Forum 1: Planning and building

Mounting and substructure and their importance for the power plant?

10TH/11TH March, Paris, France
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 foundation concepts
7. Summary
1. Introduction

Design Criteria

- safety
- material utilization
- system selection
- design calculations
- construction details

- cost optimization
- material effort
- precasting
- logistics
- mounting progress

- design/sustainability
- material selection
- durability
- recycling
- joints/fixations

Laws and Standards

Competition and Sustainability
Types of PV-Powerplants
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
Snow loads on the ground

\[ s = (s_k + \Delta s) \cdot \mu_1 \]
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

basic wind speed
Terrain categories according to Eurocode 1

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

Terrain category I (II in France)
Lakes or area with negligible vegetation and without obstacles

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

Terrain category III (III b in France)
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)

\( \rho \) weight of air (1,25 kg/m²)

Peak velocity pressure

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

Pressure field if a vertical flow impacts the screen

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 &amp; Blockage</th>
<th>Overall Force Coefficients</th>
<th>Zone A</th>
<th>Zone B</th>
<th>Zone C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td></td>
<td>0.2</td>
<td>0.5</td>
<td>1.1</td>
</tr>
<tr>
<td>5°</td>
<td></td>
<td>0.4</td>
<td>0.8</td>
<td>1.8</td>
</tr>
<tr>
<td>10°</td>
<td></td>
<td>0.5</td>
<td>1.2</td>
<td>1.8</td>
</tr>
<tr>
<td>15°</td>
<td></td>
<td>0.7</td>
<td>1.4</td>
<td>1.8</td>
</tr>
<tr>
<td>20°</td>
<td></td>
<td>0.8</td>
<td>1.7</td>
<td>2.1</td>
</tr>
<tr>
<td>25°</td>
<td></td>
<td>1.0</td>
<td>2.0</td>
<td>2.3</td>
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<tr>
<td>30°</td>
<td></td>
<td>1.2</td>
<td>2.2</td>
<td>2.4</td>
</tr>
</tbody>
</table>

**Key Plan**
- b/10
- d/10

**Key Diagrams**
- Empty, free-standing canopy (q=0)
- Canopy blocked to the downwind eaves by stored goods (q=1)
Pressure Coefficients from Windtunnel tests

According to Ruscheweyh Consult GmbH

Advantages:
- Load reduction in central areas
- Savings (less posts)
Increasing wind loads in case of isolated hills and ridges

\[ v_m : \text{mean wind velocity at height } z \text{ above terrain} \]
\[ v_{mf} : \text{mean wind velocity above flat terrain} \]
\[ c_0 = \frac{v_{mf}}{v_m} \]

Figure A.1 — Illustration of increase of wind velocities over orography

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 for ground mounted Systems

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
Foundation concepts for Carport Systems (Park@Sol)

Micro piles

+ Cost effective
+ Mounting progress
+ Work in utilization

Concrete foundations

+ Possible for most soil conditions
- Cost intensive (material)
- Mounting progress
- Damage of existing parking lots
### 6. Mounting progress of different foundation concepts

#### Ground mounted Systems

<table>
<thead>
<tr>
<th>Ram-driven posts</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MW/week</td>
<td>1 MW/3 weeks (In situ concrete)</td>
</tr>
<tr>
<td></td>
<td>1 MW/2 weeks (precasted)</td>
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</tbody>
</table>

#### Carport system Park@Sol

<table>
<thead>
<tr>
<th>Micropiles</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MW/2 weeks excluding corrugated sheets</td>
<td>1 MW/6 weeks including corrugated sheets</td>
</tr>
</tbody>
</table>

- 1 MW Germany
- 6 MW Italy
7. Conclusions

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