Quality Issues – Construction & Projectmanagement

Ground Mounted System Design

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Overview of topics:

1. Introduction
2. Load evaluation
3. Structural Design
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 according to Indian Standard IS 875

Wind loads: IS 875 Part 3

Design wind speed

\[ V_z = V_b \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \]

- \( k_1 \): Probability factor
- \( k_2 \): Terrain roughness and height
- \( k_3 \): Topography factor
- \( k_4 \): Importance factor

Wind pressure

\[ p_z = 0.6 \cdot V_z^2 \]

design wind pressure

\[ p_d = K_d \cdot K_a \cdot K_c \cdot p_z \]

- \( K_d \): Wind directionality factor
- \( K_a \): Area averaging factor
- \( K_c \): Kombination factor

Basic wind speed in m/s (50 year return period)
Load actions according to Indian Standard IS 875

Terrain categories

Risk coefficients $k_1$

Wind speed according to terrain roughness

<table>
<thead>
<tr>
<th>Class of Structure</th>
<th>Mean Probable design life of structure in years</th>
<th>$k_1$ factor for Basic Wind Speed (m/s) of</th>
</tr>
</thead>
<tbody>
<tr>
<td>All general buildings and structures</td>
<td>50</td>
<td>1.0 1.0 1.0 1.0 1.0 1.0</td>
</tr>
<tr>
<td>Temporary sheds, structures such as those used during construction operations (for example, formwork and false work), structures during construction stages, and boundary walls</td>
<td>5</td>
<td>0.82 0.76 0.73 0.71 0.70 0.67</td>
</tr>
<tr>
<td>Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings other than residential buildings, etc.</td>
<td>25</td>
<td>0.94 0.92 0.91 0.90 0.89</td>
</tr>
<tr>
<td>Important buildings and structures such as hospitals, communication buildings, towers and power plant structures</td>
<td>100</td>
<td>1.05 1.06 1.07 1.07 1.08 1.08</td>
</tr>
</tbody>
</table>

Terrain roughness an height factor $k_2$
Increasing wind loads in case of isolated hills and ridges

$k_4$ 1.30 for structures of post cyclone importance
1.15 for industrial buildings
1.00 for all other structures
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 (IS 875 part 3)

<table>
<thead>
<tr>
<th>Roof Angle (Degrees)</th>
<th>Slope Ratio</th>
<th>Maximum (Largest + Wind) and Minimum (Largest - Wind) Pressure Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall Coefficients</td>
<td>Local Coefficients</td>
</tr>
<tr>
<td>0</td>
<td>+0.2</td>
<td>+0.5</td>
</tr>
<tr>
<td>5</td>
<td>+0.4</td>
<td>+0.7</td>
</tr>
<tr>
<td>10</td>
<td>+0.5</td>
<td>+1.2</td>
</tr>
<tr>
<td>15</td>
<td>+0.7</td>
<td>+1.4</td>
</tr>
<tr>
<td>20</td>
<td>+0.8</td>
<td>+1.7</td>
</tr>
<tr>
<td>25</td>
<td>+1.0</td>
<td>+2.0</td>
</tr>
<tr>
<td>30</td>
<td>+1.2</td>
<td>+2.2</td>
</tr>
</tbody>
</table>

Note: For monopitch canopies the centre of pressure should be taken to act at 0.3 W from the windward.

Diagram showing:
- Empty, free-standing canopy (θ=0)
- Canopy blocked to the downwind eaves by stored goods (θ=1)
Pressure Coefficients from Windtunnel tests

According to Ruscheweyh Consult GmbH

Advantages:
- Load reduction in central areas
- Savings (less posts)
3. Structural Design for PV Systems

Load Combinations

LC 1: 1,2·DL ± 1,5·WL
LC 2: 1,2·(DL + SL ± WL) (uplift)
LC 3: 0,9·DL ± 1,5·WL

Verifications

- tilting
- dragging
- uplift
Stress calculations for frameless modules

Numerical model

Stress calculations for thin-film modules
Testing procedures

Module clamps

Profile cross connectors
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
Typical load bearing systems

Single post support

Double post support

Wind

G

W

M

Δx

V

G

W

G

W

front

back
Soil pressure in case of single bearing structures

- dead load + snow
- wind

\[ \sigma_g + \sigma_s + \sigma_w \]
Soil pressure in case of coupled bearing structures

- dead load + snow
- wind

\[ \sigma_g + \sigma_s \]

\[ + \]

\[ \sigma_w \]

\[ = \]

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

Building progress days/MWp

- ramming
- drilling
- concreting

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Ground Mounted System Design
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 costs
  • Mounting effort
  • Maintenance over lifetime
Thanks for your attention