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Planning documentation for the bearing system
Pitched roof system for solar modules

Project: Mattias_Andersson_36x300Wp_house

Module type: 270 poly 1670 x 1006 mm

By order

Anderssson_Mattias

September 2018

Project planning and auto-calculation

Version 4.15.0.0

Plant details

Date	14/09/2018
Customer	Anderssson_Mattias
Order	

Module selection

Manufacturer	Heckert
Module	270 poly
Peak power	270 W
Height	1,670 mm
Width	1,006 mm
Thickness	38 mm
Framing	Framed

Module arrangement

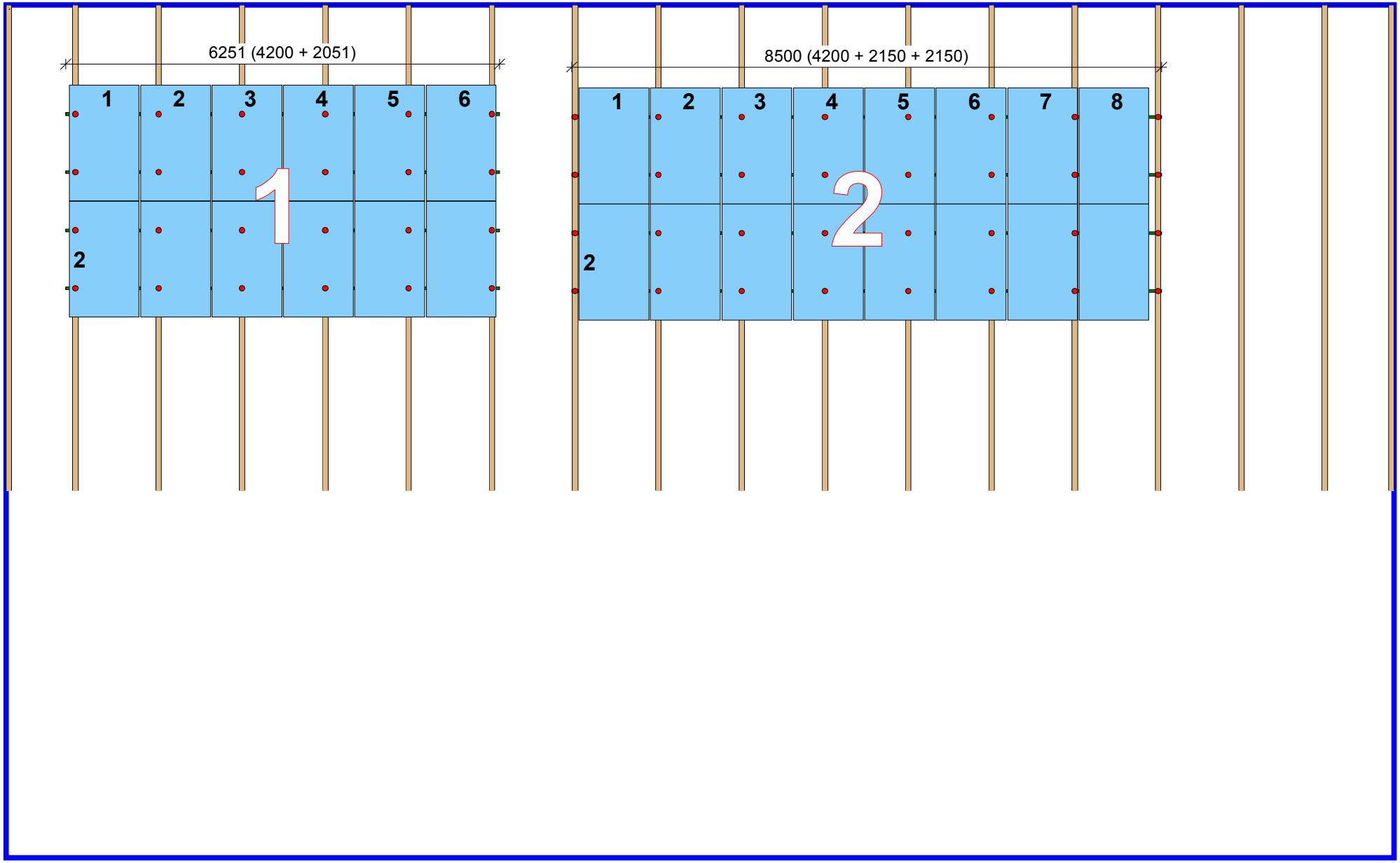
Number of modules	28
Selected support distance	1,200 mm
Cantilever	400 mm

Basic configuration

System selection	
Module-bearing rail	Solo
Clamp type	Rapid16
Fastening	Rapid 2+ Max

Results: Plant details

Peak power	7.56 kW


6251 (4200 + 2051)
1
2
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8500 (4200 + 2150 + 2150)
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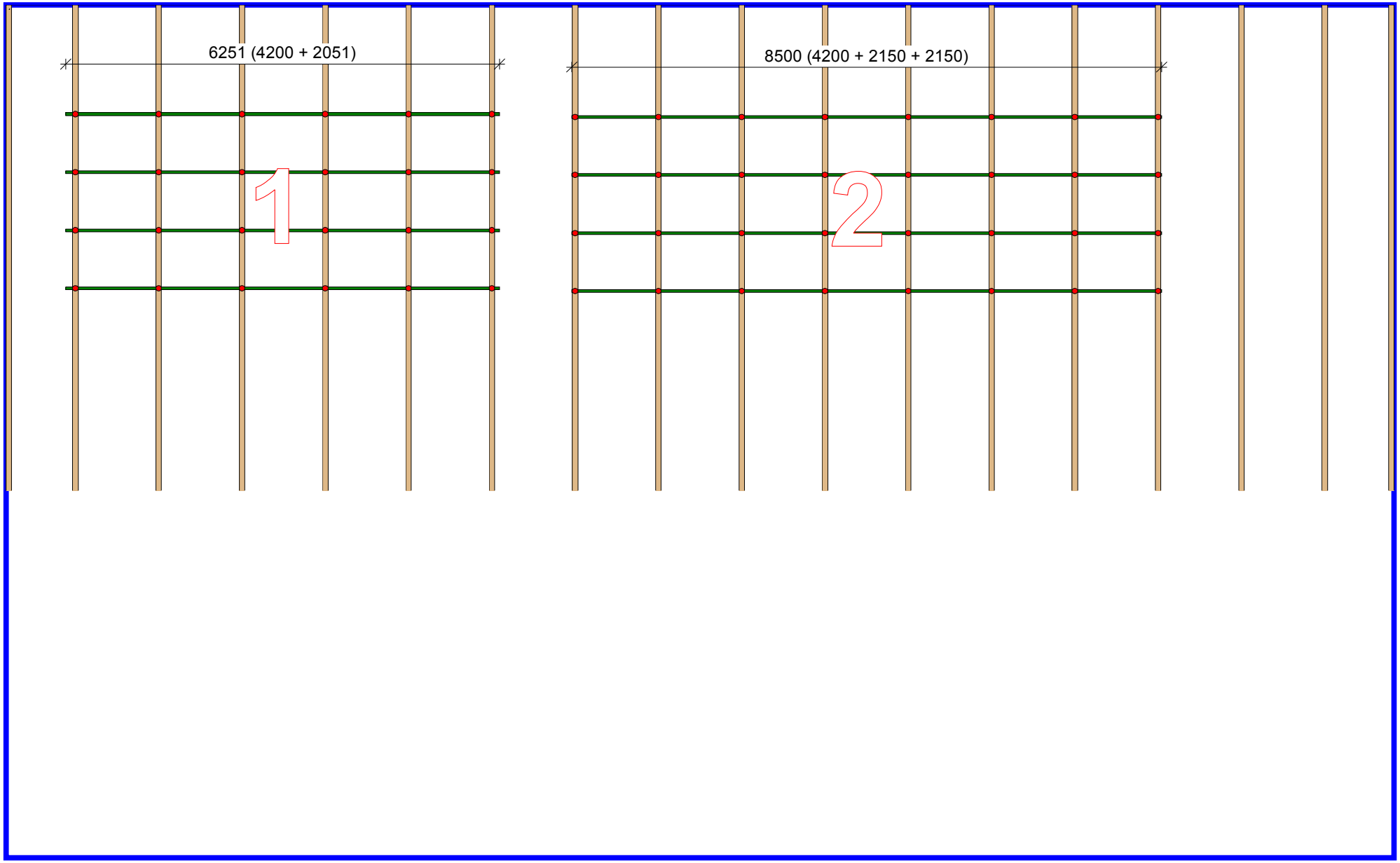

6251 (4200 + 2051)
1
8500 (4200 + 2150 + 2150)
2

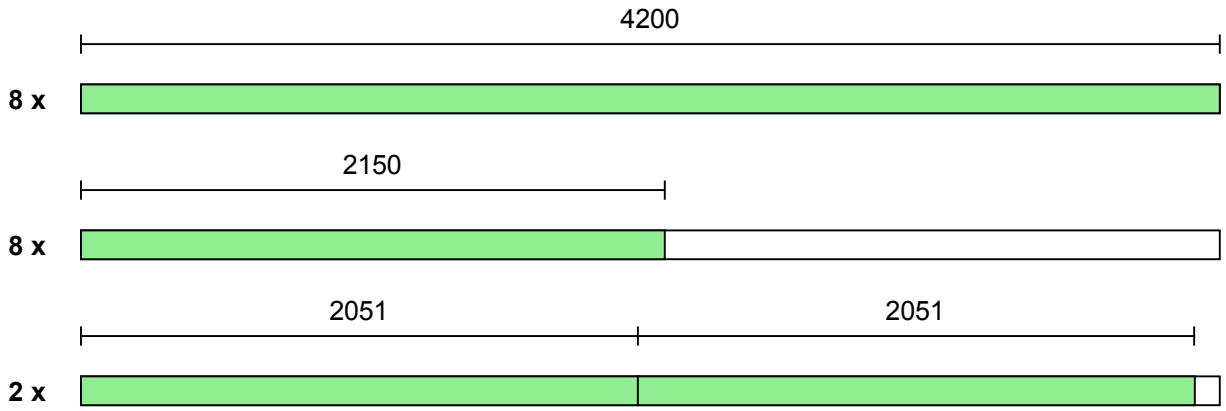
Customer	Anderssson_Mattias
Project	Mattias_Andersson_36x300Wp_house

Bill of Materials: Pitched Roof System

Pos	Item number	Item	Quantity	Length mm	Unit	Weight kg
1	120005-04200	Mod.-bearing rail Solo - 4200mm	18		ST	61.416
2	129060-001	Slide-in connector Solo kit	50 (12)		ST	2.208
3	129011-000	Plastic end cap Solo	100 (16)		ST	0.128
4	101005-000	Roof hook Rapid2+ Max	60 (56)		ST	88.480
5	943208-120	Screw 8x120 TX VA wafer-head wood	150 (112)		ST	3.136
6	131101-001	End clamp Rapid16 30 - 40	50 (16)		ST	0.848
7	131121-001	Middle clamp Rapid16 30 - 40	100 (48)		ST	2.400
8	I400105GB	ID plate Solar Mounting Systems	1			0.100
9	135003-002	Grounding and lightning prot.clamp VA M	20 (8)		ST	0.256
		Total				158.972

Cutting plan (All dimensions in mm

Module-bearing rail: Solo (120005-04200)



System configurator **Status** 4.15.0.0

Preliminary remarks

The following design calculations apply for multi-span mounting systems in midland areas with regular conditions. In coastal areas and exposed locations (with special terrain formation), the consideration of higher wind loads is required. In these cases,

Customer		Anderssson_Mattias	
Order			
Postal code construction site		**41110 Göteborg**	
		57.7072 ° northern latitude	
		11.9668 ° eastern longitude	
Tilt angle	α	**32.0**	°
Module height	h	**1.67**	m
Height above ground	z	**4.00**	m
Height of roof parapet	h_p	**0.00**	m
Cantilever module beam	a_{kr}	**0.40**	m
Span of module beam	a	**1.20**	m

Module-bearing rail

Structural system

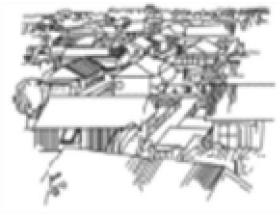
Gable roof (double pitch roof)

Module-bearing rail Solo

Load assumptions acc. to SS EN 1991-1-3 + EKS 8

Load assumptions acc. to	g	**0.11**	kN/m²
Snow load	s	**1.12**	kN/m²
Terrain category		**III**	

Terrain category III



Gebiete mit gleichmäßiger Vegetation oder Bebauung oder mit einzelnen Objekten mit Abständen von weniger als der 20-fachen Hindernishöhe (z. B. Dörfer, vorstädtische Bebauung, Waldgebiete).

Peak velocity pressure	q	**0.41**	kN/m²

Equivalent substitute loads

q_k kN/m²	q_d kN/m²
0.13	0.18

Verification of module-bearing rails (allowable spans) Solo (120005)

Applicable for Roof mounting Central area

Tilt angle	α	32	°
Module height	h	1.67	m
Height above ground	z	4.00	m
Span	a	1.20	m
Cantilever	a_{kr}	0.40	m

sin = 0.530	cos = 0.848
c_{f1} = 0.43	c_{f2} = -0.81
Peak velocity pressure	0.41 kN/m²
Snow load	1.12 kN/m²
Module weight	0.11 kN/m²

Load overview

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.848 = 0.09 kN/m²
g_y = 0.11 · 0.530 = 0.06 kN/m²

Snow load

s_v = 1.12 · 1.00 · 0.848 = 0.95 kN/m²
s_z = 0.95 · 0.848 = 0.81 kN/m²
s_y = 0.95 · 0.530 = 0.50 kN/m²

Wind pressure

w_{dz} = 0.41 · 0.43 = 0.17 kN/m²
w_{sz} = 0.41 · -0.81 = -0.33 kN/m²

W_{dz} = 0.17 · 0.84 = 0.15 kN/m
W_{sz} = -0.33 · 0.84 = -0.28 kN/m

Profile/rail characteristics

Overall system area A = 3.01 cm²
Section modulus W_y = 2.79 cm³
Section modulus W_z = 2.55 cm³

Partial safety factors and combination coefficients

γ_g = 1.35
γ_q = 1.50 · 0.9 = 1.37
$\Psi_{0,w}$ = 0.30
$\Psi_{0,s}$ = 0.70

Importance/reliability factor
K_{FI} = 0.91 (RC2)

γ_g = 0.90 (For favourable action)

Section forces factors for single and multi-span girders

n	$M_{1,total}$	$M_{1,partial}$	$M_{2,total}$	$M_{2,partial}$	$M_{B,total}$	$M_{B,partial}$	A_{total}	$A_{partial}$	B_{total}	$B_{partial}$	Q_{total}	$Q_{partial}$
1	0.125	0.125	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.500	0.500
2	0.070	0.096	0.000	0.000	-0.125	-0.125	0.375	0.438	1.250	1.250	0.625	0.625
3	0.080	0.101	0.025	0.075	-0.100	-0.117	0.400	0.450	1.100	1.200	0.600	0.617
4	0.077	0.100	0.036	0.080	-0.107	-0.121	0.393	0.446	1.143	1.223	0.607	0.621

Internal forces vertical

	Load combination 1				Load combination 2				Load combination 3			
n	$M_{z,span}$	$M_{z,supp}$	$M_{z,cant}$	A	$M_{z,span}$	$M_{z,supp}$	$M_{z,cant}$	A	$M_{z,span}$	$M_{z,supp}$	$M_{z,cant}$	A
1	0.194	0.000	-0.003	0.731	0.170	0.000	-0.003	0.639	-0.056	0.000	0.000	-0.210
2	0.145	-0.194	-0.003	1.620	0.127	-0.170	-0.003	1.416	-0.046	0.056	0.000	-0.466
3	0.154	-0.179	-0.003	1.543	0.134	-0.157	-0.003	1.347	-0.047	0.054	0.000	-0.456
4	0.152	-0.186	-0.003	1.575	0.133	-0.162	-0.003	1.375	-0.047	0.056	0.000	-0.463

Internal forces horizontal

	Load combination 1				Load combination 2				Load combination 3			
n	$M_{y,span}$	$M_{y,supp}$	$M_{y,cant}$	A	$M_{y,span}$	$M_{y,supp}$	$M_{y,cant}$	A	$M_{y,span}$	$M_{y,supp}$	$M_{y,cant}$	A
1	0.115	0.000	-0.002	0.432	0.084	0.000	-0.001	0.315	0.008	0.000	0.000	0.029
2	0.086	-0.115	-0.002	0.957	0.062	-0.084	-0.001	0.698	0.004	-0.008	0.000	0.064
3	0.091	-0.106	-0.002	0.911	0.066	-0.077	-0.001	0.663	0.005	-0.006	0.000	0.056
4	0.090	-0.110	-0.002	0.930	0.065	-0.080	-0.001	0.677	0.005	-0.007	0.000	0.059

Summary

	Midspan stresses				Stresses moments at support			
n	LC1	LC2	LC3	**Max**	LC1	LC2	LC3	**Max**
1	11.471	9.378	-1.706	**11.471**	0.000	0.000	0.000	**0.000**
2	8.579	6.971	-1.464	**8.579**	-11.471	-9.378	1.706	**11.471**
3	9.082	7.391	-1.503	**9.082**	-10.586	-8.627	1.697	**10.586**
4	8.972	7.298	-1.501	**8.972**	-10.980	-8.953	1.734	**10.980**
Stresses cantilever moment					0.189	0.141	0.018	**0.189**

Utilization ratio

$f_{y,d}$ = 18.2 kN/cm²

Single-span girder	η =	63.1%
Double-span girder	η =	63.1%
3-span girder	η =	58.2%
Multi-span girder	η =	60.4%
Cantilever	η =	1.0%

Verification of module-bearing rails (allowable spans) Solo (120005)

Applicable for Roof mounting Border zone

Tilt angle	α	32	°
Module height	h	1.67	m
Height above ground	z	4.00	m
Span	a	1.20	m
Cantilever	a_{kr}	0.40	m

sin = 0.530	cos = 0.848
c_{f1} = 0.43	c_{f2} = -1.40
Peak velocity pressure	0.41 kN/m²
Snow load	1.12 kN/m²
Module weight	0.11 kN/m²

Load overview

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.848 = 0.09 kN/m²
g_y = 0.11 · 0.530 = 0.06 kN/m²

Snow load

s_v = 1.12 · 1.00 · 0.848 = 0.95 kN/m²
s_z = 0.95 · 0.848 = 0.81 kN/m²
s_y = 0.95 · 0.530 = 0.50 kN/m²

Wind pressure

w_{dz} = 0.41 · 0.43 = 0.17 kN/m²
w_{sz} = 0.41 · -1.40 = -0.57 kN/m²

W_{dz} = 0.17 · 0.84 = 0.15 kN/m
W_{sz} = -0.57 · 0.84 = -0.48 kN/m

Profile/rail characteristics

Overall system area A = 3.01 cm²
Section modulus W_y = 2.79 cm³
Section modulus W_z = 2.55 cm³

Partial safety factors and combination coefficients

γ_g = 1.35
γ_q = 1.50 · 0.9 = 1.37
$\Psi_{0,w}$ = 0.30
$\Psi_{0,s}$ = 0.70

Importance/reliability factor
K_{FI} = 0.91 (RC2)

γ_g = 0.90 (For favourable action)

Section forces factors for single and multi-span girders

n	$M_{1,total}$	$M_{1,partial}$	$M_{2,total}$	$M_{2,partial}$	$M_{B,total}$	$M_{B,partial}$	A_{total}	$A_{partial}$	B_{total}	$B_{partial}$	Q_{total}	$Q_{partial}$
1	0.125	0.125	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.500	0.500
2	0.070	0.096	0.000	0.000	-0.125	-0.125	0.375	0.438	1.250	1.250	0.625	0.625
3	0.080	0.101	0.025	0.075	-0.100	-0.117	0.400	0.450	1.100	1.200	0.600	0.617
4	0.077	0.100	0.036	0.080	-0.107	-0.121	0.393	0.446	1.143	1.223	0.607	0.621

Internal forces vertical

	Load combination 1				Load combination 2				Load combination 3			
n	$M_{z,span}$	$M_{z,supp}$	$M_{z,cant}$	A	$M_{z,span}$	$M_{z,supp}$	$M_{z,cant}$	A	$M_{z,span}$	$M_{z,supp}$	$M_{z,cant}$	A
1	0.194	0.000	-0.003	0.731	0.170	0.000	-0.003	0.639	-0.105	0.000	0.001	-0.396
2	0.145	-0.194	-0.003	1.620	0.127	-0.170	-0.003	1.416	-0.083	0.105	0.001	-0.876
3	0.154	-0.179	-0.003	1.543	0.134	-0.157	-0.003	1.347	-0.087	0.100	0.001	-0.849
4	0.152	-0.186	-0.003	1.575	0.133	-0.162	-0.003	1.375	-0.086	0.103	0.001	-0.864

Internal forces horizontal

	Load combination 1				Load combination 2				Load combination 3			
n	$M_{y,span}$	$M_{y,supp}$	$M_{y,cant}$	A	$M_{y,span}$	$M_{y,supp}$	$M_{y,cant}$	A	$M_{y,span}$	$M_{y,supp}$	$M_{y,cant}$	A
1	0.115	0.000	-0.002	0.432	0.084	0.000	-0.001	0.315	0.008	0.000	0.000	0.029
2	0.086	-0.115	-0.002	0.957	0.062	-0.084	-0.001	0.698	0.004	-0.008	0.000	0.064
3	0.091	-0.106	-0.002	0.911	0.066	-0.077	-0.001	0.663	0.005	-0.006	0.000	0.056
4	0.090	-0.110	-0.002	0.930	0.065	-0.080	-0.001	0.677	0.005	-0.007	0.000	0.059

Summary

	Midspan stresses				Stresses moments at support			
n	LC1	LC2	LC3	**Max**	LC1	LC2	LC3	**Max**
1	11.471	9.378	-3.471	**11.471**	0.000	0.000	0.000	**0.000**
2	8.579	6.971	-2.820	**8.579**	-11.471	-9.378	3.471	**11.471**
3	9.082	7.391	-2.929	**9.082**	-10.586	-8.627	3.350	**10.586**
4	8.972	7.298	-2.913	**8.972**	-10.980	-8.953	3.443	**10.980**
Stresses cantilever moment					0.189	0.141	0.032	**0.189**

Utilization ratio

$f_{y,d}$ = 18.2 kN/cm²

Single-span girder	η =	63.1%
Double-span girder	η =	63.1%
3-span girder	η =	58.2%
Multi-span girder	η =	60.4%
Cantilever	η =	1.0%

Verification of module-bearing rails (allowable spans) Solo (120005)

Applicable for Roof mounting Corner zone

Tilt angle	α	32	°
Module height	h	1.67	m
Height above ground	z	4.00	m
Span	a	1.20	m
Cantilever	a_{kr}	0.40	m

sin = 0.530	cos = 0.848
c_{f1} = 0.43	c_{f2} = -1.10
Peak velocity pressure	0.41 kN/m²
Snow load	1.12 kN/m²
Module weight	0.11 kN/m²

Load overview

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.848 = 0.09 kN/m²
g_y = 0.11 · 0.530 = 0.06 kN/m²

Snow load

s_v = 1.12 · 1.00 · 0.848 = 0.95 kN/m²
s_z = 0.95 · 0.848 = 0.81 kN/m²
s_y = 0.95 · 0.530 = 0.50 kN/m²

Wind pressure

w_{dz} = 0.41 · 0.43 = 0.17 kN/m²
w_{sz} = 0.41 · -1.10 = -0.45 kN/m²

W_{dz} = 0.17 · 0.84 = 0.15 kN/m
W_{sz} = -0.45 · 0.84 = -0.38 kN/m

Profile/rail characteristics

Overall system area A = 3.01 cm²
Section modulus W_y = 2.79 cm³
Section modulus W_z = 2.55 cm³

Partial safety factors and combination coefficients

γ_g = 1.35
γ_q = 1.50 · 0.9 = 1.37
$\Psi_{0,w}$ = 0.30
$\Psi_{0,s}$ = 0.70

Importance/reliability factor
K_{FI} = 0.91 (RC2)

γ_g = 0.90 (For favourable action)

Section forces factors for single and multi-span girders

n	$M_{1,total}$	$M_{1,partial}$	$M_{2,total}$	$M_{2,partial}$	$M_{B,total}$	$M_{B,partial}$	A_{total}	$A_{partial}$	B_{total}	$B_{partial}$	Q_{total}	$Q_{partial}$
1	0.125	0.125	0.000	0.000	0.000	0.000	0.500	0.500	0.000	0.000	0.500	0.500
2	0.070	0.096	0.000	0.000	-0.125	-0.125	0.375	0.438	1.250	1.250	0.625	0.625
3	0.080	0.101	0.025	0.075	-0.100	-0.117	0.400	0.450	1.100	1.200	0.600	0.617
4	0.077	0.100	0.036	0.080	-0.107	-0.121	0.393	0.446	1.143	1.223	0.607	0.621

Internal forces vertical

	Load combination 1				Load combination 2				Load combination 3			
n	$M_{z,span}$	$M_{z,supp}$	$M_{z,cant}$	A	$M_{z,span}$	$M_{z,supp}$	$M_{z,cant}$	A	$M_{z,span}$	$M_{z,supp}$	$M_{z,cant}$	A
1	0.194	0.000	-0.003	0.731	0.170	0.000	-0.003	0.639	-0.080	0.000	0.001	-0.301
2	0.145	-0.194	-0.003	1.620	0.127	-0.170	-0.003	1.416	-0.064	0.080	0.001	-0.667
3	0.154	-0.179	-0.003	1.543	0.134	-0.157	-0.003	1.347	-0.067	0.077	0.001	-0.648
4	0.152	-0.186	-0.003	1.575	0.133	-0.162	-0.003	1.375	-0.066	0.079	0.001	-0.659

Internal forces horizontal

	Load combination 1				Load combination 2				Load combination 3			
n	$M_{y,span}$	$M_{y,supp}$	$M_{y,cant}$	A	$M_{y,span}$	$M_{y,supp}$	$M_{y,cant}$	A	$M_{y,span}$	$M_{y,supp}$	$M_{y,cant}$	A
1	0.115	0.000	-0.002	0.432	0.084	0.000	-0.001	0.315	0.008	0.000	0.000	0.029
2	0.086	-0.115	-0.002	0.957	0.062	-0.084	-0.001	0.698	0.004	-0.008	0.000	0.064
3	0.091	-0.106	-0.002	0.911	0.066	-0.077	-0.001	0.663	0.005	-0.006	0.000	0.056
4	0.090	-0.110	-0.002	0.930	0.065	-0.080	-0.001	0.677	0.005	-0.007	0.000	0.059

Summary

	Midspan stresses				Stresses moments at support			
n	LC1	LC2	LC3	**Max**	LC1	LC2	LC3	**Max**
1	11.471	9.378	-2.568	**11.471**	0.000	0.000	0.000	**0.000**
2	8.579	6.971	-2.127	**8.579**	-11.471	-9.378	2.568	**11.471**
3	9.082	7.391	-2.200	**9.082**	-10.586	-8.627	2.505	**10.586**
4	8.972	7.298	-2.191	**8.972**	-10.980	-8.953	2.569	**10.980**
Stresses cantilever moment					0.189	0.141	0.025	**0.189**

Utilization ratio

$f_{y,d}$ = 18.2 kN/cm²

Single-span girder	η =	63.1%
Double-span girder	η =	63.1%
3-span girder	η =	58.2%
Multi-span girder	η =	60.4%
Cantilever	η =	1.0%

Roof hooks configurator **Status** 4.15.0.0

Preliminary remarks

The following design calculations apply for multi-span mounting systems in midland areas with regular conditions. In coastal areas and exposed locations (with special terrain formation), the consideration of higher wind loads is required. In these cases,

Customer	Anderssson_Mattias
Order	
Postal code construction site	**41110 Göteborg**
	57.7072 ° northern latitude
	11.9668 ° eastern longitude

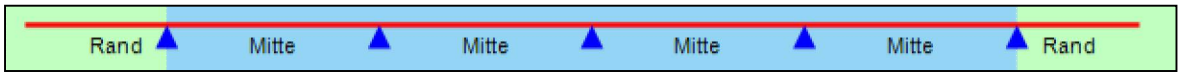
Structural system

Gable roof (double pitch roof) ☐ Resting on the roof

Load assumptions acc. to SS EN 1991-1-3 + EKS 8

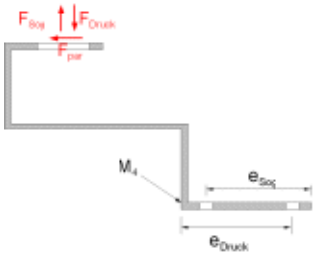
Load assumptions acc. to	g	**0.11**	kN/m²
Snow load	s	**1.12**	kN/m²
Peak velocity pressure	q	**0.41**	kN/m²

Required number of roof hooks in the different roof zones



Required number roof hooks (Center)	0.86 Pc(s)
Actually installed	1.19 Pc(s)/m²
Allowable lateral cantilever akr (Edge / Border zone)	0.66 m
Screwing depth of the wood screws	96 mm
Compaction Border zone	100%
Compaction Corner zone	100%

Vertical
68.1 kg
Horizontal
40.2 kg



Verification of the roof hook Rapid 2+ Max (101005-000)

Applicable for Roof mounting on Gable roof (double pitch roof) Central area

Tilt angle	α	32	°
Snow load	s	1.12	kN/m²
Height above ground	z	4.00	m
Module height	h	1.67	
Module weight	g	0.11	kN/m²

sin = 0.530	cos = 0.848
c_{p1} = 0.43	c_{p2} = -0.81
Peak velocity pressure	0.41 kN/m²
Modular size of substructure	1.20 m
Cantilever	0.40 m

Overview load per Square meter Roof area

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.848 = 0.09 kN/m²
g_y = 0.11 · 0.530 = 0.06 kN/m²

Snow load

s_v = 1.12 · 1.00 · 0.848 = 0.95 kN/m²
s_z = 0.95 · 0.848 = 0.81 kN/m²
s_y = 0.95 · 0.530 = 0.50 kN/m²

Wind pressure

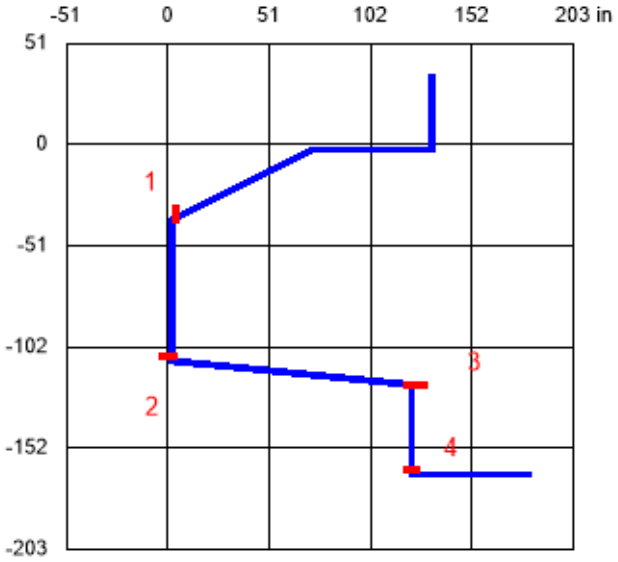
w_{dz} = 0.41 · 0.43 = 0.17 kN/m²

Wind suction

w_{sz} = 0.41 · -0.81 = -0.33 kN/m²

Profile/rail characteristics

Schematic view of profile/rail, indicating the critical sections:



Sheet metal thickness	t =	0.8	cm
Cross-sectional area	A =	2.8	cm²
Hook width	b =	3.5	cm²
Section modulus	W =	0.373	cm³

When determining the loads, the impediment of distortions of the upper leg by the absorbing girder profile is considered. The calculation assumes a partial fixation of 70 %.

Section forces factors for single, double or triple-span girders

	Force factors			
n	A_{total}	$A_{partial}$	B_{total}	$B_{partial}$
1	0.500	0.500	0.000	0.000
2	0.375	0.438	1.250	1.250
3	0.400	0.450	1.100	1.200

Load combinations

Load combinations 1: 1.35 · g + 1.365 · s + 0.3 · 1.365 · w
Load combinations 2: 1.35 · g + 0.7 · 1.365 · s + 1.365 · w
Load combinations 3: 0.9 · g + 1.365 · w
Importance/reliability factor: K_{FI} = 0.91 (RC2)

	Load combination 1				Load combination 2				Load combination 3			
	Vertical/portrait		Horizontal/landscape		Vertical/portrait		Horizontal/landscape		Vertical/portrait		Horizontal/landscape	
n	A	B	A	B	A	B	A	B	A	B	A	B
1	0.731	0.731	0.432	0.432	0.639	0.639	0.315	0.315	-0.210	-0.210	0.029	0.029
2	0.643	1.620	0.379	0.957	0.561	1.416	0.276	0.698	-0.192	-0.466	0.022	0.064
3	0.660	1.543	0.390	0.911	0.576	1.347	0.283	0.663	-0.196	-0.456	0.024	0.056

Section forces for

Partial fixation due to deformation impediment by cross beams 70%

			Load combination 1		Load combination 2		Load combination 3		Decis. comb.	
			Support A	Support B	Support A	Support B	Support A	Support B	A	B
Section 1	e_{hor}	mm	150		150		150		Abs. value	
	e_{vert}	mm	86		86		86			
	M	kNcm	4.93	11.51	4.43	10.35	1.78	4.15	4.93	11.51
	N	kN	-0.39	-0.91	-0.28	-0.66	-0.02	-0.06	-0.39	-0.91
Section 2	e_{hor}	mm	150		150		150			
	e_{vert}	mm	116		116		125			
	M	kNcm	3.78	8.83	3.59	8.40	1.85	4.32	3.78	8.83
	N	kN	-0.66	-1.54	-0.58	-1.35	0.20	0.46	-0.66	-1.54
Section 3	e_{hor}	mm	-30		-30		-30			
	e_{vert}	mm	125		125		125			
	M	kNcm	4.52	10.56	3.59	8.39	0.47	1.10	4.52	10.56
	N	kN	-0.66	-1.54	-0.58	-1.35	0.20	0.46	-0.66	-1.54
Section 4	e_{hor}	mm	-30		-30		-30			
	e_{vert}	mm	170		170		170			
	M	kNcm	6.27	14.65	4.87	11.38	0.37	0.84	6.27	14.65
	N	kN	-0.66	-1.54	-0.58	-1.35	0.20	0.46	-0.66	-1.54
								Max. load M =	**6.27**	**14.65**
								N =	**-0.66**	**-1.54**

Stress

σ = N / A + M / W A = 2.8 cm² W = 0.373333333333333 cm³

Except for a possibly existing welded joint in section 4, a plastical reserve of W_{pl} = 1.25 W_{el} can be assumed.

Foot plate, welded Yes

$R_{p0,2}$ = 46.00 kN/cm²

Allowable stress zul σ = 46.00 kN/cm²

(safety factor for components without buckling actions)

Allowable effective load influence zone per hook: A = zul σ_e / vorh σ

Required number per m² roof area n = 1 / A

	Support A		Support B	
	σ kN/cm²	n	σ kN/cm²	n
Section 1	10.70	0.2	25.00	0.5
Section 2	8.33	0.2	19.46	0.4
Section 3	9.91	0.2	23.17	0.5
Section 4	17.03	0.4	39.80	0.9
max n		0.4		0.9

Allowable cantilever a_{kr} = 0.659 m

(Edge supports have a lower load level due to the multispan action)

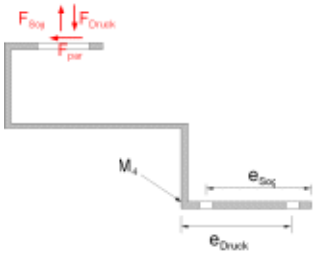
Central support 0.9 Roof hooks per 1.00 m²

Edge support 0.4 Roof hooks per 0.57 m²

Edge support a = 1.20 m

Module height a = 1.67 m

t_{erf} mm	Support A	Support B
Section 1	3.5	5.4
Section 2	3.1	4.7
Section 3	3.4	5.2
Section 4	4.9	7.5
max n	**4.9**	**7.5**



Fastening to the substructure: (acc. to DIN 1052) e_D = 50 mm e_S = 50 mm

Load	Parallel to roof area:	$P_{d,par}$ / 1.5 = 0.70 kN	$F_{Shearing\ off}$ =		0.70 kN characteristic
	Pressure:	M_{4D} = 11.29 kNcm ⇒	$F_{Pressure}$ =	M_{4D} / $e_{Pressure}$ =	2.26 kN characteristic
	Traction:	M_{4S} = 0.65 kNcm ⇒	$F_{Traction}$ =	M_{4S} / $e_{Traction}$ =	0.22 kN characteristic
Selected	2 Wood screws ø8.0 mm				
Shearing off	zul $N_A = n \cdot 1.25 \cdot 17 \cdot ds^2 \cdot s / (8 \cdot d_s)$ =		4.08 kN		
Traction	zul $N_Z = n_{Traction} \cdot 3 \cdot s_g \cdot d_s$ =		2.30 kN		
Screwing depth	s_{min} = 96 mm s_{gew} = 96 mm s_{max} = 96 mm				

Verification of the roof hook Rapid 2+ Max (101005-000)

Applicable for Roof mounting on Gable roof (double pitch roof) Border zone

Tilt angle	α	32	°
Snow load	s	1.12	kN/m²
Height above ground	z	4.00	m
Module height	h	1.67	
Module weight	g	0.11	kN/m²

sin = 0.530	cos = 0.848
c_{p1} = 0.43	c_{p2} = -1.40
Peak velocity pressure	0.41 kN/m²
Modular size of substructure	1.20 m
Cantilever	0.40 m

Overview load per Square meter Roof area

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.848 = 0.09 kN/m²
g_y = 0.11 · 0.530 = 0.06 kN/m²

Snow load

s_v = 1.12 · 1.00 · 0.848 = 0.95 kN/m²
s_z = 0.95 · 0.848 = 0.81 kN/m²
s_y = 0.95 · 0.530 = 0.50 kN/m²

Wind pressure

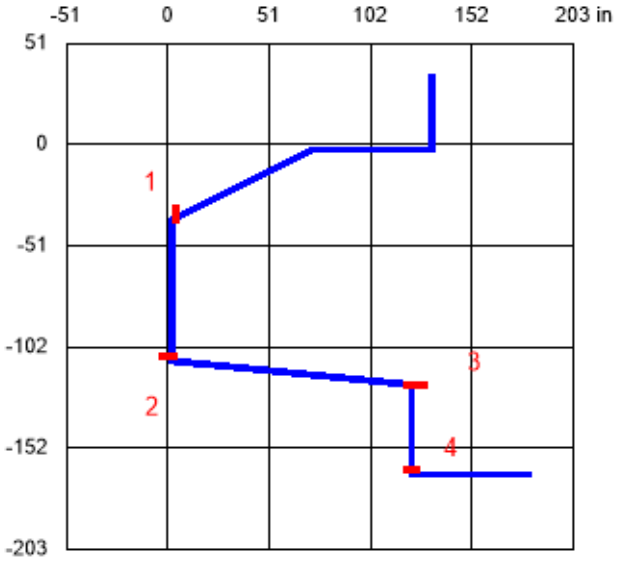
w_{dz} = 0.41 · 0.43 = 0.17 kN/m²

Wind suction

w_{sz} = 0.41 · -1.40 = -0.57 kN/m²

Profile/rail characteristics

Schematic view of profile/rail, indicating the critical sections:



Sheet metal thickness	t =	0.8	cm
Cross-sectional area	A =	2.8	cm²
Hook width	b =	3.5	cm²
Section modulus	W =	0.373	cm³

When determining the loads, the impediment of distortions of the upper leg by the absorbing girder profile is considered. The calculation assumes a partial fixation of 70 %.

Section forces factors for single, double or triple-span girders

	Force factors			
n	A_{total}	$A_{partial}$	B_{total}	$B_{partial}$
1	0.500	0.500	0.000	0.000
2	0.375	0.438	1.250	1.250
3	0.400	0.450	1.100	1.200

Load combinations

Load combinations 1: 1.35 · g + 1.365 · s + 0.3 · 1.365 · w
Load combinations 2: 1.35 · g + 0.7 · 1.365 · s + 1.365 · w
Load combinations 3: 0.9 · g + 1.365 · w
Importance/reliability factor: K_{FI} = 0.91 (RC2)

	Load combination 1				Load combination 2				Load combination 3			
	Vertical/portrait		Horizontal/landscape		Vertical/portrait		Horizontal/landscape		Vertical/portrait		Horizontal/landscape	
n	A	B	A	B	A	B	A	B	A	B	A	B
1	0.731	0.731	0.432	0.432	0.639	0.639	0.315	0.315	-0.396	-0.396	0.029	0.029
2	0.643	1.620	0.379	0.957	0.561	1.416	0.276	0.698	-0.357	-0.876	0.022	0.064
3	0.660	1.543	0.390	0.911	0.576	1.347	0.283	0.663	-0.365	-0.849	0.024	0.056

Section forces for

Partial fixation due to deformation impediment by cross beams 70%

			Load combination 1		Load combination 2		Load combination 3		Decis. comb.	
			Support A	Support B	Support A	Support B	Support A	Support B	A	B
Section 1	e_{hor}	mm	150		150		150		Abs. value	
	e_{vert}	mm	86		86		86			
	M	kNcm	4.93	11.51	4.43	10.35	3.27	7.63	4.93	11.51
	N	kN	-0.39	-0.91	-0.28	-0.66	-0.02	-0.06	-0.39	-0.91
Section 2	e_{hor}	mm	150		150		150			
	e_{vert}	mm	116		116		125			
	M	kNcm	3.78	8.83	3.59	8.40	3.34	7.79	3.78	8.83
	N	kN	-0.66	-1.54	-0.58	-1.35	0.36	0.85	-0.66	-1.54
Section 3	e_{hor}	mm	-30		-30		-30			
	e_{vert}	mm	125		125		125			
	M	kNcm	4.52	10.56	3.59	8.39	1.01	2.35	4.52	10.56
	N	kN	-0.66	-1.54	-0.58	-1.35	0.36	0.85	-0.66	-1.54
Section 4	e_{hor}	mm	-30		-30		-30			
	e_{vert}	mm	170		170		170			
	M	kNcm	6.27	14.65	4.87	11.38	0.90	2.09	6.27	14.65
	N	kN	-0.66	-1.54	-0.58	-1.35	0.36	0.85	-0.66	-1.54
								Max. load M =	**6.27**	**14.65**
								N =	**-0.66**	**-1.54**

Stress

σ = N / A + M / W A = 2.8 cm² W = 0.373333333333333 cm³

Except for a possibly existing welded joint in section 4, a plastical reserve of W_{pl} = 1.25 W_{el} can be assumed.

Foot plate, welded Yes

$R_{p0,2}$ = 46.00 kN/cm²

Allowable stress zul σ = 46.00 kN/cm²

(safety factor for components without buckling actions)

Allowable effective load influence zone per hook: A = zul σ_e / vorh σ

Required number per m² roof area n = 1 / A

Allowable cantilever a_{kr} = 0.659 m

(Edge supports have a lower load level due to the multispan action)

	Support A		Support B	
	σ kN/cm²	n	σ kN/cm²	n
Section 1	10.70	0.2	25.00	0.5
Section 2	8.33	0.2	19.46	0.4
Section 3	9.91	0.2	23.17	0.5
Section 4	17.03	0.4	39.80	0.9
max n		0.4		0.9

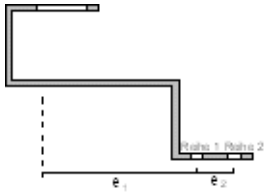
Central support 0.9 Roof hooks per 1.00 m²

Edge support 0.4 Roof hooks per 0.57 m²

Edge support a = 1.20 m

Module height a = 1.67 m

t_{erf} mm	Support A	Support B
Section 1	3.5	5.4
Section 2	3.1	4.7
Section 3	3.4	5.2
Section 4	4.9	7.5
max n	**4.9**	**7.5**



Fastening to the substructure: (acc. to DIN 1052) e_D = 50 mm e_S = 50 mm

Load	Parallel to roof area:	$P_{d,par}$ / 1.5 = 0.70 kN	$F_{Shearing\ off}$ =		0.70 kN characteristic
	Pressure:	M_{4D} = 11.29 kNcm ⇒	$F_{Pressure}$ =	M_{4D} / $e_{Pressure}$ =	2.26 kN characteristic
	Traction:	M_{4S} = 1.61 kNcm ⇒	$F_{Traction}$ =	M_{4S} / $e_{Traction}$ =	0.49 kN characteristic
Selected	2 Wood screws ø8.0 mm				
Shearing off	zul $N_A = n \cdot 1.25 \cdot 17 \cdot ds^2 \cdot s / (8 \cdot d_s)$ =	4.08 kN			
Traction	zul $N_Z = n_{Traction} \cdot 3 \cdot s_g \cdot d_s$ =	2.30 kN			
Screwing depth	s_{min} = 96 mm s_{gew} = 96 mm s_{max} = 96 mm				

Verification of the roof hook Rapid 2+ Max (101005-000)

Applicable for Roof mounting on Gable roof (double pitch roof) Corner zone

Tilt angle	α	32	°
Snow load	s	1.12	kN/m²
Height above ground	z	4.00	m
Module height	h	1.67	
Module weight	g	0.11	kN/m²

sin = 0.530	cos = 0.848
c_{p1} = 0.43	c_{p2} = -1.10
Peak velocity pressure	0.41 kN/m²
Modular size of substructure	1.20 m
Cantilever	0.40 m

Overview load per Square meter Roof area

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.848 = 0.09 kN/m²
g_y = 0.11 · 0.530 = 0.06 kN/m²

Snow load

s_v = 1.12 · 1.00 · 0.848 = 0.95 kN/m²
s_z = 0.95 · 0.848 = 0.81 kN/m²
s_y = 0.95 · 0.530 = 0.50 kN/m²

Wind pressure

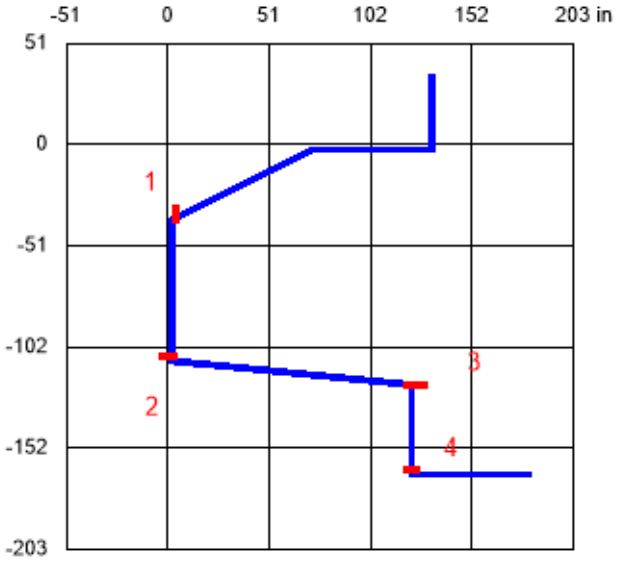
w_{dz} = 0.41 · 0.43 = 0.17 kN/m²

Wind suction

w_{sz} = 0.41 · -1.10 = -0.45 kN/m²

Profile/rail characteristics

Schematic view of profile/rail, indicating the critical sections:



Sheet metal thickness	t =	0.8	cm
Cross-sectional area	A =	2.8	cm²
Hook width	b =	3.5	cm²
Section modulus	W =	0.373	cm³

When determining the loads, the impediment of distortions of the upper leg by the absorbing girder profile is considered. The calculation assumes a partial fixation of 70 %.

Section forces factors for single, double or triple-span girders

	Force factors			
n	A_{total}	$A_{partial}$	B_{total}	$B_{partial}$
1	0.500	0.500	0.000	0.000
2	0.375	0.438	1.250	1.250
3	0.400	0.450	1.100	1.200

Load combinations

Load combinations 1: 1.35 · g + 1.365 · s + 0.3 · 1.365 · w
Load combinations 2: 1.35 · g + 0.7 · 1.365 · s + 1.365 · w
Load combinations 3: 0.9 · g + 1.365 · w
Importance/reliability factor: K_{FI} = 0.91 (RC2)

	Load combination 1				Load combination 2				Load combination 3			
	Vertical/portrait		Horizontal/landscape		Vertical/portrait		Horizontal/landscape		Vertical/portrait		Horizontal/landscape	
n	A	B	A	B	A	B	A	B	A	B	A	B
1	0.731	0.731	0.432	0.432	0.639	0.639	0.315	0.315	-0.301	-0.301	0.029	0.029
2	0.643	1.620	0.379	0.957	0.561	1.416	0.276	0.698	-0.273	-0.667	0.022	0.064
3	0.660	1.543	0.390	0.911	0.576	1.347	0.283	0.663	-0.278	-0.648	0.024	0.056

Section forces for

Partial fixation due to deformation impediment by cross beams 70%

			Load combination 1		Load combination 2		Load combination 3		Decis. comb.	
			Support A	Support B	Support A	Support B	Support A	Support B	A	B
Section 1	e_{hor}	mm	150		150		150		Abs. value	
	e_{vert}	mm	86		86		86			
	M	kNcm	4.93	11.51	4.43	10.35	2.51	5.85	4.93	11.51
	N	kN	-0.39	-0.91	-0.28	-0.66	-0.02	-0.06	-0.39	-0.91
Section 2	e_{hor}	mm	150		150		150			
	e_{vert}	mm	116		116		125			
	M	kNcm	3.78	8.83	3.59	8.40	2.58	6.02	3.78	8.83
	N	kN	-0.66	-1.54	-0.58	-1.35	0.28	0.65	-0.66	-1.54
Section 3	e_{hor}	mm	-30		-30		-30			
	e_{vert}	mm	125		125		125			
	M	kNcm	4.52	10.56	3.59	8.39	0.74	1.71	4.52	10.56
	N	kN	-0.66	-1.54	-0.58	-1.35	0.28	0.65	-0.66	-1.54
Section 4	e_{hor}	mm	-30		-30		-30			
	e_{vert}	mm	170		170		170			
	M	kNcm	6.27	14.65	4.87	11.38	0.63	1.45	6.27	14.65
	N	kN	-0.66	-1.54	-0.58	-1.35	0.28	0.65	-0.66	-1.54
								Max. load M =	**6.27**	**14.65**
								N =	**-0.66**	**-1.54**

Stress

σ = N / A + M / W A = 2.8 cm² W = 0.373333333333333 cm³

Except for a possibly existing welded joint in section 4, a plastical reserve of W_{pl} = 1.25 W_{el} can be assumed.

Foot plate, welded Yes

$R_{p0,2}$ = 46.00 kN/cm²

Allowable stress zul σ = 46.00 kN/cm²

(safety factor for components without buckling actions)

Allowable effective load influence zone per hook: A = zul σ_e / vorh σ

Required number per m² roof area n = 1 / A

Allowable cantilever a_{kr} = 0.659 m

(Edge supports have a lower load level due to the multispan action)

	Support A		Support B	
	σ kN/cm²	n	σ kN/cm²	n
Section 1	10.70	0.2	25.00	0.5
Section 2	8.33	0.2	19.46	0.4
Section 3	9.91	0.2	23.17	0.5
Section 4	17.03	0.4	39.80	0.9
max n		0.4		0.9

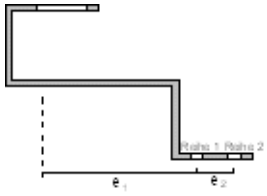
Central support 0.9 Roof hooks per 1.00 m²

Edge support 0.4 Roof hooks per 0.57 m²

Edge support a = 1.20 m

Module height a = 1.67 m

t_{erf} mm	Support A	Support B
Section 1	3.5	5.4
Section 2	3.1	4.7
Section 3	3.4	5.2
Section 4	4.9	7.5
max n	**4.9**	**7.5**



Fastening to the substructure: (acc. to DIN 1052) e_D = 50 mm e_S = 50 mm

Load	Parallel to roof area:	$P_{d,par}$ / 1.5 = 0.70 kN	$F_{Shearing\ off}$ =		0.70 kN characteristic
	Pressure:	M_{4D} = 11.29 kNcm ⇒	$F_{Pressure}$ =	M_{4D} / $e_{Pressure}$ =	2.26 kN characteristic
	Traction:	M_{4S} = 1.12 kNcm ⇒	$F_{Traction}$ =	M_{4S} / $e_{Traction}$ =	0.35 kN characteristic
Selected	2 Wood screws ø8.0 mm				
Shearing off	zul $N_A = n \cdot 1.25 \cdot 17 \cdot ds^2 \cdot s / (8 \cdot d_s)$ =		4.08 kN		
Traction	zul $N_Z = n_{Traction} \cdot 3 \cdot s_g \cdot d_s$ =		2.30 kN		
Screwing depth	s_{min} = 96 mm s_{gew} = 96 mm s_{max} = 96 mm				

Verification of connections

Tilt angle	α	32	°
Snow load	s	1.12	kN/m²
Height above ground	z	4.00	m
Module height	h	1.67	
Module weight	g	0.11	kN/m²

sin = 0.530	cos = 0.848	
Peak velocity pressure	0.41 kN/m²	
Zone F	$c_{p,1}$ = -1.50	
Zone G	$c_{p,1}$ = -2.00	Pressure coefficients $C_{pe,1}$
Zone H	$c_{p,1}$ = -1.20	

Load overview

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.848 = 0.09 kN/m²
g_y = 0.11 · 0.530 = 0.06 kN/m²

Snow load

s_v = 1.12 · 1.00 · 0.848 = 0.95 kN/m²
s_z = 0.95 · 0.848 = 0.81 kN/m²
s_y = 0.95 · 0.530 = 0.50 kN/m²

Wind suction

w_{dz} = 0.41 · 0.43 = 0.17 kN/m²
w_{sz} = 0.41 · $c_{p,1}$

Module clamps according to general technical approval Z-14.4-631

Middle clamps		End clamps	
$F_{R,d}$ kN	$V_{R,d}$ kN	$F_{R,d}$ kN	$V_{R,d}$ kN
4.63	0.67	1.63	0.45

Module surface A = 1.68 m²
Frictional connection A = 0.34 kN ($F_{S,d} \cdot \mu$))

Internal forces at module clamps

	$V_{S,d}$ kN	$F_{S,d}$ kN		
		Zone F	Zone G	Zone H
Middle clamps	0.30	0.60	0.83	0.46
End clamps	0.15	0.30	0.42	0.23

$V_{S,d} = V_{S,dy} - F_{S,dz} \cdot \mu$ (μ = 0.50)

Utilization ratio 45.4%
Utilization ratio 33.4%

Screwed connections in accordance with general technical approval Z-14.4-639 Appendix 7

Z_{Rd} = 5.10 kN
V_{Rd} = 2.00 kN

Rated value of acting forces

	kN	LC1	LC2	LC3			η
				Zone F	Zone G	Zone H	%
Vertical forces	N_{Sd}			-0.46	-0.86	-0.66	9.1
Shear forces	V_{Sd}	0.93	0.68	0.06	0.06	0.06	46.5