Session 6: Designing trough to installation

Structural analyses as precondition for safe mounting systems

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Overview of topics:

1. Introduction
2. Load evaluation
3. Design calculations
4. Weight optimized systems (AluLight 12°)
5. Numerical simulations
6. Testing procedures
7. Conclusions
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-Plants

- Pitched roof
- Flatroof (tilted)
- Aerodynamic optimized
- Ground mounted
- Carport systems Park@Sol
2. Load actions BS EN 1991-1-3/NA June 2007

Snow Loads

\[ s_k = [0,15+(0,1 \cdot Z + 0,05)] + (A-100)/525 \]

Ground snow loads
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
Wind load

Influence of height above mean sea level

\[ v_{b,0} = v_{b,\text{map}} \cdot c_{\text{alt}} \]
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:
\[ q_b = \frac{1}{2} \cdot \rho \cdot v_{b,0}^2 \] (basic pressure)
\[ \rho \] weight of air (1,25 kg/m\(^2\))

Peak velocity pressure
\[ q_b(z) = C_e(z) \cdot q_b \]
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: \(0,9 \cdot g + 1,5 \cdot w\)

(uptilt)

Verifications

- tilting
- dragging
- uplift
Net pressure factures for pitched roofs

Complex rules can be transmitted in a simplified system:

- corner zones
- edge zones
- interior zone parallel to the roof

Complex rules can be transmitted in a simplified system:

- corner zones
- edge zones
- interior zone parallel to the roof

Load influence areas

<table>
<thead>
<tr>
<th>Zone F</th>
<th>Zone G</th>
<th>Zone H</th>
<th>Druck</th>
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<tr>
<td>0</td>
<td>-2.00</td>
<td>-1.25</td>
<td>-0.70</td>
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<td>5</td>
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<td>-1.10</td>
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</table>

Dr. Zapfe GmbH 2011

Solarpraxis 2011
Aerodynamic characteristics

Pressure field if a vertical flow impacts the screen

Wind flow velocity

Pressure field (qualitative)

Source: Final report 0327229 A, patronized by the Federal Ministry of Economy and Technology
Aerodynamic correlations (45° inclination)

Wind direction
Pressure and Force Coefficients (BS EN 1991-1-4)

<table>
<thead>
<tr>
<th>Roof angle $\alpha$</th>
<th>Blockage $\varphi$</th>
<th>Overall Force Coefficients $c_f$</th>
<th>Zone A</th>
<th>Zone B</th>
<th>Zone C</th>
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<td>0°</td>
<td>Maximum all $\varphi$</td>
<td>+0.2</td>
<td>+0.5</td>
<td>+1.8</td>
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<td>-3.0</td>
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<td>20°</td>
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<tr>
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<tr>
<td>30°</td>
<td>Maximum all $\varphi$</td>
<td>+1.2</td>
<td>+2.2</td>
<td>+3.2</td>
<td>+2.4</td>
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<td>-2.2</td>
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</tbody>
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Empty, free-standing canopy ($\varphi=0$)

Canopy blocked to the downwind eaves by stored goods ($\varphi=1$)
4. Weight optimized systems (AluLight 12°)

Performed by wind tunnel tests

stationary, north wind

instationary, north wind

stationary, south wind

instationary, south wind
5. Numerical simulations

Module design

20,000 Shell elements per panel
- PVB Encapsulant 0.76 mm
- 1300x1100; Frame 50 mm
- Load 2.400 Pa (IEC 61646)

→ Influence of clamp position
6. Testing procedures

Module clamps

Profile cross connectors
6. 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
- Wind tunnel optimized systems for roofs with limited rest bearing capacity
Thanks for your attention

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