Gewaarmerkt als
behorende bij besluit
16 oktober 2018

PowerField

Datasheets en constructiebrief zonnepark

1. Datasheet frames Schletter
2. Datasheet panelen Astronergy
3. Datasheet omvormers Sungrow
4. Constructeursbrief zonnepark Stadskanaal

1. Datasheet frames Schletter

FS Duo

- Maximum level of pre-fabrication
- No soil sealing
- Quick and simple mounting
- Perfectly synchronized system components
- High economic efficiency
- 5-year durability guarantee

The FS open area mounting system has been installed by Schletter for many years in a large number of projects in Germany, Europe and other parts of the world.

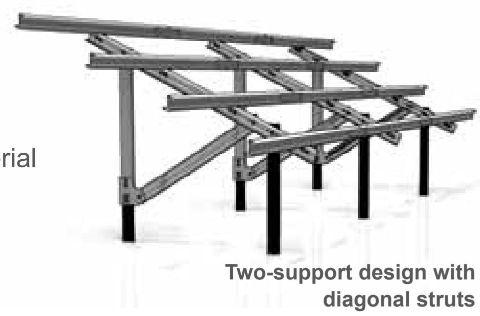
All the experience gained in these projects was made use of in the development of this new steel design, which resulted in an even more price-efficient fastening system for solar mounting, because especially in the sector of open area plants, the increasing cost-pressure makes an optimum material utilization unavoidable. With our the FS steel system, this principle was implemented uncompromisingly.

Two-support design without diagonal struts

On request, all possibilities of project-specific in-house pre-fabrication are utilized to reduce the mounting time on the construction site.
Two different designs of the two-support rack are available - with or without diagonal struts. Depending on the soil conditions, these two basic designs allow an individual project planning with maximum economic efficiency.

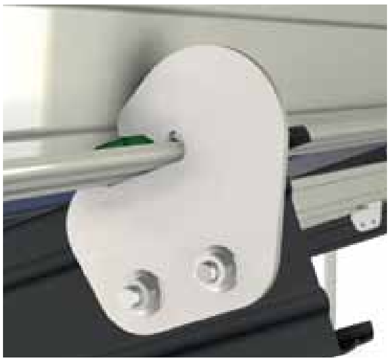
FS Duo - your advantages

- Efficient material utilization
- Wider support distances modified to the terrain are possible
- Galvanized sheet metal edges made of strip galvanised material
- Average thickness of zinc layer up to 80µm



Two-support design with diagonal struts

Short description of the mounting

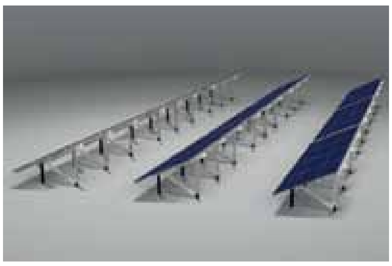


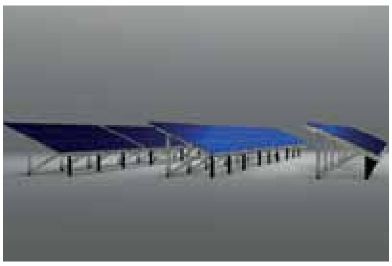
The girder profile is fastened to the pile-driven U-profiles. The module-bearing profiles are hooked in using connector hooks and are fastened with a fastening device made of high-grade steel. For this purpose, the fastening device is accurately hammered in using a hammer in order to create a fixed connection with prestress. This safeguards durable stability also in difficult conditions.

Technical data

Material	Fastening elements, bolts: Steel, hot-dip galvanised respectively high-grade steel (fixing device, bolts) Profiles: Steel, hot-dip galvanized Pile-driven foundations: Steel, hot-dip galvanized
Logistics	• Delivery of single components as well as a maximum level of pre-assembly are possible. • Transport to the installation site appropriate to the specific kind of mounting
Construction	• Quick and easy mounting
Delivery and services	• Ground survey and structural analysis • Structural analysis of the individual rack based on regional data • Pile driving of the foundations and delivery of the complete mounting material • **Optional:** Rack mounting • **Optional:** Complete module mounting
Structural analysis	• Structural analysis of the respective terrain based on a geological survey • Individual systems analysis based on regional load values Load assumptions according to DIN 1055, part 4 (03/2006), part 5 (06/2005), part 100 (03/2001), Eurocode 1 (06/2002), DIN 4113, DIN 18800, Eurocode 9 DIN 4113, DIN 18800, Eurocode 9 and further respectively country-specific standards • Highly efficient, material-saving profile geometries • Verification of all construction components based on FEM-calculation

Further information at www.schletter.eu





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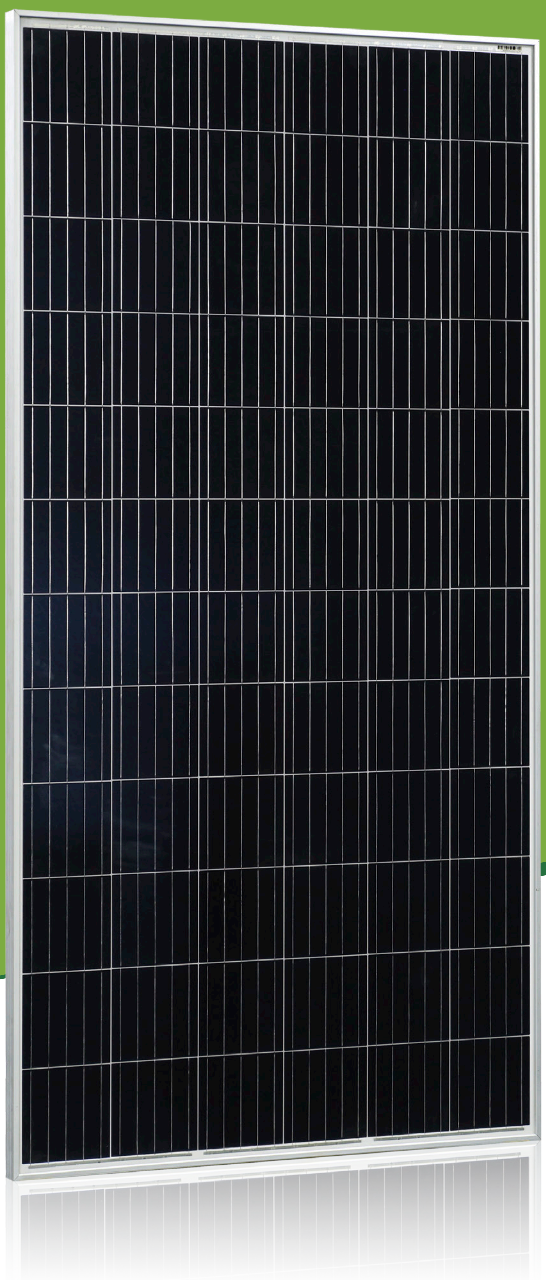
2. Datasheet panelen Astronergy

For Global Market



STAVE™ II
330W ~ 345W

5BB-Polycrystalline PV Module

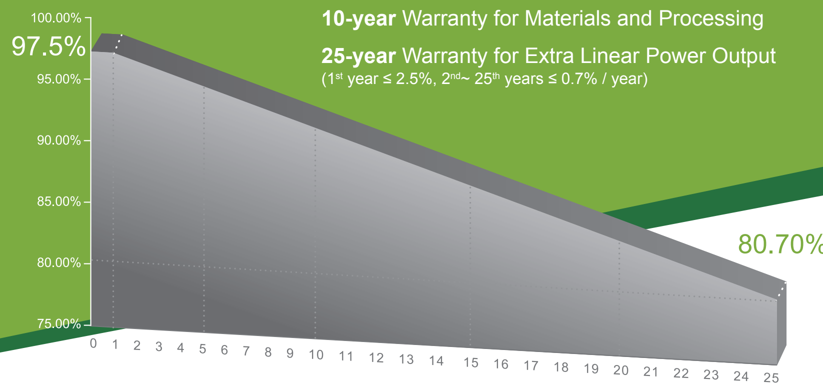
CHSM6612P Series
CHSM6612P/HV Series

CHSM6612P max system voltage 1000V standard
CHSM6612P/HV max system voltage 1500V standard

Tier 1 Bloomberg | No.1 PHOTON | MunichRe Insured | DNV GL 2017 TOP Performance

10-year Warranty for Materials and Processing

25-year Warranty for Extra Linear Power Output
(1st year ≤ 2.5%, 2nd~ 25th years ≤ 0.7% / year)



KEY FEATURES

+5W
OUTPUT POSITIVE TOLERANCE
Guaranteed 0~+5W positive tolerance ensures power output reliability.

INNOVATIONAL 5-BUSBAR CELLS
Reduces the cell series resistance and internal stress, decreases the risk of mirco-crack and improves the module output.

PERC
INNOVATIVE PERC CELL TECHNOLOGY
Excellent cell efficiency and output.

6000 3600
EXCELLENT MECHANICAL LOAD CAPABILITY
Certified to withstand: snow load (6000 Pa) and wind load (3600 Pa).

HIGHER RELIABILITY AND DURABILITY
Effectively deals with harsh environments,such as sand, salt mist and ammonia resistance.

PASSED HAIL TEST
Certified to hail resistence: ice ball size (d=45mm) and ice ball velocity (v=30.7m/s).

Anti PID
PID RESISTANCE
Excellent PID resistance at 96 hours (@85℃/85%) test, and also can be improved to meet higher standards for the particularly harsh environment.

COMPREHENSIVE CERTIFICATES

CQC | TÜVRheinland CERTIFIED | SP C US | INMETRO
CE | ISO 9001 | ISO 14001 | OHSAS 18001 | 신·재생에너지 New & Renewable Energy
JET www.jet.or.jp | APPROVED PRODUCT MCS | CNAS | SATELLITE Intertek
TÜV NORD IEC TS 62941

First solar company which passed the TUV Nord IEC/TS 62941 certification audit.

A CHINT COMPANY

ASTRONERGY

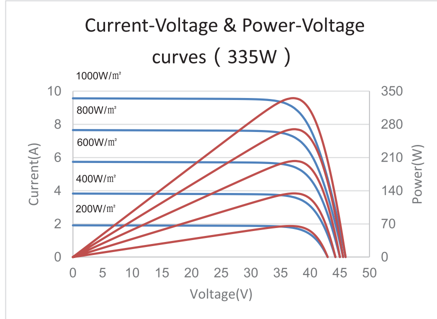
ELECTRICAL SPECIFICATIONS

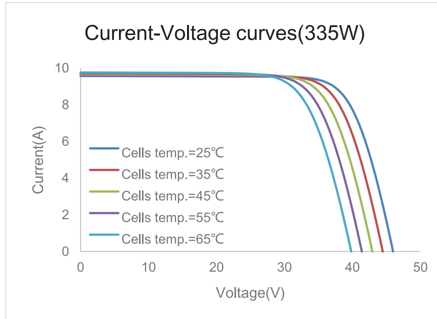
STC rated output (Pmpp)*	330 Wp	335 Wp	340 Wp	345 Wp
Rated voltage (Vmpp) at STC	37.15 V	37.26 V	37.33 V	37.38 V
Rated current (Impp) at STC	8.89 A	9.00 A	9.11 A	9.23 A
Open circuit voltage (Voc) at STC	45.86 V	45.98 V	46.16 V	46.37 V
Short circuit current (Isc) at STC	9.52 A	9.57 A	9.62 A	9.67 A
Module efficiency	17.1%	17.3%	17.6%	17.8%
Rated output (Pmpp) at NOCT	230.4 Wp	233.9 Wp	237.4 Wp	240.9 Wp
Rated voltage (Vmpp) at NOCT	33.92 V	34.01 V	34.10 V	34.15 V
Rated current (Impp) at NOCT	6.79 A	6.88 A	6.96 A	7.05 A
Open circuit voltage (Voc) at NOCT	42.08 V	42.19 V	42.36 V	42.55 V
Short circuit current (Isc) at NOCT	7.37 A	7.40 A	7.44 A	7.48 A
Temperature coefficient (Pmpp)	- 0.408%/°C			
Temperature coefficient (Isc)	+0.050%/°C			
Temperature coefficient (Voc)	- 0.311%/°C			
Normal operating cell temperature (NOCT)	46±2°C			
Maximum system voltage (IEC/UL)	1000V$_{DC}$ or 1500V$_{DC}$			
Number of diodes	3			
Junction box IP rating	IP 67			
Maximum series fuse rating	15 A			

* Measurement tolerance +/- 3%

STC: Irradiance 1000W/m², Cell Temperature 25°C, AM=1.5
NOCT: Irradiance 800W/m², Ambient Temperature 20°C, AM=1.5, Wind Speed 1m/s

CURVE





MECHANICAL SPECIFICATIONS

Outer dimensions (L x W x H)	1954 x 990 x 40 mm 76.93 x 38.98 x 1.57 in
Frame technology	Aluminum, silver anodized
Module composition	Glass / EVA / Backsheet (white)
Front glass thickness	3.2 mm / 0.13 in
①Cable length (IEC/UL)	1150 mm / 45.28 in
Cable diameter (IEC/UL)	4 mm² / 12 AWG
②Maximum mechanical test load	6000 Pa
Fire performance (IEC/UL)	Class C (IEC) or Type 1 (UL)
Connector type (IEC/UL)	MC4 compatible

① Option: 900(+) /600(-) mm for defined projects in advance.

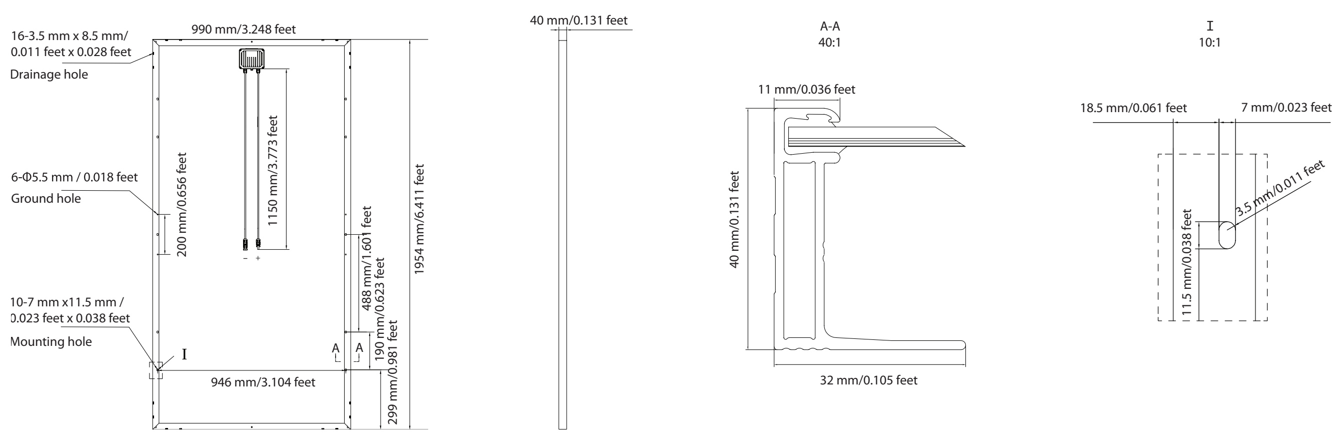
② Refer to Astronergy crystalline installation manual or contact technical department.
Maximum Mechanical Test Load=1.5×Maximum Mechanical Design Load.

PACKING SPECIFICATIONS

①Weight (module only)	21.8 kg / 48.06 lbs
②Packing unit	27 pcs / box
Weight of packing unit (for 40'HQ container)	646 kg / 1424 lbs
Number of modules per 40'HQ container	648 pcs

① Tolerance +/- 1.0kg
② Subject to sales contract

MODULE DIMENSION DETAILS



PowerField

3. Datasheet omvormers Sungrow

SUNGROW

SG125HV

String Inverter for 1500 Vdc System

High Yield

- Patent five-level topology, max. efficiency 98.9 %, European efficiency 98.7 %, CEC efficiency 98.5 %
- Full power operation without derating at 50 ℃

Easy O&M

- Virtual central solution, easy for O&M
- Compact design and light weight for easy installation

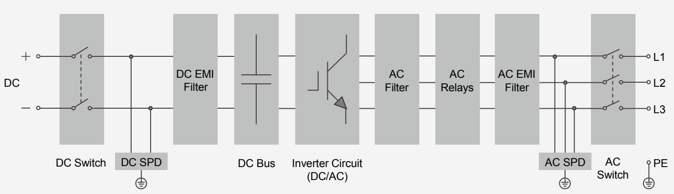
Saved Investment

- DC 1500 V, AC 600 V, low system initial investment
- 1 to 5 MW power block design for lower MV transformer and labor cost
- Max. DC/AC ratio up to 1.5

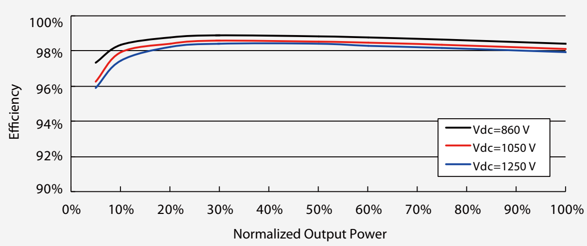
Grid Support

- Compliance with both IEC and UL safety, EMC and grid support regulations
- Low/High voltage ride through (L/HVRT)
- Active & reactive power control and power ramp rate control

Circuit Diagram



Efficiency Curve



Input (DC)	SG125HV
Max. PV input voltage	1500 V
Min. PV input voltage / Startup input voltage	860 V / 920 V
Nominal input voltage	1050 V
MPP voltage range	860 – 1450 V
MPP voltage range for nominal power	860 – 1250 V
No. of independent MPP inputs	1
No. of DC inputs	1
Max. PV input current	148 A
Max. DC short-circuit current	240 A
Output (AC)	
AC output power	125000 VA @ 50 ℃
Max. AC output current	120 A
Nominal AC voltage	3 / PE, 600 V
AC voltage range	480 – 690 V
Nominal grid frequency / Grid frequency range	50 Hz / 45 – 55 Hz, 60 Hz / 55 – 65 Hz
THD	< 3 % (at nominal power)
DC current injection	< 0.5 % In
Power factor at nominal power / Adjustable power factor	> 0.99 / 0.8 leading – 0.8 lagging
Feed-in phases / Connection phases	3 / 3
Efficiency	
Max. efficiency / Euro. efficiency / CEC effciency	98.9 % / 98.7 % / 98.5 %
Protection	
DC reverse connection protection	Yes
AC short-circuit protection	Yes
Leakage current protection	Yes
Grid monitoring	Yes
DC switch / AC switch	Yes / Yes
Overvoltage protection	DC Type II / AC Type II
General Data	
Dimensions (W*H*D)	670*902*296 mm 26.4''*35.5''*11.7''
Weight	72 kg 158.7 lb
Isolation method	Transformerless
Degree of protection	NEMA 4X
Night power consumption	< 4 W
Operating ambient temperature range	-25 to 60 ℃ (> 50 ℃ derating) -13 to 140 ℉ (> 122 ℉ derating)
Allowable relative humidity range (non-condensing)	0 – 100 %
Cooling method	Smart forced air cooling
Max. operating altitude	4000 m (> 3000 m derating) 13123 ft (> 9843 ft derating)
Display / Communication	LED, Bluetooth+APP / RS485
DC connection type	OT or DT terminal (Max. 350 Kcmil)
AC connection type	OT or DT terminal (Max. 350 Kcmil)
Compliance	CE, IEC 62109-1/-2, IEC 61000-6-2/-4, IEC 61727, IEC 62116, IEC 61000-3-11/-12, UL 1741, UL 1741 SA, IEEE 1547, IEEE 1547.1, CSA C22.2 107.1-01 and California Rule 21
Grid support	LVRT, HVRT, active & reactive power control and power ramp rate control
Type designation	SG125HV-10

4. Constructeursbrief zonnepark Stadskanaal

A&I | KWANT adviseurs & ingenieurs

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adviseurs & ingenieurs
Transportweg 67
9645 KZ VEENDAM
Postbus 387
9640 AJ VEENDAM

Telefoon
(0598) 619 357
(0598) 393 739

E-mail
info@ibkwant.nl

Internet
www.ibkwant.nl

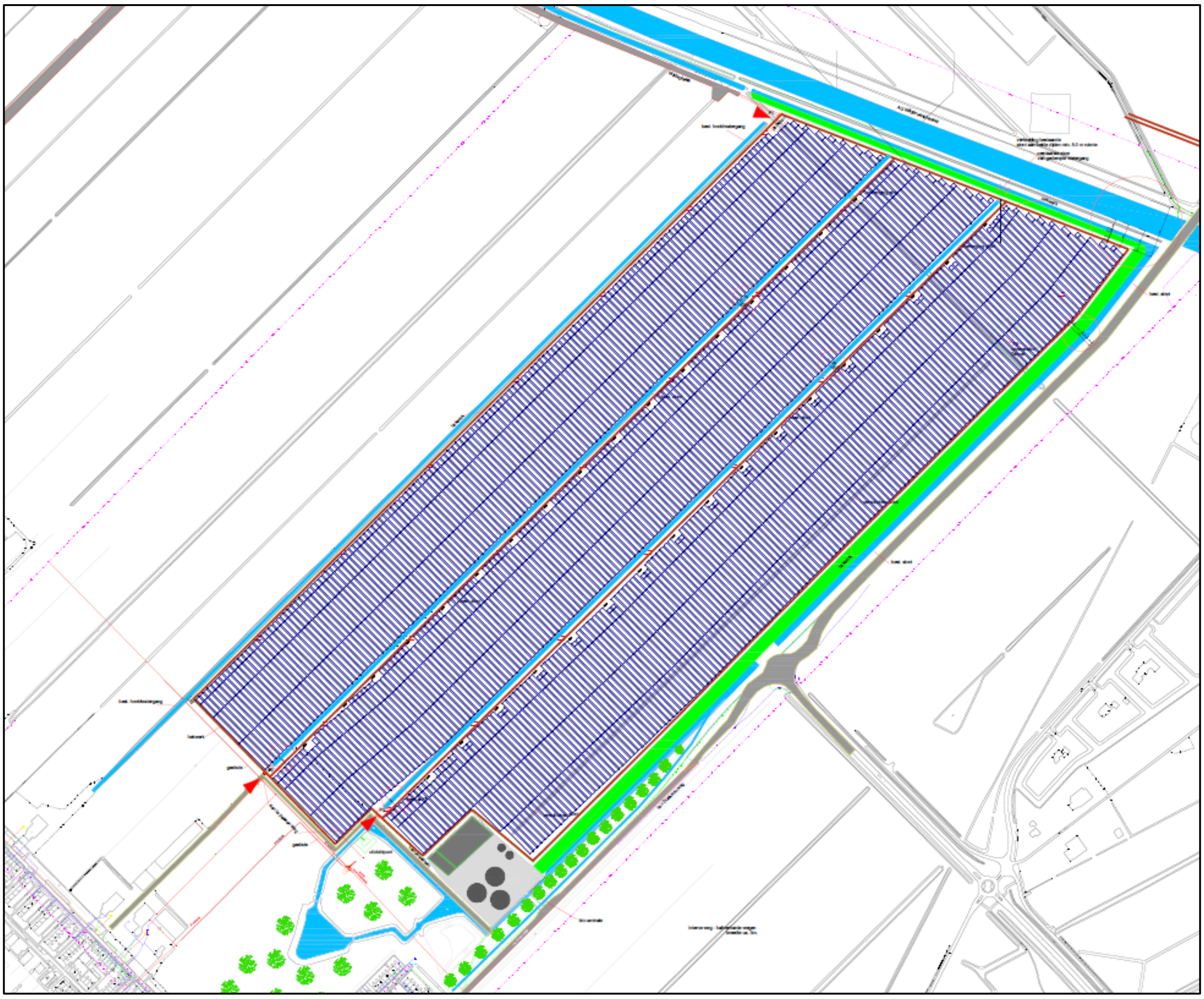
Constructieve ontwerpnota t.g.v. aanvraag omgevingsvergunning

Projectnummer: 16-188 ME-01 V1.0
Project: Zonnepark Stadskanaal
Opdrachtgever: POWERFIELD
Contactpersoon: de heer J. van Leeuwen
Datum: 08-05-2018
Onderwerp: Modules zonnepanelen
Auteur: D. Scheven
Bureaucheck: D. van Dijk

Inleiding:

Aan de van Boekerenweg te Stadskanaal wordt een zonnepark gerealiseerd. De zonnepanelen worden geplaatst op stalen modules van dunwandige gezette stalen profielen. Dit document dient als begeleidend schrijven op het constructief ontwerp ten geleide van de Aanvraagprocedure voor de Omgevingsvergunning voor de stalen modules.

In dit document worden de constructieve uitgangspunten vastgelegd voor de stalen modules en dient als basis voor de in een later stadium te verzorgen UO-berekening.



Figuur 1: Locatie zonnepark Stadskanaal

Referentie

Tekening: LL01-AB index 2, d.d. 30-04-2018

Normen

Deze berekening is gebaseerd op de volgende Nederlandse normen:

- NEN-EN 1990:2011 Grondslagen van het constructief ontwerp + NB:2011;
- NEN-EN 1991:2011 Belastingen op constructies + NB:2011;
- NEN-EN 1993:2011 Ontwerp en berekening van staalconstructies + NB:2011.
- NEN-EN 1997:2011 Geotechnisch ontwerp.
- NEN-EN 1999:2008 Ontwerp en berekening van aluminiumconstructies

Eigenschappen materialen

Staalkwaliteit

Voor de modules wordt gebruik gemaakt van Duitse profielen met Duitse staalkwaliteiten.

Gordingen:	S380 GD (zie berekening 01 9600 t/m 03 9600)
Liggers	S500 GD (zie berekening 01 9600 t/m 03 9600)
Kolommen:	S380 GD (zie berekening 01 9600 t/m 03 9600)

De berekeningen zijn voor een project in Hoogezand maar worden in dit stadium ook voor dit project aangehouden.

Verbindingsmiddelen:	A2-70
Fundering:	Vaste grondslag dient nader bepaald te worden.

Klasse indeling Eurocode

Betrouwbaarheidsklasse:	□ RC1	
Gevolgklasse:	□ CC1	(tabel NB.21 van NEN-EN1990+NB)
Ontwerplevensduurklasse:	□ 2	(tabel NB.1 – 2.1 van NEN-EN1990+NB)
Ontwerplevensduur:	□ 15 jaar	
Uitvoeringsklasse:	□ EXC1	

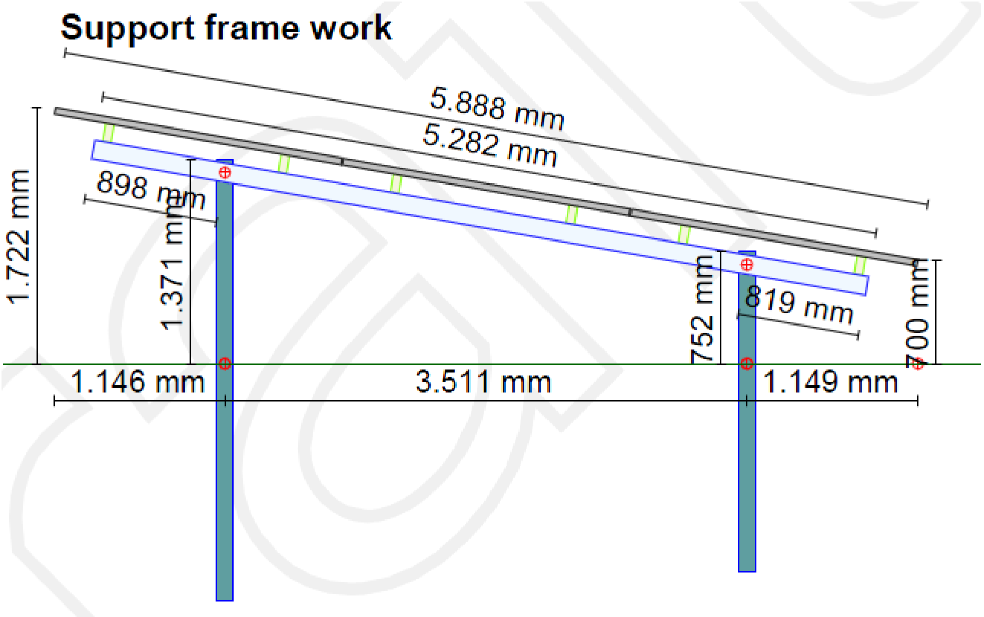
Belastingfactoren

	ULS	SLS
Permanent:	$\gamma_{f;G}$ = 0,9/1,08/1,22	$\gamma_{f;ser;G}$ = 1,0
Veranderlijk:	$\gamma_{f;Q}$ = 1,35	$\gamma_{f;ser;Q}$ = 1,0

Waarden Ψ-factoren

Ψ-factoren	Ψ_0	Ψ_1	Ψ_2
Categorie H: daken niet toegankelijk	0,00	0,00	0,00
Sneeuwbelasting	0,00	0,20	0,00
Belasting door regenwater	0,00	0,20	0,00
Windbelasting	0,00	0,20	0,00

Ontwerp constructie
Middels een stalen frame worden de zonnepanelen in het zonnepark gedragen. In het figuur hieronder wordt een doorsnede van het frame geplaatst.



Figuur 2: Doorsnede stalen module

<u>Opsomming kerngegevens</u>
Soort gebouw : Bouwwerk geen gebouw zijnde
Locatie : Stadskanaal (Windgebied II).

<u>Kerngegevens stalen module</u>

Er zijn 3 type modules:
Type 01: Document 01 9600 Hoogezand–FS3V-Duo-10°-29-Conergy Global Solutions GmbH
Lengte = 29,38m (in het grondvlak)
Breedte = 5,80m (in het grondvlak)
Lengte panelen = 5,89m (in het dakvlak)
Hoogte = 1,72m (in het verticale vlak)
Aantal zonnepanelen = 29 x 3 = 87 panelen

Type 02: Document 02 9600 Hoogezand–FS3V-Duo-10°-15-Conergy Global Solutions GmbH
Lengte = 15,19m (in het grondvlak)
Breedte = 5,80m (in het grondvlak)
Lengte panelen = 5,89m (in het dakvlak)
Hoogte = 1,72m (in het verticale vlak)
Aantal zonnepanelen = 15 x 3 = 45 panelen

Type 03: Document 03 9600 Hoogezand–FS3V-Duo-10°-8-Conergy Global Solutions GmbH
Lengte = 8,09m (in het grondvlak)
Breedte = 5,80m (in het grondvlak)
Lengte panelen = 5,89m (in het dakvlak)
Hoogte = 1,72m (in het verticale vlak)
Aantal zonnepanelen = 8 x 3 = 24 panelen

Constructie opzet

Staalconstructie: Stabiliteit wordt gehaald uit de inklemming van de kolommen in de grond.

Fundering op staal: De kolommen worden in de grond geslagen in de vaste laag.

Gordingen: Zeta – profiel, materiaal S350 GD (zie berekening 01 9600 Hoogezand–FS3V-Duo-10°-29-Conergy Global Solutions GmbH)

Liggers: Eta – profiel, materiaal S500 GD (zie berekening 01 9600 Hoogezand–FS3V-Duo-10°-29-Conergy Global Solutions GmbH)

Kolommen: SRF 6 – profiel, materiaal S380 (zie berekening 01 9600 Hoogezand–FS3V-Duo-10°-29-Conergy Global Solutions GmbH)

Zonnepanelen: Crystalline PV Module ASM6610P Series, 1654mm x 989mm x 40mm, gewicht 18,2kg
Belasting per m² = 0,182kN / (1,654m x 0,989m) = 0,11kN/m² → kies 0,12kN/m²

Belasting aannames

Permanete belastingen

Materialen

stalen onderdelen ρ_{staal} = 78,5 kN/m³

Zonnepaneel = 0,12kN/m²

Windbelasting

NEN-EN 1991-1-4 art. 5.3, windkrachten $w_e = q_{p(ze)} \cdot c_{pe}$

Extreme stuwdruk $q_{p(ze)}$ = 0,60 kN/m² (windgebied II, onbebouwd, gebouwhoogte h = 1.7m)

Windvormfactor C_{f1} = 1,30
C_{f2} = -1,32

$C_{p,net}$ = 1,60 (neerwaarts)
$C_{p,net}$ = -1,80 (opwaarts)

Sneeuwbelasting

Sneeuw op plattedaken $s = \mu_1 \times C_e \times C_t \times s_k$ = 0,8 x 1,0 x 1,0 x 0,70 kN/m² = 0,56 kN/m².

NEN-EN 1991-1-3 Sneeuwbelastingen voor blijvende / tijdelijke ontwerpsituaties.

Belasting combinaties

Uiterste grenstoestanden

De volgende uiterste grenstoestanden zijn getoetst:

- STR: Intern bezwijken of buitensporige vervorming.

Belastingcombinaties

De volgende belastingcombinaties zijn, indien nodig, getoetst:

Uiterste grenstoestanden:

$1{,}35 * G_{kj,sup} + 1{,}5 * \psi_{0,i} * Q_{k,I}$	$(i \geq 1)$	(STR/GEO comb. 6.10a);
$1{,}2 * G_{kj,sup} + 1{,}5 * Q_{k,1} + 1{,}5 * \psi_{0,i} * Q_{k,i}$	$(i > 1)$	(STR/GEO comb. 6.10b)
$0{,}9 * G_{kj,inf} + 1{,}5 * \psi_{0,i} * Q_{k,I}$	$(i \geq 1)$	(STR/GEO comb. 6.10a)
$0{,}9 * G_{kj,inf} + 1{,}5 * Q_{k,1} + 1{,}5 * \psi_{0,i} * Q_{k,i}$	$(i > 1)$	(STR/GEO comb. 6.10b)
$1{,}0 * G_{kj,sup} + 1{,}3 * Q_{k,1} + 1{,}3 * \psi_{0,i} * Q_{k,i}$		(STR/GEO comb. 6.10)
$1{,}0 * G_{kj,inf} + 1{,}3 * Q_{k,1} + 1{,}3 * \psi_{0,i} * Q_{k,i}$		(STR/GEO comb. 6.10)

Bruikbaarheidsgrenstoestanden:

$G_{kj} + Q_{k,1} + \psi_{0,i} * Q_{k,i}$	$(i > 1)$	(Karakteristieke comb. 6.14b)
$G_{kj} + \psi_{1,1} * Q_{k,1} + \psi_{2,i} * Q_{k,i}$	$(i > 1)$	(Frequente comb. 6.15b)
$G_{kj} + \psi_{2,i} * Q_{k,i}$	$(i \geq 1)$	(Quasi-blijvende comb. 6.16b)

Acties UO-berekening

- Berekening staalconstructie en toetsing van het stalenframe;
- Berekening van de fundering.

Bovenstaande punten worden in de uitvoeringsfase nader uitgewerkt.

Versie 1.0
Veendam, 08-05-2018
D. Scheven
- constructeur-

FS3V10°1956x991_29ZetaFG26x8

Design calculations (FS3V)
For mounting of photovoltaic modules in open areas

Project	**01 9600 Hoogezand - FS3V-Duo-10°-29 - Conergy Global Solutions GmbH** NL-9600 Hoogezand
Customer	Schletter GmbH Gewerbegebiet B15 Alustraße 1 D-83527 Kirchdorf/Haag in Oberbayern
Owner	Conergy Global Solutions GmbH Bleichenbrücke 10 D-20354 Hamburg
Design	Schletter GmbH Gewerbegebiet B15 Alustraße 1 D-83527 Kirchdorf/Haag in Oberbayern
Structural design	Dr. Zapfe GmbH Ingenieurbüro für konstruktiven Ingenieurbau und Solartechnik Gewerbegebiet B15 Alustraße 1 D-83527 Kirchdorf/Haag in Oberbayern

The design calculation contains the following pages:
Structural analysis: Pages 1 - 9
Annex

Date 19/05/2016

1 General

1.1 Project description

This static calculation contains the determination following sections contain the calculation of the internal forces and the verifications of structural safety of the load carrying construction, which is set up in an open area.
The location is
NL-9600 Hoogezand 53° 9' 42" North 6° 45' 40" East
Height above sea level < 2 m

1.2 Construction

The support-system ist an inclined construction, to which the solar modules are fixed with clamps. The purlins are positioned on the girders, which are supported in several joint locations.
The modules have the following dimensions:

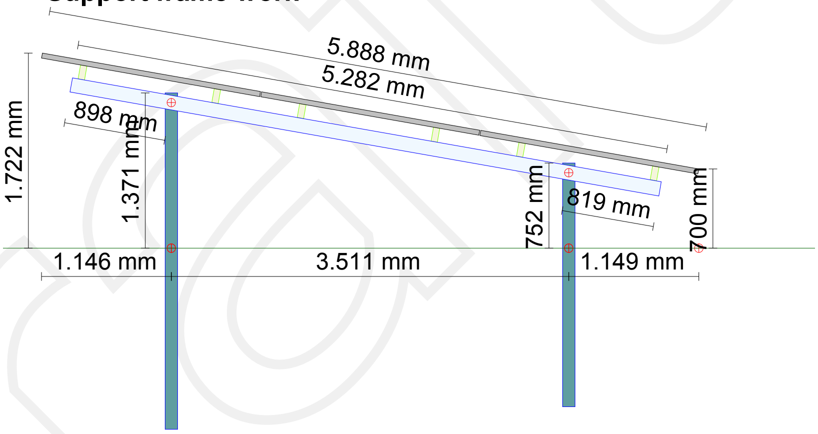
h = 1956 mm b = 991 mm c = 45 mm

Modules per row x = 29
Number of rows: y = 3
Peak power of module 320.0 Wp
Total dimensions of a solar mounting unit

L = 29.38 m Support frame length
B = 5.80 m Projection of the PV body
H = 5.89 m Total panel height
h = 1.72 m Total body height

Module type JAP6-72 4BB
Size of facility 98.72 MWp
Number of support frames 3546

Support frame work



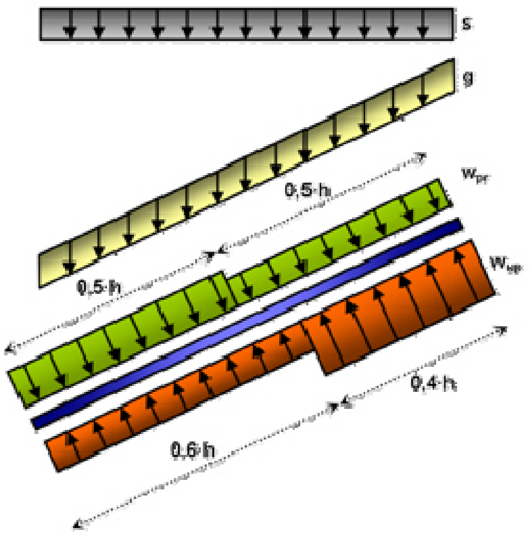
Number of support sections 8
Number of fields 7
Girder span 3.76 m
Purlin cantilever 1.54 m On both sides
Inclination of modules towards horizontal β = 10°
Minimum height above ground level h_{min} = 70 cm

1.3 Technical codes

Ausführungsklasse EXC1

- NEN-EN 1990 Basis of structural design
- NEN-EN 1991-1-3/NA General actions - Snow loads
- NEN-EN 1991-1-4/NA General actions - Wind actions
- NEN-EN 1993 Design of steel structures
- NEN-EN 1997 Geotecnical design
- NEN-EN 1998 Design of structures for earthquake resistance
- NEN-EN 1999 Design of aluminium structures
- NEN-EN 1090 Execution of steel structures
- NEN-EN ISO 14713 Zinc coatings. Guidelines and recommendations for the protection against corrosion of iron and steel in structures

2 Actions



With

β	°	Inclination to the horizontal
g	kN/m²	According to NEN EN 1991-1 According to manufacturers certificate
s	kN/m²	NEN EN 1991-1-3
w	kN/m²	NEN EN 1991-1-4
W	kN/m	NEN EN 1991-1-4

2.1 Permanent loads

g = 0.12 kN/m² Self-weight of solar modules according to manufacturer`s data/ certificate

2.2 Snow loads

Snow zone

s_k = 0.70 kN/m²

μ = 0.80

$s = s_k \cdot \mu$ = 0.56 kN/m²

2.3 Wind loads

Wind zone **2** Terrain category **II**

Height above ground z < 1.7 m

v_{ref} = 27.5 m/s

q_{ref} = 0.47 kN/m²

$q_{(z)}$ = 0.78 kN/m² (Peak velocity pressure)

Wind forces Force coeffic.

c_{f1} = 1.30

c_{f2} = -1.32

Top	$c_{p,net}$	=	1.60	Loading
	$c_{p,net}$	=	-1.80	Uplifting
Center	$c_{p,net}$	=	1.60	Loading
	$c_{p,net}$	=	-1.80	Uplifting
Bottom	$c_{p,net}$	=	1.60	Loading
	$c_{p,net}$	=	-1.80	Uplifting

Load increase in sidewise edge zones

$f_{Suction}$ = 1.28 On a length A/10

$f_{Pressure}$ = 1.00 On a length A/10

2.4 Action combinations

Partial safety factors for actions and resistance

Importance factor K_{FI} = 0.90

$\gamma_g = 1.35 \cdot 0.90 = 1.22$ $\gamma_g = 0.90$ For favourable load action

$\gamma_q = 1.50 \cdot 0.90 = 1.35$

Combination coefficients $\Psi_{0,w} = 0.60$

$\Psi_{0,s} = 0.50$

For the verifications in the limit state of load-bearing capacity, the following load combination are examined:

LK 1: $\gamma_g \cdot g + \gamma_q \cdot s + \Psi_{0,w} \cdot \gamma_q \cdot w$

LK 2: $\gamma_g \cdot g + \Psi_{0,s} \cdot \gamma_q \cdot s + \gamma_q \cdot w$

LK 3: $0.9 \cdot g + \gamma_q \cdot w$ For lifting wind actions

3 Design calculations

3.1 Purlin

Steel purlins are applied for the transmission of the loads into the supporting elements. From a structural point of view, these are regarded as continuous beams with edge cantilevers. While producing and assembling these can be considered as beam with internal hinges and be jointed with splices in the specific gerber positions.

Material S350 GD f_{yk} = 35.0 kN/cm² γ_M = 1.1

f_d = 31.8

Profile Zeta

A = 5.0 cm²
W_y = 19.0 cm³
W_z = 4.5 cm³
I_y = 117.8 cm⁴
I_z = 12.2 cm⁴
g = 4.0 kg/m

Total length l_{ges} = 29.383 m β = 10°

a = 3.757 m $\sin\beta$ = 0.174

l_{kr} = 1.540 m $\cos\beta$ = 0.985

The load effects by wind and snow have to be positioned unfavourably span-wise for the determination of the internal forces. The calculation is performed using the factors for continous beams with equidistant spans.

Bending moment coefficients

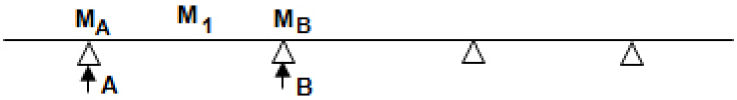
$M_{1,Total\ load}$	$M_{1,Partial}$	$M_{B,Total\ load}$	$M_{B,Partial}$
0.040	0.055	-0.084	-0.102

Force coeffic.

$A_{Total\ load}$	$A_{Partial}$	$B_{Total\ load}$	$B_{Partial}$
0.910	0.527	1.000	1.110

Permanent loads	$g_{k,z}$ = 0.151 kN/m	$g_{k,y}$ = 0.027 kN/m Incl. Profile
Snow loads	$s_{k,z}$ = 0.531 kN/m	$s_{k,y}$ = 0.094 kN/m
Wind load (pressure)	$W_{k,D}$ = 5.999 kN/m	$w_{k,D}$ = 1.226 kN/m
Wind load (suction)	$W_{k,Z}$ = -6.092 kN/m	$w_{k,Z}$ = -1.380 kN/m

Inner purlin



LK 1	$M_{1,y}$ = 1.433 kNm	$M_{1,z}$ = 0.117 kNm
LK 2	$M_{1,y}$ = 1.669 kNm	$M_{1,z}$ = 0.068 kNm
LK 3	$M_{1,y}$ = -1.368 kNm	$M_{1,z}$ = 0.014 kNm
LK 1	$M_{A,y}$ = 2.247 kNm	$M_{A,z}$ = 0.188 kNm
LK 2	$M_{A,y}$ = 2.607 kNm	$M_{A,z}$ = 0.113 kNm
LK 3	$M_{A,y}$ = -2.661 kNm	$M_{A,z}$ = 0.029 kNm
LK 1	$M_{B,y}$ = -2.681 kNm	$M_{B,z}$ = -0.221 kNm
LK 2	$M_{B,y}$ = -3.118 kNm	$M_{B,z}$ = -0.129 kNm
LK 3	$M_{B,y}$ = 2.520 kNm	$M_{B,z}$ = -0.035 kNm
LK 1	A = 4.013 kN	A_h = 0.361 kN
LK 2	A = 4.614 kN	A_h = 0.224 kN
LK 3	A = -3.218 kN	A_h = 0.082 kN
LK 1	B = 7.825 kN	B_h = 0.649 kN
LK 2	B = 9.092 kN	B_h = 0.386 kN
LK 3	B = -7.256 kN	B_h = 0.090 kN

Stress verification of purlin profiles

	max M_y	σ_x	max M_z	σ_x	$\Sigma\sigma_x$		η %
LK 1	2.68	14.13	0.22	4.87	19.00	kN/cm²	59.7
LK 2	3.12	16.44	0.13	2.86	19.30	kN/cm²	60.6
LK 3	2.66	14.03	0.03	0.76	14.79	kN/cm²	46.5

Verification format

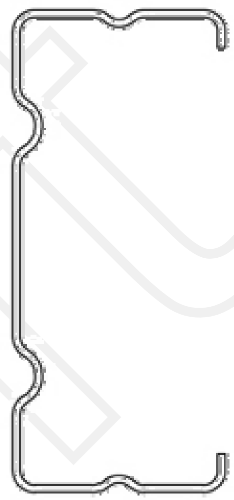
$$\frac{M_y}{W_y} + \frac{M_z}{W_z} \leq f_d$$

Purlin sections

3.2 Verification of cross beams

The transfer of the load components from purlins into the centrically positioned post follows an inclined girder, which ist fixed at the ram driven steel section with trapezoidal shape. The load actions on the girder result from the support reaction of the purlins. For the determination of forces unfavourable onesided acting variable loadings have to be applied.

Cross beam profile Extruded profile Eta

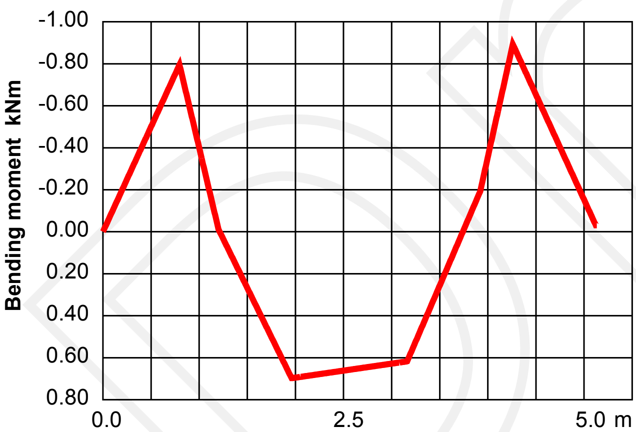


Material S500 GD $\quad f_{yk}$ = 50.0 kN/cm²
f_d = 45.5 kN/cm²

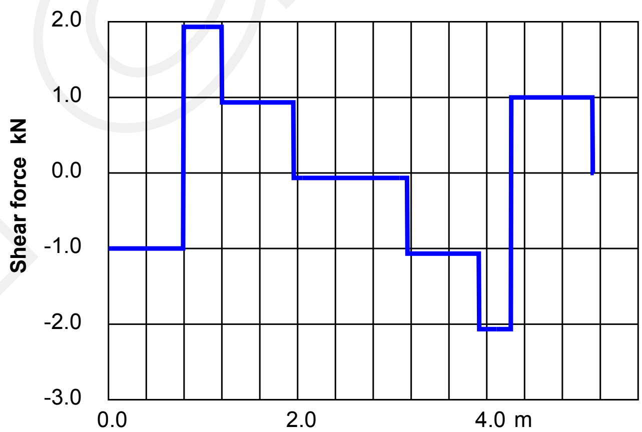
A	=	5.05	cm²
W_y	=	19.59	cm³
W_z	=	4.31	cm³
I_y	=	124.82	cm⁴
I_z	=	16.87	cm⁴
g	=	3.96	kg/m

Shapes of initial force variables with uniform concentrated load F ="1" at purlin connections

Bending moments (uniform load)



Shear force behavior (standardized)



Total girder length	l_R = 5.13 m		
Factor for moment in span	f_F = 0.70		
Factor for moment at support	f_S = -0.80 (Left)	f_S = -0.89 (Right)	
Shear force factor	f_V = 3.07		
Joint eccentricity of girder	e_z = 20 mm		

For determination of the internal force variables of the substructure the wind forces have to be positioned as a concentrated load in the quarter points of the module surface.
Hence are resulting two load postions of wind forces in each load combination. According to this 6 load combinations have to be evaluated for determination of the decisive loading.

Internal forces at the support construction	Load combination 1		Load combination 2		Load combination 3		
	Frontal	Rear	Frontal	Rear	Frontal	Rear	
Maximum of axial force	2.04		3.41		-4.81		kN
Eccentricity moment M_{ez}	0.04		0.07		-0.10		kNm
Max mid-span bending moment	5.46		6.34		-5.06		kNm
Max. moment at support left	-6.22		-7.23		5.77		kNm
Max. moment at support right	-6.99		-8.12		6.48		kNm
Vertical supporting force of the support	20.90	1.02	24.17	-9.29	-11.75	-21.65	kN
Horizontal supporting force of the support	2.94	0.58	4.90	0.96	-4.99	-0.97	kN
Mid-span stresses	28.26		33.03		-24.87		kN/cm²
Stresses moment at support left	-31.77		-36.92		30.41		kN/cm²
Stresses moment at support right	-35.67		-41.44		34.03		kN/cm²

Max mid-span bending moment $M_F = \max(A;B) \cdot f_F + M_{ez} = 9.09 \cdot 0.70 + 0.07 = 6.41$ kNm

Max. moment at support left $M_S = \max(A;B) \cdot f_S - M_{ez} = 9.09 \cdot -0.80 - 0.00 = -7.23$ kNm

Max. moment at support right $M_S = \max(A;B) \cdot f_S - M_{ez} = 9.09 \cdot -0.89 - 0.00 = -8.12$ kNm

Verification $\frac{N}{A} + \frac{M}{W_y} \leq f_d$

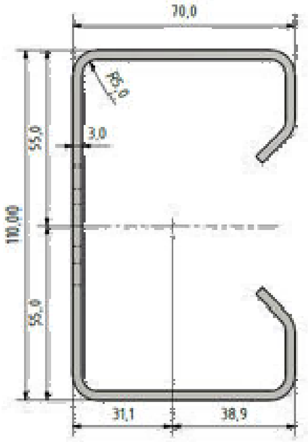
Maximum stress max σ_x = 41.44 kN/cm² Utilization ratio 91 %

Mounting system

Front support is connected at 16 % of the planned girder length
Rear support Is connected at 83 % Of the planned girder length

4 Verification of ram driven posts

The construction of the post ist planned by using a steel sheet with a trapazoidal shape, which is ram driven in ground with defined depth. This item affords soil examinations and eventually loading tests to evaluate the transferable forces.



Profile parameters SRF 6

b_f = 70 mm
h = 110 mm
t = 3 mm
A = 9.18 cm²
W_y = 30.23 cm³
I_y = 166.28 cm⁴
g = 7.10 kg/m

Material properties S380

$f_{y,k}$ = 38.00 kN/cm²
γ_M = 1.1
$f_{y,d}$ = 34.55 kN/cm²
σ_x = 16.59 kN/cm²

Utilization ratio η = 48 %

Non usable soil layer t = 0 cm
Estimated anchoring depth rear t_{soil} = 160 cm
Estimated anchoring depth frontal t_{soil} = 140 cm

Initial forces at bottom fixed support	Load combination 1		Load combination 2		Load combination 3		
	Frontal	Rear	Frontal	Rear	Frontal	Rear	
Axial force at fixed support	21.17	3.36	23.86	-6.17	-11.60	-20.49	kN
Shear force at fixed support	2.65	0.58	4.90	0.96	-4.99	-0.97	kN
Resulting for screw verification	21.33	3.41	24.36	6.24	12.63	20.51	kN
Cantilever moment	2.28	0.84	4.23	1.41	-4.30	-1.41	kNm
Stress verification	9.86	3.16	16.59	5.32	15.49	6.91	kN/cm²

Front support
Max. tensile loads on support N_{max} = 11.60 kN belonging to V = 4.99 kN
Max. compression force at post N_{min} = 23.86 kN belonging to V = -2.65 kN
Max. bendig moment at post M_e = 4.23 kNm

Rear support
Max. tensile loads on support N_{max} = 20.49 kN belonging to V = 0.97 kN
Max. compression force at post N_{min} = 3.36 kN belonging to V = -0.58 kN
Max. bendig moment at post M_e = 1.41 kNm

The restraint post support in the ground features a plastic reserve of 66 %
M_{pl} = 9.0 kNm

Verification in lateral direction under wind loads:
Friction factor: f_r = 0,04 A_{fr} = 22,1 m² F_{fr} = 0,9 kN M_{fr} = 0,65 kNm σ_x = 1,88 kN/cm²

5 Verification of joints and connections

5.1 Anchorage of modules on the purlins and connection of the purlins to the girder

The notch ist designed in such a manner that the bolt in operating position is located approximately in the center of gravity of the net section. Therefore, only negligible bending portions arise.

The connection of the purlins to the girder feature clamp festeners.Due to limited standards for reliable calculations, the strength of the clamp fasteners has been evaluated by tests.

Fastening of modules to purlins	max F_z =	2.05	kN< P_{Rd} =	3.6	kN
Clamping of purlins to girders	max F_z =	7.26	kN< P_{Rd} =	11.0	kN

(strength of connections according to spec sheets from Schletter-Solarmontage GmbH)

5.2 Connection of the girder to the foundation post

The basical constructive feature of the construction is the design of the connection between the inclined girders and the post head of the ram driven profiles. The following technical requirements have to be considered:

- Transmission of forces in unfavourable distribution $\Delta z = \pm 20$ mm
- Compensation of tolerances caused by the pile driving of the support profiles $\Delta\beta = \pm 2°$
- Tolerances in longitudinal and lateral direction $\Delta x = \pm 15$ mm

By means of a bolt, the girder is connected to an adjustable strut that is hooked in in the course of the mounting process. The height adjustment is realized using a slotted hole whose position is secured by corrugated plates and a corrugated structure of the connection profile. The utilization of the basic material is verified, the screws are verified regarding shearing-off and bearing stress.

Bolts for load transmission
M12 A2-70

Shearing-off bolts
V_{aRd} = 34.90 kN η = 71 %
Bearing resistance steel U-Profile
V_{lRd} = 25.92 kN η = 95 %
Bearing resistance steel Coil sheet
V_{lRd} = 26.40 kN η = 93 %

Connection binder/support

max N = 21.65 kN
max V = 0.97 kN

F_{sd} = 24.66 kN < 33 kN (test report) η = 75 %

Planning documentation for the bearing system FS-Duo 3V for solar modules

Project: 02 9600 Hoogezand - FS3V-Duo-10°-15 - Conergy Global Solutions GmbH

Module type: JAP6-72 4BB 1956 x 991 mm

Schletter GmbH

Gewerbegebiet B15
Alustraße 1
D-83527 Kirchdorf/Haag i. OB

Phone: +498072 9191-270
Fax: +498072 9191-9270

solar@schletter.de

http://www.solar.schletter.de/

By order of

Conergy Global Solutions GmbH

Bleichenbrücke 10
D-20354 Hamburg

May 2016

FS3V10°1956x991_15ZetaFG26x4

Design calculations (FS3V)
For mounting of photovoltaic modules in open areas

Project	**02 9600 Hoogezand - FS3V-Duo-10°-15 - Conergy Global Solutions GmbH**
	NL-9600 Hoogezand
Customer	Schletter GmbH Gewerbegebiet B15 Alustraße 1 D-83527 Kirchdorf/Haag in Oberbayern
Owner	Conergy Global Solutions GmbH Bleichenbrücke 10 D-20354 Hamburg
Design	Schletter GmbH Gewerbegebiet B15 Alustraße 1 D-83527 Kirchdorf/Haag in Oberbayern
Structural design	Dr. Zapfe GmbH Ingenieurbüro für konstruktiven Ingenieurbau und Solartechnik Gewerbegebiet B15 Alustraße 1 D-83527 Kirchdorf/Haag in Oberbayern

The design calculation contains the following pages:
Structural analysis: Pages 1 - 9
Annex

Date 19/05/2016

1 General

1.1 Project description

This static calculation contains the determination following sections contain the calculation of the internal forces and the verifications of structural safety of the load carrying construction, which is set up in an open area.
The location is
NL-9600 Hoogezand 53° 9' 42" North 6° 45' 40" East
Height above sea level < 2 m

1.2 Construction

The support-system ist an inclined construction, to which the solar modules are fixed with clamps. The purlins are positioned on the girders, which are supported in several joint locations.
The modules have the following dimensions:

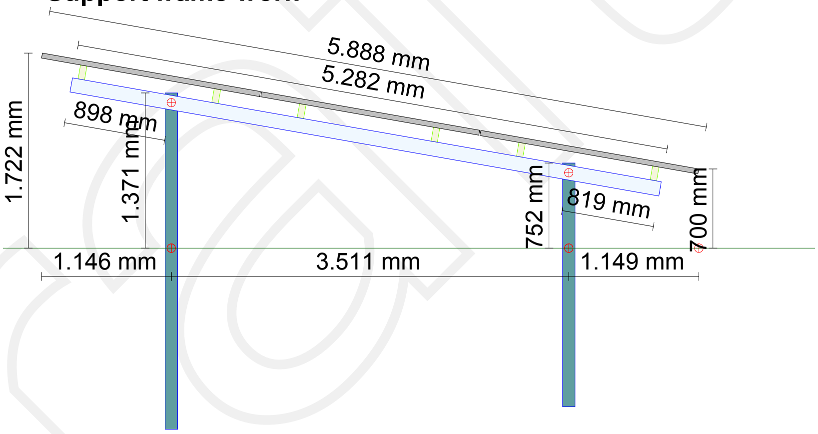
h = 1956 mm b = 991 mm c = 45 mm

Modules per row x = 15
Number of rows: y = 3
Peak power of module 320.0 Wp
Total dimensions of a solar mounting unit

L = 15.19 m Support frame length
B = 5.80 m Projection of the PV body
H = 5.89 m Total panel height
h = 1.72 m Total body height

Module type JAP6-72 4BB
Size of facility 2.88 MWp
Number of support frames 200

Support frame work



Number of support sections 4
Number of fields 3
Girder span 4.09 m
Purlin cantilever 1.55 m On both sides
Inclination of modules towards horizontal β = 10°
Minimum height above ground level h_{min} = 70 cm

1.3 Technical codes

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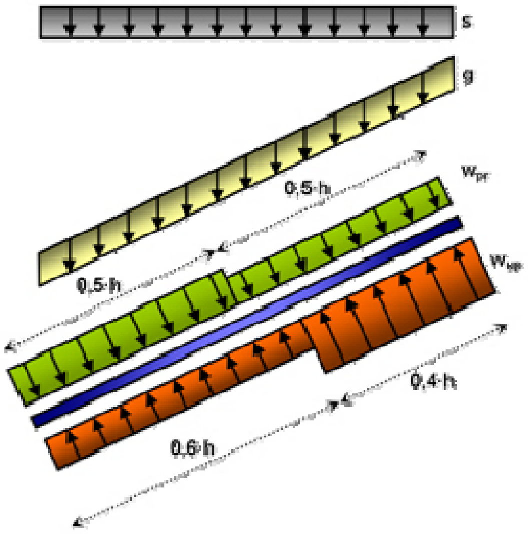
- NEN-EN ISO 14713 Zinc coatings. Guidelines and recommendations for the protection against corrosion of iron and steel in structures

2 Actions



With

β	°	Inclination to the horizontal
g	kN/m²	According to NEN EN 1991-1
		According to manufacturers certificate
s	kN/m²	NEN EN 1991-1-3
w	kN/m²	NEN EN 1991-1-4
W	kN/m	NEN EN 1991-1-4

2.1 Permanent loads

g = 0.12 kN/m² Self-weight of solar modules according to manufacturer`s data/ certificate

2.2 Snow loads

Snow zone

s_k = 0.70 kN/m²

μ = 0.80

$s = s_k \cdot \mu$ = 0.56 kN/m²

2.3 Wind loads

Wind zone **2** Terrain category **II**

Height above ground z < 1.7 m

v_{ref} = 27.5 m/s

q_{ref} = 0.47 kN/m²

$q_{(z)}$ = 0.78 kN/m² (Peak velocity pressure)

Wind forces Force coeffic.

c_{f1} = 1.30

c_{f2} = -1.32

Top	$c_{p,net}$	=	1.60	Loading
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Center	$c_{p,net}$	=	1.60	Loading
	$c_{p,net}$	=	-1.80	Uplifting
Bottom	$c_{p,net}$	=	1.60	Loading
	$c_{p,net}$	=	-1.80	Uplifting

Load increase in sidewise edge zones

$f_{Suction}$ = 1.28 On a length A/10

$f_{Pressure}$ = 1.00 On a length A/10

2.4 Action combinations

Partial safety factors for actions and resistance

Importance factor K_{FI} = 0.90

$\gamma_g = 1.35 \cdot 0.90 = 1.22$ $\gamma_g = 0.90$ For favourable load action
$\gamma_q = 1.50 \cdot 0.90 = 1.35$

Combination coefficients $\Psi_{0,w} = 0.60$
$\Psi_{0,s} = 0.50$

For the verifications in the limit state of load-bearing capacity, the following load combination are examined:

LK 1: $\gamma_g \cdot g + \gamma_q \cdot s + \Psi_{0,w} \cdot \gamma_q \cdot w$
LK 2: $\gamma_g \cdot g + \Psi_{0,s} \cdot \gamma_q \cdot s + \gamma_q \cdot w$
LK 3: $0.9 \cdot g + \gamma_q \cdot w$ For lifting wind actions

3 Design calculations

3.1 Purlin

Steel purlins are applied for the transmission of the loads into the supporting elements. From a structural point of view, these are regarded as continuous beams with edge cantilevers. While producing and assembling these can be considered as beam with internal hinges and be jointed with splices in the specific gerber positions.

Material S350 GD f_{yk} = 35.0 kN/cm² $\gamma_M = 1.1$
f_d = 31.8

Profile Zeta

A = 5.0 cm²
W_y = 19.0 cm³
W_z = 4.5 cm³
I_y = 117.8 cm⁴
I_z = 12.2 cm⁴
g = 4.0 kg/m

Total length l_{ges} = 15.187 m β = 10°
a = 4.087 m $\sin\beta$ = 0.174
l_{kr} = 1.550 m $\cos\beta$ = 0.985

The load effects by wind and snow have to be positioned unfavourably span-wise for the determination of the internal forces. The calculation is performed using the factors for continous beams with equidistant spans.

$M_{1,Total\ load}$	$M_{1,Partial}$	$M_{B,Total\ load}$	$M_{B,Partial}$
0.040	0.056	-0.080	-0.101

Bending moment coefficients

$A_{Total\ load}$	$A_{Partial}$	$B_{Total\ load}$	$B_{Partial}$
0.911	0.939	1.000	1.115

Force coeffic.

Permanent loads $g_{k,z}$ = 0.151 kN/m $g_{k,y}$ = 0.027 kN/m Incl. Profile
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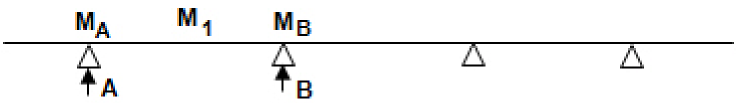
Wind load (suction) $W_{k,Z}$ = -6.092 kN/m $w_{k,Z}$ = -1.380 kN/m

Inner purlin



LK 1	$M_{1,y}$ = 2.060 kNm	$M_{1,z}$ = 0.165 kNm
LK 2	$M_{1,y}$ = 2.403 kNm	$M_{1,z}$ = 0.094 kNm
LK 3	$M_{1,y}$ = -2.010 kNm	$M_{1,z}$ = 0.017 kNm
LK 1	$M_{A,y}$ = 2.276 kNm	$M_{A,z}$ = 0.191 kNm
LK 2	$M_{A,y}$ = 2.641 kNm	$M_{A,z}$ = 0.115 kNm
LK 3	$M_{A,y}$ = -2.695 kNm	$M_{A,z}$ = 0.029 kNm
LK 1	$M_{B,y}$ = -3.143 kNm	$M_{B,z}$ = -0.259 kNm
LK 2	$M_{B,y}$ = -3.655 kNm	$M_{B,z}$ = -0.152 kNm
LK 3	$M_{B,y}$ = 2.952 kNm	$M_{B,z}$ = -0.041 kNm
LK 1	A = 3.872 kN	A_h = 0.325 kN
LK 2	A = 4.492 kN	A_h = 0.183 kN
LK 3	A = -3.528 kN	A_h = 0.049 kN
LK 1	B = 8.494 kN	B_h = 0.705 kN
LK 2	B = 9.869 kN	B_h = 0.419 kN
LK 3	B = -7.872 kN	B_h = 0.098 kN

Stress verification of purlin profiles

	max M_y	σ_x	max M_z	σ_x	$\Sigma\sigma_x$		η %
LK 1	3.14	16.57	0.26	5.71	22.27	kN/cm²	70.0
LK 2	3.65	19.27	0.15	3.35	22.62	kN/cm²	71.1
LK 3	2.95	15.56	0.04	0.90	16.46	kN/cm²	51.7

Verification format

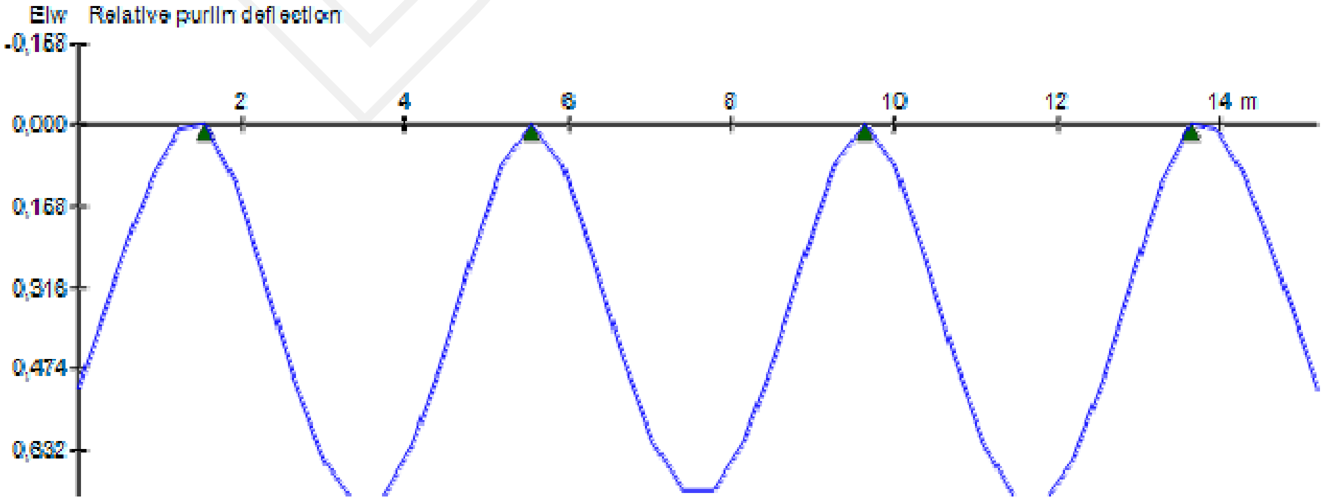
$$\frac{M_y}{W_y} + \frac{M_z}{W_z} \leq f_d$$

Deflections of purlins perpendicular to the module plane

Youngs modulus E = 21000 kN/cm²
Moment of inertia I_y = 117.80 cm⁴ EI = 247.38 kN/m²
Span deflections: EIw = 0.7315
Cantilever deflections: EIw = 0.5121

Self weight	Snow	Wind pressure	Uplift	
0.448	1.57	17.74	-18.01	mm
0.314	1.10	12.42	-12.61	mm

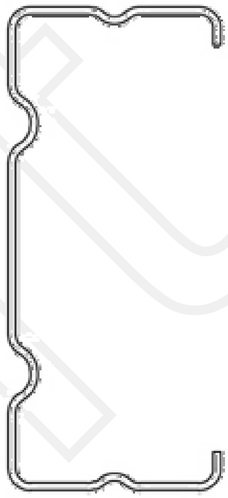
LK1:	12.66 mm (a / 323)		8.87 mm (a_{kr} / 175)	relativ
LK2Midspan	18.97 mm (a / 215)	Cantilever	13.28 mm (a_{kr} / 117)	(a_{kr} / 124)
LK3:	-17.56 mm (a / 233)		-12.30 mm (a_{kr} / 126)	



3.2 Verification of cross beams

The transfer of the load components from purlins into the centrically positioned post follows an inclined girder, which ist fixed at the ram driven steel section with trapezoidal shape. The load actions on the girder result from the support reaction of the purlins. For the determination of forces unfavourable onesided acting variable loadings have to be applied.

Cross beam profile Extruded profile Eta

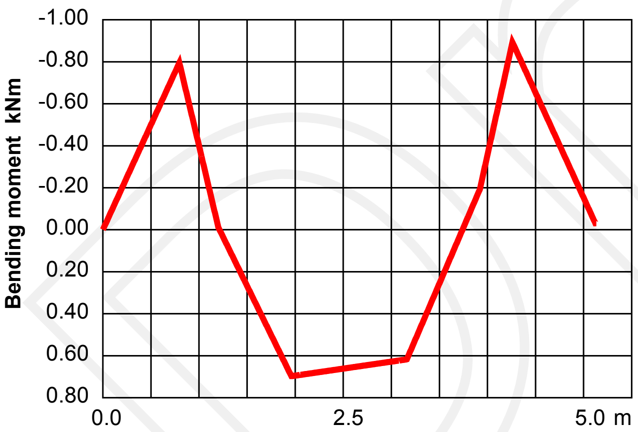


Material S500 GD f_{yk} = 50.0 kN/cm²
f_d = 45.5 kN/cm²

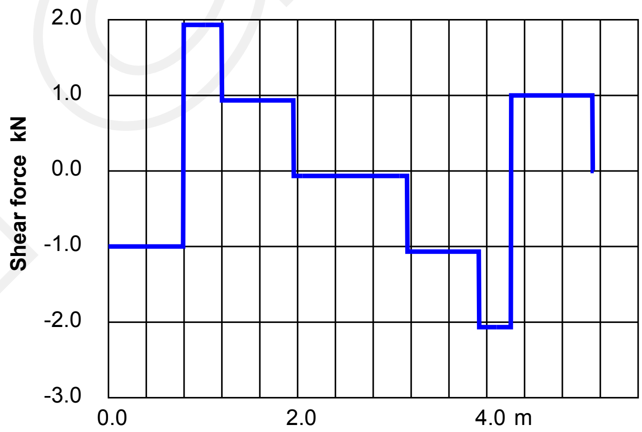
A	=	5.05 cm²
W_y	=	19.59 cm³
W_z	=	4.31 cm³
I_y	=	124.82 cm⁴
I_z	=	16.87 cm⁴
g	=	3.96 kg/m

Shapes of initial force variables with uniform concentrated load F ="1" at purlin connections

Bending moments (uniform load)



Shear force behavior (standardized)



Total girder length	l_R = 5.13 m	
Factor for moment in span	f_F = 0.70	
Factor for moment at support	f_S = -0.80 (Left)	f_S = -0.89 (Right)
Shear force factor	f_V = 3.07	
Joint eccentricity of girder	e_z = 20 mm	

For determination of the internal force variables of the substructure the wind forces have to be positioned as a concentrated load in the quarter points of the module surface.
Hence are resulting two load postions of wind forces in each load combination. According to this 6 load combinations have to be evaluated for determination of the decisive loading.

Internal forces at the support construction	Load combination 1		Load combination 2		Load combination 3		
	Frontal	Rear	Frontal	Rear	Frontal	Rear	
Maximum of axial force	2.22		3.70		-5.22		kN
Eccentricity moment M_{ez}	0.04		0.07		-0.10		kNm
Max mid-span bending moment	5.92		6.88		-5.49		kNm
Max. moment at support left	-6.76		-7.85		6.26		kNm
Max. moment at support right	-7.59		-8.81		7.03		kNm
Vertical supporting force of the support	22.68	1.11	26.23	-10.08	-12.75	-23.49	kN
Horizontal supporting force of the support	3.19	0.62	5.32	1.04	-5.41	-1.05	kN
Mid-span stresses	30.67		35.86		-26.99		kN/cm²
Stresses moment at support left	-34.49		-40.07		33.00		kN/cm²
Stresses moment at support right	-38.72		-44.99		36.92		kN/cm²

Max mid-span bending moment $M_F = \max(A;B) \cdot f_F + M_{ez} = 9.87 \cdot 0.70 + 0.07 = 6.96$ kNm
Max. moment at support left $M_S = \max(A;B) \cdot f_S - M_{ez} = 9.87 \cdot -0.80 - 0.00 = -7.85$ kNm
Max. moment at support right $M_S = \max(A;B) \cdot f_S - M_{ez} = 9.87 \cdot -0.89 - 0.00 = -8.81$ kNm

Verification $\frac{N}{A} + \frac{M}{W_y} \leq f_d$

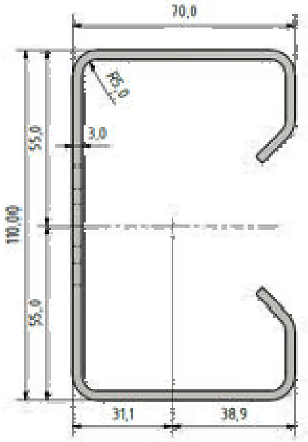
Maximum stress max σ_x = 44.99 kN/cm² Utilization ratio 99 %

Mounting system

Front support is connected at 16 % of the planned girder length
Rear support Is connected at 83 % Of the planned girder length

4 Verification of ram driven posts

The construction of the post ist planned by using a steel sheet with a trapazoidal shape, which is ram driven in ground with defined depth. This item affords soil examinations and eventually loading tests to evaluate the transferable forces.



Profile parameters SRF 6

b_f = 70 mm
h = 110 mm
t = 3 mm
A = 9.18 cm²
W_y = 30.23 cm³
I_y = 166.28 cm⁴
g = 7.10 kg/m

Material properties S380

$f_{y,k}$ = 38.00 kN/cm²
γ_M = 1.1
$f_{y,d}$ = 34.55 kN/cm²
σ_x = 18.01 kN/cm²

Utilization ratio η = 52 %

Non usable soil layer t = 0 cm
Estimated anchoring depth rear t_{soil} = 160 cm
Estimated anchoring depth frontal t_{soil} = 140 cm

Initial forces at bottom fixed support	Load combination 1		Load combination 2		Load combination 3		
	Frontal	Rear	Frontal	Rear	Frontal	Rear	
Axial force at fixed support	21.81	2.37	25.98	-6.73	-12.64	-22.32	kN
Shear force at fixed support	2.88	0.63	5.32	1.05	-5.41	-1.05	kN
Resulting for screw verification	22.00	2.45	26.52	6.81	13.75	22.35	kN
Cantilever moment	2.49	0.92	4.59	1.53	-4.67	-1.53	kNm
Stress verification	10.61	3.29	18.01	5.78	16.82	7.51	kN/cm²

Front support
Max. tensile loads on support N_{max} = 12.64 kN belonging to V = 5.41 kN
Max. compression force at post N_{min} = 25.98 kN belonging to V = -2.88 kN
Max. bendig moment at post M_e = 4.59 kNm

Rear support
Max. tensile loads on support N_{max} = 22.32 kN belonging to V = 1.05 kN
Max. compression force at post N_{min} = 2.37 kN belonging to V = -0.63 kN
Max. bendig moment at post M_e = 1.53 kNm

The restraint post support in the ground features a plastic reserve of 66 %
M_{pl} = 9.0 kNm

Verification in lateral direction under wind loads:
Friction factor: f_r = 0,04 A_{fr} = 24,1 m² F_{fr} = 1,0 kN M_{fr} = 0,71 kNm σ_x = 2,04 kN/cm²

5 Verification of joints and connections

5.1 Anchorage of modules on the purlins and connection of the purlins to the girder

The notch ist designed in such a manner that the bolt in operating position is located approximately in the center of gravity of the net section. Therefore, only negligible bending portions arise.

The connection of the purlins to the girder feature clamp festeners.Due to limited standards for reliable calculations, the strength of the clamp fasteners has been evaluated by tests.

Fastening of modules to purlins	max F_z =	2.05	kN< P_{Rd} =	3.6	kN
Clamping of purlins to girders	max F_z =	7.87	kN< P_{Rd} =	11.0	kN

(strength of connections according to spec sheets from Schletter-Solarmontage GmbH)

5.2 Connection of the girder to the foundation post

The basical constructive feature of the construction is the design of the connection between the inclined girders and the post head of the ram driven profiles. The following technical requirements have to be considered:

- Transmission of forces in unfavourable distribution $\Delta z = \pm 20$ mm
- Compensation of tolerances caused by the pile driving of the support profiles $\Delta\beta = \pm 2°$
- Tolerances in longitudinal and lateral direction $\Delta x = \pm 15$ mm

By means of a bolt, the girder is connected to an adjustable strut that is hooked in in the course of the mounting process. The height adjustment is realized using a slotted hole whose position is secured by corrugated plates and a corrugated structure of the connection profile. The utilization of the basic material is verified, the screws are verified regarding shearing-off and bearing stress.

Bolts for load transmission
M12 A2-70

Shearing-off bolts
V_{aRd} = 34.90 kN η = 77 %
Bearing resistance steel U-Profile
V_{lRd} = 25.92 kN η = 103 %
Bearing resistance steel Coil sheet
V_{lRd} = 26.40 kN η = 101 %

Connection binder/support

max N = 23.49 kN
max V = 1.05 kN

F_{sd} = 26.76 kN < 33 kN (test report) η = 81 %

Planning documentation for the bearing system FS-Duo 3V for solar modules

Project: 03 9600 Hoogezand - FS3V-Duo-10°-8 - Conergy Global Solutions GmbH

Module type: JAP6-72 4BB 1956 x 991 mm

Schletter GmbH

Gewerbegebiet B15
Alustraße 1
D-83527 Kirchdorf/Haag i. OB

Phone: +498072 9191-270
Fax: +498072 9191-9270

solar@schletter.de

http://www.solar.schletter.de/

By order of

Conergy Global Solutions GmbH

Bleichenbrücke 10
D-20354 Hamburg

May 2016

FS3V10°1956x991_8ZetaFG26x3

Design calculations (FS3V)
For mounting of photovoltaic modules in open areas

Project	**03 9600 Hoogezand - FS3V-Duo-10°-8 - Conergy Global Solutions GmbH**
	NL-9600 Hoogezand
Customer	Schletter GmbH Gewerbegebiet B15 Alustraße 1 D-83527 Kirchdorf/Haag in Oberbayern
Owner	Conergy Global Solutions GmbH Bleichenbrücke 10 D-20354 Hamburg
Design	Schletter GmbH Gewerbegebiet B15 Alustraße 1 D-83527 Kirchdorf/Haag in Oberbayern
Structural design	Dr. Zapfe GmbH Ingenieurbüro für konstruktiven Ingenieurbau und Solartechnik Gewerbegebiet B15 Alustraße 1 D-83527 Kirchdorf/Haag in Oberbayern

The design calculation contains the following pages:
Structural analysis: Pages 1 - 9
Annex

Date 19/05/2016

1 General

1.1 Project description

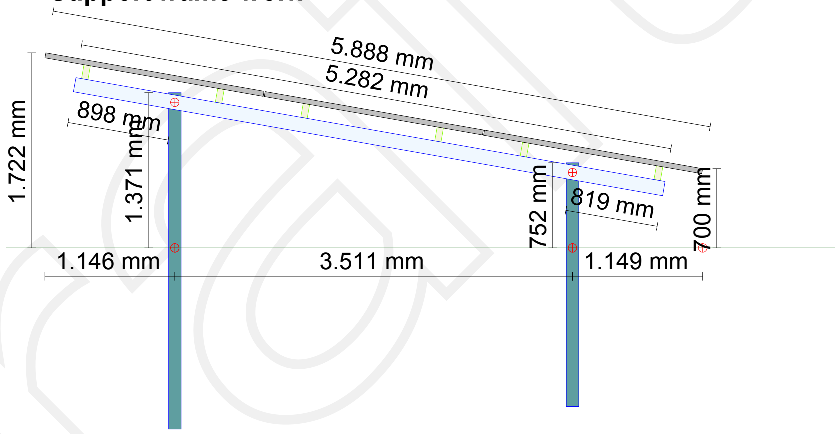
This static calculation contains the determination following sections contain the calculation of the internal forces and the verifications of structural safety of the load carrying construction, which is set up in an open area.
The location is
NL-9600 Hoogezand 53° 9' 42" North 6° 45' 40" East
Height above sea level < 2 m

1.2 Construction

The support-system ist an inclined construction, to which the solar modules are fixed with clamps. The purlins are positioned on the girders, which are supported in several joint locations.
The modules have the following dimensions:

h = 1956 mm b = 991 mm c = 45 mm

Support frame work



Modules per row x = 8
Number of rows: y = 3
Peak power of module 320.0 Wp
Total dimensions of a solar mounting unit

L = 8.09 m Support frame length
B = 5.80 m Projection of the PV body
H = 5.89 m Total panel height
h = 1.72 m Total body height

Module type JAP6-72 4BB
Size of facility 1.44 MWp
Number of support frames 188

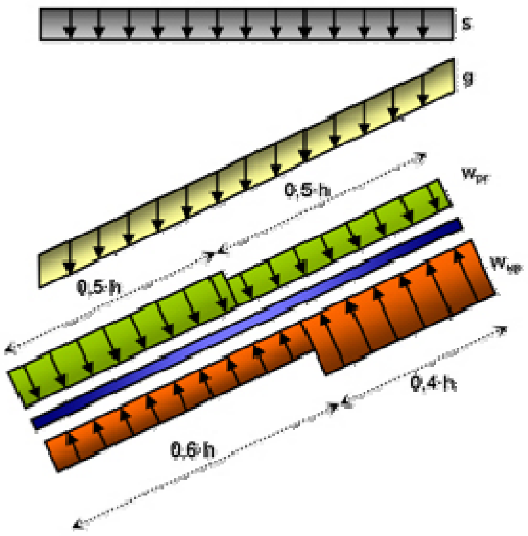
Number of support sections	3	
Number of fields	2	
Girder span	2.87 m	
Purlin cantilever	1.17 m	On both sides
Inclination of modules towards horizontal	β =	10°
Minimum height above ground level	h_{min} =	70 cm

1.3 Technical codes

Ausführungsklasse EXC1

- NEN-EN 1990 Basis of structural design
- NEN-EN 1991-1-3/NA General actions - Snow loads
- NEN-EN 1991-1-4/NA General actions - Wind actions
- NEN-EN 1993 Design of steel structures
- NEN-EN 1997 Geotecnical design
- NEN-EN 1998 Design of structures for earthquake resistance
- NEN-EN 1999 Design of aluminium structures
- NEN-EN 1090 Execution of steel structures
- NEN-EN ISO 14713 Zinc coatings. Guidelines and recommendations for the protection against corrosion of iron and steel in structures

2 Actions



With

β	°	Inclination to the horizontal
g	kN/m²	According to NEN EN 1991-1
		According to manufacturers certificate
s	kN/m²	NEN EN 1991-1-3
w	kN/m²	NEN EN 1991-1-4
W	kN/m	NEN EN 1991-1-4

2.1 Permanent loads

g = 0.12 kN/m²   Self-weight of solar modules according to manufacturer`s data/ certificate

2.2 Snow loads   Snow zone

s_k = 0.70 kN/m²

μ = 0.80

$s = s_k \cdot \mu$ = 0.56 kN/m²

2.3 Wind loads   Wind zone **2**   Terrain category **II**

Height above ground   z < 1.7 m

v_{ref} = 27.5 m/s

q_{ref} = 0.47 kN/m²

$q_{(z)}$ = 0.78 kN/m² (Peak velocity pressure)

Wind forces   Force coeffic. c_{f1} = 1.30

c_{f2} = -1.32

Top	$c_{p,net}$	=	1.60	Loading
	$c_{p,net}$	=	-1.80	Uplifting
Center	$c_{p,net}$	=	1.60	Loading
	$c_{p,net}$	=	-1.80	Uplifting
Bottom	$c_{p,net}$	=	1.60	Loading
	$c_{p,net}$	=	-1.80	Uplifting

Load increase in sidewise edge zones $f_{Suction}$ = 1.28 On a length A/10

$f_{Pressure}$ = 1.00 On a length A/10

2.4 Action combinations

Partial safety factors for actions and resistance

Importance factor K_{FI} = 0.90

γ_g = 1.35 · 0.90 = 1.22 γ_g = 0.90 For favourable load action

γ_q = 1.50 · 0.90 = 1.35

Combination coefficients $\Psi_{0,w}$ = 0.60

$\Psi_{0,s}$ = 0.50

For the verifications in the limit state of load-bearing capacity, the following load combination are examined:

LK 1: $\gamma_g \cdot g + \gamma_q \cdot s + \Psi_{0,w} \cdot \gamma_q \cdot w$

LK 2: $\gamma_g \cdot g + \Psi_{0,s} \cdot \gamma_q \cdot s + \gamma_q \cdot w$

LK 3: $0.9 \cdot g + \gamma_q \cdot w$ For lifting wind actions

3 Design calculations

3.1 Purlin

Steel purlins are applied for the transmission of the loads into the supporting elements. From a structural point of view, these are regarded as continuous beams with edge cantilevers. While producing and assembling these can be considered as beam with internal hinges and be jointed with splices in the specific gerber positions.

Material S350 GD f_{yk} = 35.0 kN/cm² γ_M = 1.1

f_d = 31.8

Profile Zeta

A = 5.0 cm²

W_y = 19.0 cm³

W_z = 4.5 cm³

I_y = 117.8 cm⁴

I_z = 12.2 cm⁴

g = 4.0 kg/m

Total length l_{ges} = 8.089 m β = 10°

a = 2.874 m sin β = 0.174

l_{kr} = 1.170 m cos β = 0.985

The load effects by wind and snow have to be positioned unfavourably span-wise for the determination of the internal forces. The calculation is performed using the factors for continous beams with equidistant spans.

$M_{1,Total\ load}$	$M_{1,Partial}$	$M_{B,Total\ load}$	$M_{B,Partial}$
0.041	0.058	-0.083	-0.010

Bending moment coefficients

$A_{Total\ load}$	$A_{Partial}$	$B_{Total\ load}$	$B_{Partial}$
0.911	0.943	0.998	1.124

Force coeffic.

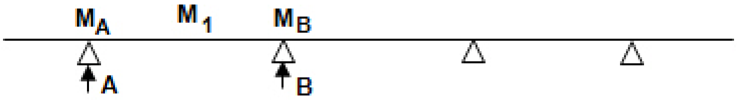
Permanent loads $g_{k,z}$ = 0.151 kN/m $g_{k,y}$ = 0.027 kN/m Incl. Profile

Snow loads $s_{k,z}$ = 0.531 kN/m $s_{k,y}$ = 0.094 kN/m

Wind load (pressure) $W_{k,D}$ = 5.999 kN/m $w_{k,D}$ = 1.226 kN/m

Wind load (suction) $W_{k,Z}$ = -6.092 kN/m $w_{k,Z}$ = -1.380 kN/m

Inner purlin



LK 1	$M_{1,y}$ = 0.939 kNm	$M_{1,z}$ = 0.076 kNm
LK 2	$M_{1,y}$ = 1.095 kNm	$M_{1,z}$ = 0.043 kNm
LK 3	$M_{1,y}$ = -0.909 kNm	$M_{1,z}$ = 0.008 kNm
LK 1	$M_{A,y}$ = 1.297 kNm	$M_{A,z}$ = 0.109 kNm
LK 2	$M_{A,y}$ = 1.505 kNm	$M_{A,z}$ = 0.065 kNm
LK 3	$M_{A,y}$ = -1.536 kNm	$M_{A,z}$ = 0.016 kNm
LK 1	$M_{B,y}$ = -1.601 kNm	$M_{B,z}$ = -0.131 kNm
LK 2	$M_{B,y}$ = -1.862 kNm	$M_{B,z}$ = -0.077 kNm
LK 3	$M_{B,y}$ = 1.510 kNm	$M_{B,z}$ = -0.021 kNm
LK 1	A = 2.722 kN	A_h = 0.228 kN
LK 2	A = 3.159 kN	A_h = 0.128 kN
LK 3	A = -2.481 kN	A_h = 0.035 kN
LK 1	B = 6.064 kN	B_h = 0.502 kN
LK 2	B = 7.047 kN	B_h = 0.298 kN
LK 3	B = -5.634 kN	B_h = 0.069 kN

Stress verification of purlin profiles

	max M_y	σ_x	max M_z	σ_x	$\Sigma\sigma_x$		η %
LK 1	1.60	8.44	0.13	2.90	11.34	kN/cm²	35.6
LK 2	1.86	9.82	0.08	1.70	11.51	kN/cm²	36.2
LK 3	1.54	8.10	0.02	0.46	8.55	kN/cm²	26.9

Verification format

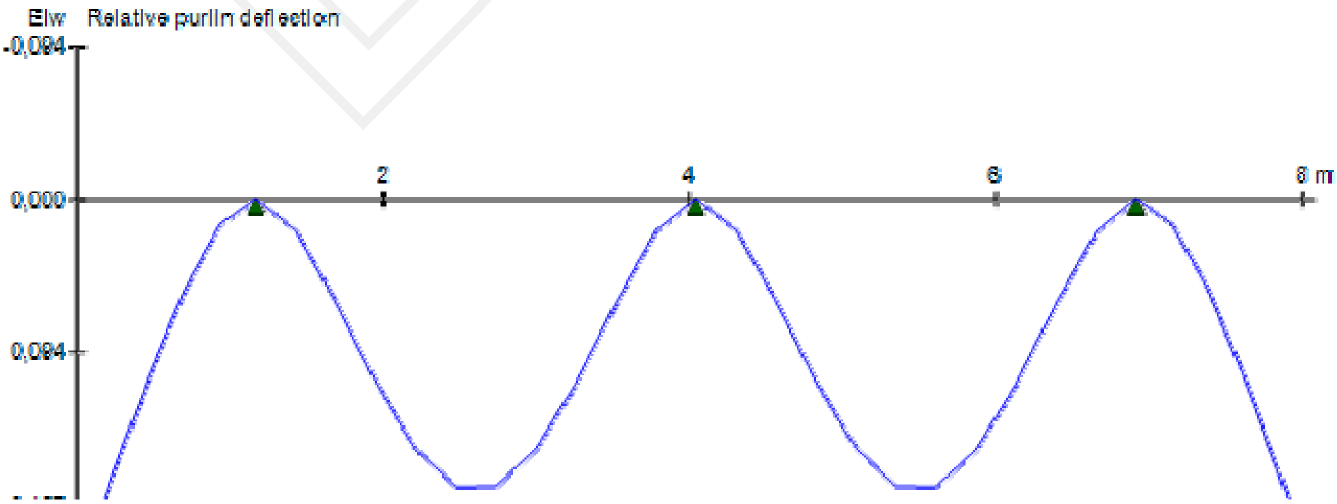
$$\frac{M_y}{W_y} + \frac{M_z}{W_z} \leq f_d$$

Deflections of purlins perpendicular to the module plane

Youngs modulus E = 21000 kN/cm²
Moment of inertia I_y = 117.80 cm⁴ EI = 247.38 kN/m²
Span deflections: EIw = 0.1760
Cantilever deflections: EIw = 0.2308

Self weight	Snow	Wind pressure	Uplift	
0.108	0.38	4.27	-4.33	mm
0.141	0.50	5.60	-5.68	mm

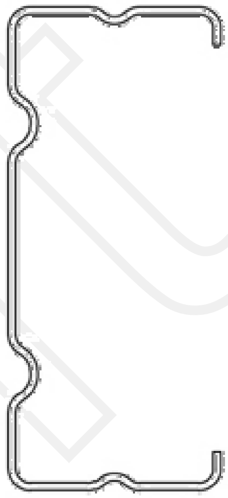
LK1: 3.05 mm (a / 943) 3.99 mm (a_{kr} / 293) relativ
LK2Midspan 4.57 mm (a / 630) Cantilever 5.99 mm (a_{kr} / 195) (a_{kr} / 289)
LK3: -4.23 mm (a / 680) -5.54 mm (a_{kr} / 211)



3.2 Verification of cross beams

The transfer of the load components from purlins into the centrically positioned post follows an inclined girder, which ist fixed at the ram driven steel section with trapezoidal shape. The load actions on the girder result from the support reaction of the purlins. For the determination of forces unfavourable onesided acting variable loadings have to be applied.

Cross beam profile Extruded profile Eta



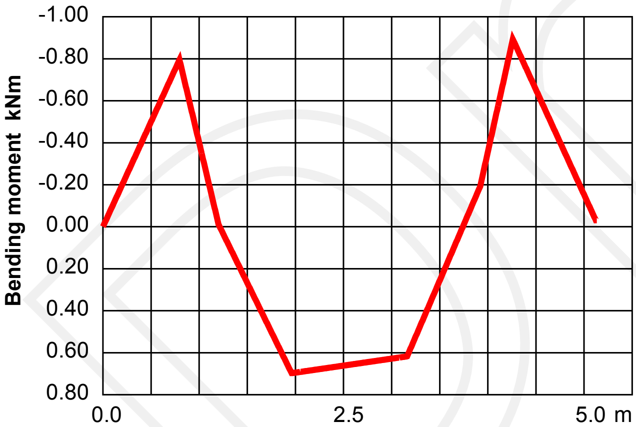
Material S500 GD

f_{yk} = 50.0 kN/cm²
f_d = 45.5 kN/cm²

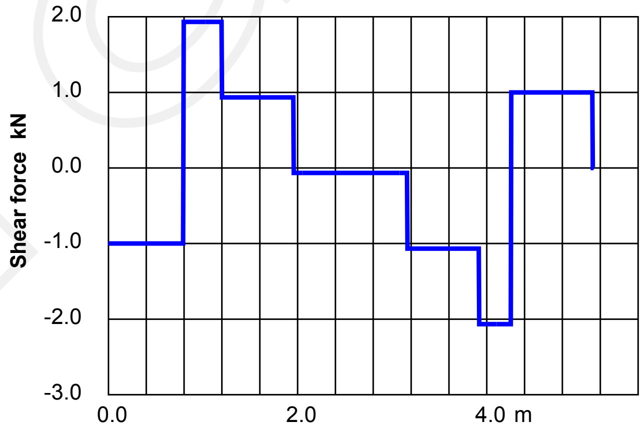
A = 5.05 cm²
W_y = 19.59 cm³
W_z = 4.31 cm³
I_y = 124.82 cm⁴
I_z = 16.87 cm⁴
g = 3.96 kg/m

Shapes of initial force variables with uniform concentrated load F ="1" at purlin connections

Bending moments (uniform load)



Shear force behavior (standardized)



Total girder length	l_R = 5.13 m		
Factor for moment in span	f_F = 0.70		
Factor for moment at support	f_S = -0.80 (Left)	f_S = -0.89 (Right)	
Shear force factor	f_V = 3.07		
Joint eccentricity of girder	e_z = 20 mm		

For determination of the internal force variables of the substructure the wind forces have to be positioned as a concentrated load in the quarter points of the module surface.
Hence are resulting two load postions of wind forces in each load combination. According to this 6 load combinations have to be evaluated for determination of the decisive loading.

Internal forces at the support construction	Load combination 1		Load combination 2		Load combination 3		
	Frontal	Rear	Frontal	Rear	Frontal	Rear	
Maximum of axial force	1.58		2.64		-3.73		kN
Eccentricity moment M_{ez}	0.03		0.05		-0.07		kNm
Max mid-span bending moment	4.23		4.91		-3.93		kNm
Max. moment at support left	-4.82		-5.61		4.48		kNm
Max. moment at support right	-5.41		-6.29		5.03		kNm
Vertical supporting force of the support	16.21	0.79	18.75	-7.21	-9.12	-16.80	kN
Horizontal supporting force of the support	2.28	0.45	3.80	0.75	-3.87	-0.75	kN
Mid-span stresses	21.90		25.61		-19.32		kN/cm²
Stresses moment at support left	-24.62		-28.61		23.62		kN/cm²
Stresses moment at support right	-27.64		-32.12		26.42		kN/cm²

Max mid-span bending moment $M_F = \max(A;B) \cdot f_F + M_{ez} = 7.05 \cdot 0.70 + 0.05 = 4.97$ kNm
Max. moment at support left $M_S = \max(A;B) \cdot f_S - M_{ez} = 7.05 \cdot -0.80 - 0.00 = -5.61$ kNm
Max. moment at support right $M_S = \max(A;B) \cdot f_S - M_{ez} = 7.05 \cdot -0.89 - 0.00 = -6.29$ kNm

Verification $\frac{N}{A} + \frac{M}{W_y} \leq f_d$

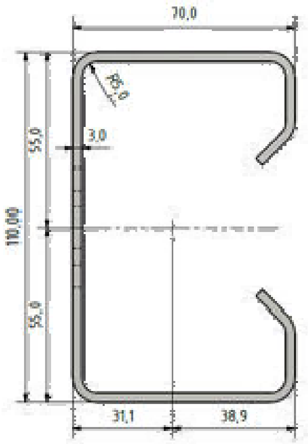
Maximum stress max σ_x = 32.12 kN/cm² Utilization ratio 71 %

Mounting system

Front support is connected at 16 % of the planned girder length
Rear support Is connected at 83 % Of the planned girder length

4 Verification of ram driven posts

The construction of the post ist planned by using a steel sheet with a trapazoidal shape, which is ram driven in ground with defined depth. This item affords soil examinations and eventually loading tests to evaluate the transferable forces.



Profile parameters SRF 6

b_f = 70 mm
h = 110 mm
t = 3 mm
A = 9.18 cm²
W_y = 30.23 cm³
I_y = 166.28 cm⁴
g = 7.10 kg/m

Material properties S380

$f_{y,k}$ = 38.00 kN/cm²
γ_M = 1.1
$f_{y,d}$ = 34.55 kN/cm²
σ_x = 12.84 kN/cm²

Utilization ratio η = 37 %

Non usable soil layer t = 0 cm
Estimated anchoring depth rear t_{soil} = 160 cm
Estimated anchoring depth frontal t_{soil} = 140 cm

Initial forces at bottom fixed support	Load combination 1		Load combination 2		Load combination 3		
	Frontal	Rear	Frontal	Rear	Frontal	Rear	
Axial force at fixed support	15.22	1.55	18.30	-4.70	-8.88	-15.67	kN
Shear force at fixed support	2.03	0.45	3.80	0.75	-3.87	-0.75	kN
Resulting for screw verification	15.36	1.61	18.69	4.76	9.68	15.69	kN
Cantilever moment	1.75	0.66	3.28	1.09	-3.34	-1.10	kNm
Stress verification	7.45	2.34	12.84	4.12	12.01	5.34	kN/cm²

Front support
Max. tensile loads on support N_{max} = 8.88 kN belonging to V = 3.87 kN
Max. compression force at post N_{min} = 18.30 kN belonging to V = -2.03 kN
Max. bendig moment at post M_e = 3.28 kNm

Rear support
Max. tensile loads on support N_{max} = 15.67 kN belonging to V = 0.75 kN
Max. compression force at post N_{min} = 1.55 kN belonging to V = -0.45 kN
Max. bendig moment at post M_e = 1.09 kNm

The restraint post support in the ground features a plastic reserve of 66 %
M_{pl} = 9.0 kNm

Verification in lateral direction under wind loads:
Friction factor: f_r = 0,04 A_{fr} = 16,9 m² F_{fr} = 0,7 kN M_{fr} = 0,50 kNm σ_x = 1,44 kN/cm²

5 Verification of joints and connections

5.1 Anchorage of modules on the purlins and connection of the purlins to the girder

The notch ist designed in such a manner that the bolt in operating position is located approximately in the center of gravity of the net section. Therefore, only negligible bending portions arise.

The connection of the purlins to the girder feature clamp festeners.Due to limited standards for reliable calculations, the strength of the clamp fasteners has been evaluated by tests.

Fastening of modules to purlins	max F_z =	2.05	kN< P_{Rd} =	3.6	kN
Clamping of purlins to girders	max F_z =	5.63	kN< P_{Rd} =	11.0	kN

(strength of connections according to spec sheets from Schletter-Solarmontage GmbH)

5.2 Connection of the girder to the foundation post

The basical constructive feature of the construction is the design of the connection between the inclined girders and the post head of the ram driven profiles. The following technical requirements have to be considered:

- Transmission of forces in unfavourable distribution — $\Delta z = \pm 20$ mm
- Compensation of tolerances caused by the pile driving of the support profiles — $\Delta\beta = \pm 2°$
- Tolerances in longitudinal and lateral direction — $\Delta x = \pm 15$ mm

By means of a bolt, the girder is connected to an adjustable strut that is hooked in in the course of the mounting process. The height adjustment is realized using a slotted hole whose position is secured by corrugated plates and a corrugated structure of the connection profile. The utilization of the basic material is verified, the screws are verified regarding shearing-off and bearing stress.

Bolts for load transmission
M12 A2-70

Shearing-off bolts
V_{aRd} = 34.90 kN η = 55 %
Bearing resistance steel U-Profile
V_{lRd} = 25.92 kN η = 74 %
Bearing resistance steel Coil sheet
V_{lRd} = 26.40 kN η = 72 %

Connection binder/support

max N = 16.80 kN
max V = 0.75 kN

F_{sd} = 19.13 kN < 33 kN (test report) η = 58 %

For USA Market

Datasheet
Crystalline PV Module
ASM6610P Series

EN

ELECTRICAL SPECIFICATIONS [1]	240	245	250	255	260	265
STC [2] rated output (P_{mpp})	240 Wp	245 Wp	250 Wp	255 Wp	260 Wp	265 Wp
Standard sorted output	-0/+5W					
Warranted power output STC ($P_{nominal}$)	240 Wp	245 Wp	250 Wp	255 Wp	260 Wp	265 Wp
Rated voltage (V_{mpp}) at STC	29.86 V	30.12 V	30.38 V	30.64 V	30.90 V	31.16 V
Rated current (I_{mpp}) at STC	8.10 A	8.20 A	8.29 A	8.39 A	8.48 A	8.57 A
Open circuit voltage (V_{oc}) at STC	36.45 V	36.78 V	37.12 V	37.45 V	37.78 V	38.12 V
Short circuit current (I_{sc}) at STC	8.59 A	8.68 A	8.76 A	8.85 A	8.93 A	9.01 A
Module efficiency	14.67%	14.98%	15.28%	15.59%	15.98%	16.20%
Rated output (P_{mpp}) at NOCT [3]	178.7 Wp	182.3 Wp	186.0 Wp	189.6 Wp	193.4 Wp	197.3 Wp
Rated voltage (V_{mpp}) at NOCT	27.83 V	28.07 V	28.31 V	28.56 V	28.80 V	28.90 V
Rated current (I_{mpp}) at NOCT	6.42 A	6.49 A	6.57 A	6.64 A	6.72 A	6.89 A
Open circuit voltage (V_{oc}) at NOCT	34.63 V	34.94 V	35.26 V	35.58 V	35.89 V	36.20 V
Short circuit current (I_{sc}) at NOCT	6.88 A	6.94 A	7.01 A	7.08 A	7.14 A	7.21 A

Temperature coefficient (P_{mpp})	- 0.42 % / K
Temperature coefficient (I_{sc})	+0.059 % / K
Temperature coefficient (V_{oc})	- 0.32 % / K
Normal operating cell temperature (NOCT)	46 °C ±2 °C

Maximum system voltage	1000 V_{DC}
Number of diodes	3
Reverse current loadability (IR)	20 A
Maximum series fuse rating	15 A

[1] Measuring uncertainity Pmpp: +/–3 %; Tolerance for Voc, Isc, Vmpp and Impp: +/–10 %
[2] Standard test conditions that are defined as follows:
1.000 W/m² irradiation at a spectral density of AM 1.5 and a cell temperature of 25° C,
[3] Nominal operating temperature of the cell at 800 W/m² irradiation, 20°C ambient temperature, wind speed of 1 m/s
[4] Manufactured in an UL 1703 certified facility

ANSI/UL 1703

ISO 9001
ISO 14001 [4]

BS OHSAS 18001

Made in Germany

A CHINT COMPANY

ASTRONERGY

RELATED PARAMETERS

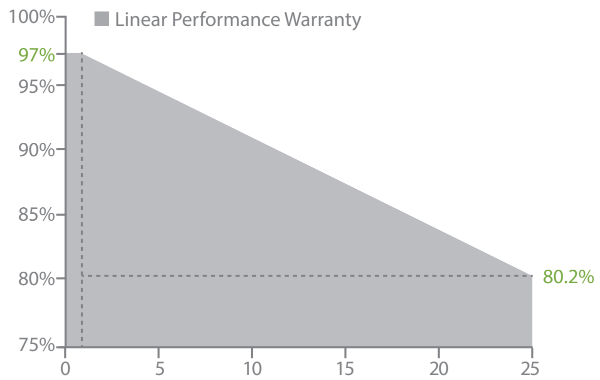
Cell type	Polycrystalline cell, 3-busbar technology
Number of cells / cell arrangement	60 / 6 x 10
Cells dimension	156 x 156 mm^2

MECHANICAL SPECIFICATIONS

Outer dimensions (L x W x H) [5]	1654 x 989 x 40 mm
Frame technology	Aluminum, silver anodized
Module composition	Glass / EVA / Backsheet (white)
Weight (module only)	18.2 kg
Front glass thickness	3.2 mm
Junction box IP rating	IP 67
Cable length (UL)	1000 mm
Cable diameter (UL)	12 AWG
Maximum load capacity	6000 Pa
Fire performance	Type 2
Connector type (UL)	MC4 pluggable

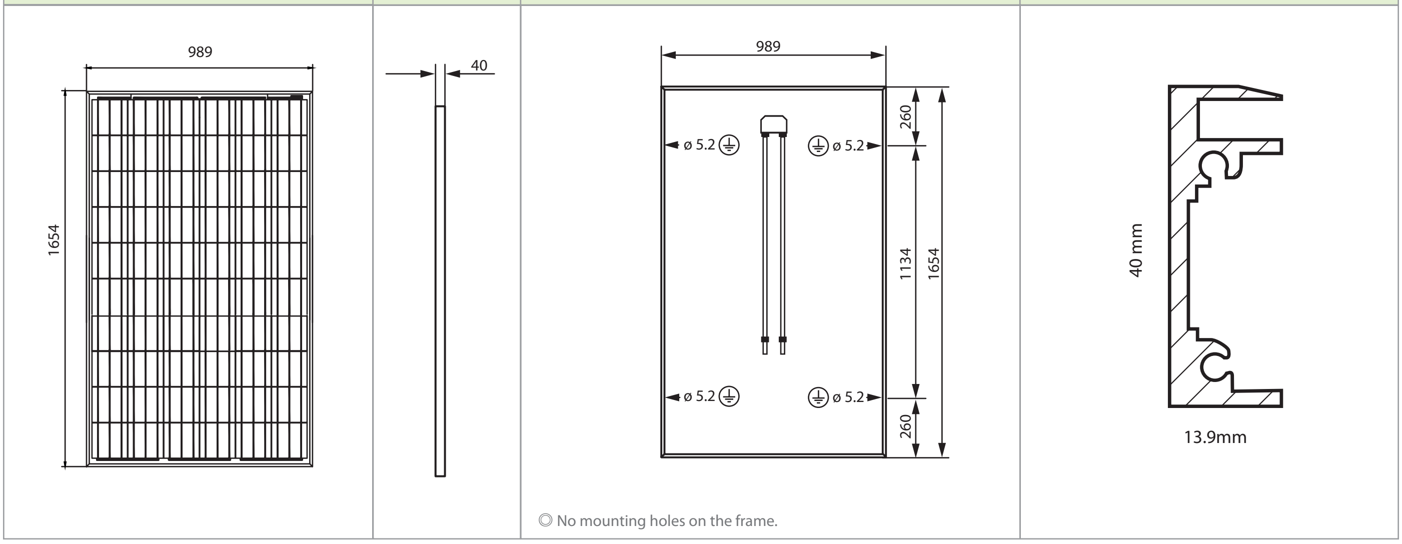
QUALIFICATION AND LINEAR WARRANTIES

Product standard	UL ANSI/UL1703
Extended product warranty [6]	10 years
Performance warranty [6]	Linear performance warranty
Year 1	>97 % of warranted output power
Year 25	>80 % of warranted output power



MODULE DIMENSION DETAILS

Front view	Side view	Rear view	Frame cross section



[5] Dimensional tolerance: +/–2 mm
[6] According to the current warranty conditions of Astronergy Solarmodule GmbH