

**Gewerbegebiet B15**

**Alustraße 1**

D-83527 Kirchdorf/Haag i. OB

Tel: 08072 9191-231

Fax: 08072 9191-9231

solar@schletter.de

www.solar.schletter.de

***Planning documentation for the bearing system  
PvMax 3 for solar modules***

***Project: 01-PE11 PvM Mr Dean - PvM3-1V-25°-10 -  
Alternergy***

***Module type: 1640 x 992 mm***



By order of

**Alternergy**

Turnham Green Terrace Mews  
UK-W4

**January 2015**

## Design calculations

PvMax3 (400610-3)

Applicable for freefield installations

|                   |          |      |                   |
|-------------------|----------|------|-------------------|
| tilt              | $\alpha$ | 25   | °                 |
| snow load         | s        | 0.34 | kN/m <sup>2</sup> |
| total roof height | z        | 1.29 | m                 |
| module height     | h        | 1.64 | m                 |
| module weight     | g        | 0.15 | kN/m <sup>2</sup> |
| module height     | H        | 1.64 | m                 |

|                                               |                  |
|-----------------------------------------------|------------------|
| $\sin = 0.423$                                | $\cos = 0.906$   |
| $c_{f1} = 1.40$                               | $c_{f2} = -1.36$ |
| $c_{p1} = 1.70$                               | $c_{p2} = -1.90$ |
| peak velocity pressure 0.39 kN/m <sup>2</sup> |                  |
| material EN AW-6063 T66                       |                  |

## load assembly per Module area

### dead load

$$\begin{aligned} g_v &= 0.15 \cdot 1.00 \cdot 1.00 = 0.15 \text{ kN/m}^2 \\ g_z &= 0.15 \cdot 0.906 = 0.14 \text{ kN/m}^2 \\ g_y &= 0.15 \cdot 0.423 = 0.06 \text{ kN/m}^2 \end{aligned}$$

### wind pressure

$$\begin{aligned} w_{dz} &= 0.39 \cdot 1.70 = 0.66 \text{ kN/m}^2 \\ w_{sz} &= 0.39 \cdot -1.90 = -0.74 \text{ kN/m}^2 \end{aligned}$$

### snow load

$$\begin{aligned} s_v &= 0.34 \cdot 1.00 \cdot 0.906 = 0.31 \text{ kN/m}^2 \\ s_z &= 0.31 \cdot 0.906 = 0.28 \text{ kN/m}^2 \\ s_y &= 0.31 \cdot 0.423 = 0.13 \text{ kN/m}^2 \end{aligned}$$

### wind load (MFRS)

$$\begin{aligned} W_{dz} &= 0.39 \cdot 1.64 \cdot 1.40 = 0.90 \text{ kN/m} \\ W_{sz} &= 0.39 \cdot 1.64 \cdot -1.36 = -0.87 \text{ kN/m} \end{aligned}$$

## partial safety factors and combin. Coefficients

Importance factor  $K_{FI} = 0.9$

$$\gamma_g = 1.35 \cdot 0.9 = 1.21 = 0.90 \text{ for favourable load action}$$

$$\gamma_q = 1.50 \cdot 0.9 = 1.35$$

$$\Psi_{0,w} = 0.50$$

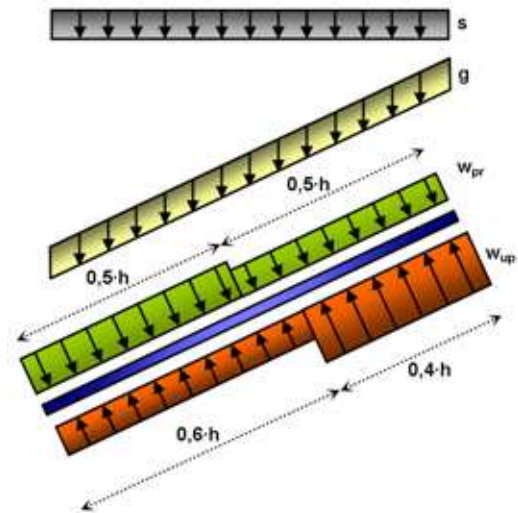
$$\Psi_{0,s} = 0.50$$

## load combinations

$$\text{LC 1: } \gamma_g \cdot g + \gamma_q \cdot s + \Psi_{0,w} \cdot \gamma_q \cdot W_{1,j}$$

$$\text{LC 2: } \gamma_g \cdot g + \Psi_{0,s} \cdot \gamma_q \cdot s + \gamma_q \cdot W_{1,j}$$

$$\text{LC 3: } 0.9 \cdot g + \gamma_q \cdot W_{2,j} \text{ uplifting}$$



## section properties of purlins purlin S0

|                 |                           |
|-----------------|---------------------------|
| total area      | $A = 6.9 \text{ cm}^2$    |
| section modulus | $W_y = 14.1 \text{ cm}^3$ |
| section modulus | $W_z = 7.6 \text{ cm}^3$  |

|                         |                           |
|-------------------------|---------------------------|
| Number of supports/rack | $n = 3$                   |
| support distance        | $a = 3.86 \text{ m}$      |
|                         | $a_{kr} = 1.22 \text{ m}$ |

## Initial forces factors for single and multispan beams

| n | $M_{1,tot}$ | $M_{1,part}$ | $M_{2,tot}$ | $M_{2,part}$ | $M_{B,tot}$ | $M_{B,part}$ | $A_{tot}$ | $A_{part}$ | $B_{tot}$ | $B_{part}$ | $Q_{tot}$ | $Q_{part}$ |
|---|-------------|--------------|-------------|--------------|-------------|--------------|-----------|------------|-----------|------------|-----------|------------|
| 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      |

## intersection forces vertical

|   | load combination 1     |                        |                           |       | load combination 2     |                        |                           |       | load combination 3     |                        |                           |        |
|---|------------------------|------------------------|---------------------------|-------|------------------------|------------------------|---------------------------|-------|------------------------|------------------------|---------------------------|--------|
| n | M <sub>y-midspan</sub> | M <sub>y-support</sub> | M <sub>y-cantilever</sub> | A     | M <sub>y-midspan</sub> | M <sub>y-support</sub> | M <sub>y-cantilever</sub> | A     | M <sub>y-midspan</sub> | M <sub>y-support</sub> | M <sub>y-cantilever</sub> | A      |
| 1 | 1.510                  | 0.000                  | -0.598                    | 2.549 | 1.908                  | 0.000                  | -0.756                    | 3.221 | -1.343                 | 0.000                  | -0.050                    | -2.680 |
| 2 | 1.107                  | -1.510                 | -0.598                    | 3.911 | 1.413                  | -1.908                 | -0.756                    | 4.942 | -1.070                 | 1.343                  | -0.050                    | -2.508 |
| 3 | 1.177                  | -1.379                 | -0.598                    | 3.702 | 1.499                  | -1.751                 | -0.756                    | 4.692 | -1.117                 | 1.283                  | -0.050                    | -2.541 |
| 4 | 1.161                  | -1.433                 | -0.598                    | 3.785 | 1.480                  | -1.818                 | -0.756                    | 4.793 | -1.109                 | 1.321                  | -0.050                    | -2.530 |

### horizontal section forces

|   | load combination 1      |                         |                            |       | load combination 2      |                         |                            |       | load combination 3      |                         |                            |       |
|---|-------------------------|-------------------------|----------------------------|-------|-------------------------|-------------------------|----------------------------|-------|-------------------------|-------------------------|----------------------------|-------|
| n | M <sub>z</sub> -midspan | M <sub>z</sub> -support | M <sub>z</sub> -cantilever | A     | M <sub>z</sub> -midspan | M <sub>z</sub> -support | M <sub>z</sub> -cantilever | A     | M <sub>z</sub> -midspan | M <sub>z</sub> -support | M <sub>z</sub> -cantilever | A     |
| 1 | 0.385                   | 0.000                   | -0.152                     | 0.650 | 0.251                   | 0.000                   | -0.100                     | 0.424 | 0.087                   | 0.000                   | 0.349                      | 0.000 |
| 2 | 0.271                   | -0.385                  | -0.152                     | 0.997 | 0.168                   | -0.251                  | -0.100                     | 0.651 | 0.049                   | -0.087                  | 0.349                      | 0.091 |
| 3 | 0.291                   | -0.344                  | -0.152                     | 0.933 | 0.183                   | -0.219                  | -0.100                     | 0.600 | 0.056                   | -0.070                  | 0.349                      | 0.093 |
| 4 | 0.286                   | -0.359                  | -0.152                     | 0.956 | 0.179                   | -0.230                  | -0.100                     | 0.617 | 0.054                   | -0.075                  | 0.349                      | 0.092 |

### conclusion kN/m<sup>2</sup>

|                             | midspan stress |        |        |              | stress support section |        |        |              | maximum stress<br>$\sigma_x = 16.83 \text{ kN/cm}^2$<br>$\sigma_x = 16.83 \text{ kN/cm}^2$<br>$\sigma_x = 16.83 \text{ kN/cm}^2$<br>$\sigma_x = 15.30 \text{ kN/cm}^2$<br>$\sigma_x = 15.92 \text{ kN/cm}^2$<br>$\sigma_x = 6.67 \text{ kN/cm}^2$ |
|-----------------------------|----------------|--------|--------|--------------|------------------------|--------|--------|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| n                           | LK1            | LK2    | LK3    | maßg         | LK1                    | LK2    | LK3    | maßg         |                                                                                                                                                                                                                                                   |
| 1                           | 15.760         | 16.834 | 10.676 | <b>16.83</b> | 0.000                  | 0.000  | 0.000  | <b>0.00</b>  |                                                                                                                                                                                                                                                   |
| 2                           | 11.410         | 12.236 | 8.238  | <b>12.24</b> | 15.760                 | 16.834 | 10.676 | <b>16.83</b> |                                                                                                                                                                                                                                                   |
| 3                           | 12.174         | 13.042 | 8.658  | <b>13.04</b> | 14.298                 | 15.304 | 10.018 | <b>15.30</b> |                                                                                                                                                                                                                                                   |
| 4                           | 11.995         | 12.854 | 8.575  | <b>12.85</b> | 14.882                 | 15.922 | 10.355 | <b>15.92</b> |                                                                                                                                                                                                                                                   |
| stresses cantilever moments |                |        |        |              | 6.246                  | 6.672  | -4.926 | <b>6.67</b>  |                                                                                                                                                                                                                                                   |

### Calculation of support reactions

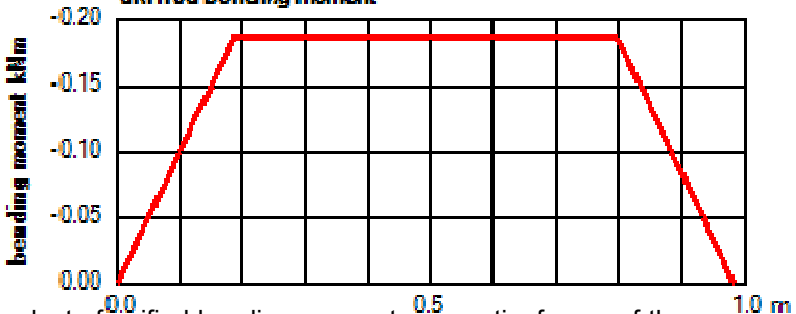
| n | A <sub>tot</sub> | A <sub>part</sub> | B <sub>tot</sub> | B <sub>part</sub> | Q <sub>tot</sub> | Q <sub>part</sub> | B = 0.90 m              | e <sub>u</sub> = 0.054 |
|---|------------------|-------------------|------------------|-------------------|------------------|-------------------|-------------------------|------------------------|
| 1 | 0.500            | 0.500             | 0.000            | 0.000             | 0.500            | 0.500             | X <sub>A</sub> = 0.45 m | e <sub>o</sub> = 0.079 |
| 2 | 0.375            | 0.438             | 1.250            | 1.250             | 0.625            | 0.625             | X <sub>B</sub> = 0.45 m |                        |
| 3 | 0.400            | 0.450             | 1.100            | 1.200             | 0.600            | 0.617             | h <sub>A</sub> = 0.73 m |                        |
| 4 | 0.393            | 0.446             | 1.143            | 1.223             | 0.607            | 0.621             |                         |                        |

### center supports

$$\begin{aligned} \min B &= 1/B \cdot (f_V \cdot 0.90 \cdot h \cdot g_z / \cos \beta \cdot X_A + f_T \cdot 1.3 \cdot W_{k2} \cdot (X_A / \cos \beta + h \cdot e_o + h_A \cdot \sin \beta)) \cdot a \\ \max B &= 1/B \cdot (f_V \cdot 1.21 \cdot h \cdot g_z / \cos \beta \cdot X_A + f_T \cdot 1.3 \cdot (s \cdot h / \cos \beta \cdot X_A + 0.5 \cdot W_{k1} \cdot (X_A / \cos \beta + h \cdot e_u + h_A \cdot \sin \beta))) \cdot a \\ \max B &= 1/B \cdot (f_V \cdot 1.21 \cdot h \cdot g_z / \cos \beta \cdot X_A + f_T \cdot 1.3 \cdot (0.5 \cdot s \cdot h / \cos \beta \cdot X_A + W_{k1} \cdot (X_A / \cos \beta + h \cdot e_u + h_A \cdot \sin \beta))) \cdot a \\ \min A &= 1/B \cdot (f_V \cdot 0.90 \cdot h \cdot g_z / \cos \beta \cdot X_B + f_T \cdot 1.3 \cdot W_{k2} \cdot (B \cdot \cos \beta - X_A / \cos \beta + h \cdot e_o - h_A \cdot \sin \beta)) \cdot a \\ \max A &= 1/B \cdot (f_V \cdot 1.21 \cdot h \cdot g_z / \cos \beta \cdot X_B + f_T \cdot 1.3 \cdot (s \cdot h / \cos \beta \cdot X_A \\ &\quad + 0.5 \cdot W_{k1} \cdot (B \cdot \cos \beta - X_A / \cos \beta + h \cdot e_u - h_A \cdot \sin \beta))) \cdot a \\ \max A &= 1/B \cdot (f_V \cdot 1.21 \cdot h \cdot g_z / \cos \beta \cdot X_B + f_T \cdot 1.3 \cdot (0.5 \cdot s \cdot h / \cos \beta \cdot X_A \\ &\quad + W_{k1} \cdot (B \cdot \cos \beta - X_A / \cos \beta + h \cdot e_u - h_A \cdot \sin \beta))) \cdot a \\ \max C &= 1.3 \cdot f_T \cdot c_{f1} \cdot q_{(z)} \cdot a \cdot \sin \beta \\ \min C &= 1.3 \cdot f_T \cdot c_{f2} \cdot q_{(z)} \cdot a \cdot \sin \beta \end{aligned}$$

### edge support

$$\begin{aligned} \min B &= 1/B \cdot (f_V \cdot 0.90 \cdot h \cdot g_z / \cos \beta \cdot X_A + f_T \cdot 1.3 \cdot W_{k2} \cdot (X_A / \cos \beta + h \cdot e_o + h_A \cdot \sin \beta)) \cdot a \\ &\quad + 1/B \cdot (0.9 \cdot h \cdot g_z / \cos \beta \cdot X_A + 1.3 \cdot W_{k2} \cdot (X_A / \cos \beta + h \cdot e_o + h_A \cdot \sin \beta)) \cdot a_r \\ \max B &= 1/B \cdot (f_V \cdot 1.21 \cdot h \cdot g_z / \cos \beta \cdot X_A + f_T \cdot 1.3 \cdot (s \cdot h / \cos \beta \cdot X_A + 0.5 \cdot W_{k1} \cdot (X_A / \cos \beta + h \cdot e_u + h_A \cdot \sin \beta))) \cdot a \\ &\quad + 1/B \cdot (1.21 \cdot h \cdot g_z / \cos \beta \cdot X_A + 1.3 \cdot (s \cdot h / \cos \beta \cdot X_A + 0.5 \cdot W_{k1} \cdot (X_A / \cos \beta + h \cdot e_u + h_A \cdot \sin \beta))) \cdot a_r \\ \max B &= 1/B \cdot (1.21 \cdot h \cdot g_z / \cos \beta \cdot X_A + 1.3 \cdot (0.5 \cdot s \cdot h / \cos \beta \cdot X_A + W_{k1} \cdot (X_A / \cos \beta + h \cdot e_u + h_A \cdot \sin \beta))) \cdot a \\ &\quad + 1/B \cdot (f_V \cdot 1.21 \cdot h \cdot g_z / \cos \beta \cdot X_A + f_T \cdot 1.3 \cdot (0.5 \cdot s \cdot h / \cos \beta \cdot X_A + W_{k1} \cdot (X_A / \cos \beta + h \cdot e_u + h_A \cdot \sin \beta))) \cdot a_r \\ \min A &= 1/B \cdot (f_V \cdot 0.90 \cdot h \cdot g_z / \cos \beta \cdot X_B + f_T \cdot 1.3 \cdot W_{k2} \cdot (B \cdot \cos \beta - X_A / \cos \beta + h \cdot e_o - h_A \cdot \sin \beta)) \cdot a \\ &\quad + 1/B \cdot (0.90 \cdot h \cdot g_z / \cos \beta \cdot X_B + 1.3 \cdot W_{k2} \cdot (B \cdot \cos \beta - X_A / \cos \beta + h \cdot e_o - h_A \cdot \sin \beta)) \cdot a_r \\ \max A &= 1/B \cdot (f_V \cdot 1.21 \cdot h \cdot g_z / \cos \beta \cdot X_B + f_T \cdot 1.3 \cdot (s \cdot h / \cos \beta \cdot X_B \\ &\quad + 0.5 \cdot W_{k1} \cdot (B \cdot \cos \beta - X_A / \cos \beta + h \cdot e_u - h_A \cdot \sin \beta))) \cdot a \\ &\quad + 1/B \cdot (1.21 \cdot h \cdot g_z / \cos \beta \cdot X_B + 1.3 \cdot (s \cdot h / \cos \beta \cdot X_B + 0.5 \cdot W_{k1} \cdot (B \cdot \cos \beta - X_A / \cos \beta + h \cdot e_u - h_A \cdot \sin \beta))) \cdot a_r \\ \max A &= 1/B \cdot (f_V \cdot 1.21 \cdot h \cdot g_z / \cos \beta \cdot X_B + f_T \cdot 1.3 \cdot (0.5 \cdot s \cdot h / \cos \beta \cdot X_A \\ &\quad + W_{k1} \cdot (B \cdot \cos \beta - X_A / \cos \beta + h \cdot e_u - h_A \cdot \sin \beta))) \cdot a \\ &\quad + 1/B \cdot (1.21 \cdot h \cdot g_z / \cos \beta \cdot X_B + 1.3 \cdot (0.5 \cdot s \cdot h / \cos \beta \cdot X_A + W_{k1} \cdot (B \cdot \cos \beta - X_A / \cos \beta + h \cdot e_u - h_A \cdot \sin \beta))) \cdot a_r \\ \max C &= 1.3 \cdot (f_T \cdot a + a_r) \cdot c_{f1} \cdot q_{(z)} \cdot h \cdot \sin \beta \\ \min C &= 1.3 \cdot (f_T \cdot a + a_r) \cdot c_{f2} \cdot q_{(z)} \cdot h \cdot \sin \beta \end{aligned}$$

| reaction forces center                                                                                           |                                        |                 |       |                                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
|------------------------------------------------------------------------------------------------------------------|----------------------------------------|-----------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|-------------------------------|----------------|-------|--------------------|---------------|-------|-------|--|
| kN                                                                                                               |                                        |                 |       |                                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
|                                                                                                                  | load combination 1                     |                 |       |                                                                                                                                             | load combination 2                                                                                     |                               |                |       | load combination 3 |               |       |       |  |
| n                                                                                                                | max A                                  | zug B           | max B | zug A                                                                                                                                       | max A                                                                                                  | zug B                         | max B          | zug A | max A              | zug B         | max B | zug A |  |
| 1                                                                                                                | 0.00                                   | 0.00            | 0.00  | 0.00                                                                                                                                        | 0.00                                                                                                   | 0.00                          | 0.00           | 0.00  | 0.00               | 0.00          | 0.00  | 0.00  |  |
| 2                                                                                                                | 2.68                                   | 4.68            | 4.68  | 2.68                                                                                                                                        | 2.19                                                                                                   | 6.19                          | 6.19           | 2.19  | 1.28               | -5.35         | -5.35 | 1.28  |  |
| 3                                                                                                                | 2.52                                   | 4.44            | 4.44  | 2.52                                                                                                                                        | 2.04                                                                                                   | 5.88                          | 5.88           | 2.04  | 1.19               | -5.18         | -5.18 | 1.19  |  |
| 4                                                                                                                | 2.58                                   | 4.53            | 4.53  | 2.58                                                                                                                                        | 2.09                                                                                                   | 6.01                          | 6.01           | 2.09  | 1.22               | -5.27         | -5.27 | 1.22  |  |
| reaction forces edge                                                                                             |                                        |                 |       |                                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
| kN                                                                                                               |                                        |                 |       |                                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
|                                                                                                                  | load combination 1                     |                 |       |                                                                                                                                             | load combination 2                                                                                     |                               |                |       | load combination 3 |               |       |       |  |
| n                                                                                                                | max A                                  | zug B           | max B | zug A                                                                                                                                       | max A                                                                                                  | zug B                         | max B          | zug A | max A              | zug B         | max B | zug A |  |
| 1                                                                                                                | 1.75                                   | 3.05            | 3.05  | 1.75                                                                                                                                        | 1.43                                                                                                   | 4.03                          | 4.03           | 1.43  | 0.83               | -3.49         | -3.49 | 0.83  |  |
| 2                                                                                                                | 1.58                                   | 2.78            | 2.78  | 1.58                                                                                                                                        | 1.28                                                                                                   | 3.69                          | 3.69           | 1.28  | 0.74               | -3.25         | -3.25 | 0.74  |  |
| 3                                                                                                                | 1.61                                   | 2.84            | 2.84  | 1.61                                                                                                                                        | 1.31                                                                                                   | 3.76                          | 3.76           | 1.31  | 0.76               | -3.30         | -3.30 | 0.76  |  |
| 4                                                                                                                | 1.60                                   | 2.82            | 2.82  | 1.60                                                                                                                                        | 1.30                                                                                                   | 3.73                          | 3.73           | 1.30  | 0.76               | -3.28         | -3.28 | 0.76  |  |
| compostion central support                                                                                       |                                        |                 |       |                                                                                                                                             |                                                                                                        | compostion edge support       |                |       |                    |               |       |       |  |
|                                                                                                                  | pressure loads                         |                 |       | tension loads                                                                                                                               |                                                                                                        |                               | pressure loads |       |                    | tension loads |       |       |  |
| n                                                                                                                | max A                                  | max B           | max Σ | min A                                                                                                                                       | min B                                                                                                  | min Σ                         | max A          | max B | max Σ              | min A         | min B | min Σ |  |
| 1                                                                                                                | 0.00                                   | 0.00            | 0.00  | 0.00                                                                                                                                        | 0.00                                                                                                   | 0.00                          | 1.75           | 4.03  | 5.46               | 0.83          | -3.49 | -2.66 |  |
| 2                                                                                                                | 2.68                                   | 6.19            | 8.37  | 1.28                                                                                                                                        | -5.35                                                                                                  | -4.07                         | 1.58           | 3.69  | 4.97               | 0.74          | -3.25 | -2.51 |  |
| 3                                                                                                                | 2.52                                   | 5.88            | 7.92  | 1.19                                                                                                                                        | -5.18                                                                                                  | -4.00                         | 1.61           | 3.76  | 5.07               | 0.76          | -3.30 | -2.54 |  |
| 4                                                                                                                | 2.58                                   | 6.01            | 8.10  | 1.22                                                                                                                                        | -5.27                                                                                                  | -4.05                         | 1.60           | 3.73  | 5.04               | 0.76          | -3.28 | -2.53 |  |
| horizontal loads                                                                                                 |                                        |                 |       |                                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
| (The horizontal loads are to be transmitted at rear support by adequate joints)                                  |                                        |                 |       |                                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
| center supports                                                                                                  |                                        | edge support    |       | vertical loads                                                                                                                              |                                                                                                        |                               |                |       |                    |               |       |       |  |
| 0.00 kN                                                                                                          |                                        | 1.56 kN         |       | max A = 2.68 kN                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
| 2.40 kN                                                                                                          |                                        | 1.44 kN         |       | min A = 0.74 kN                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
| 2.30 kN                                                                                                          |                                        | 1.47 kN         |       | Sumation LC 1 LC 2 LC 3                                                                                                                     |                                                                                                        |                               |                |       |                    |               |       |       |  |
| 2.35 kN                                                                                                          |                                        | 1.46 kN         |       | 7.36 8.37 -3.26                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
| geometrie of super structure                                                                                     |                                        |                 |       |                                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
| girder length                                                                                                    | $l_R$                                  |                 |       | 0.98 m                                                                                                                                      |                                                                                                        |                               |                |       |                    |               |       |       |  |
| basic width                                                                                                      | $B$                                    |                 |       | 0.90 m                                                                                                                                      |                                                                                                        |                               |                |       |                    |               |       |       |  |
| span length                                                                                                      | $l_C$                                  |                 |       | 0.61 m                                                                                                                                      |                                                                                                        |                               |                |       |                    |               |       |       |  |
| length of front support                                                                                          | $l_A$                                  |                 |       | 0.73 m                                                                                                                                      |                                                                                                        |                               |                |       |                    |               |       |       |  |
| rear support                                                                                                     | $l_B$                                  |                 |       | 1.04 m                                                                                                                                      |                                                                                                        |                               |                |       |                    |               |       |       |  |
| tilt of rear support                                                                                             | $\alpha$                               |                 |       | 19.41 °                                                                                                                                     |                                                                                                        |                               |                |       |                    |               |       |       |  |
| length of diagonal slab                                                                                          | $l_D$                                  |                 |       | 1.16 m                                                                                                                                      |                                                                                                        |                               |                |       |                    |               |       |       |  |
| cantilever                                                                                                       |                                        |                 |       | 19 %                                                                                                                                        |                                                                                                        |                               |                |       |                    |               |       |       |  |
|                                                                                                                  |                                        |                 |       | <div><div>unified bending moment</div><div></div></div> |                                                                                                        |                               |                |       |                    |               |       |       |  |
| The initial forces of the girder results from product of unified bending moment an reactionforces of the purlins |                                        |                 |       |                                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
| $M_{span}$ kNm                                                                                                   |                                        | $M_{supp.}$ kNm |       | $N$ kN                                                                                                                                      |                                                                                                        | maximum purlin reaction force |                |       |                    |               |       |       |  |
| 0.000                                                                                                            |                                        | -0.924          |       | 1.994                                                                                                                                       |                                                                                                        | $V = 4.94$ kN                 |                |       |                    |               |       |       |  |
|                                                                                                                  |                                        |                 |       |                                                                                                                                             |                                                                                                        | $H = 1.00$ kN                 |                |       |                    |               |       |       |  |
| girder verification                                                                                              |                                        |                 |       |                                                                                                                                             |                                                                                                        |                               |                |       |                    |               |       |       |  |
| verification                                                                                                     | $\frac{N}{A} + \frac{M}{W_y} \leq f_d$ |                 |       |                                                                                                                                             | $\frac{1.99}{12.15} + \frac{92.40}{23.21} = 4.14 \text{ kN/cm}^2 < 20.0 / 1.10 = 18.2 \text{ kN/cm}^2$ |                               |                |       |                    |               |       |       |  |
| girder type                                                                                                      | BF0 (124500)                           |                 |       |                                                                                                                                             | $A = 12.15 \text{ cm}^2$ $W_y = 23.21 \text{ cm}^3$                                                    |                               |                |       |                    |               |       |       |  |

## support verification

**frontal**      profile RHP 55x55    A = 6.64 cm<sup>2</sup>    I<sub>z</sub> = 27.90 cm<sup>4</sup>    W<sub>z</sub> = 10.10 cm<sup>3</sup>    i = 2.05 cm  
**diagonal slab**    profile RHP 55x55    A = 6.64 cm<sup>2</sup>    I<sub>z</sub> = 27.90 cm<sup>4</sup>    W<sub>z</sub> = 10.10 cm<sup>3</sup>    i = 2.05 cm  
**rear**            profile RHP 55x55    A = 6.64 cm<sup>2</sup>    I<sub>z</sub> = 27.90 cm<sup>4</sup>    W<sub>z</sub> = 10.10 cm<sup>3</sup>    i = 2.05 cm

| axial forces  |         | axial forces |       |       | length | λ    | ω    | stress kN/cm <sup>2</sup> |       |       | η   |
|---------------|---------|--------------|-------|-------|--------|------|------|---------------------------|-------|-------|-----|
|               |         | LK1          | LK2   | LK3   | cm     | -    | -    | LK1                       | LK2   | LK3   | %   |
| front support | central | -2.68        | -2.19 | -1.28 | 72.7   | 35.5 | 1.15 | -0.46                     | -0.38 | -0.19 | 2.5 |
|               | edge    | -1.58        | -1.28 | -0.74 | 72.7   | 35.5 | 1.15 | -0.27                     | -0.22 | -0.11 | 1.5 |
| diagonal slab | central | 0.29         | -1.42 | 5.25  | 115.7  | 56.4 | 1.46 | 0.04                      | -0.31 | 0.79  | 4.3 |
|               | edge    | 0.15         | -0.88 | 3.18  | 115.7  | 56.4 | 1.46 | 0.02                      | -0.19 | 0.48  | 2.6 |
| rear support  | central | -5.46        | -6.21 | 5.07  | 104.4  | 50.9 | 1.35 | -1.11                     | -1.26 | 0.76  | 6.9 |
|               | edge    | -3.24        | -3.69 | 3.09  | 104.4  | 50.9 | 1.35 | -0.66                     | -0.75 | 0.47  | 4.1 |

member verification (pressure)  $\frac{\omega \cdot N}{A} \leq f_d$

member verification (tension)  $\frac{N}{A} \leq f_d \text{ LC3}$

### verification of bolt fixations

(bolts M12 A2-70)

η (%)

front support

t1 = 5 mm

V<sub>a,R,d</sub> = 38.0 kN

V<sub>l,R,d</sub> = 18.8 kN

7.1

t2 = 4 mm

shear surfaces 2

diagonal slab

t1 = 5 mm

V<sub>a,R,d</sub> = 38.0 kN

V<sub>l,R,d</sub> = 18.8 kN

13.9

t2 = 4 mm

shear surfaces 2

rear support

t1 = 5 mm

V<sub>a,R,d</sub> = 38.0 kN

V<sub>l,R,d</sub> = 18.8 kN

16.5

t2 = 4 mm

shear surfaces 2

safety factors       $\eta$   $K \geq 1.5$  tilt  
                           $\eta$   $G \geq 1.5$  sliding  
                           $\eta$   $A \geq 1.5$  uplift

## dimensions of foundation

|                 |                   |                      |
|-----------------|-------------------|----------------------|
| center supports | req g = 5.11 kN/m | (total load 7.15 kN) |
| edge support    | req g = 4.16 kN/m | (total load 5.83 kN) |

|                 |                   |                      |
|-----------------|-------------------|----------------------|
| center supports | req g = 4.74 kN/m | (total load 4.26 kN) |
| edge support    | req g = 3.86 kN/m | (total load 3.47 kN) |

|                 |                   |                      |
|-----------------|-------------------|----------------------|
| center supports | req g = 4.02 kN/m | (total load 3.62 kN) |
| edge support    | req g = 3.28 kN/m | (total load 2.95 kN) |

verification of allowable soil pressure  $\sigma = 26.8 \text{ kN/m}^2 < 40.0 \text{ kN/m}^2$   
Reinforcement of foundation: minimum corrugated Q 257 rebar steel

fixation at foundation with bonding anchors Fischer Ankerbolzen FAZ II 10/10  
Europäische Technische Zulassung ETA-05/0069 or equal

## Regulations and calculation basics

DIN EN 1992

Fischer Befestigungssysteme

Bemessung nach ETAG Anhang C

Europäische Technische Zulassung ETA-05/0069

**Fischer Ankerbolzen FAZ II 10/10**  $\eta = 45\%$

Art. Nr. 94981

embedment depth  $h_{ef} = 60 \text{ mm}$

minimum thickness of concrete  $d = 100 \text{ mm}$

concrete compressive strength class C20/25

cracked concrete, normal reinforcement

### actions:

Connection front connection on the back

$N_d = 1.27 \text{ kN}$   $N_d = 5.35 \text{ kN}$

$e = 66 \text{ mm}$   $V_d = 5.77 \text{ kN}$

### Structural analyses:

The design is carried out with the "Design method for anchors with European technical approvals for use in concrete, Appendix C of the European technical approval decisions." Design method A

#### verification connection on the front

##### Steel failure:

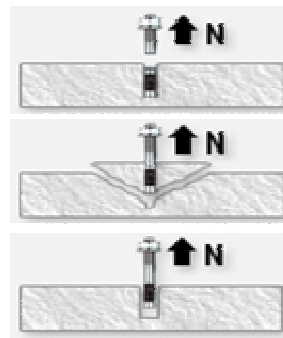
$$N_d / N_{Rd,s} = 1.3 / 18.0 = 0.07$$

##### Concrete cone failure:

$$N_d / N_{Rd,c} = 1.3 / 11.2 = 0.11$$

##### pull out:

$$N_d / N_{Rd,p} = 1.3 / 6.0 = 0.21$$



#### verification connection on the back

**There are 2 anchors needed!**

##### Steel failure:

$$N_d / N_{Rd,s} = 5.4 / 36.0 = 0.15$$

##### Concrete cone failure:

$$N_d / N_{Rd,c} = 5.4 / 18.5 = 0.29$$

##### pull out:

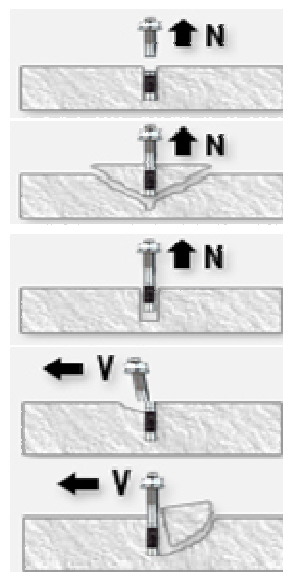
$$N_d / N_{Rd,p} = 5.4 / 12.0 = 0.45$$

##### Steel failure:

$$V_d / V_{Rd,s} = 5.4 / 32.0 = 0.17$$

##### Concrete failure on the opposing side of the load:

$$V_d / V_{Rd,cp} = 5.4 / 41.0 = 0.13$$



Combined Force:

Utilization due to interaction for combined tension and shear loading:

$$\eta_N = 0.45 < 1$$

$$\eta_V = 0.17 < 1$$

$$(\eta_N + \eta_V) / 1.2 = (0.45 + 0.17) / 1.2 = 0.51 < 1$$

**the anchor Fischer Ankerbolzen FAZ II 10/10 is suitable for the system**

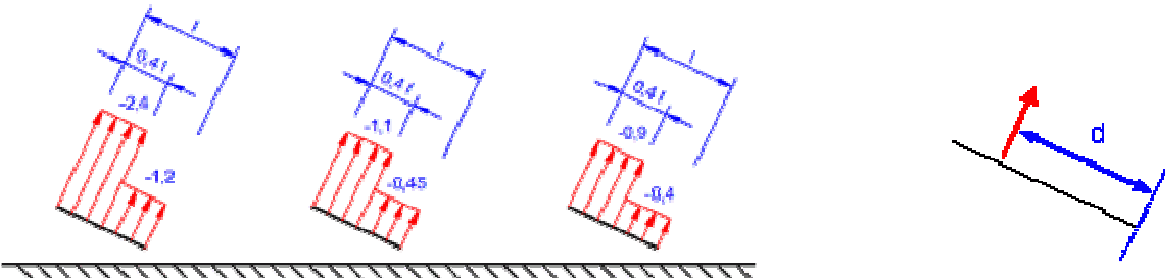
Alternatively, the following anchor types are used:

|                                                     |                          |
|-----------------------------------------------------|--------------------------|
| Hilti Anker HST M10x90/10 (5.8)                     | Art. Nr. 00371584        |
| Würth Anker W-FAZ/HCR M10 (5.8)                     | W-FAZ/HCR M10-10*90      |
| Hilti HIT-HY 150 MAX + HIT-V (5.8) M10              | Art. Nr. 430621/00387146 |
| Hilti Anker HST M12x115/20 (5.8)                    | Art. Nr. 00371587        |
| Würth Anker W-FAZ/HCR M12 (5.8)                     | W-FAZ/HCR M12-15*110     |
| Würth W-VIZ/HCR D -75 M10                           | W-VIZ/HCR D-75 M10       |
| Würth WIT-PE 500/HCR M12 -10*135                    | Art. Nr. 5915212135      |
| Hilti HIT-HY 150 MAX + HIT-V (5.8) M12              | Art. Nr. 430621/00387147 |
| Fischer FIS EM Injektionssystem FIS A M10x110 (5.8) | Art. Nr. 090278          |
| Fischer Ankerbolzen FAZ II 12/10                    | Art. Nr. 95419           |
| Fischer FIS EM Injektionssystem FIS A M10x130 (8.8) |                          |
| Hilti HIT-HY 150 MAX + HIT-V (8.8) M10              | Art. Nr. 430621/00387146 |
| Fischer FIS EM Injektionssystem FIS A M12x140 (8.8) |                          |
| Hilti HIT-HY 150 MAX + HIT-V (5.8) M16              |                          |
| Hilti HIT-HY 150 MAX + HIT-V (8.8) M12              | Art. Nr. 430621/00387147 |
| Fischer FIS EM Injektionssystem FIS A M10x150 (8.8) |                          |
| Fischer FIS EM Injektionssystem FIS A M12x180 (8.8) |                          |
| Fischer FIS EM Injektionssystem FIS A M12x180 (8.8) |                          |

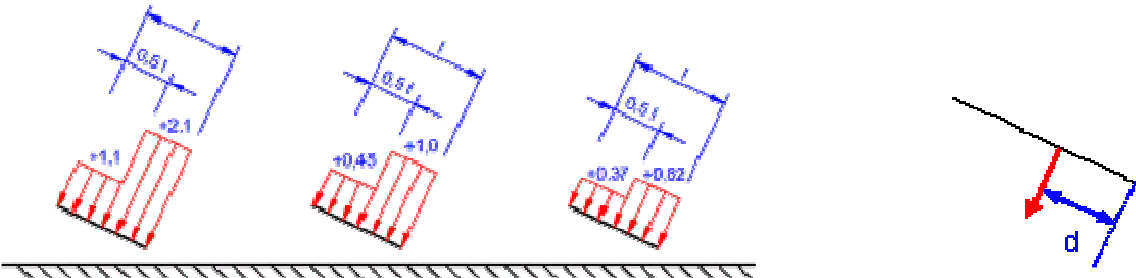
## Explanations regarding the structural analysis of an open area plant

On customer demand, the pressure and suction coefficients have been taken from the expert's report by the Ruscheweyh Consult GmbH for the open area project Zeithain. The comparison with the load assumptions according to BS EN 1991-1-4:2004 shows a slightly more economic dimensioning, which appears justifiable in view of the special competence of the expert.

### Pressure coefficients in case of north wind (suction) according to Ruscheweyh force coeffic.



### Pressure coefficients in case of south wind (pressure) according to Ruscheweyh



In the evaluation of the resulting pressure coefficients, the respective load application areas were considered:

upper and lower purlin: half module height  $h$   
middle purlin: total module height  $h$  (weighted average of pressure coefficients)  
pressure:  $c_p = 1/2 \cdot (c_{p, \text{top}} + c_{p, \text{bottom}})$   
suction:  $c_p = 0,15 \cdot c_{p, \text{top}} + 0,35 \cdot c_{p, \text{bottom}}$

|                    | upper purlin |               | middle purlin |              | lower purlin |             | force coefficient $c_f$ |              |
|--------------------|--------------|---------------|---------------|--------------|--------------|-------------|-------------------------|--------------|
|                    | suction      | pressure      | suction       | pressure     | suction      | pressure    | suction                 | pressure     |
| <b>border zone</b> | <b>-2,4</b>  | <b>+ 1,1</b>  | <b>-1,56</b>  | <b>1,6</b>   | <b>-1,2</b>  | <b>2,1</b>  | <b>-1,68</b>            | <b>1,6</b>   |
| <b>inner area</b>  | <b>-0,9</b>  | <b>+ 0,37</b> | <b>-0,55</b>  | <b>0,595</b> | <b>-0,4</b>  | <b>0,82</b> | <b>-0,6</b>             | <b>0,595</b> |

On the basis of BS EN 1991-1-4:2004, in case of monoslope canopies, the loads that have been determined by means of the force coefficient  $c_f$  have to be applied at the upper and lower quarter point for the verification of the substructure. The force coefficients comply with the weighted average of the pressure coefficients.

$$\text{pressure: } c_f = 1/2 \cdot (c_{p, \text{top}} + c_{p, \text{bottom}})$$

$$\text{suction: } c_f = 0,4 \cdot c_{p, \text{top}} + 0,6 \cdot c_{p, \text{bottom}}$$

Different from BS EN 1991-1-4:2004 the forces are not applied at the quarter points, but at the center of gravity of the load model. The distance is measured from the front edge to the center of mass of the module field:

|              |           |                                                                                       |
|--------------|-----------|---------------------------------------------------------------------------------------|
| border zone: | suction:  | $d = (2,40 \cdot 0,4 \cdot 0,80 + 1,20 \cdot 0,6 \cdot 0,30) / 1,680 = 0,585 \cdot l$ |
|              | pressure: | $d = (1,10 \cdot 0,5 \cdot 0,75 + 2,10 \cdot 0,5 \cdot 0,25) / 1,600 = 0,422 \cdot l$ |
| inner area:  | suction:  | $d = (0,90 \cdot 0,4 \cdot 0,80 + 0,40 \cdot 0,6 \cdot 0,30) / 0,600 = 0,600 \cdot l$ |
|              | pressure: | $d = (0,37 \cdot 0,5 \cdot 0,75 + 0,82 \cdot 0,5 \cdot 0,25) / 0,595 = 0,405 \cdot l$ |

# system sketch

