Forum 1

Technology – Mounting and Substructure

Which mounting systems are suitable for open areas?

25\textsuperscript{th}/26\textsuperscript{th} January, Prague, Czech Republic
Overview of topics:

1. Introduction
2. Load evaluation
3. Design calculations
4. Decision criteria for a substructure selection
5. Foundation concepts
6. Mounting progress of different foundation concepts
7. Summary
1. Introduction

Design Criteria

- Safety
  - Material utilization
  - System selection
  - Design calculations
  - Construction details

- Cost optimization
  - Material effort
  - Production procedure
  - Logistics
  - Mounting time

- Design/Sustainability
  - Material selection
  - Durability
  - Recycling
  - Joints/fixations

focus
2. Load actions

Climatic Regions

Guidelines provided by EU
Implementation by individual member states

- Alpine Region
- Central East
- Central West
- Greece
- Iberian Peninsula
- Mediterranean Region
- Norway
- Sweden, Finland
- UK, Republic of Ireland

Example: International system for snow load evaluation

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Solarpraxis 2010
Czech Republic  CSN 1991-1-3

Snow loads on the ground

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European wind zone map according to Eurocode 1

Basis:
Measurements (188 in D)
10-minutes median in 10 m height above ground
That occurs once every 50 years
Observation period: 40-107 years
Contains no gusts
Applicable for flat, even terrain
Terrain categories according to Eurocode 1

Terrain category 0
Sea, coastal area exposed to the open sea

Terrain category I
Lakes or area with negligible vegetation and without obstacles

Terrain category II
Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights

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

Terrain category IV
Area in which at least 15\% of the surface is covered with buildings and their average height exceeds 15 m

Basis:
\[ q_b = \frac{1}{2} \cdot \rho \cdot v^2 \] (basic pressure)

Peak velocity pressure
\[ q_b(z) = C_e(z) \cdot q_b \]
Aerodynamic characteristics

Pressure field if a vertical flow impacts the screen

Pressure field (qualitative)

Strömungsgeschwindigkeiten

Source: Final report 0327229 A, patronized by the Federal Ministry of Economy and Technology
Aerodynamic correlations (45° inclination)
Pressure and force coefficients (DIN EN 1991-1-4)

### Table: Pressure Coefficients

<table>
<thead>
<tr>
<th>Roof angle $\alpha$</th>
<th>Blockage $\varphi$</th>
<th>Overall Force Coefficients $c_0$</th>
<th>Zone A</th>
<th>Zone B</th>
<th>Zone C</th>
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</tbody>
</table>

Empty, free-standing canopy ($\varphi=0$)

Canopy blocked to the downwind eaves by stored goods ($\varphi=1$)

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Increasing wind loads in case of isolated hills and ridges

$\nu_{m}$: mean wind velocity at height $z$ above terrain
$\nu_{mf}$: mean wind velocity above flat terrain
$C_0 = \nu_{mf}/\nu_{m}$

Increasing wind loads up to 42% in case of changing topology (isolated hills and ridges)
3. Design calculations for PV systems

Load combinations

LC 1: $1,35\cdot g + 1,5\cdot s + 0,6\cdot 1,5\cdot w$

LC 2: $1,35\cdot g + 0,5\cdot 1,5\cdot s + 1,5\cdot w$

LC 3: $0,9\cdot g + 1,5\cdot w$

(uplift)

Verifications

- tilting
- dragging
- uplift
Wind-induced vibrations / seismic design
Stress calculations for frameless modules

Numerical model

Stress calculations for thin-film modules
4. Decision criteria for substructure selection

Material (dimensioning acc. to basic material standards)

Aluminum
- low selfweight
- shaping by extrusion process
- easy to install (tolerance equalization)
- remaining value
- floating material prices
- low youngs modulus

Steel
- availability / well-proven solutions
- corrosion protection
- mounting effort
- high weight

Timber
- cost-saving for self-mounting
- durability
- contour accuracy
5. Foundation concepts

**Pile-driven posts**
- Pull-out capacity (vertical)
- Horizontal stiffness
- Bending moment in posts
- Drilling in case of rocks
- Chemical composition (corrosion)

**Screw foundations**
- Pull-out capacity
- No horizontal stiffness
- Axial forces
- Drilling in case of rocks
- Chemical composition (corrosion)

**Concrete foundation**
- Pressure stability of the soil
- Sensitivity of the top soil towards water
- Aggressive soil

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Typical load bearing systems

Single post support

Double post support

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Soil pressure in case of single bearing structures

\[
\sigma_d + \sigma_s + \sigma_w = \sigma_{\text{total}}
\]
Soil pressure in case of coupled bearing structures

dead load + snow + wind

bending moment steel

\[ \sigma_f + \sigma_s \]

\[ \sigma_w \]

\[ \sigma_{geo} \]
6. Mounting progress of different foundation concepts

Example 1: Airport Rote Jahne

- Module First Solar
- Installation time 3 month
- 92,700 modules
- Optimum soil
- Minimum height 0.8 m (mechanical)
  - structurally optimized
  - terrain care by machines

Chosen System:
Single post ram foundations

Example 2: Landfill Malsch

- Installation time 3 months
- 9280 modules
- Bearing capacity of the soil 0.45 KN/m²
- Minimum height 1.2 meters
  - Requirement
    - terrain care by grazing sheep

Chosen System: PvCombi

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7. Conclusions

- Design calculations according to national standards
- Safety standards have to be verified for
  - Authorities
  - Insurance
  - Banking
- The suitable system depends on soil conditions
- Ram systems can be mounted significantly faster
- Target: Minimum BOS costs
  - Material cost
  - Mounting effort
  - Maintenance over life time
Thanks for your attention