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

Project: Pétfürdő Önkormányzat keleti 2 tető

Module type: SPR-P3-415-COM 2066 x 998 mm

By order

January 2021

Project planning and auto-calculation

Version 5.112.0.0

Plant details

Date	28/01/2021
Customer	
Order	
Plant	2 R à 7 Mod

Module selection

Manufacturer	Sunpower
Module	SPR-P3-415-COM
Peak power	415 W
Height	2,066 mm
Width	998 mm
Thickness	40 mm
Framing	Framed

Module arrangement

Modules per row	7
Module rows	2
Number of modules	12
Selected support distance	800 mm
Cantilever	400 mm
Number of identical module fields	1

Basic configuration

System selection	
Module-bearing rail	Eco 05
Clamp type	Rapid16
Fastening	Roof hook Rapid2+ 45

Results: Plant details

Peak power	4.98 kW

Project Pétfürdő Önkormányzat keleti 2 tető

Bill of Materials: Pitched Roof System

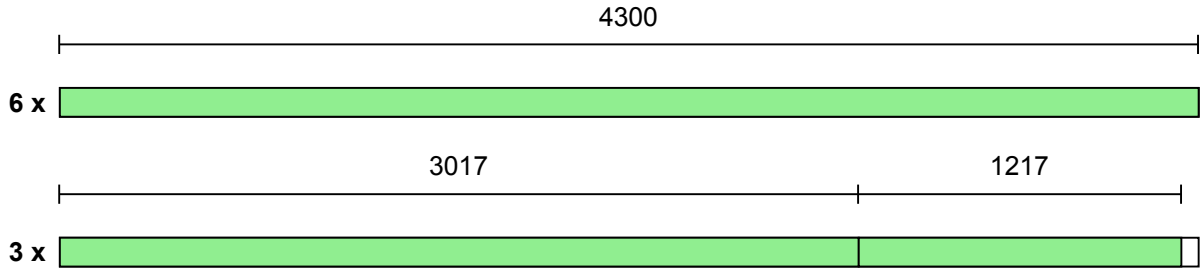
Po	Item number	Item	Total amoun	Length m	Uni	Total weight k
1	120001-0430	Module bearing rail Eco5 - 4300mm	9		ST	26.667
2	129001-004	Eco 05 interior connector kit	6		ST	0.498
3	101001-000	Roof hook Rapid2+ 45	48		ST	49.056
4	943208-120	Screw 8x120 TX VA wafer-head wood	96		ST	2.688
5	131101-001	End clamp Rapid16 V 30 - 40	12		ST	0.636
6	131121-001	Middle clamp Rapid16 30 - 40	30		ST	1.500
		Total				81.045

Attention! If you want to order directly from Schletter Solar GmbH only complete packing units will be provided!

Cutting plan

(All dimensions in mm)

Module-bearing rail: Eco 05 (120001-04300)



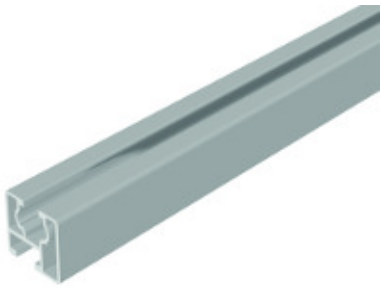
System configurator **Status** 5.112.0.0

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.

Customer			
Order			
Postal code construction site	**8105 Pétfürdo**		
	47.1667 ° northern latitude		
	18.1167 ° eastern longitude		
Tilt angle	α	**30.0**	°
Module length	h	**2.07**	m
Height above sea level	H	**126**	m
Height above ground	z	**9.00**	m
Height of roof parapet	h_p	**0.00**	m
Cantilever module beam	a_{kr}	**0.40**	m
Span of module beam	a	**0.80**	m

Module-bearing rail



Structural system

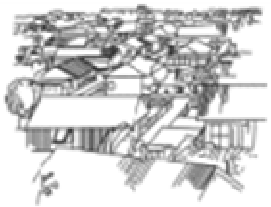
Gable roof (double pitch roof)

Module-bearing rail Eco 05

Load assumptions acc. to MSZ EN 1991-1

Load assumptions acc. to	g	**0.11**	kN/m²
Snow load	s	**1.00**	kN/m²
Terrain category		**III**	

Terrain category III



Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (villages, suburban terrain, permanent forest)

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) Eco 05 (120001)

Applicable for Roof mounting Central area

Tilt angle	α	30	°
Module length	h	2.07	m
Height above ground	z	9.00	m
Span	a	0.80	m
Cantilever	a_{kr}	0.40	m

sin = 0.500	cos = 0.866
c_{f1} = 0.40	c_{f2} = -0.80
Peak velocity pressure	0.41 kN/m²
Snow load	1.00 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 · 0.866 = 0.06 kN/m²
g_y = 0.11 · 0.500 = 0.04 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.58 kN/m²
s_z = 0.58 · 0.866 = 0.50 kN/m²
s_y = 0.58 · 0.500 = 0.29 kN/m²

Wind pressure

w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
w_{sz} = 0.41 · -0.80 = -0.33 kN/m²

W_{dz} = 0.16 · 1.03 = 0.11 kN/m
W_{sz} = -0.33 · 1.03 = -0.23 kN/m

Profile/rail characteristics

Overall system area	A =	2.56 cm²
Section modulus	W_y =	1.50 cm³
Section modulus	W_z =	1.74 cm³

Partial safety factors and combination coefficients

γ_g =	1.35	Importance/reliability factor
γ_q =	1.50 · 1.0 = 1.50	K_{FI} = 1.00 (RC2)
$\Psi_{0,w}$ =	0.60	
$\Psi_{0,s}$ =	0.50	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	0.068	0.000	-0.052	0.571	0.049	0.000	-0.038	0.410	-0.030	0.000	0.010	-0.254
2	0.051	-0.068	-0.052	0.761	0.037	-0.049	-0.038	0.547	-0.024	0.030	0.010	-0.338
3	0.054	-0.063	-0.052	0.725	0.039	-0.045	-0.038	0.519	-0.025	0.029	0.010	-0.328
4	0.054	-0.066	-0.052	0.740	0.038	-0.047	-0.038	0.531	-0.025	0.030	0.010	-0.333

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	0.034	0.000	-0.026	0.280	0.018	0.000	-0.014	0.154	0.002	0.000	-0.002	0.019
2	0.025	-0.034	-0.026	0.373	0.013	-0.018	-0.014	0.205	0.001	-0.002	-0.002	0.025
3	0.027	-0.031	-0.026	0.355	0.014	-0.017	-0.014	0.194	0.001	-0.002	-0.002	0.022
4	0.026	-0.032	-0.026	0.363	0.014	-0.018	-0.014	0.199	0.001	-0.002	-0.002	0.023

Summary

	Midspan stresses				Stresses moments at support			
n	LC1	LC2	LC3	**Max**	LC1	LC2	LC3	**Max**
1	6.483	4.334	-1.894	**6.483**	0.000	0.000	0.000	**0.000**
2	4.857	3.206	-1.536	**4.857**	-6.483	-4.334	1.894	**6.483**
3	5.140	3.403	-1.596	**5.140**	-5.988	-3.977	1.826	**5.988**
4	5.078	3.359	-1.587	**5.078**	-6.210	-4.129	1.877	**6.210**
Stresses cantilever moment					4.970	3.322	0.775	**4.970**

Utilization ratio

$f_{y,d}$ = 18.2 kN/cm²

Single-span girder	η =	35.7%
Double-span girder	η =	35.7%
3-span girder	η =	32.9%
Multi-span girder	η =	34.2%
Cantilever	η =	27.3%

Verification of module-bearing rails (allowable spans) Eco 05 (120001)

Applicable for Roof mounting Border zone

Tilt angle	α	30	°
Module length	h	2.07	m
Height above ground	z	9.00	m
Span	a	0.80	m
Cantilever	a_{kr}	0.40	m

sin = 0.500	cos = 0.866
c_{f1} = 0.40	c_{f2} = -1.40
Peak velocity pressure	0.41 kN/m²
Snow load	1.00 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 · 0.866 = 0.06 kN/m²
g_y = 0.11 · 0.500 = 0.04 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.58 kN/m²
s_z = 0.58 · 0.866 = 0.50 kN/m²
s_y = 0.58 · 0.500 = 0.29 kN/m²

Wind pressure

w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
w_{sz} = 0.41 · -1.40 = -0.57 kN/m²

W_{dz} = 0.16 · 1.03 = 0.11 kN/m
W_{sz} = -0.57 · 1.03 = -0.40 kN/m

Profile/rail characteristics

Overall system area A = 2.56 cm²
Section modulus W_y = 1.50 cm³
Section modulus W_z = 1.74 cm³

Partial safety factors and combination coefficients

γ_g = 1.35 Importance/reliability factor
γ_q = 1.50 · 1.0 = 1.50 K_{FI} = 1.00 (RC2)
$\Psi_{0,w}$ = 0.60
$\Psi_{0,s}$ = 0.50 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	0.068	0.000	-0.052	0.571	0.049	0.000	-0.038	0.410	-0.056	0.000	0.020	-0.468
2	0.051	-0.068	-0.052	0.761	0.037	-0.049	-0.038	0.547	-0.044	0.056	0.020	-0.624
3	0.054	-0.063	-0.052	0.725	0.039	-0.045	-0.038	0.519	-0.046	0.053	0.020	-0.603
4	0.054	-0.066	-0.052	0.740	0.038	-0.047	-0.038	0.531	-0.046	0.055	0.020	-0.613

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	0.034	0.000	-0.026	0.280	0.018	0.000	-0.014	0.154	0.002	0.000	-0.002	0.019
2	0.025	-0.034	-0.026	0.373	0.013	-0.018	-0.014	0.205	0.001	-0.002	-0.002	0.025
3	0.027	-0.031	-0.026	0.355	0.014	-0.017	-0.014	0.194	0.001	-0.002	-0.002	0.022
4	0.026	-0.032	-0.026	0.363	0.014	-0.018	-0.014	0.199	0.001	-0.002	-0.002	0.023

Summary

	Midspan stresses				Stresses moments at support			
n	LC1	LC2	LC3	**Max**	LC1	LC2	LC3	**Max**
1	6.483	4.334	-3.607	**6.483**	0.000	0.000	0.000	**0.000**
2	4.857	3.206	-2.851	**4.857**	-6.483	-4.334	3.607	**6.483**
3	5.140	3.403	-2.980	**5.140**	-5.988	-3.977	3.429	**5.988**
4	5.078	3.359	-2.957	**5.078**	-6.210	-4.129	3.535	**6.210**
Stresses cantilever moment					4.970	3.322	1.432	**4.970**

Utilization ratio

$f_{y,d}$ = 18.2 kN/cm²

Single-span girder	η =	35.7%
Double-span girder	η =	35.7%
3-span girder	η =	32.9%
Multi-span girder	η =	34.2%
Cantilever	η =	27.3%

Verification of module-bearing rails (allowable spans) Eco 05 (120001)

Applicable for Roof mounting Corner zone

Tilt angle	α	30	°
Module length	h	2.07	m
Height above ground	z	9.00	m
Span	a	0.80	m
Cantilever	a_{kr}	0.40	m

sin = 0.500	cos = 0.866
c_{f1} = 0.40	c_{f2} = -1.10
Peak velocity pressure	0.41 kN/m²
Snow load	1.00 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 · 0.866 = 0.06 kN/m²
g_y = 0.11 · 0.500 = 0.04 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.58 kN/m²
s_z = 0.58 · 0.866 = 0.50 kN/m²
s_y = 0.58 · 0.500 = 0.29 kN/m²

Wind pressure

w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
w_{sz} = 0.41 · -1.10 = -0.45 kN/m²

W_{dz} = 0.16 · 1.03 = 0.11 kN/m
W_{sz} = -0.45 · 1.03 = -0.31 kN/m

Profile/rail characteristics

Overall system area A = 2.56 cm²
Section modulus W_y = 1.50 cm³
Section modulus W_z = 1.74 cm³

Partial safety factors and combination coefficients

γ_g = 1.35 Importance/reliability factor
γ_q = 1.50 · 1.0 = 1.50 K_{FI} = 1.00 (RC2)
$\Psi_{0,w}$ = 0.60
$\Psi_{0,s}$ = 0.50 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	0.068	0.000	-0.052	0.571	0.049	0.000	-0.038	0.410	-0.043	0.000	0.015	-0.361
2	0.051	-0.068	-0.052	0.761	0.037	-0.049	-0.038	0.547	-0.034	0.043	0.015	-0.481
3	0.054	-0.063	-0.052	0.725	0.039	-0.045	-0.038	0.519	-0.036	0.041	0.015	-0.465
4	0.054	-0.066	-0.052	0.740	0.038	-0.047	-0.038	0.531	-0.035	0.042	0.015	-0.473

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	0.034	0.000	-0.026	0.280	0.018	0.000	-0.014	0.154	0.002	0.000	-0.002	0.019
2	0.025	-0.034	-0.026	0.373	0.013	-0.018	-0.014	0.205	0.001	-0.002	-0.002	0.025
3	0.027	-0.031	-0.026	0.355	0.014	-0.017	-0.014	0.194	0.001	-0.002	-0.002	0.022
4	0.026	-0.032	-0.026	0.363	0.014	-0.018	-0.014	0.199	0.001	-0.002	-0.002	0.023

Summary

	Midspan stresses				Stresses moments at support			
n	LC1	LC2	LC3	**Max**	LC1	LC2	LC3	**Max**
1	6.483	4.334	-2.750	**6.483**	0.000	0.000	0.000	**0.000**
2	4.857	3.206	-2.193	**4.857**	-6.483	-4.334	2.750	**6.483**
3	5.140	3.403	-2.288	**5.140**	-5.988	-3.977	2.627	**5.988**
4	5.078	3.359	-2.272	**5.078**	-6.210	-4.129	2.706	**6.210**
Stresses cantilever moment					4.970	3.322	1.103	**4.970**

Utilization ratio

$f_{y,d}$ = 18.2 kN/cm²

Single-span girder	η =	35.7%
Double-span girder	η =	35.7%
3-span girder	η =	32.9%
Multi-span girder	η =	34.2%
Cantilever	η =	27.3%

Verification of the roof hook Roof hook Rapid2+ 45 (101001-000)
Applicable for Roof mounting on Gable roof (double pitch roof)

Tilt angle	α	30	°
Height above ground	z	9.00	m
Module length	h	2.07	m
Modular size of substructure	a	0.80	m
Cantilever	l_{kr}	0.40	m

sin =	0.500	cos =	0.866
Module weight	g	0.11	kN/m²
Snow load	s	1.00	kN/m²
Peak velocity pressure	$q(z)$	0.41	kN/m²

Wind force coefficients				Zo
c_{p1}	0.40	c_{p2}	-0.80	H
c_{p1}	0.40	c_{p2}	-1.40	F
c_{p1}	0.40	c_{p2}	-1.10	G

Load chart per Square meter of roof area

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.866 = 0.09 kN/m²
g_y = 0.11 · 0.500 = 0.05 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.87 kN/m²
s_z = 0.87 · 0.866 = 0.75 kN/m²
s_y = 0.87 · 0.500 = 0.43 kN/m²

Wind pressure

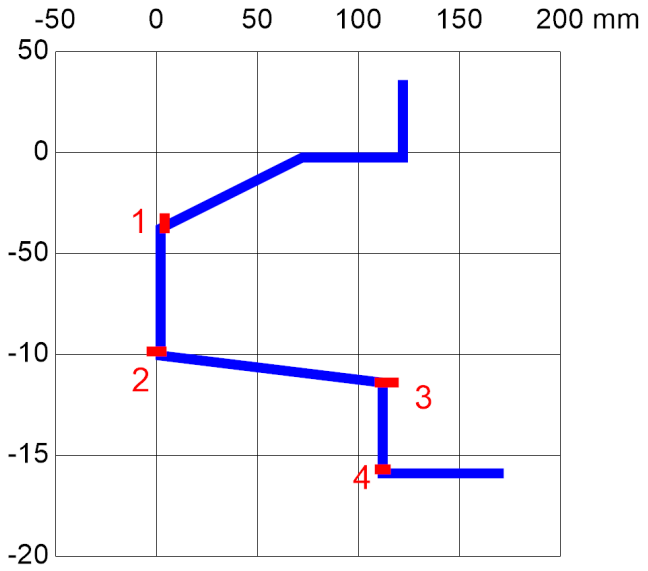
Zone H w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
Zone G w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
Zone F w_{dz} = 0.41 · 0.40 = 0.16 kN/m²

Wind suction

Zone H w_{sz} = 0.41 · -0.80 = -0.33 kN/m²
Zone G w_{sz} = 0.41 · -1.40 = -0.57 kN/m²
Zone F w_{sz} = 0.41 · -1.10 = -0.45 kN/m²

Profile/rail characteristics

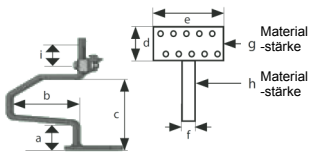
Schematic view of profile/rail, indicating the critical sections:



Sheet metal thickness	t =	0.6	cm
Cross-sectional area	A =	2.1	cm²
Hook width	b =	3.5	cm
Section modulus	W =	0.210	cm³

Roof hook Rapid2+ 45

	a	b	c	d	e	f	g	h	i
mm	45	110	118	60	150	35	5	6	30

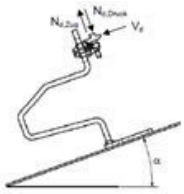


Load combinations

Importance/reliability factor: K_{FI} = 1.00 (RC2)
Load combination 1: $1.35 \cdot g + 1.5 \cdot s + 0.6 \cdot 1.5 \cdot w$
Load combination 2: $1.35 \cdot g + 0.5 \cdot 1.5 \cdot s + 1.5 \cdot w$
Load combination 3: $0.9 \cdot g + 1.5 \cdot w$

Due to the relatively soft PV supporting structure and the identical spans, the internal forces factor was set at 1.0.

Zone	LK 1		LK 2		LK 3	
	$F_{z,d}$	$F_{y,d}$	$F_{z,d}$	$F_{y,d}$	$F_{z,d}$	$F_{y,d}$
Zone H	0.867	0.448	0.580	0.247	-0.253	0.030
Zone G	0.867	0.448	0.580	0.247	-0.482	0.030
Zone F	0.867	0.448	0.580	0.247	-0.367	0.030



Load-bearing capacity of the roof hook

Partial fixation due to deformation impediment by cross beams 70%

			LK 1	LK 2	LK 3 H	LK 3 G	LK 3 F	abs. H	abs. G	abs. F
Section 1	e_{hor}	mm	140.0							
	e_{vert}	mm	86.0							
	M	kNcm	6.14	4.23	2.15	4.05	3.10	6.14	6.14	6.14
	N	kNcm	-0.45	-0.25	-0.03	-0.03	-0.03	0.45	0.45	0.45
Section 2	e_{hor}	mm	140.0							
	e_{vert}	mm	115.5		125.0					
	M	kNcm	4.82	3.50	2.24	4.14	3.19	4.82	4.82	4.82
	N	kNcm	-0.87	-0.58	0.25	0.48	0.37	0.87	0.87	0.87
Section 3	e_{hor}	mm	-30.0							
	e_{vert}	mm	125.0							
	M	kNcm	5.15	3.11	-0.51	-1.14	-0.82	5.15	5.15	5.15
	N	kNcm	-0.87	-0.58	0.25	0.48	0.37	0.87	0.87	0.87
Section 4	e_{hor}	mm	-30.0							
	e_{vert}	mm	170.0							
	M	kNcm	7.16	4.22	-0.37	-1.00	-0.69	7.16	7.16	7.16
	N	kNcm	-0.87	-0.58	0.25	0.48	0.37	0.87	0.87	0.87

Except for a possibly existing welded joint in section 4, a plastical reserve of W_{pl} = 1.5 W_{el} can be assumed.

Foot plate, welded: Yes

	Zone H		Zone G		Zone F	
	σ kN/cm²	η	σ kN/cm²	η	σ kN/cm²	η
Section 1	21.36	0.51	21.36	0.51	21.36	0.51
Section 2	17.01	0.41	17.01	0.41	17.01	0.41
Section 3	18.14	0.43	18.14	0.43	18.14	0.43
Section 4	37.41	0.89	37.41	0.89	37.41	0.89

Material 1.4301
$R_{p0,2}$ = 46.00 kN/cm²
$f_{y,d}$ = 41.82 kN/cm²

Permissible	1.12	1.12	1.12
Required	0.89	0.89	0.89

m² Effective load influence zone per roof hook
Roof hooks per 0.83 m²

Verification of connections

Tilt angle	α	30	°
Snow load	s	1.00	kN/m²
Height above ground	z	9.00	m
Module length	h	2.07	
Module weight	g	0.11	kN/m²

$\sigma\iota\nu$ = 0.500	$\chi o\sigma$ = 0.866	
Peak velocity pressure	0.41 kN/m²	
Zone F	$c_{p,1}$ = -1.10	
Zone G	$c_{p,1}$ = -1.40	Pressure coefficients $C_{pe,1}$
Zone H	$c_{p,1}$ = -0.80	

Load overview

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.866 = 0.06 kN/m²
g_y = 0.11 · 0.500 = 0.04 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.58 kN/m²
s_z = 0.58 · 0.866 = 0.50 kN/m²
s_y = 0.58 · 0.500 = 0.29 kN/m²

Wind suction

w_{dz} = 0.41 · 0.40 = 0.16 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
4.65	0.67	1.63	0.45

Module surface A = 2.06 m²
Frictional connection A = 0.26 kN ($F_{S,d} \cdot \mu$))

Internal forces at module clamps

Middle clamp $|F_{S,d}| = 0.50 \cdot (0.9 \cdot g_v + 1.5 \cdot 0.41 \cdot c_p) \cdot 2.06$
End clamp $|F_{S,d}| = 0.25 \cdot (0.9 \cdot g_v + 1.5 \cdot 0.41 \cdot c_p) \cdot 2.06$

	$V_{S,d}$ kN	$F_{S,d}$ kN		
		Zone F	Zone G	Zone H
Middle clamps	0.07	0.27	0.36	0.28
End clamps	0.04	0.14	0.18	0.14

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

Utilization ratio 10.5%
Utilization ratio 10.9%

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

Z_{Rd} = 4.60 kN
V_{Rd} = 2.00 kN

Rated value of acting forces

	kN	LC1	LC2	LC3			η
				Zone H	Zone G	Zone F	%
Vertical forces	N_{Sd}			-0.25	-0.48	-0.37	5.5
Shear forces	V_{Sd}	0.45	0.25	0.03	0.03	0.03	22.4

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

Project: Pétfürdő Önkormányzat keleti 2 tető

Module type: SPR-P3-415-COM 2066 x 998 mm

By order

January 2021

Project planning and auto-calculation

Version 5.112.0.0

Plant details

Date	28/01/2021
Customer	
Order	
Plant	2 R à 7 Mod

Module selection

Manufacturer	Sunpower
Module	SPR-P3-415-COM
Peak power	415 W
Height	2,066 mm
Width	998 mm
Thickness	40 mm
Framing	Framed

Module arrangement

Modules per row	7
Module rows	2
Number of modules	12
Selected support distance	800 mm
Cantilever	400 mm
Number of identical module fields	1

Basic configuration

System selection	
Module-bearing rail	Eco 05
Clamp type	Rapid16
Fastening	Roof hook Rapid2+ 45

Results: Plant details

Peak power	4.98 kW

Project Pétfürdő Önkormányzat keleti 2 tető

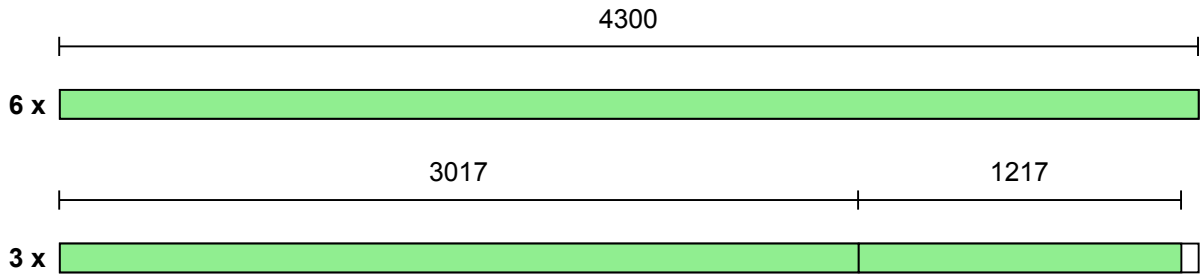
Bill of Materials: Pitched Roof System 2V

Pos	Item number	Item	Total amount	Length mm	Unit	Total weight kg
1	120001-04300	Module bearing rail Eco5 - 4300mm	9		ST	26.667
2	129001-004	Eco 05 interior connector kit	6		ST	0.498
3	101001-000	Roof hook Rapid2+ 45	48		ST	49.056
4	943208-120	Screw 8x120 TX VA wafer-head wood	96		ST	2.688
5	131101-001	End clamp Rapid16 V 30 - 40	12		ST	0.636
6	131121-001	Middle clamp Rapid16 30 - 40	30		ST	1.500
		Total				81.045

Attention! If you want to order directly from Schletter Solar GmbH only complete packing units will be provided!

Cutting plan (All dimensions in mm)

Module-bearing rail: Eco 05 (120001-04300)



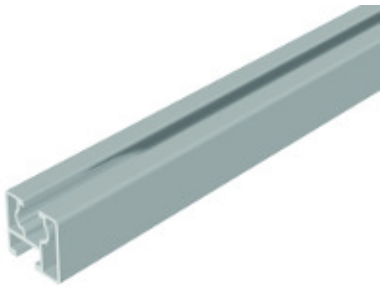
System configurator **Status** 5.112.0.0

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.

Customer			
Order			
Postal code construction site	**8105 Pétfürdo**		
	47.1667 ° northern latitude		
	18.1167 ° eastern longitude		
Tilt angle	α	**30.0**	°
Module length	h	**2.07**	m
Height above sea level	H	**126**	m
Height above ground	z	**9.00**	m
Height of roof parapet	h_p	**0.00**	m
Cantilever module beam	a_{kr}	**0.40**	m
Span of module beam	a	**0.80**	m

Module-bearing rail



Structural system

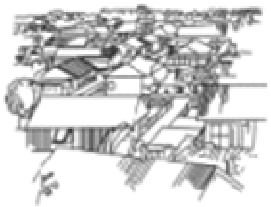
Gable roof (double pitch roof)

Module-bearing rail Eco 05

Load assumptions acc. to MSZ EN 1991-1

Load assumptions acc. to	g	**0.11**	kN/m²
Snow load	s	**1.00**	kN/m²
Terrain category		**III**	

Terrain category III



Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (villages, suburban terrain, permanent forest)

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) Eco 05 (120001)

Applicable for Roof mounting Central area

Tilt angle	α	30	°
Module length	h	2.07	m
Height above ground	z	9.00	m
Span	a	0.80	m
Cantilever	a_{kr}	0.40	m

sin = 0.500	cos = 0.866
c_{f1} = 0.40	c_{f2} = -0.80
Peak velocity pressure	0.41 kN/m²
Snow load	1.00 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 · 0.866 = 0.06 kN/m²
g_y = 0.11 · 0.500 = 0.04 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.58 kN/m²
s_z = 0.58 · 0.866 = 0.50 kN/m²
s_y = 0.58 · 0.500 = 0.29 kN/m²

Wind pressure

w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
w_{sz} = 0.41 · -0.80 = -0.33 kN/m²

W_{dz} = 0.16 · 1.03 = 0.11 kN/m
W_{sz} = -0.33 · 1.03 = -0.23 kN/m

Profile/rail characteristics

Overall system area A = 2.56 cm²
Section modulus W_y = 1.50 cm³
Section modulus W_z = 1.74 cm³

Partial safety factors and combination coefficients

γ_g = 1.35 Importance/reliability factor
γ_q = 1.50 · 1.0 = 1.50 K_{FI} = 1.00 (RC2)
$\Psi_{0,w}$ = 0.60
$\Psi_{0,s}$ = 0.50 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	0.068	0.000	-0.052	0.571	0.049	0.000	-0.038	0.410	-0.030	0.000	0.010	-0.254
2	0.051	-0.068	-0.052	0.761	0.037	-0.049	-0.038	0.547	-0.024	0.030	0.010	-0.338
3	0.054	-0.063	-0.052	0.725	0.039	-0.045	-0.038	0.519	-0.025	0.029	0.010	-0.328
4	0.054	-0.066	-0.052	0.740	0.038	-0.047	-0.038	0.531	-0.025	0.030	0.010	-0.333

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	0.034	0.000	-0.026	0.280	0.018	0.000	-0.014	0.154	0.002	0.000	-0.002	0.019
2	0.025	-0.034	-0.026	0.373	0.013	-0.018	-0.014	0.205	0.001	-0.002	-0.002	0.025
3	0.027	-0.031	-0.026	0.355	0.014	-0.017	-0.014	0.194	0.001	-0.002	-0.002	0.022
4	0.026	-0.032	-0.026	0.363	0.014	-0.018	-0.014	0.199	0.001	-0.002	-0.002	0.023

Summary

	Midspan stresses				Stresses moments at support			
n	LC1	LC2	LC3	**Max**	LC1	LC2	LC3	**Max**
1	6.483	4.334	-1.894	**6.483**	0.000	0.000	0.000	**0.000**
2	4.857	3.206	-1.536	**4.857**	-6.483	-4.334	1.894	**6.483**
3	5.140	3.403	-1.596	**5.140**	-5.988	-3.977	1.826	**5.988**
4	5.078	3.359	-1.587	**5.078**	-6.210	-4.129	1.877	**6.210**
Stresses cantilever moment					4.970	3.322	0.775	**4.970**

Utilization ratio

$f_{y,d}$ = 18.2 kN/cm²

Single-span girder	η =	35.7%
Double-span girder	η =	35.7%
3-span girder	η =	32.9%
Multi-span girder	η =	34.2%
Cantilever	η =	27.3%

Verification of module-bearing rails (allowable spans) Eco 05 (120001)

Applicable for Roof mounting Border zone

Tilt angle	α	30	°
Module length	h	2.07	m
Height above ground	z	9.00	m
Span	a	0.80	m
Cantilever	a_{kr}	0.40	m

sin = 0.500	cos = 0.866
c_{f1} = 0.40	c_{f2} = -1.40
Peak velocity pressure	0.41 kN/m²
Snow load	1.00 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 · 0.866 = 0.06 kN/m²
g_y = 0.11 · 0.500 = 0.04 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.58 kN/m²
s_z = 0.58 · 0.866 = 0.50 kN/m²
s_y = 0.58 · 0.500 = 0.29 kN/m²

Wind pressure

w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
w_{sz} = 0.41 · -1.40 = -0.57 kN/m²

W_{dz} = 0.16 · 1.03 = 0.11 kN/m
W_{sz} = -0.57 · 1.03 = -0.40 kN/m

Profile/rail characteristics

Overall system area A = 2.56 cm²
Section modulus W_y = 1.50 cm³
Section modulus W_z = 1.74 cm³

Partial safety factors and combination coefficients

γ_g = 1.35 Importance/reliability factor
γ_q = 1.50 · 1.0 = 1.50 K_{FI} = 1.00 (RC2)
$\Psi_{0,w}$ = 0.60
$\Psi_{0,s}$ = 0.50 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	0.068	0.000	-0.052	0.571	0.049	0.000	-0.038	0.410	-0.056	0.000	0.020	-0.468
2	0.051	-0.068	-0.052	0.761	0.037	-0.049	-0.038	0.547	-0.044	0.056	0.020	-0.624
3	0.054	-0.063	-0.052	0.725	0.039	-0.045	-0.038	0.519	-0.046	0.053	0.020	-0.603
4	0.054	-0.066	-0.052	0.740	0.038	-0.047	-0.038	0.531	-0.046	0.055	0.020	-0.613

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	0.034	0.000	-0.026	0.280	0.018	0.000	-0.014	0.154	0.002	0.000	-0.002	0.019
2	0.025	-0.034	-0.026	0.373	0.013	-0.018	-0.014	0.205	0.001	-0.002	-0.002	0.025
3	0.027	-0.031	-0.026	0.355	0.014	-0.017	-0.014	0.194	0.001	-0.002	-0.002	0.022
4	0.026	-0.032	-0.026	0.363	0.014	-0.018	-0.014	0.199	0.001	-0.002	-0.002	0.023

Summary

	Midspan stresses				Stresses moments at support			
n	LC1	LC2	LC3	**Max**	LC1	LC2	LC3	**Max**
1	6.483	4.334	-3.607	**6.483**	0.000	0.000	0.000	**0.000**
2	4.857	3.206	-2.851	**4.857**	-6.483	-4.334	3.607	**6.483**
3	5.140	3.403	-2.980	**5.140**	-5.988	-3.977	3.429	**5.988**
4	5.078	3.359	-2.957	**5.078**	-6.210	-4.129	3.535	**6.210**
Stresses cantilever moment					4.970	3.322	1.432	**4.970**

Utilization ratio

$f_{y,d}$ = 18.2 kN/cm²

Single-span girder	η =	35.7%
Double-span girder	η =	35.7%
3-span girder	η =	32.9%
Multi-span girder	η =	34.2%
Cantilever	η =	27.3%

Verification of module-bearing rails (allowable spans) Eco 05 (120001)

Applicable for Roof mounting Corner zone

Tilt angle	α	30	°
Module length	h	2.07	m
Height above ground	z	9.00	m
Span	a	0.80	m
Cantilever	a_{kr}	0.40	m

sin = 0.500	cos = 0.866
c_{f1} = 0.40	c_{f2} = -1.10
Peak velocity pressure	0.41 kN/m²
Snow load	1.00 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 · 0.866 = 0.06 kN/m²
g_y = 0.11 · 0.500 = 0.04 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.58 kN/m²
s_z = 0.58 · 0.866 = 0.50 kN/m²
s_y = 0.58 · 0.500 = 0.29 kN/m²

Wind pressure

w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
w_{sz} = 0.41 · -1.10 = -0.45 kN/m²

W_{dz} = 0.16 · 1.03 = 0.11 kN/m
W_{sz} = -0.45 · 1.03 = -0.31 kN/m

Profile/rail characteristics

Overall system area A = 2.56 cm²
Section modulus W_y = 1.50 cm³
Section modulus W_z = 1.74 cm³

Partial safety factors and combination coefficients

γ_g = 1.35 Importance/reliability factor
γ_q = 1.50 · 1.0 = 1.50 K_{FI} = 1.00 (RC2)
$\Psi_{0,w}$ = 0.60
$\Psi_{0,s}$ = 0.50 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	0.068	0.000	-0.052	0.571	0.049	0.000	-0.038	0.410	-0.043	0.000	0.015	-0.361
2	0.051	-0.068	-0.052	0.761	0.037	-0.049	-0.038	0.547	-0.034	0.043	0.015	-0.481
3	0.054	-0.063	-0.052	0.725	0.039	-0.045	-0.038	0.519	-0.036	0.041	0.015	-0.465
4	0.054	-0.066	-0.052	0.740	0.038	-0.047	-0.038	0.531	-0.035	0.042	0.015	-0.473

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	0.034	0.000	-0.026	0.280	0.018	0.000	-0.014	0.154	0.002	0.000	-0.002	0.019
2	0.025	-0.034	-0.026	0.373	0.013	-0.018	-0.014	0.205	0.001	-0.002	-0.002	0.025
3	0.027	-0.031	-0.026	0.355	0.014	-0.017	-0.014	0.194	0.001	-0.002	-0.002	0.022
4	0.026	-0.032	-0.026	0.363	0.014	-0.018	-0.014	0.199	0.001	-0.002	-0.002	0.023

Summary

	Midspan stresses				Stresses moments at support			
n	LC1	LC2	LC3	**Max**	LC1	LC2	LC3	**Max**
1	6.483	4.334	-2.750	**6.483**	0.000	0.000	0.000	**0.000**
2	4.857	3.206	-2.193	**4.857**	-6.483	-4.334	2.750	**6.483**
3	5.140	3.403	-2.288	**5.140**	-5.988	-3.977	2.627	**5.988**
4	5.078	3.359	-2.272	**5.078**	-6.210	-4.129	2.706	**6.210**
Stresses cantilever moment					4.970	3.322	1.103	**4.970**

Utilization ratio

$f_{y,d}$ = 18.2 kN/cm²

Single-span girder	η =	35.7%
Double-span girder	η =	35.7%
3-span girder	η =	32.9%
Multi-span girder	η =	34.2%
Cantilever	η =	27.3%

Verification of the roof hook Roof hook Rapid2+ 45 (101001-000)
Applicable for Roof mounting on Gable roof (double pitch roof)

Tilt angle	α	30	°
Height above ground	z	9.00	m
Module length	h	2.07	m
Modular size of substructure	a	0.80	m
Cantilever	l_{kr}	0.40	m

sin =	0.500	cos =	0.866
Module weight	g	0.11	kN/m²
Snow load	s	1.00	kN/m²
Peak velocity pressure	$q(z)$	0.41	kN/m²

Wind force coefficients				Zo
c_{p1}	0.40	c_{p2}	-0.80	H
c_{p1}	0.40	c_{p2}	-1.40	F
c_{p1}	0.40	c_{p2}	-1.10	G

Load chart per Square meter of roof area

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.866 = 0.09 kN/m²
g_y = 0.11 · 0.500 = 0.05 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.87 kN/m²
s_z = 0.87 · 0.866 = 0.75 kN/m²
s_y = 0.87 · 0.500 = 0.43 kN/m²

Wind pressure

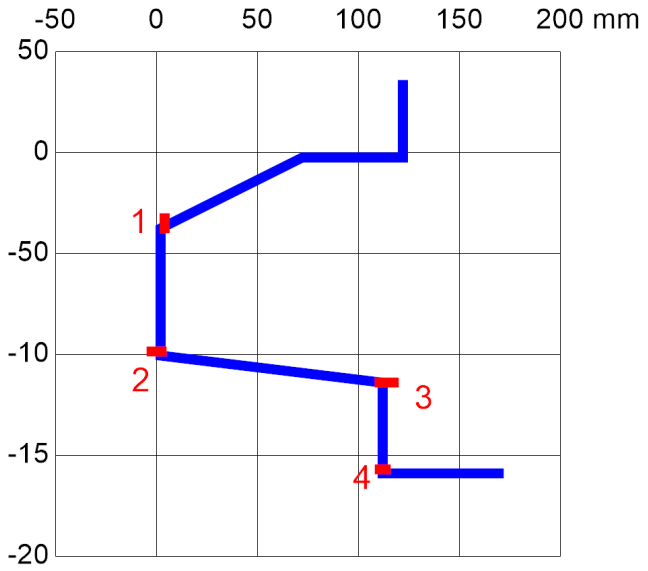
Zone H w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
Zone G w_{dz} = 0.41 · 0.40 = 0.16 kN/m²
Zone F w_{dz} = 0.41 · 0.40 = 0.16 kN/m²

Wind suction

Zone H w_{sz} = 0.41 · -0.80 = -0.33 kN/m²
Zone G w_{sz} = 0.41 · -1.40 = -0.57 kN/m²
Zone F w_{sz} = 0.41 · -1.10 = -0.45 kN/m²

Profile/rail characteristics

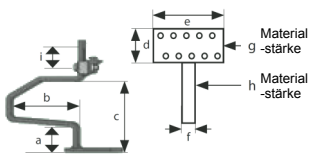
Schematic view of profile/rail, indicating the critical sections:



Sheet metal thickness	t =	0.6	cm
Cross-sectional area	A =	2.1	cm²
Hook width	b =	3.5	cm
Section modulus	W =	0.210	cm³

Roof hook Rapid2+ 45

	a	b	c	d	e	f	g	h	i
mm	45	110	118	60	150	35	5	6	30

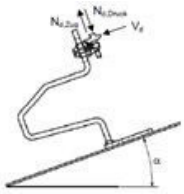


Load combinations

Importance/reliability factor: K_{FI} = 1.00 (RC2)
Load combination 1: $1.35 \cdot g + 1.5 \cdot s + 0.6 \cdot 1.5 \cdot w$
Load combination 2: $1.35 \cdot g + 0.5 \cdot 1.5 \cdot s + 1.5 \cdot w$
Load combination 3: $0.9 \cdot g + 1.5 \cdot w$

Due to the relatively soft PV supporting structure and the identical spans, the internal forces factor was set at 1.0.

Zone	LK 1		LK 2		LK 3	
	$F_{z,d}$	$F_{y,d}$	$F_{z,d}$	$F_{y,d}$	$F_{z,d}$	$F_{y,d}$
Zone H	0.867	0.448	0.580	0.247	-0.253	0.030
Zone G	0.867	0.448	0.580	0.247	-0.482	0.030
Zone F	0.867	0.448	0.580	0.247	-0.367	0.030



Load-bearing capacity of the roof hook

Partial fixation due to deformation impediment by cross beams 70%

			LK 1	LK 2	LK 3 H	LK 3 G	LK 3 F	abs. H	abs. G	abs. F
Section 1	e_{hor}	mm	140.0							
	e_{vert}	mm	86.0							
	M	kNcm	6.14	4.23	2.15	4.05	3.10	6.14	6.14	6.14
	N	kNcm	-0.45	-0.25	-0.03	-0.03	-0.03	0.45	0.45	0.45
Section 2	e_{hor}	mm	140.0							
	e_{vert}	mm	115.5		125.0					
	M	kNcm	4.82	3.50	2.24	4.14	3.19	4.82	4.82	4.82
	N	kNcm	-0.87	-0.58	0.25	0.48	0.37	0.87	0.87	0.87
Section 3	e_{hor}	mm	-30.0							
	e_{vert}	mm	125.0							
	M	kNcm	5.15	3.11	-0.51	-1.14	-0.82	5.15	5.15	5.15
	N	kNcm	-0.87	-0.58	0.25	0.48	0.37	0.87	0.87	0.87
Section 4	e_{hor}	mm	-30.0							
	e_{vert}	mm	170.0							
	M	kNcm	7.16	4.22	-0.37	-1.00	-0.69	7.16	7.16	7.16
	N	kNcm	-0.87	-0.58	0.25	0.48	0.37	0.87	0.87	0.87

Except for a possibly existing welded joint in section 4, a plastical reserve of W_{pl} = 1.5 W_{el} can be assumed.

Foot plate, welded: Yes

	Zone H		Zone G		Zone F	
	σ kN/cm²	η	σ kN/cm²	η	σ kN/cm²	η
Section 1	21.36	0.51	21.36	0.51	21.36	0.51
Section 2	17.01	0.41	17.01	0.41	17.01	0.41
Section 3	18.14	0.43	18.14	0.43	18.14	0.43
Section 4	37.41	0.89	37.41	0.89	37.41	0.89

Material 1.4301
$R_{p0,2}$ = 46.00 kN/cm²
$f_{y,d}$ = 41.82 kN/cm²

Permissible	1.12	1.12	1.12
Required	0.89	0.89	0.89

m² Effective load influence zone per roof hook
Roof hooks per 0.83 m²

Verification of connections

Tilt angle	α	30	°
Snow load	s	1.00	kN/m²
Height above ground	z	9.00	m
Module length	h	2.07	
Module weight	g	0.11	kN/m²

$\sigma\iota\nu$ = 0.500	$\chi o\sigma$ = 0.866	
Peak velocity pressure	0.41 kN/m²	
Zone F	$c_{p,1}$ = -1.10	
Zone G	$c_{p,1}$ = -1.40	Pressure coefficients $C_{pe,1}$
Zone H	$c_{p,1}$ = -0.80	

Load overview

Dead load Modules

g_v = 0.11 · 1.00 · 1.00 = 0.11 kN/m²
g_z = 0.11 · 0.866 = 0.06 kN/m²
g_y = 0.11 · 0.500 = 0.04 kN/m²

Snow load

s_v = 1.00 · 0.87 · 1.00 = 0.58 kN/m²
s_z = 0.58 · 0.866 = 0.50 kN/m²
s_y = 0.58 · 0.500 = 0.29 kN/m²

Wind suction

w_{dz} = 0.41 · 0.40 = 0.16 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
4.65	0.67	1.63	0.45

Module surface A = 2.06 m²
Frictional connection A = 0.26 kN ($F_{S,d} \cdot \mu$))

Internal forces at module clamps

Middle clamp $|F_{S,d}| = 0.50 \cdot (0.9 \cdot g_v + 1.5 \cdot 0.41 \cdot c_p) \cdot 2.06$
End clamp $|F_{S,d}| = 0.25 \cdot (0.9 \cdot g_v + 1.5 \cdot 0.41 \cdot c_p) \cdot 2.06$

	$V_{S,d}$ kN	$F_{S,d}$ kN		
		Zone F	Zone G	Zone H
Middle clamps	0.07	0.27	0.36	0.28
End clamps	0.04	0.14	0.18	0.14

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

Utilization ratio 10.5%
Utilization ratio 10.9%

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

Z_{Rd} = 4.60 kN
V_{Rd} = 2.00 kN

Rated value of acting forces

	kN	LC1	LC2	LC3			η
				Zone H	Zone G	Zone F	%
Vertical forces	N_{Sd}			-0.25	-0.48	-0.37	5.5
Shear forces	V_{Sd}	0.45	0.25	0.03	0.03	0.03	22.4