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Floline curved metal panels



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I. Technical description

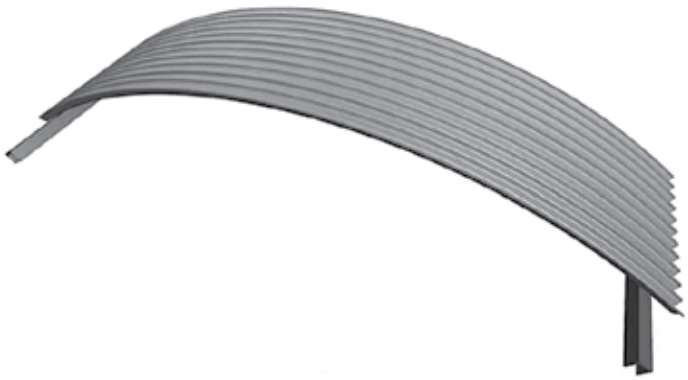
1. DESCRIPTION, STATIC FEATURES

Trapezoidal metal sheets, bent into a circular arch according to a patented technology, are used in curved systems (Fig. 1).

Bending trapezoidal sheets into a circular arch changes static behaviour of the elements: they are no longer girders subject to bending loads, but two-hinged arches.

An advantage of such system is the fact that structural elements of the identical profile and sheet thickness and subject to the same load can be used at much larger spans than traditional trapezoidal panels. The horizontal forces generated at the arch supports are usually compensated by stays.

Fig. 1. Curved metal panel



Curved panels can be used as single or double-layer structures.

In case of the double-layer system, the space between the load-bearing and roofing panel is filled with insulation material (most often mineral wool).

The insulation layer thickness is equal to the height of distance profiles.

2. RANGE OF CURVED PANELS

Florprofile offers curved metal panels made from two types of trapezoidal sheets.

Depending on the sheet thickness, the profiles can be bent to specified minimum radii (table 1 and table 2).

FLOLINE 40 panels with TS40 profiles

A1
Convex side*

A2
Concave side*

* used to specify the side covered with decorative coat

Fig. 2. FLOLINE 40

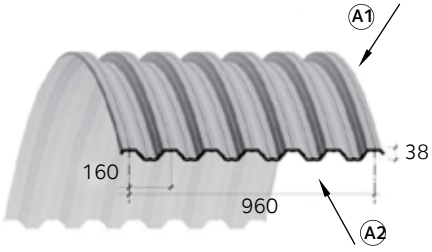


Table 1. FLOLINE 40 bending table

PANEL Profile type	Sheet thickness [mm]	Weight per 1 m^2	Minimum radius [m]
FLOLINE 40 construction width 960 mm	0,63	6,44	12,50
	0,75	7,67	9,50
	0,88	8,99	7,00
	1,00	10,22	5,00
	1,25	12,78	4,50
	1,50	15,33	

FLOLINE 70 panels with TR70 profiles

A1
Convex side*

A2
Concave side*

* used to specify the side covered with decorative coat

Fig. 3. FLOLINE 70

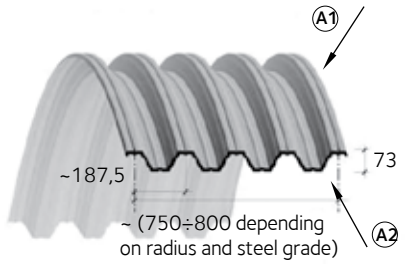


Table 2. FLOLINE 70 bending table

PANEL Profile type	Sheet thickness [mm]	Weight per 1 m²	Minimum radius [m]
FLOLINE 70 construction width 750 mm	0,75	9,82	14,50
	0,88	11,52	10,50
	1,00	13,09	8,00
	1,25	16,36	6,50
	1,50	19,63	6,00

3. MATERIALS

The usual input material is the FeE 320 G steel.

(yield strength at least 320 N/mm²) according to EN 10147.

Sheet thickness: 0.75, 0.88, 1.25 and 1.50 mm (also 0.63 mm for FLOLINE 40).

4. ANTICORROSION PROTECTION

Sheets are hot dip galvanized using the Sendzimir process. The zinc layer thickness is 275 g/m² according to EN 10147.

The panels are supplied with additional anticorrosion protection:

Standard:

thin-layer polyester 15 µm
protective varnish on the other side

or

polyester 25 µm
protective varnish on the other side

5. TYPICAL CROSS-SECTION PARAMETERS

Table 3 specifies cross-section parameters for curved panels made of trapezoidal sheets for the steel yield strength of f_y = 320 N/mm².

Table 3. Cross-section parameters for f_y=320 N/mm²

Sheet thickness	For stiffness and tension			For axial compression		For bending		
t_n mm	A_g cm²/m	I_g cm⁴/m	i_g cm	A_{ef} cm²/m	i_{ef} cm	I_{ef} cm	W_{cef} cm³/m	W_{sef} cm³/m
TR 40/160	yield strength f_y = 320 N/mm²							
0,75	8,87	20,49	1,52	7,47	1,54	20,46	10,62	10,61
0,88	10,49	24,24	1,52	9,21	1,53	24,20	12,66	12,66
1,00	11,99	27,70	1,52	10,83	1,53	27,66	14,56	14,56
1,25	15,11	34,91	1,52	14,27	1,53	34,87	18,43	18,43
1,50	18,23	42,12	1,52	17,76	1,52	42,07	22,29	22,28
TR 0/187,5	yield strength f_y = 320 N/mm²							
0,75	10,98	86,08	2,80	6,95	2,97	85,97	23,44	23,23
0,88	12,99	101,84	2,80	8,96	2,92	101,72	28,19	27,48
1,00	14,84	116,35	2,80	10,89	2,89	116,25	32,63	31,41
1,25	18,71	146,69	2,80	14,99	2,86	146,52	41,80	39,58
1,50	22,57	176,95	2,80	19,20	2,84	176,79	50,63	47,76

Legend:

A_g
gross cross-section

I_g
moment of inertia for gross cross-section

i_g
radius of inertia for gross cross-section

A_{ef}
effective cross-section

i_{ef}
radius of inertia for effective cross-section

I_{ef}
moment of inertia for effective cross-section

W_{cef}
strength factor for compressed zone in the upper strip

W_{sef}
strength factor for compressed zone in the lower strip

Table 4 specifies cross-section parameters for curved panels made of trapezoidal sheets for the steel yield strength of 280 N/mm^2.

Table 4. Cross-section parameters for f_y = 280 N/mm^2

Sheet thickness	For stiffness and tension			For axial compression		For bending		
t_n mm	A_g cm^2/m	I_g cm^4/m	i_g cm	A_{ef} cm^2/m	i_{ef} cm	I_{ef} cm	W_{cef} cm^3/m	W_{sef} cm^3/m
TR 40/160	yield strength f_y = 280 N/mm^2							
0,75	8,87	20,49	1,52	7,72	1,54	20,46	10,68	10,68
0,88	10,49	24,24	1,52	9,48	1,53	24,20	12,74	12,73
1,00	11,99	27,70	1,52	11,12	1,53	27,66	14,63	14,63
1,25	15,11	34,91	1,52	14,60	1,53	34,87	18,48	18,47
1,50	18,23	42,12	1,52	18,12	1,52	42,07	22,29	22,28
TR 0/187,5	yield strength f_y = 280 N/mm^2							
0,75	10,98	86,08	2,80	7,44	2,93	85,97	23,71	23,23
0,88	12,99	101,84	2,80	9,52	2,89	101,72	28,52	27,48
1,00	14,84	116,35	2,80	11,48	2,87	116,25	33,04	31,41
1,25	18,71	146,69	2,80	15,65	2,85	146,52	41,96	39,58
1,50	22,57	176,95	2,80	19,93	2,83	176,79	50,63	47,76

Legend:

A_g gross cross-section

I_g moment of inertia for gross cross-section

i_g radius of inertia for gross cross-section

A_{ef} effective cross-section

i_{ef} radius of inertia for effective cross-section

I_{ef} moment of inertia for effective cross-section

W_{cef} strength factor for compressed zone in the upper strip

W_{sef} strength factor for compressed zone in the lower strip

6. CALCULATION PRINCIPLES

As it has been already mentioned, the curved systems are calculated as single- or double-layer two-hinged arches.
In the latter case, both layers are made of concentric curved trapezoidal panels.

An adequate static diagram should be assumed in order to make the calculation using one of available programs for rigid-frame statics.

In a single-layer system, the arch is represented as a single polygon with adequate resolution, and in a double-layer system as two concentric polygons separated by radial bars which simulate trapezoidal distance profiles.

Due to a "straddling" position of the trapezoidal distance profile on the lower profile, the connection of radial bars to the inside layer is treated as rigid, but the connection with outer layer through a narrow top shelf is treated a articulated (figures 4 and 5).

Centre of gravity is assumed as the location of the trapezoidal panels. Location of distance bars is in their vertical axis. Spacing of distance profiles (a) is usually 1.25 – 1.50 m.

Fig. 4. Single-layer curved system

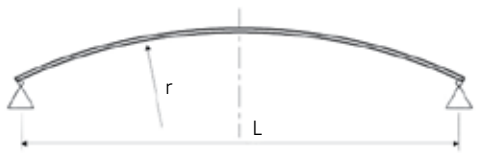
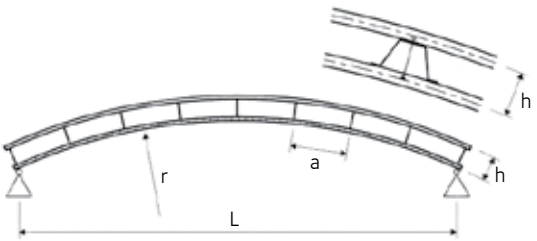


Fig. 5. Double-layer curved system

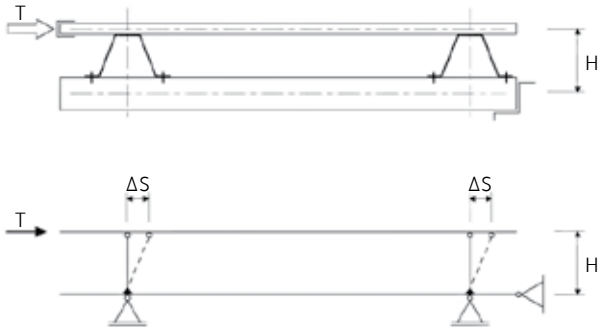


Cross-section of trapezoidal profile

From the statics point of view, the trapezoidal distance profiles used in double-layer systems are treated as bars with experimentally determined stiffness.

Moment of inertia I_H and limit shearing force T_H have been calculated on the basis of analysis of shearing forces T and corresponding strains ΔS determined experimentally during the tests carried out on the substitute diagram (Fig. 6).

Fig. 6. Substitute diagram for determination of distance profile stiffness



Typical values of distance trapezoidal profile

(Continuous profile used with FLOLINE 40 or FLOLINE 70 curved panels)

Note:
For load tests the distance profiles have been fastened to each shelf of the lower panel with one dia 4.8 mm blind rivet.

Tabela 5

Double-layer system		h [cm]	Distance profile	
Lower panel	Upper panel		I_{HK} [cm4/,]	T_{HK} [kN/m]
FLOLINE 40 – 0,88	FLOLINE 40 – 0,75	17,12	0,9	12,5
FLOLINE 40 – 1,25	FLOLINE 40 – 1,25	17,12	1,0	12,5
FLOLINE 70 – 1,50	FLOLINE 40 – 0,75	21,20	1,1	7,0
FLOLINE 70 – 1,50	FLOLINE 40 – 0,88	21,21	2,0	7,0
FLOLINE 70 – 0,88	FLOLINE 70 – 0,75	23,49	1,5	7,0
FLOLINE 70 – 1,50	FLOLINE 70 – 1,25	23,49	2,0	7,0

Legend:

h
Apparent length of the bar (trapezoidal profile height + distance between centres of gravity of lower and upper panels)

I_{HK}
Comparative, typical moment of inertia

T_{HK}
Transmitted shearing force

Typical cross-section values for combination of one arch with a plastic strip

Table 6

Double-layer system		H [cm]	Distance profile	
Lower panel	Upper panel		I_{HK} [cm4/,]	T_{HK} [kN/m]
FLOLINE 40 – 0,88	FLOLINE 40 – 0,75	18,10	1,17	11,23
FLOLINE 40 – 1,00	FLOLINE 40 – 0,75	18,10	1,17	14,58
FLOLINE 70 – 1,00	FLOLINE 40 – 0,75	21,40	1,36	9,84
FLOLINE 70 – 0,88	FLOLINE 70 – 0,75	24,70	2,60	10,97
FLOLINE 70 – 1,00	FLOLINE 70 – 0,75	24,70	2,60	12,18

Legenda:

H
Length of a substitute bar used in calculations.

I_{HK}
Comparative, typical moment of inertia of a substitute bar for limit load condition.

T_{HK}
Typical limit shearing force

Calculation of typical profile values and dimensioning of curved structures shall be performed according to EUROCODE 3.

Calculations of double-layer systems are usually carried out according to theory II.

Calculation according to the theory I is sufficient for single-layer systems if the stresses have been determined in accordance with the interactive formula given in DIN 18807, part 3, section, item 3.3.6.1.

After determination of internal forces in the assumed bar system, check if the following inequalities are satisfied for the cross sections with greatest effort.

$$N_D/N_{dD} + M/Md \leq 1$$

$$N_D/N_{dD} \cdot [1 + 0{,}5 \cdot a \cdot (1 - N_D/N_{dD})] + M/M_d \leq 1$$

Legend:

N_D
g-fold compression force

M
g-fold bending moment

a
is calculated according to DIN 18807, part 1, 4.2.3.6, depending on typical profile values and active widths on the profile cross section determined from the load conditions.

N_{dD}
maximum allowed compression force

M_d
maximum allowed compression force

**.....
Full cross section values are used to calculate deflection or determine stiffness in static calculations. .

Note:
Values presented in tables 5, 6, and 7 are results of laboratory tests carried out at the Karlsruhe University.

Table 7. Limit moments and normal forces

Curved panel type	Sheet thickness [mm]	Limit Normal Force [kN/m] N_{RK} - tension	N_{RK} - compression	Limit Moment M_{RK} [kNm/m]
FLOLINE 40 f_y = 280 N/mm²	0,75	248,36	217,84	2,94
	0,88	293,72	267,40	3,54
	1,00	335,72	313,60	4,10
	1,25	423,08	411,32	5,16
	1,50	510,44	510,44	6,23
FLOLINE 70 f_y = 280 N/mm²	0,75	309,40	219,80	6,57
	0,88	365,96	279,72	7,78
	1,00	418,04	336,00	8,89
	1,25	526,96	455,00	11,20
	1,50	635,88	576,52	13,52

7. LOAD CAPACITY OF CURVED STRUCTURES

Tables for trapezoidal sheets can be used to select appropriate panels. Tables include detailed data for given loads, static diagrams and spans.

In case of curved panels, it is not possible to compile such tables because the load capacity of curved panels depends not only on the span and load conditions, but to a large extent also on the ratio of the span to the radius of curvature.

With all intermediate radius values, the number of tables for various spans and loads would be infinite, which is practically impossible.

Calculations for this enormous number of cases indicate however that there is a certain span-to-radius ratio for which (or for values close to it), the optimum economic effect is achieved in terms of statics.

Design principles

- span-to-radius ratio should be equal or as close to 1:1 as possible;
- roof skylights, built without an additional supporting structure, should not exceed 10% of the roof area;
- ratio of curvature height to the span should be minimum 1:10;
- openings in the roof should be placed as close as possible to the top of the curvature;
- ratio of curvature length L to its radius R must not exceed 1.20.

The limit span values for single-layer curved systems calculated according to DIN 18800, DIN 18807, parts 1 – 3, and EUROCODE 3 may be helpful for indicative purposes.

Data

Building:

Enclosed hall with curved roof. Span-to-radius ratio = 1/1.

Eaves height = 6 metres above ground.

Loads:

Two snow load variants (0.75 kN/m^2 and 1,00 kN/m^2) plus deadweight of the panels.

Wind loads: basic wind speed 125 km/h. Terrain type: 2.

Hence, the wind load q = 0.57 kN/m^2.

Limit spans for a single-layer FLOLINE 40 curved system

Table 8. Limit spans

Sheet thickness	Snow load = 0,75 kN/m^2	Snow load = 1,00 kN/m^2
0,75 mm	8,75 m	7,75 m
1,00 mm	9,75 m	8,50 m
1,25 mm	10,50 m	9,5 m

Limit spans for a single-layer FLOLINE 70 curved system

Table 9. Limit spans

Sheet thickness	Snow load = 0,75 kN/m^2	Snow load = 1,00 kN/m^2
0,75 mm	13,50 m	12,25 m
1,00 mm	15,00 m	13,50 m
1,25 mm	16,50 m	15,00 m
1,50 mm	17,50 m	16,00 m

General remarks:

Limit spans specified above apply exclusively to the defined system geometry and assumed loads and standards.

In addition, please note that in many cases when smaller radii are used, the sheet thickness choice depends not only on statics conditions but also on the requirements of technology.

Limit spans for a double-layer curved system made with two FLOLINE 40 sheets. Distance between layers: 130 mm.

Table 10. Limit spans

Sheet thickness	Snow load = 0,75 kN/m^2	Snow load = 1,00 kN/m^2
0,88 + 0,75 mm	13,00 m [2] (16,00 m)	13,00 m [2] (15,00 m)
1,25 + 0,88 mm	14,25 m [2] (17,50 m)	14,25 m [2] (15,75 m)

Limit spans for a double-layer curved system made with two FLOLINE 70 sheets. Distance between layers: 130 mm.

Table 11. Limit spans

Sheet thickness	Snow load = 0,75 kN/m^2	Snow load = 1,00 kN/m^2
0,88 + 0,75 mm	20,00 m [1]	20,00 m [1]

General remarks:

1) Maximum span is not a result of statics conditions, but of limitations in terms of production, transport and installation.

2) The decisive factor was not static limit states of individual combinations of the profiles, but the results of stability tests during installation.

They were determined as follows:

We studied a combination of loads which consisted of the deadweight of the inner layer and the load concentrated at 1/4 of the arch (curvature) equal to 1.50 kN, assuming the safety factor g_F = 1.35 and g_M = 1.1 only for the inner layer. This was used to determine the limit span.

The fact that during the installation of the first layer, when riveting is not yet finished, the system is relatively very sensitive.

The spans which would be achievable for the whole, ready structure arte given in parentheses.

8. OTHER SYSTEM ELEMENTS

8.1. Supports, stays

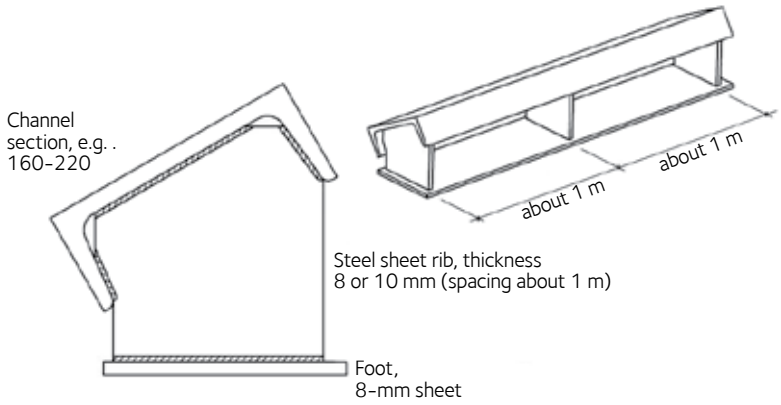
The best supports for curved metal panels are customized welded steel profiles with a upper shelf at the angle corresponding to the curvature inclination.

Such profiles are made from rolled sections (most frequently 160-200 mm channels and 8-10 mm steel sheets for ribbing and base).

The most often used rib spacing is about 1 metre.

Stays are designed as steel bars of tubes with tensioning adjustment (drawbolts, etc.) and the cross sections are dimensioned for tension.

Fig. 7 - Typical support element for curved metal panels



8.2. Clamping plates

The curved trapezoidal panels are fastened to the supports with galvanized steel clamping plates, using self-vulcanizing or EPDM washers and centrally located screw with a washer and nut.

It is recommended to use the 8-mm plates of the following dimensions:

- 40 x 50 mm with M10 fastening bolts for FLOLINE 40 curved panels
- 50 x 50 mm with M16 fastening bolts for FLOLINE 70 curved panels

Minimum bolts class: 4.6.

Experimentally determined limit loads transmitted by the above-mentioned clamping connections are presented in Table 12.

Note:

Force values marked with *) relate to clamp fastening in every other depression; all other to fastening in all depressions of the curved panel.

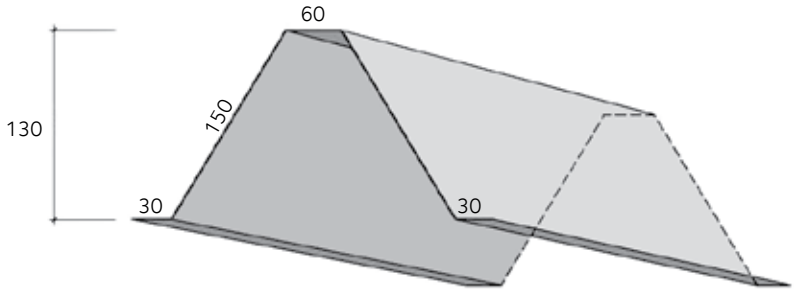
Table 12. Limit loads for clamping connections

CURVED PANEL TYPE	M16 BOLT (FLOLINE 70) or M10 BOLT (FLOLINE 40) TIGHTENING TORQUE Ma [Nm]	FLAT CLAMPING PLATE Washer yes/no	AVERAGE CRITICAL FORCE for 2 clamping points F_{GK} [kN]	AVERAGE CRITICAL FORCE for 1 linear metre $F_{GK/m}$ [kN/m]
FLOLINE 70	100	nie	42,81	85,62
FLOLINE 40	300	nie	53,33	106,66
FLOLINE 40	33	nie	31,86	99,56
FLOLINE 40	33	nie	31,86	49,78 *)
FLOLINE 40	33	tak	22,88	71,50
FLOLINE 40	33	tak	22,88	35,75 *)

8.3. Distance structures

- Galvanized trapezoid profiles; thickness 1.00, 1.25 or 1.50 mm (Fig. 8)
- Profile height: 130 – 250 mm.
- Profile length: up to 6000 mm.
- Apply thermal insulation tape (e.g. 40 x 7 mm) on the upper shelf of the distance profile to limit the thermal bridge effect.

Fig. 8 Typical trapezoid profile with the height of 130 mm



8.4. Curved panels for gable edges

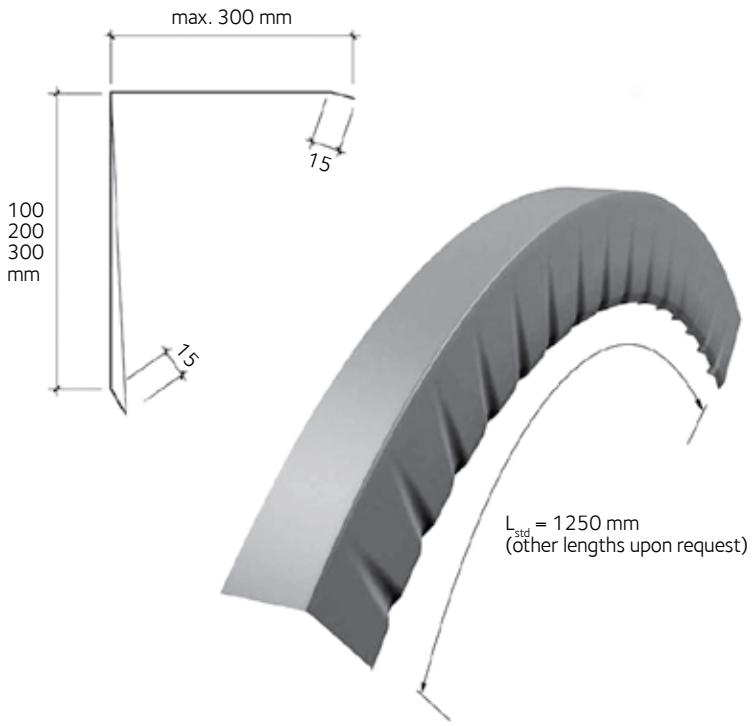
Angular curved panels are used for covering of gable edges. They are made in three standard heights (100, 200 and 300 mm).

Arch bending is achieved by pressing creases in the vertical arm of the panel.

Spacing of creases determines the radius of curvature.

Minimum bending radius of such panels is 3.0 m, and the maximum length measured along the arc is 5 m.

Fig. 8 - Curved panels for gable edges - section

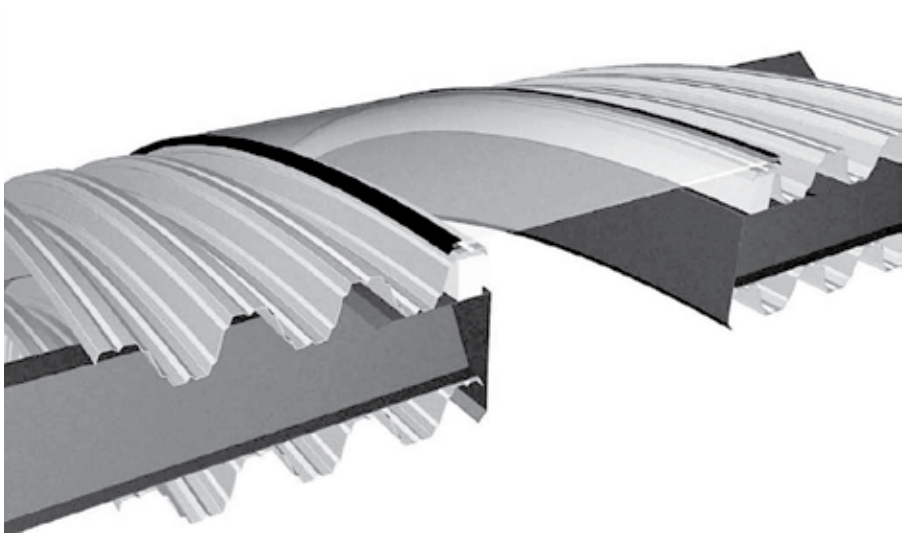


8.5. Skylights

Standard solution for skylights are arch-shaped, polycarbonate triple glazed units. Typical solution is presented on the drawings of structural details.

Internal skylight frames are of the same type as the curved panels for gable edges (see section 8.4 above).

Fig. 10 - A model of integrated skylights



II. Installation instructions

1. Transport

Trapezoid curved panels with large radius and limited length (up to about 12 metres) are transported traditionally, using small supports in the middle of the span.

When transporting long, large-span panels pay attention to the total vehicle height which must not exceed 4.2 m. Choose a correct transport route to arrive safely at the construction site.

Check also the site for adequate conditions in terms of transport height.

2. Unloading

Packages of curved panels below 3.000 kg in weight are unloaded just like ordinary straight trapezoid panels, using belts of high lifting capacity.

The belts are threaded under the pallets adjacent to the package centre. Length of the belts should ensure that the angle at the lifting sling (hook) is acute. This will minimize horizontal forces which could move the pallets. Lighter packages (up to 2.000 kg) consisting of shorter panels can be handled with a forklift.

3. Storage

Store the curved panel packages as close as possible to the place of installation.

Standard packages contain about 20 curved panels, which gives the total weight of 2.000 to 3.500 kg (max).

In some cases, it is advantageous to have a special arrangement of panels in packages. The manufacturer offers customized packages of various sizes for an additional fee.

The storage area should be levelled and the package edges should be placed on wooden sleepers. The centres of the packages should be supported by trestles of suitable height.

If you intend to store the panels for longer than a few days, cover the packages tightly with a film to protect them against wind and weather conditions.

4. Installation team

The installation team should consist of minimum four people: at least three people on the roof and one on the ground.

The qualifications and experience used for installing ordinary straight panels are absolutely sufficient in case of curved panels. Installation tools and instruments are also the same.

Because of necessary finishing works with fittings and flashing, it is advisable that at least one member of the team is a tinsmith.

5. Installation specifications

Correct installation requires detailed descriptions and specifications as well as related scopes of work.

Always mark the starting point and the direction in which the panels will be installed.

6. Installation of curved panels – single-layer systems

Before starting installation works, check if the supporting structures are complete and if they are durably fastened to the load-bearing parts of the building.

Usually, gutter brackets, bails, outlets, etc. are installed along with the curved panels. Make sure these elements are ready before starting the work.

Very carefully place and fasten the first curved panel, paying attention to the plumb line. This is easier if the gable wall is already built.

Lift the panels with a mobile crane with lifting capacity of at least 500 kg at maximum outreach.

Spare lifting capacity facilitates work for the installation team and speeds up the installation. Put barriers on the roof edges to protect the roofers from falling.

Protections should conform to the OH&S regulations on work at heights.

DESCRIPTION OF THE INSTALLATION

The curved panels are lifted and put in place using an installation fork in which the panel is clamped to prevent its falling caused by a gust of wind.

The starting point direction of installation should be specified in the design. When the panel is in a plumb line and the fixing screws are tightened, release clamps on the installation fork. You can walk on the curved panel using rope ladders fastened on both ends. Put the second curved panel in place, fasten it to the supports and make the connection on the overlap, starting from the top of the curve, using connectors spaced at maximum 500 mm.

In case of single-layer roofs, the connectors should be stainless steel self-drilling screws with self-vulcanizing washers.

Follow the same procedure to install next panels.

After installing 3 – max. 5 panels, check the installation correctness, plumb line, etc.

Continue the installation to the end of the roof or the place for skylight or another element.

The opening in the roof (e.g. for skylights) are made by simply skipping one curved panel.

Then, continue the installation works as described above.

Before installing the skylights (usually polycarbonate, two-web panels), put in transversal connecting profiles under the skylight strip, spaced at minimum 1.50 m. The profiles will prevent sideways parting of curved panels under the load of the skylight. The final load-bearing capacity of the curved roof is achieved when all screws on the supports are tightened, all longitudinal connections are made, and the stay is tensioned (if provided for in the static diagram).

7. Installation of curved panels – double-layer systems

Follow the procedure described in section 6 above to install the lower layer of the roof.

The overlap connections of the panels can be made with rivets.

After riveting the inside (lower) layer, seal the overlap and the rivet heads with the sealing tape to make the inner layer a tight vapour barrier.

Then, install the distance structure.

7. Installation of curved panels – double-layer systems

There are two types of distance elements:

- **Type A** involves using a continuous distance profile with a cross-section of a single trapezoid which enables achieving k = 0.51 W/m²K for the whole structure.
- **Type B**, comprising single trapezoid arches with a continuous plastic (or wooden) strip enables achieving k = 0.38 W/m²K for the entire structure.

Put the distance elements, starting from the supports towards the gable end, spaced at 1.25 – 1.50 m.

Installation of type A distance elements:

- Before lifting to the roof, fill the trapezoid distance elements with insulation material (mineral wool) and secure with adhesive tape.
- Lift such prepared distance profiles to the roof and fix them with rivets (both feet of the profile) to each upper shelf of the inner roof layer.
- Place a 50x3 m insulation strip on the upper shelf of the distance profiles.

Installation of type B distance elements:

- Use rivets to fasten trapezoid arches to each upper shelf of the FLOLINE 70 curved panel, or possibly to every other shelf in the inner layer is made of the FLOLINE 40 panels.
- Fasten a continuous plastic profile (or a wooden square-sawn element) to the arches, using countersunk self-drilling screws.
- Then, fill the inside of arches with insulation material, place the thermal insulation and install the curved panels of the outer layer.

The detailed guidelines for using type A or type B should be included in the installation design.

After fastening the distance profiles, install the curved panels of the outer layer.

Use the mobile crane and installation fork to lift the panels to the roof in smaller packages of 5 – 10 pieces. Place the panels on the distance elements at the distance corresponding to the number of pieces multiplied by the construction width of the panels.

Insulation materials (mats, panels, rolls) are also lifted to the roof by a crane and then placed evenly on the surface of the roof.

Later, you will need the mobile crane only when the outer layer is made from heavy FLOLINE 70 panels.

Generally, FLOLINE 40 panels are used to make the outer layer and further works are carried out manually.

Take the curved panels for the outer layer from the stack, place them onto the roof part covered with the insulation material and fix to the distance elements using stainless steel, self-drilling screws with self-vulcanizing washers.

Rules of fastening the outer layer panels:

- FLOLINE 40 outer curved panels are fastened to the distance elements nearest to the eaves line and in the gable line at each lower shelf. On all other distance elements – to every other lower shelf.
- FLOLINE 70 outer curved panels are fastened to all distance elements, at each lower shelf.
- Gutters and other flashing are usually installed simultaneously with outer roof layer.

The last operation is installing the skylights with flashing.

Final remark: Always use the necessary protections required in the OH&S regulations.

8.1. Single-layer curved roof

Fastening to the supports with clamping plates and M16 or M10 screws (class 4.6).:

- FLOLINE 70 panels – at each lower shelf, screw diameter: 16 mm;
- FLOLINE 40 panels – depending on the load, to the supports:
  - o for load < 19 kN per 1 metre – fasten at every other upper shelf;
  - o for loads ≥ 19 kN per 1 metre – fasten at every upper shelf;
  - o screw diameter: 10 mm.

Longitudinal overlap connections of curved panels: maximum spacing 500 mm, stainless steel, self-drilling screws with self-vulcanizing washers.

Screw length: minimum 25 mm, screw diameter: 5.5 mm.

8.2. Double-layer curved roof

Fastening to supports is identical as in case of single-layer roofs.
Longitudinal connections of the inner layer – 4.8/10 mm blind rivets, maximum spacing 500 mm.

Overlap sealing – adhesive tapes with vapour deposited aluminium, minimum width 50 mm, totally covering the overlap and the rivet holes.

Continuous or arch distance profiles – fastening to the inner roof layer:

- from FLOLINE 70 profiles: at each upper shelf;
- from FLOLINE 40 profiles: at every other upper shelf;

Connectors – rivets with a single-side closing – 4.8/10 mm

Insulation of thermal bridges:

- continuous distance profiles – foam rubber adhesive tape, 50 x 23 mm;
- arch distance profiles – battens/strips fastened with 5.5x60 mm countersunk self-drilling screws.

Fastening of outer curved panels :

- FLOLINE 70 panels – at each upper shelf;
- FLOLINE 40 panels – at the eaves and gable, and the remaining at every other upper shelf. Stainless steel, self-drilling screws with self-vulcanizing (neoprene) washers. Length at least 25 mm (35 mm for arch distance elements). Diameter: 5.5 mm.

If the roofing requires enhanced fire rating, do not use rivets made of aluminium or alloys with melting point lower then steel.

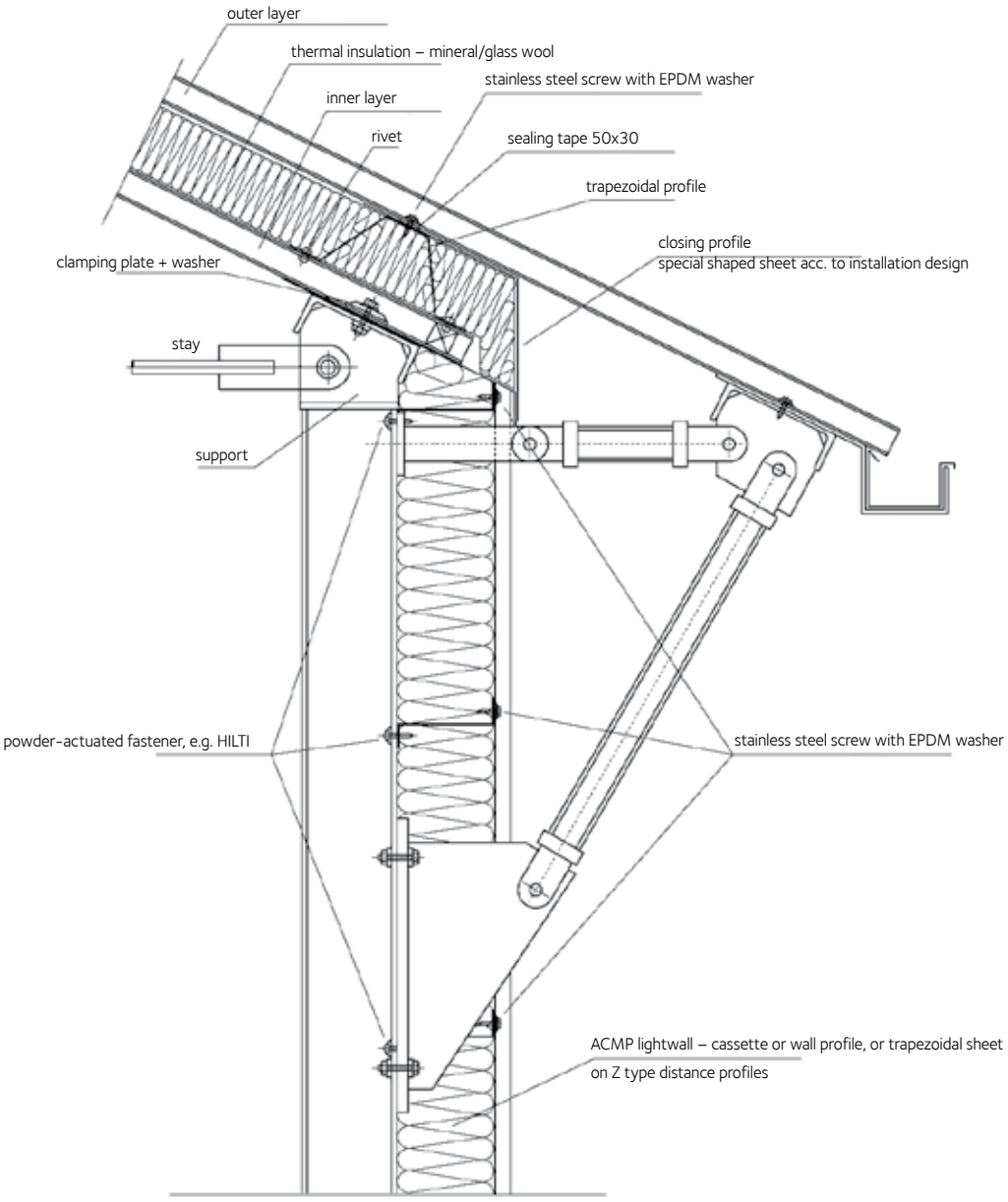
8.3. Flashing

- **roof** – fastened with stainless steel, self-drilling screws with self-vulcanizing washers. Diameter 5.5 mm, length minimum 25 mm, maximum screw spacing 333 mm (3 screws per 1 metre).
- **walls** – fastened with aluminium or stainless alloy 4.8/10 mm blind rivets; maximum rivet spacing 333 mm (3 rivets per 1 metre).

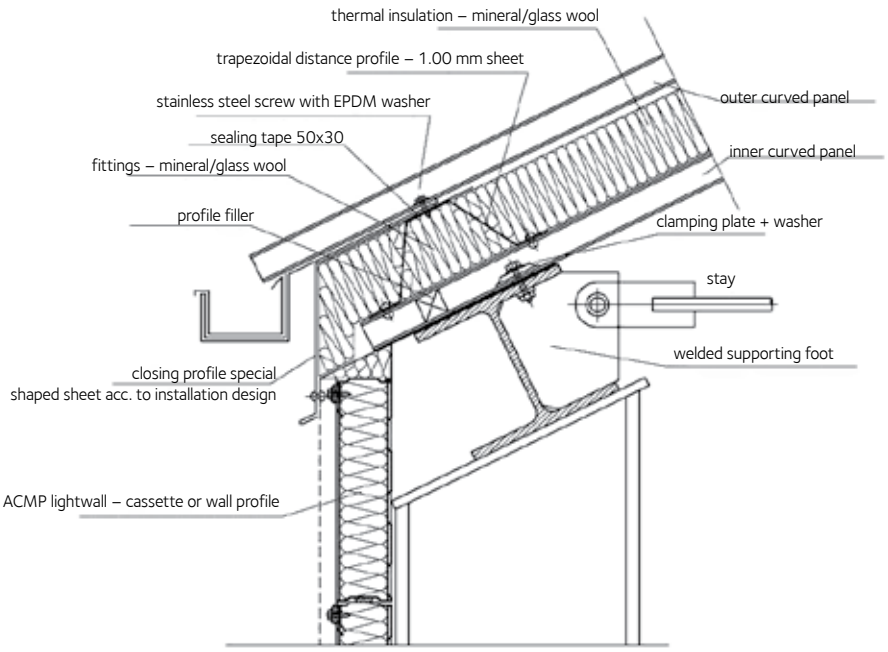
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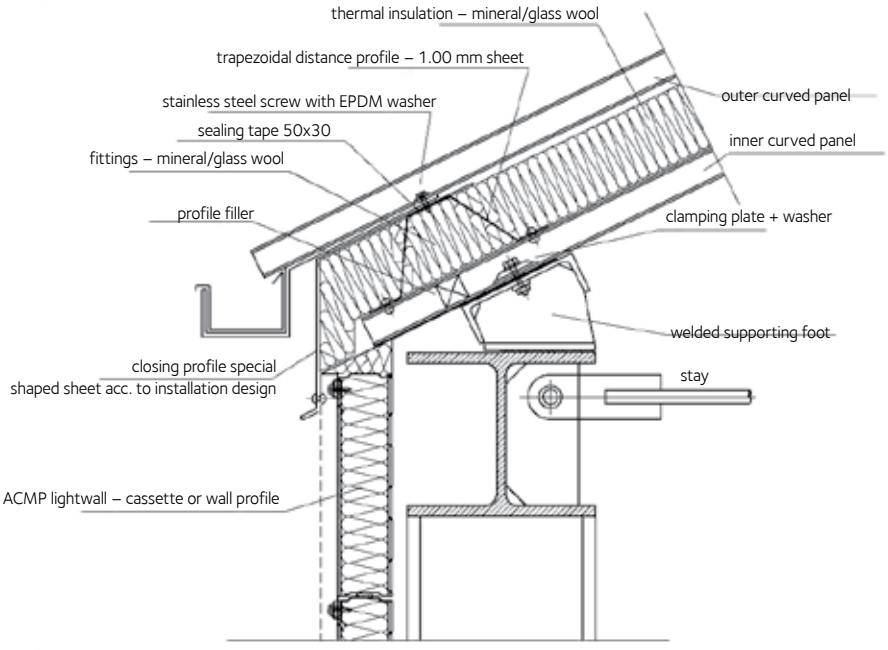
1. Curved roof
Eaves with projection



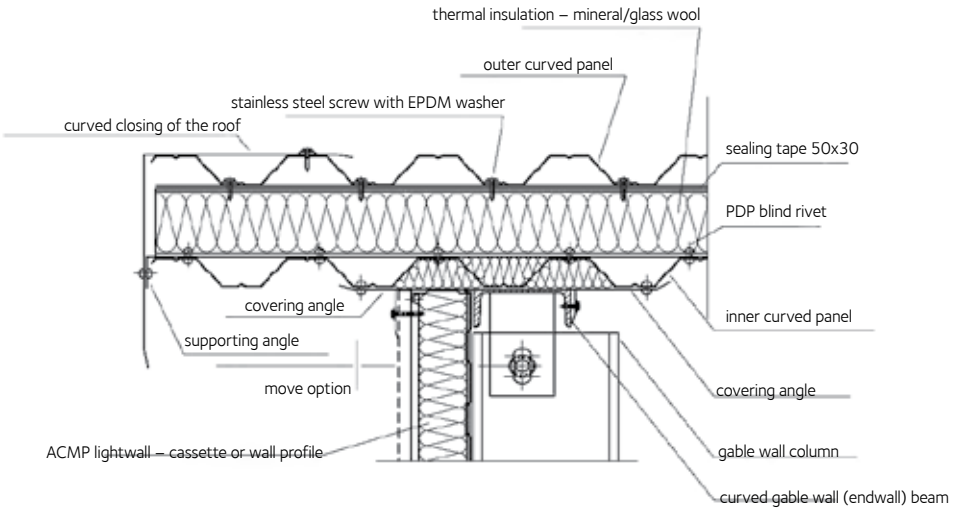
2. Curved roof
Eaves at the support on steel structure Version I



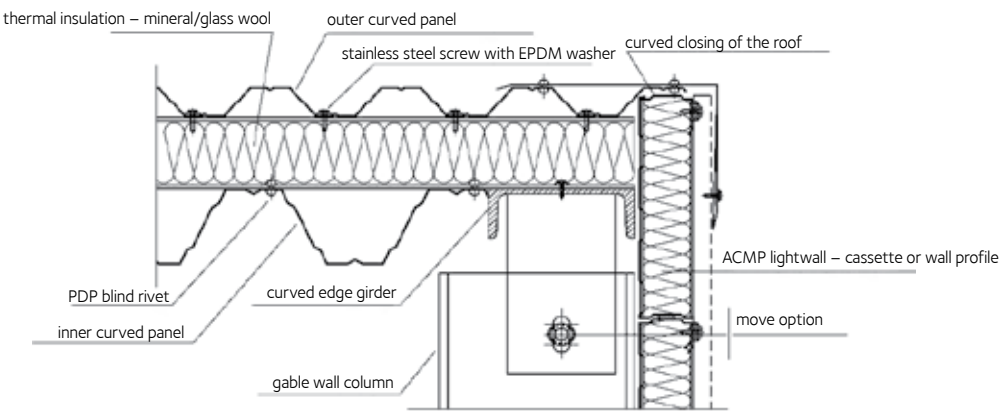
3. Curved roof
Eaves at the support on steel structure Version II



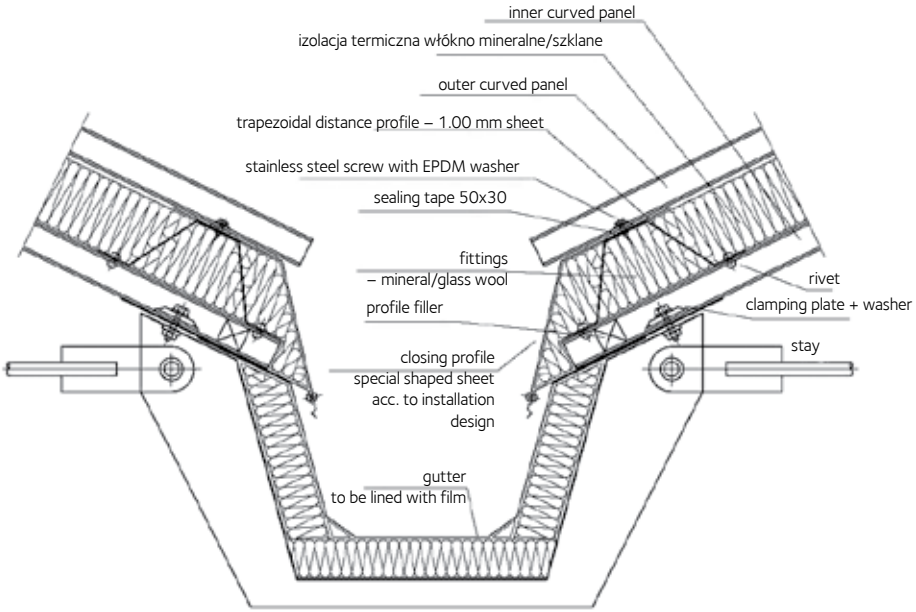
4. Gable cover with projection



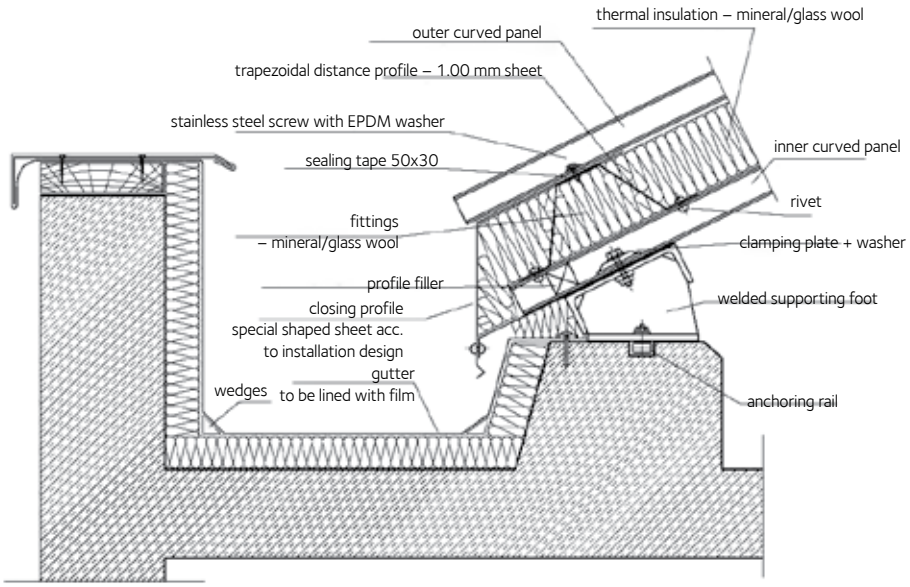
5. Gable cover



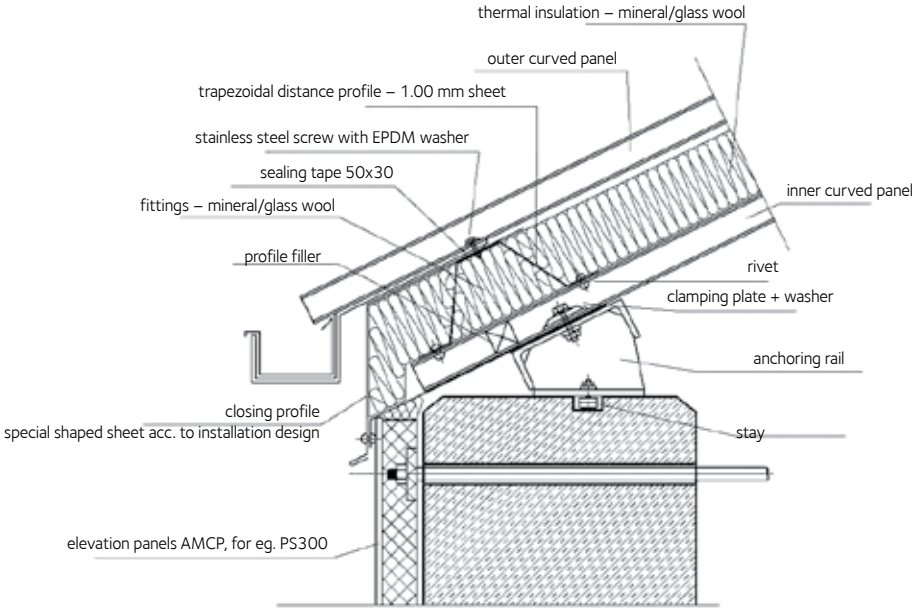
6. Curved roof
Valley gutter (steel)



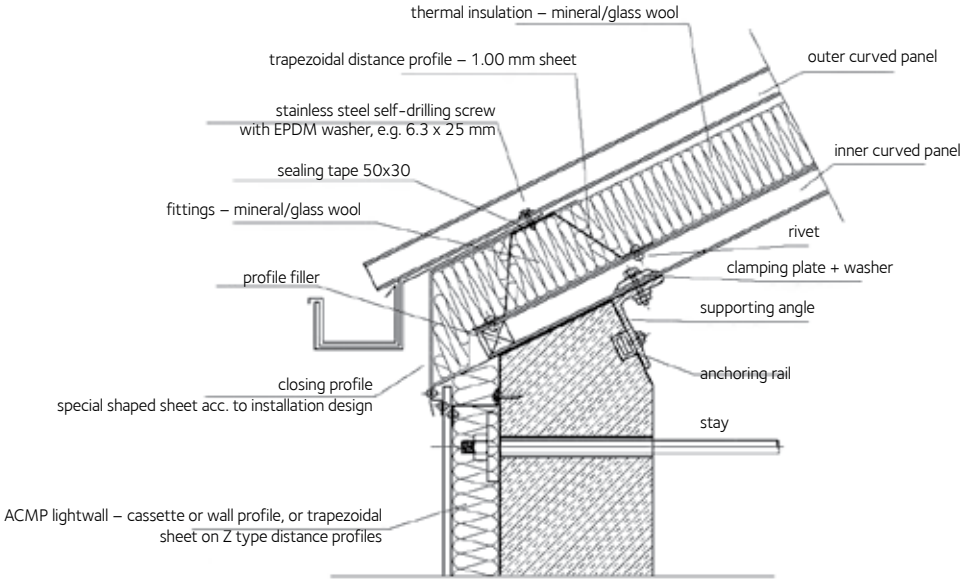
7. Curved roof
Eaves supported on the ceiling slab



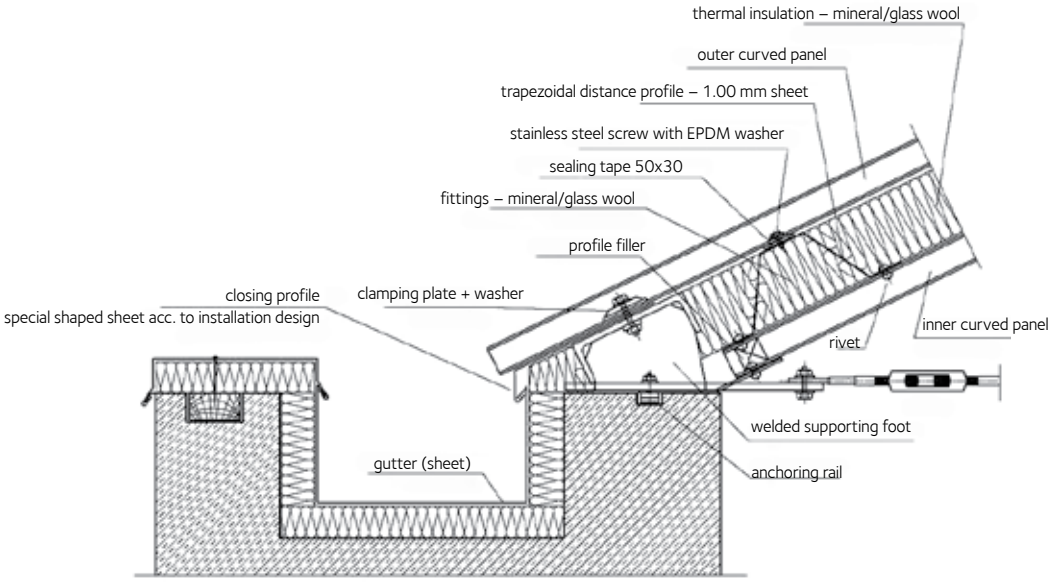
8. Curved roof
Eaves supported on concrete structure Version I



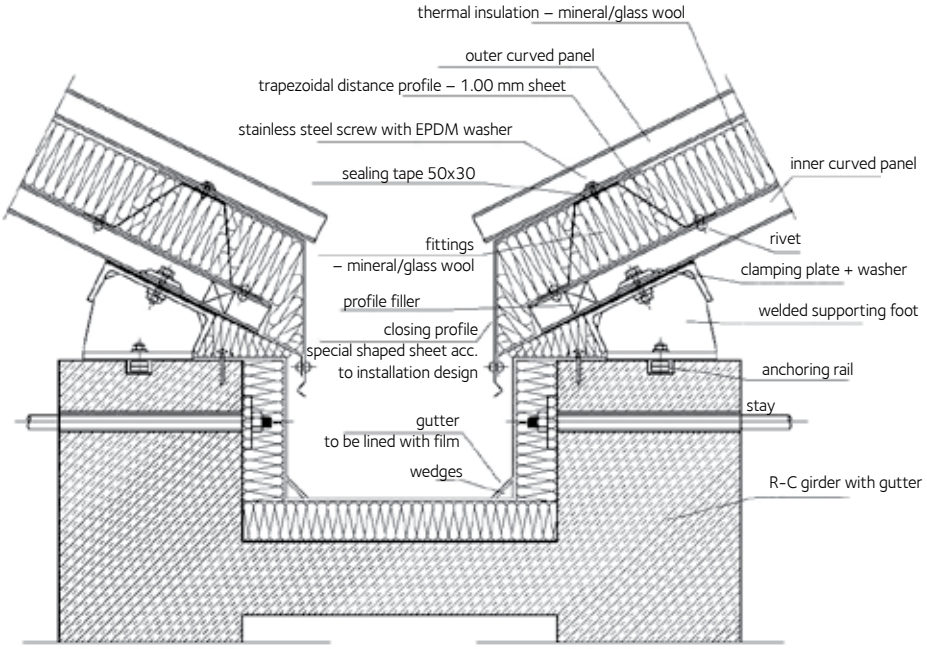
9. Curved roof
Eaves supported on concrete structure Version II



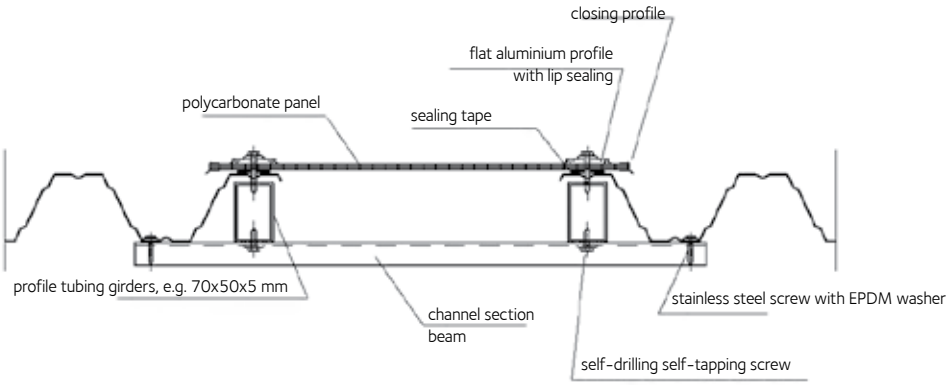
10. Curved roof
Eaves supported on concrete structure Version III



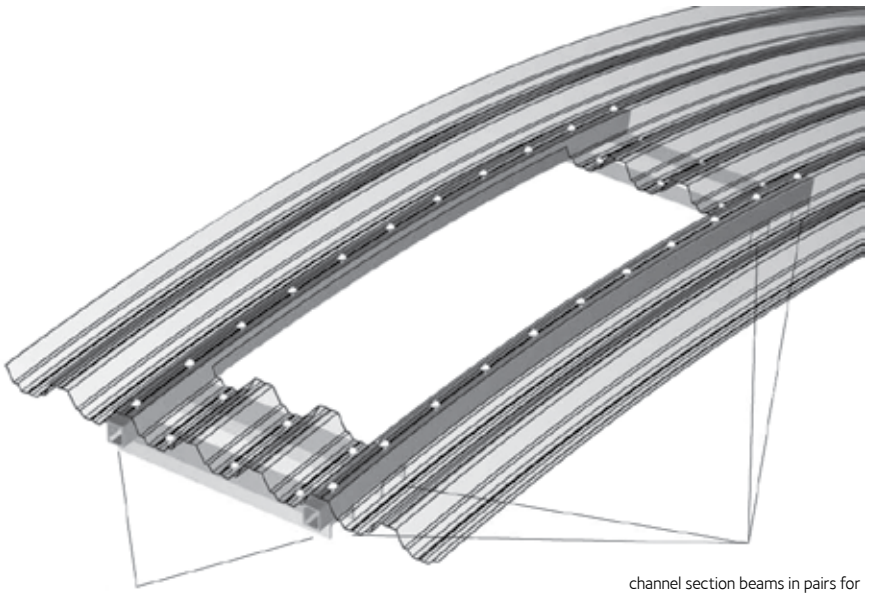
11. Curved roof
Eaves supported on concrete structure Version IV



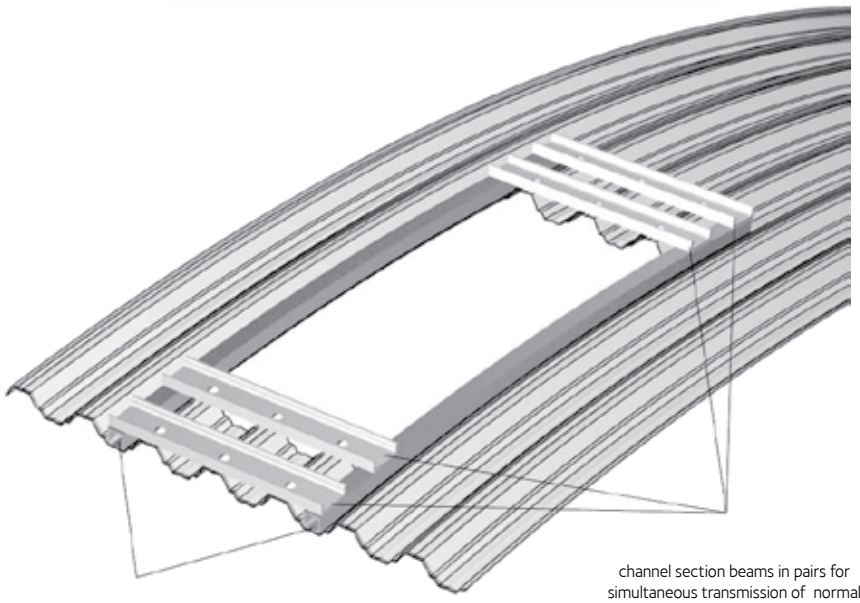
12. Skylight in a single-layer roof



13. Frame – trimmer
Single-layer roof



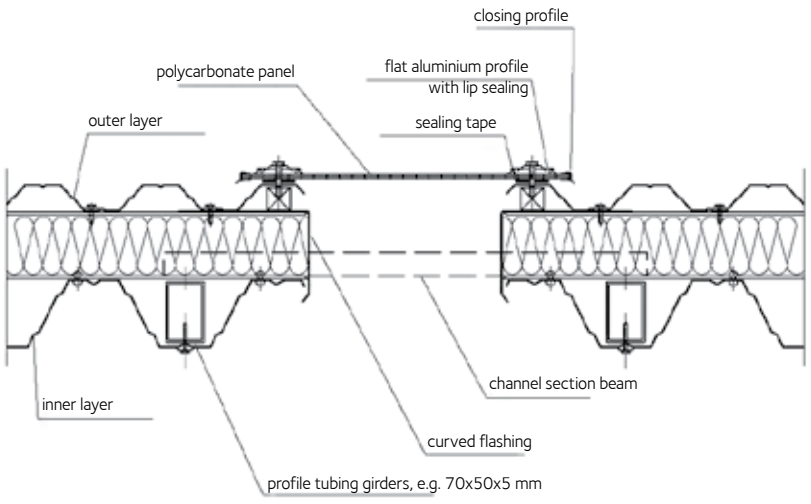
14. Frame – trimmer
Double-layer roof



profile tubing girders

channel section beams in pairs for simultaneous transmission of normal forces and moments

15. Skylight in a double-layer roof



IV. Reference developments

PKL (Polish Aerial Tramways) – Góra Żar (Żar Hill)







Curved metal panels – Ukraine



Curved metal panels – Ukraine



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