø190 mm		

10 Fixing specifications

BONDING (see application instruction of glue supplier)

11 Health and safety aspects

During the mechanical machining of panels, dust can be released which can irritate the airways and eyes. Apart from this, the inhalation of fine (respirable size) quartz containing dust, particularly when in high concentrations or over prolonged periods of time can lead to lung disease and an increased risk of lung cancer. Depending on the working conditions, adequate machinery with dust extraction and/or ventilation should be foreseen. For more ample information, please check the Safety Data Sheet based on 1907/2006/EC, article 31.

12 More information

Information about the GLASAL-T panels can be found in the EURO PANELS OVERSEAS NV product information sheets. Special cleaning advice and Material Safety Data Sheet are also available. They can be found on the website or can be obtained on demand by phone. Information about external suppliers can also be downloaded from the website.

These application instructions replace any previous editions. EURO PANELS OVERSEAS NV reserves the right to amend these instructions without prior notice. Readers should always satisfy themselves that they are referring to the most recent version of this document. No part of this text can be changed without permission of EURO PANELS OVERSEAS NV.

EURO PANELS OVERSEAS NV,

p.o. Central Services
 Kuiermansstraat 1
 B-1880 Kapelle-op-den-Bos
 Belgium
 Tel 0032 (0)15 71 73 80
 Fax 0032 (0)15 71 73 89
info@europanels.be
www.europanels.be



Registered office address: Bormstraat 24, B-2830 Willebroek - BELGIUM
 RPR 0 466 056 888, Mechelen – VAT BE 0 466 056 888 – Bank account nr. 482-9098051-96