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	Cost optimization	Design/Sustainability
Material utilization	Material effort	Material selection
System selection	Production procedure	Durability
Design calculations	Logistics	Recycling
Construction details	Mounting time	Joints/fixations

focus

2. Load actions according to Indian Standard IS 875

basic wind speed in m/s (50 year return period)

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 an 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

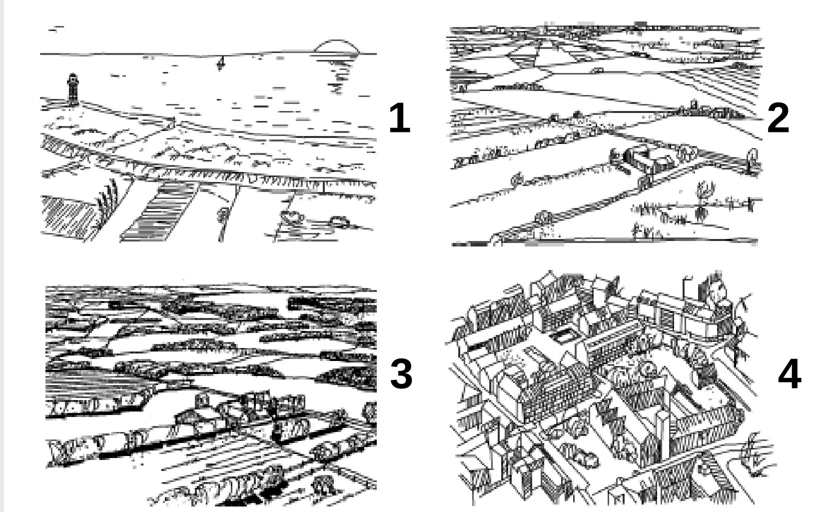
1,0 in PV

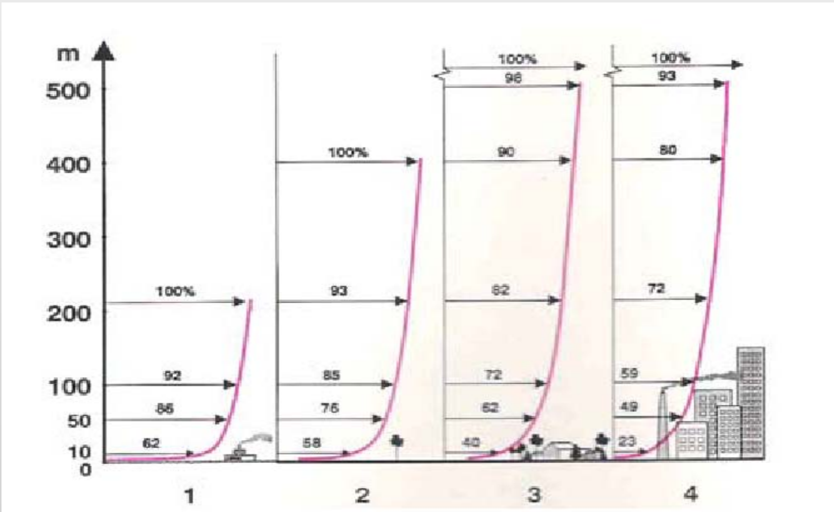
Load actions according to Indian Standard IS 875

Class of Structure	Mean Probable design life of structure in years	k_1 factor for Basic Wind Speed (m/s) of					
		33	39	44	47	50	55
All general buildings and structures	50	1.0	1.0	1.0	1.0	1.0	1.0
Temporary sheds, structures such as those used during construction operations (for example, formwork and false work), structures during construction stages, and boundary walls	5	0.82	0.76	0.73	0.71	0.70	0.67
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.	25	0.94	0.92	0.91	0.90	0.90	0.89
Important buildings and structures such as hospitals, communication buildings, towers and power plant structures	100	1.05	1.06	1.07	1.07	1.08	1.08

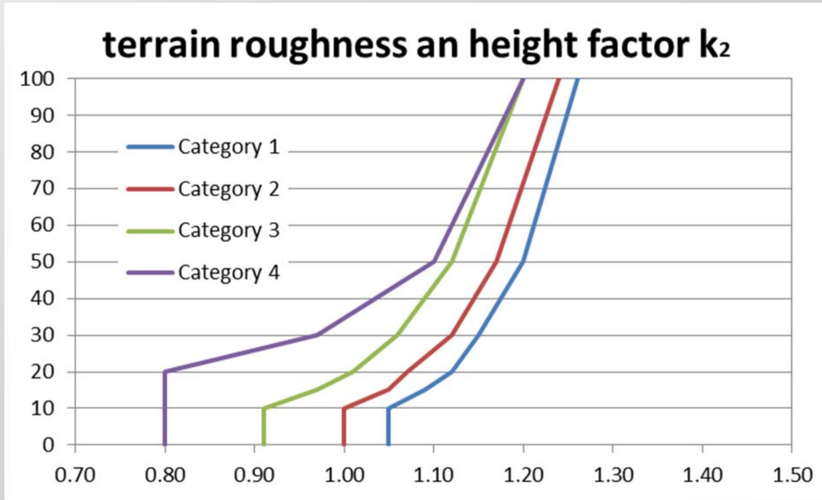
Risk coefficients k_1

Terrain categories





Wind speed according to terrain roughness



Increasing wind loads in case of isolated hills and ridges

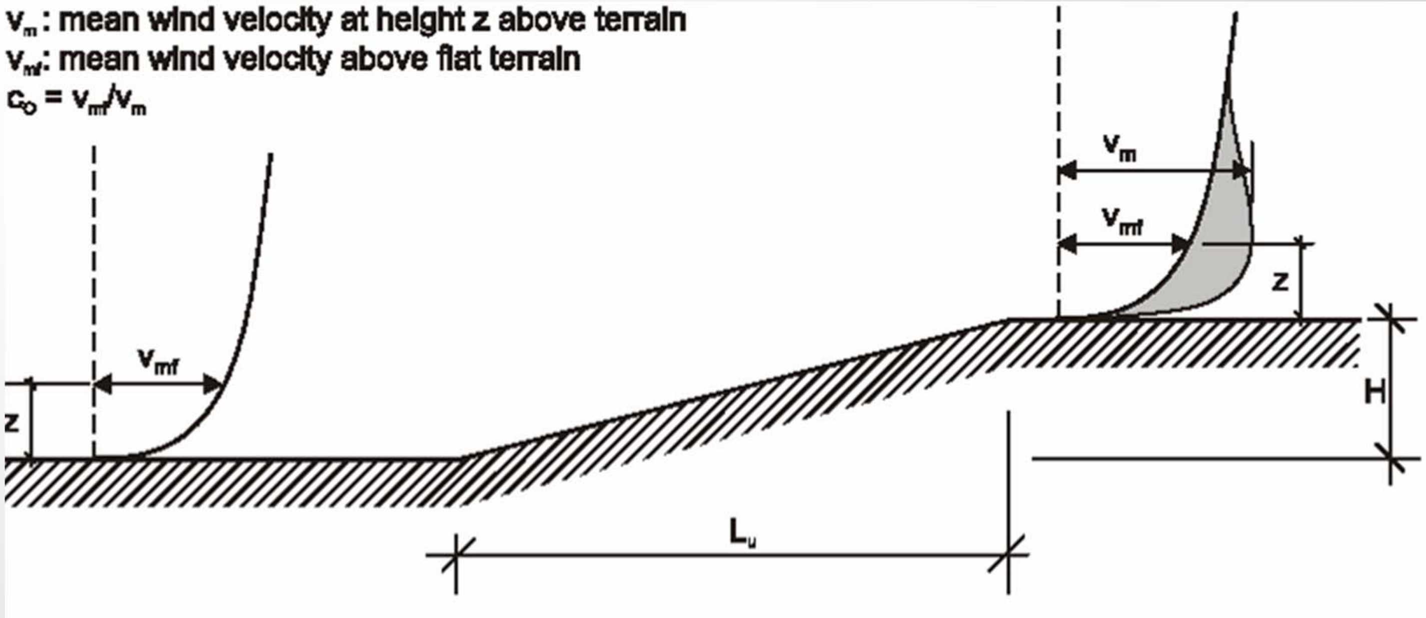


Figure A.1 — Illustration of increase of wind velocities over orography

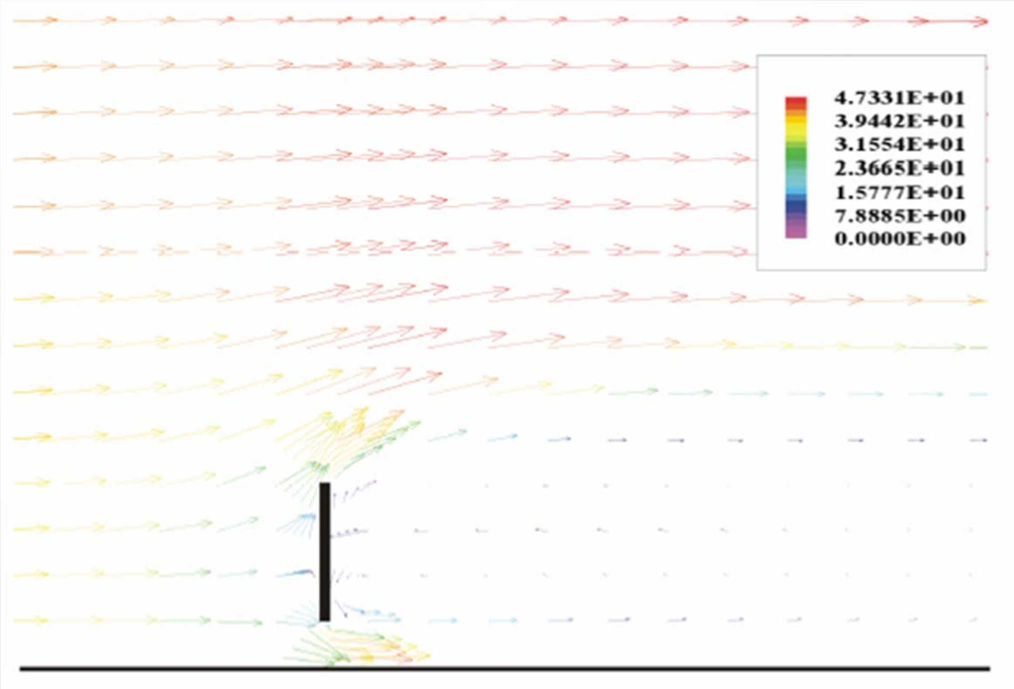
Increasing wind loads in case of changig topology (isolated hills and ridges) } **k_3**

k_4	**1,30**	**for structures of post cyclone importance**
	1,15	**for industrial buildings**
	1,00	**for all other structures**

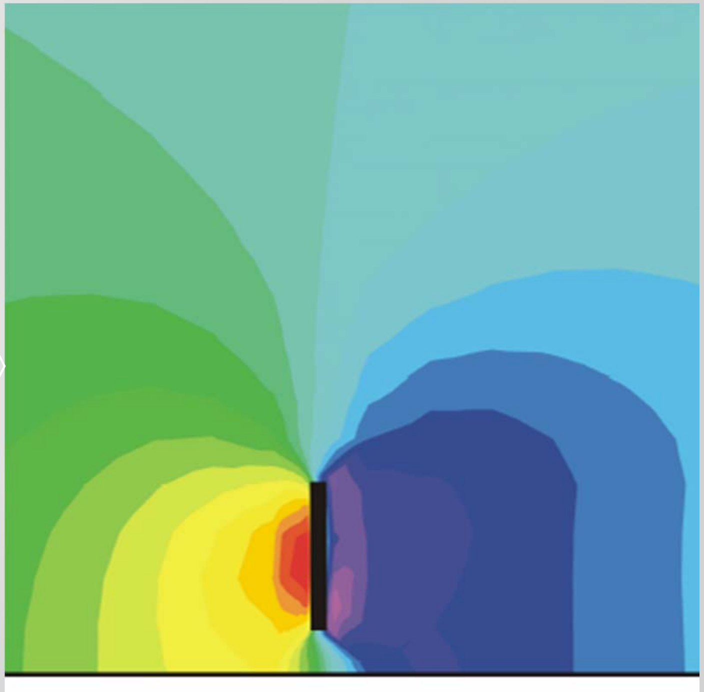
Aerodynamic characteristics

Pressure field if a vertical flow impacts the screen

Strömungsgeschwindigkeiten



Pressure field (qualitative)

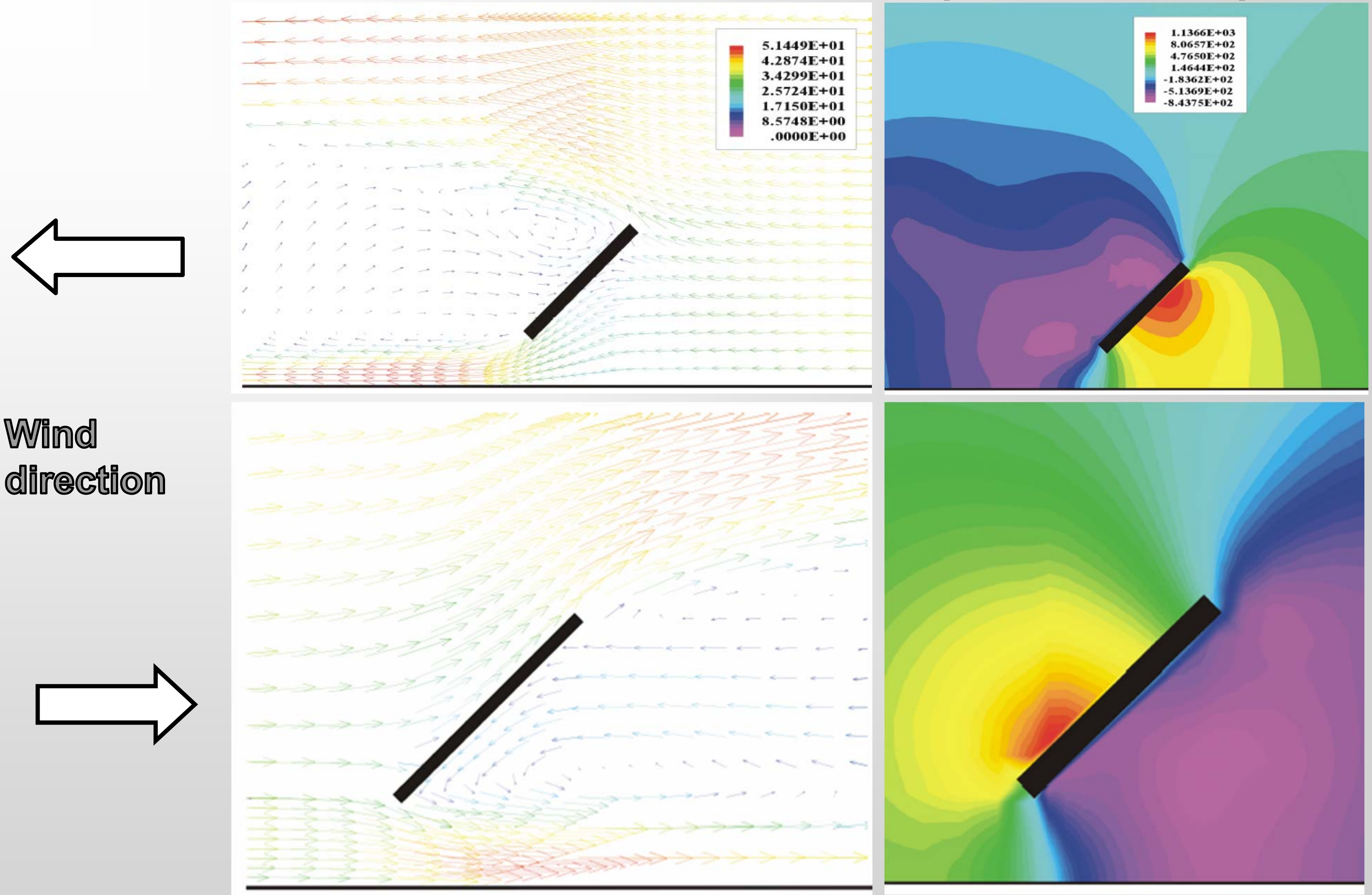


Source: Final report 0327229 A, patronized by the Federal Ministry of Economy and Technology

Aerodynamic correlations

(45° inclination)

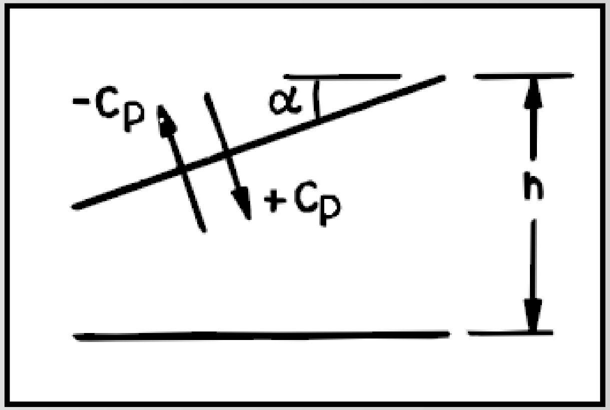
Wind direction

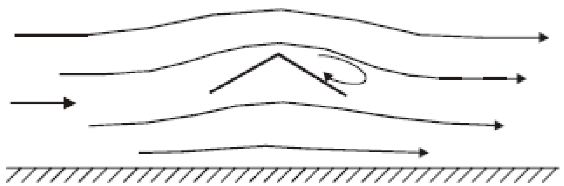


Pressure- and Force coefficients (IS 875 part 3)

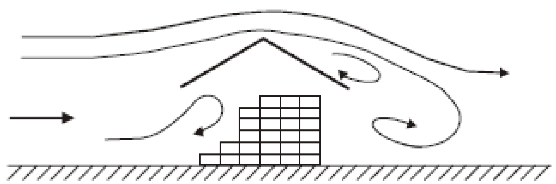
Roof Angle (Degrees)	Solidity Ratio	Maximum (Largest + ve) and Minimum (Largest − ve) Pressure Coefficients			
		Overall Coefficients	Local Coefficients		
0	All values of ϕ	+0·2	+0·5	+1·8	+1·1
5		+0·4	+0·8	+2·1	+1·3
10		+0·5	+1·2	+2·4	+1·6
15		+0·7	+1·4	+2·7	+1·8
20		+0·8	+1·7	+2·9	+2·1
25		+1·0	+2·0	+3·1	+2·3
30		+1·2	+2·2	+3·2	+2·4
0	ϕ=0	−0·5	−0·6	−1·3	−1·4
	ϕ=1	−1·0	−1·2	−1·8	−1·9
5	ϕ=0	−0·7	−1·1	−1·7	−1·8
	ϕ=1	−1·1	−1·6	−2·2	−2·3
10	ϕ=0	−0·9	−1·5	−2·0	−2·1
	ϕ=1	−1·3	−2·1	−2·6	−2·7
15	ϕ=0	−1·1	−1·8	−2·4	−2·5
	ϕ=1	−1·4	−2·3	−2·9	−3·0
20	ϕ=0	−1·3	−2·2	−2·8	−2·9
	ϕ=1	−1·5	−2·6	−3·1	−3·2
25	ϕ=0	−1·6	−2·6	−3·2	−3·2
	ϕ=1	−1·7	−2·8	−3·5	−3·5
30	ϕ=0	−1·8	−3·0	−3·8	−3·6
	ϕ=1	−1·8	−3·0	−3·8	−3·6

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





Empty, free-standing canopy (φ=0)



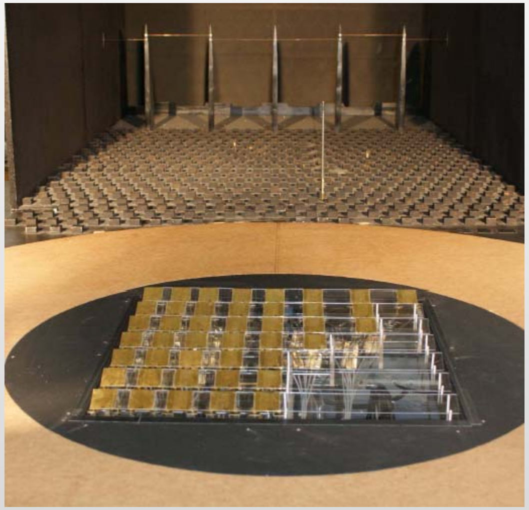
Canopy blocked to the downwind eaves by stored goods (φ=1)

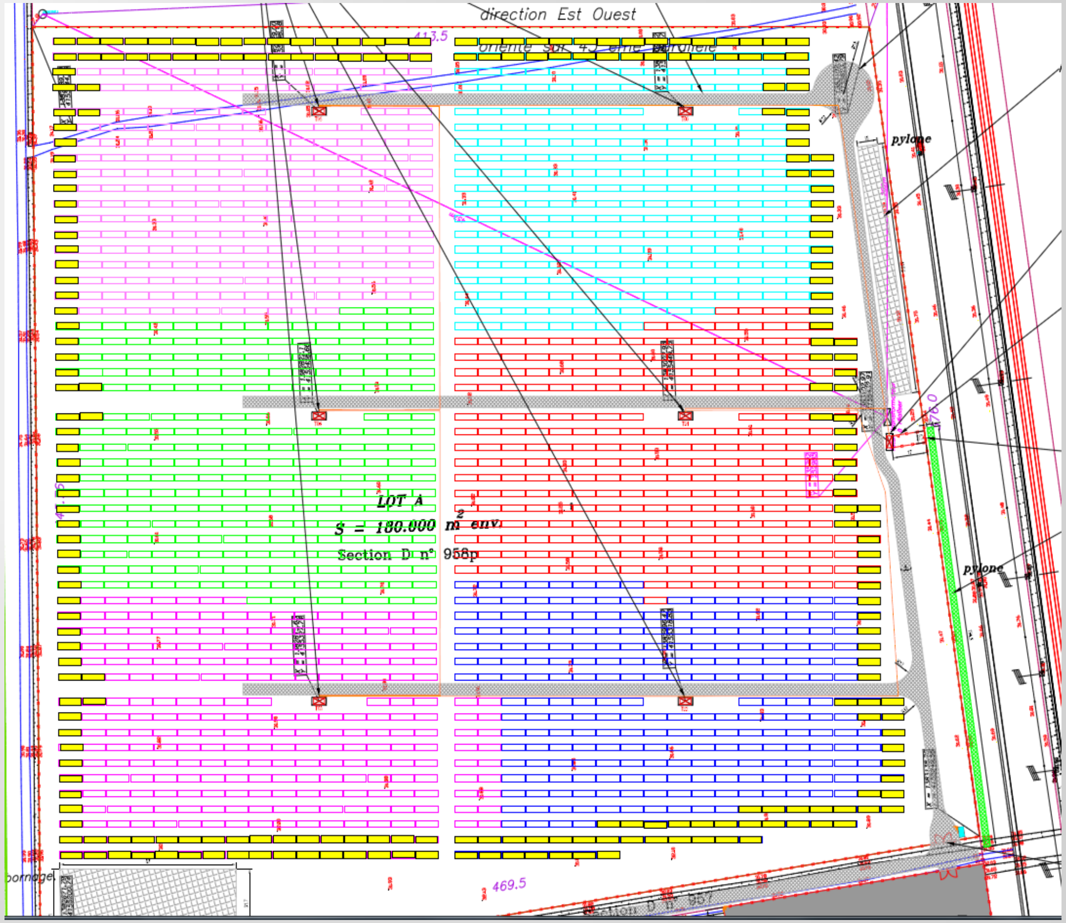
Pressure Coefficients from Windtunnel tests

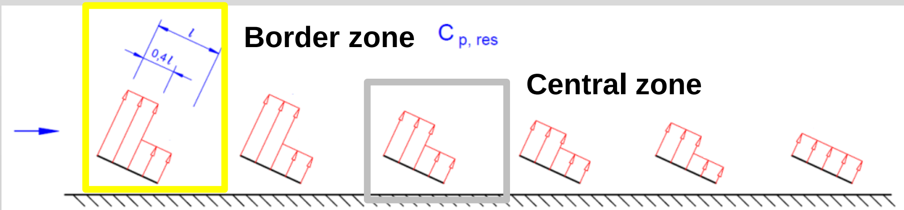
According to Ruscheweyh Consult GmbH

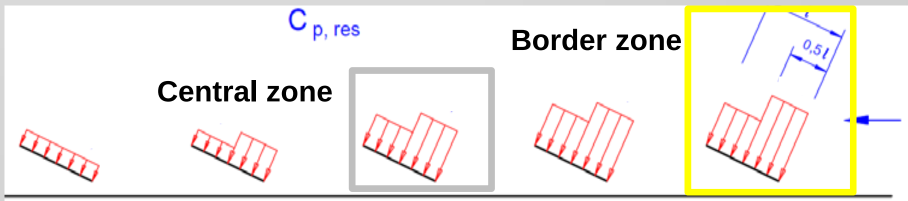
Advantages:

- **Load reduction in central areas**
- **Savings (less posts)**









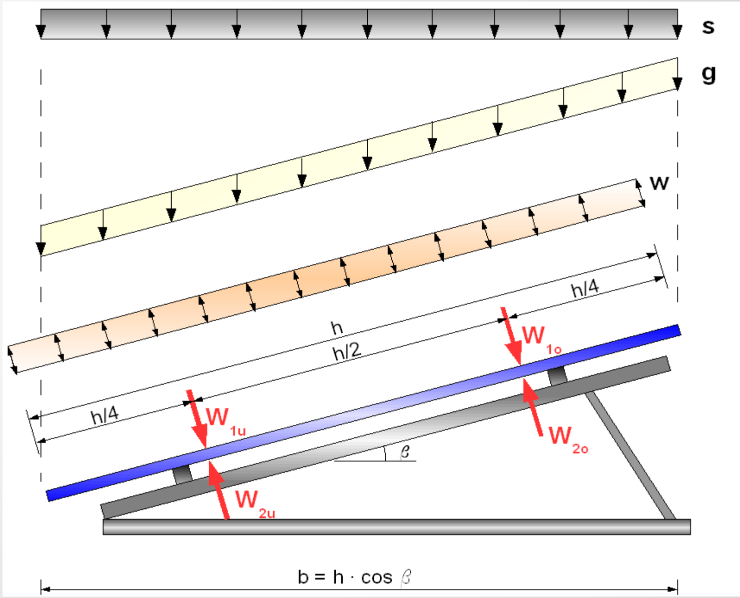
3. Structural Design for PV Systems

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

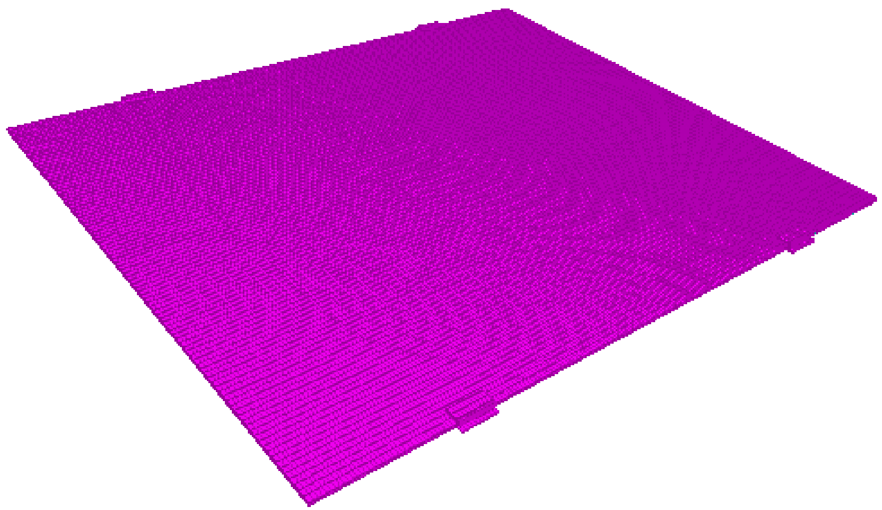


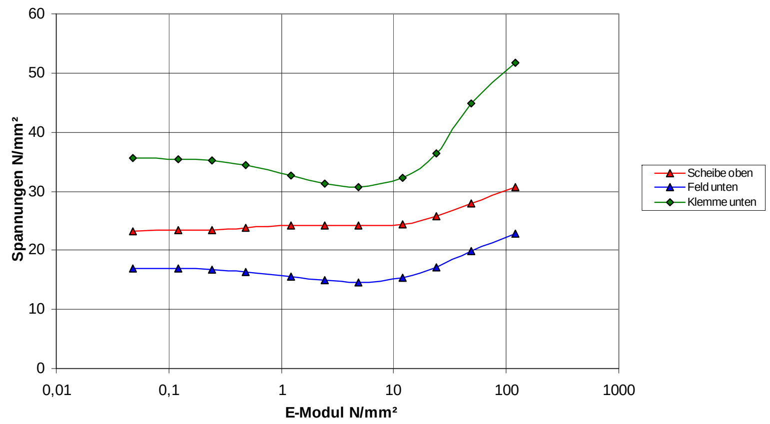
Verifications

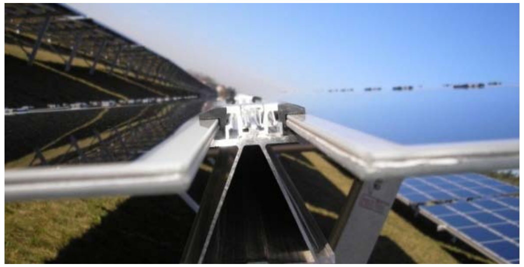
- tilting
- dragging
- uplift

Stress calculations for frameless modules

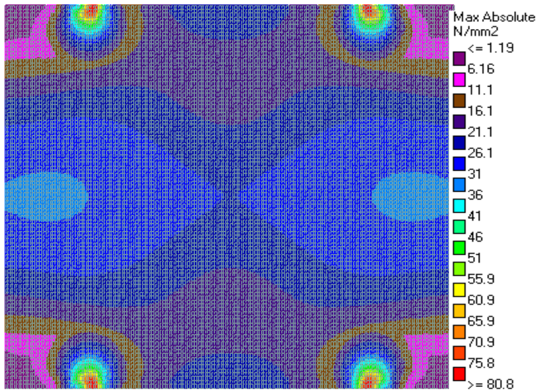
Numerical model

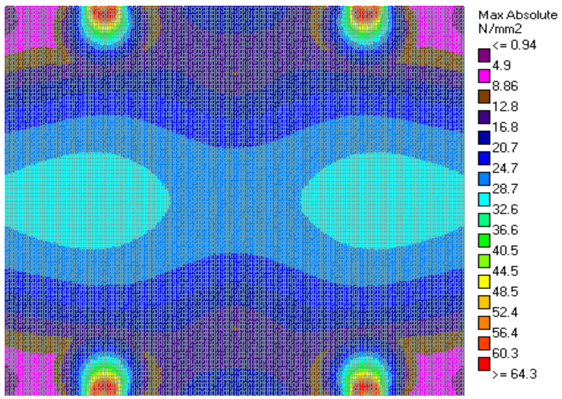


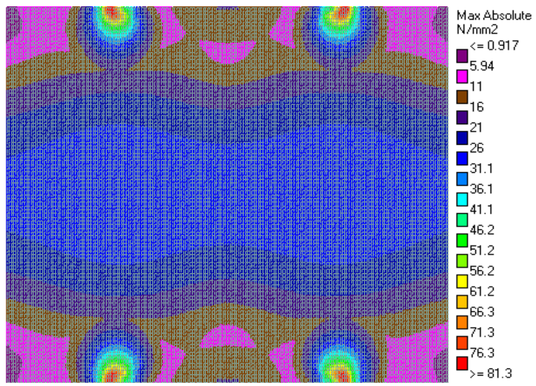




Stress calculations for thin-film modules



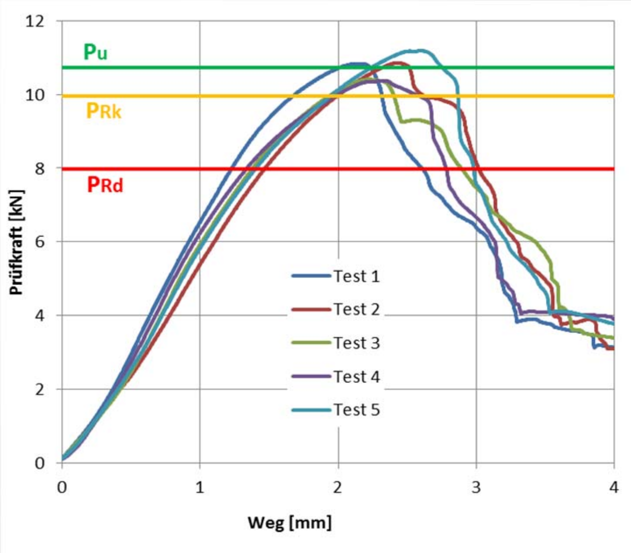




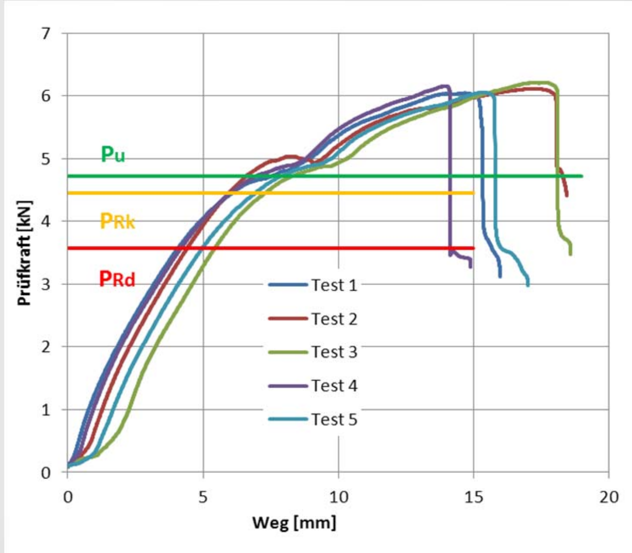
Testing procedures

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)

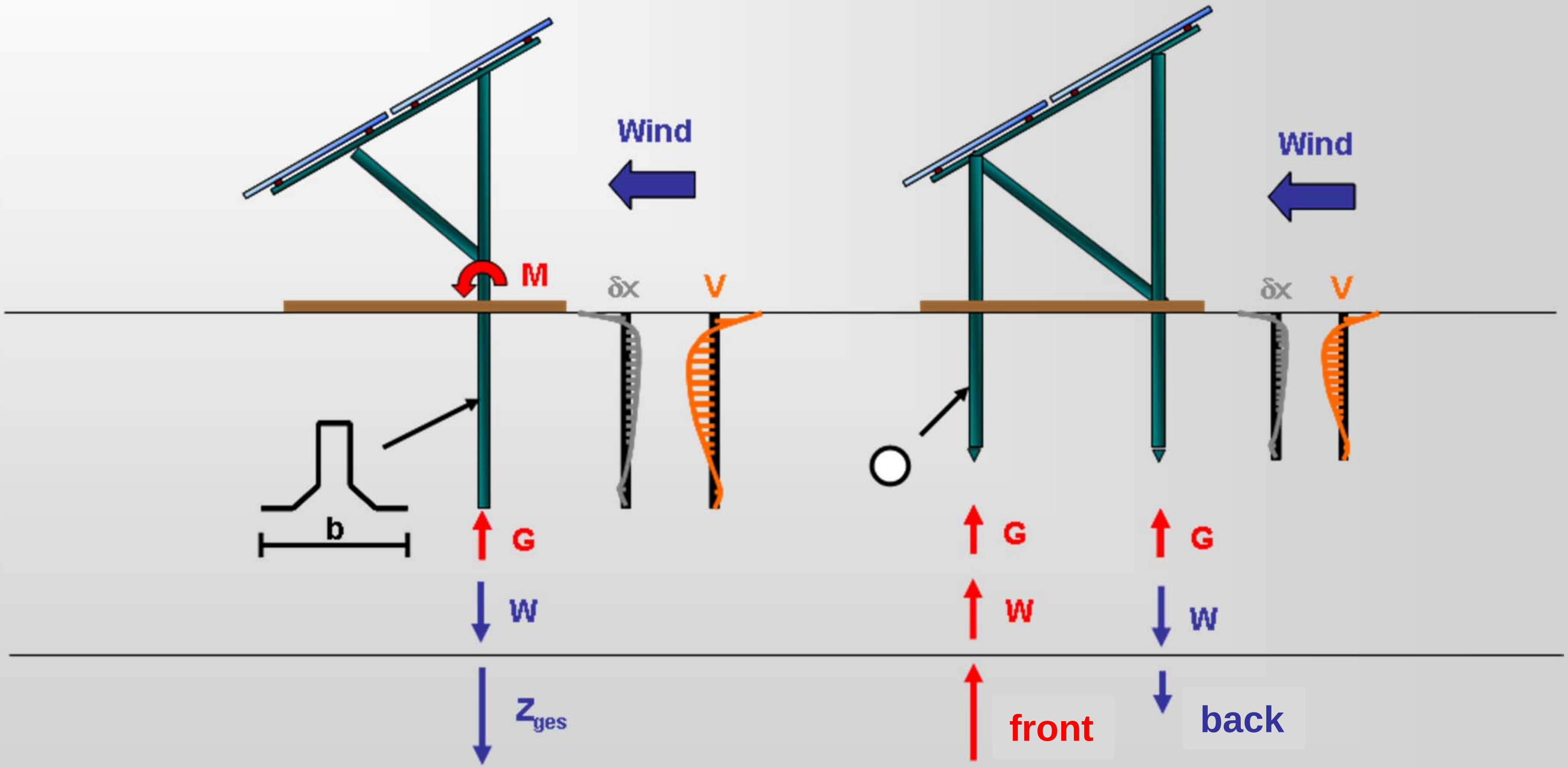
Concrete foundation

- Pressure stability of the soil
- Sensitivity of the top soil towards water
- Aggressive soil

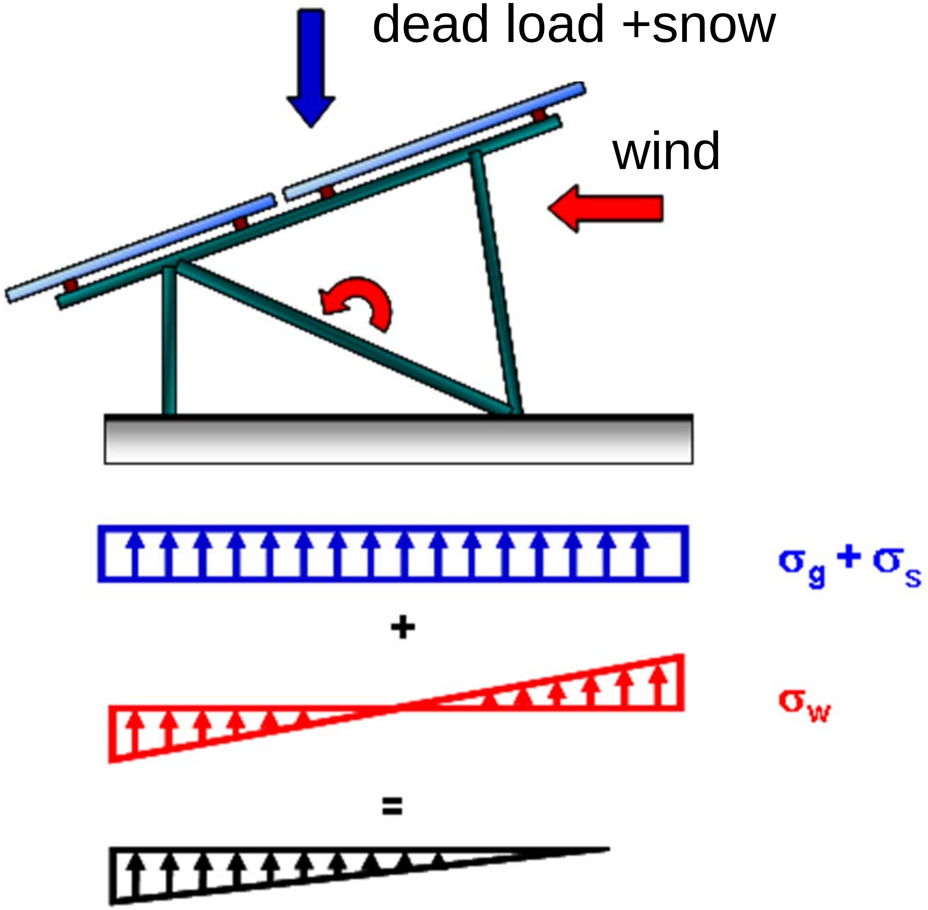
Typical load bearing systems

Single post support

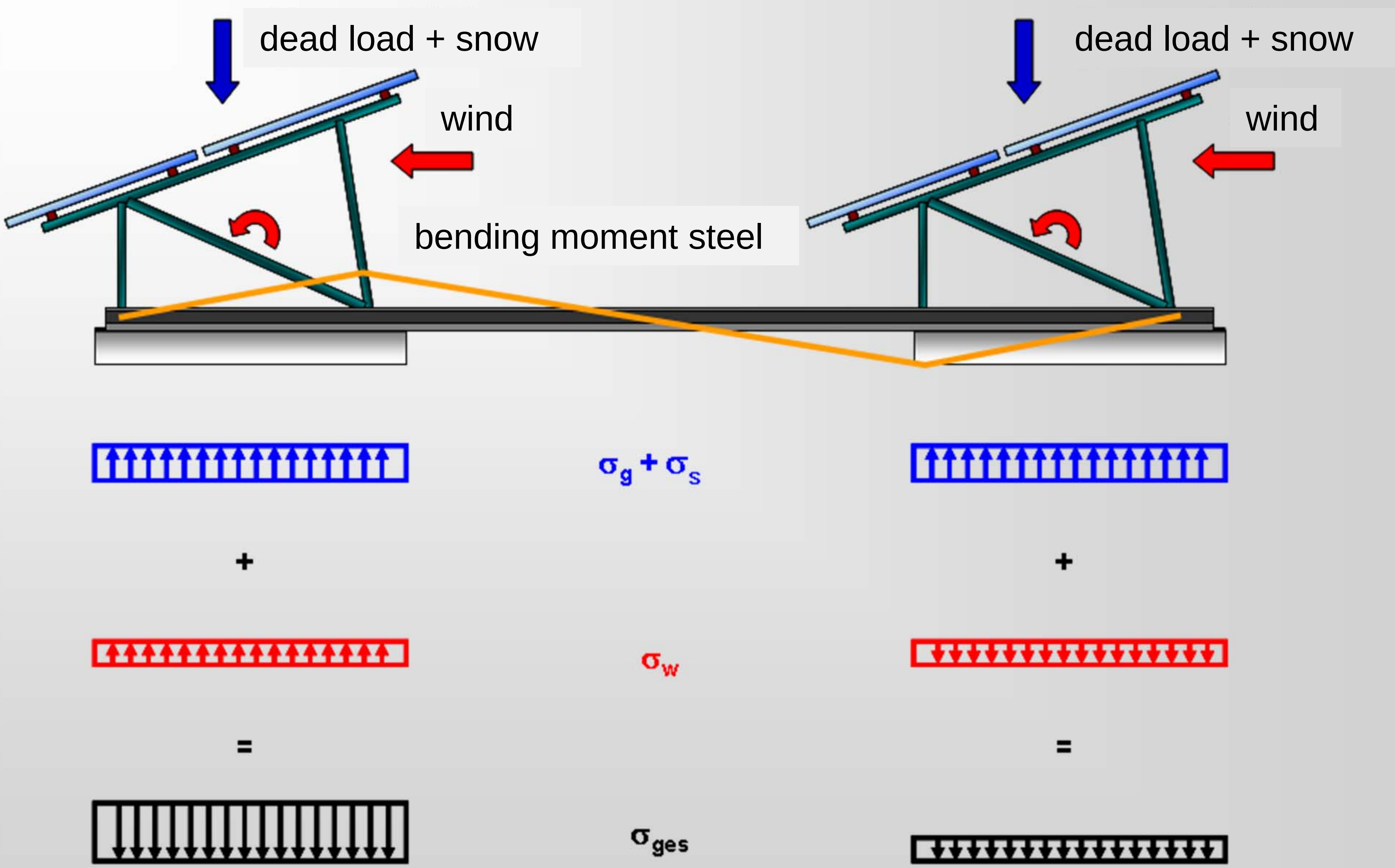
Double post support



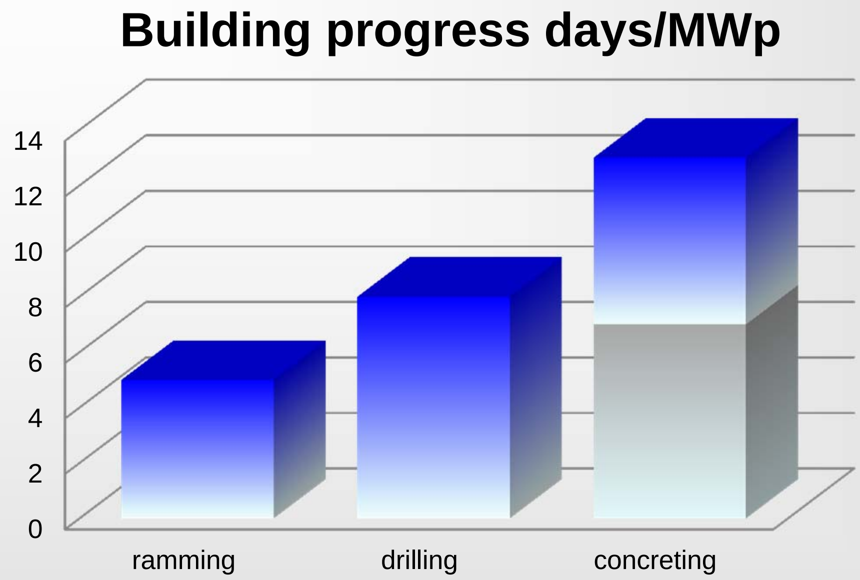
Soil pressure in case of single bearing structures



Soil pressure in case of coupled bearing structures

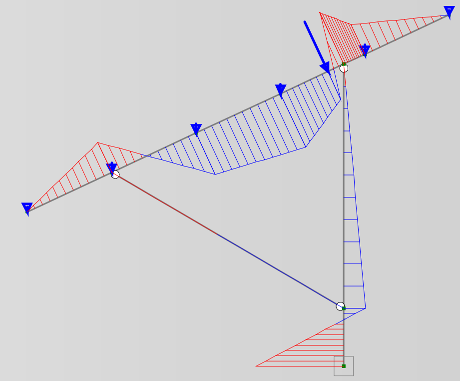


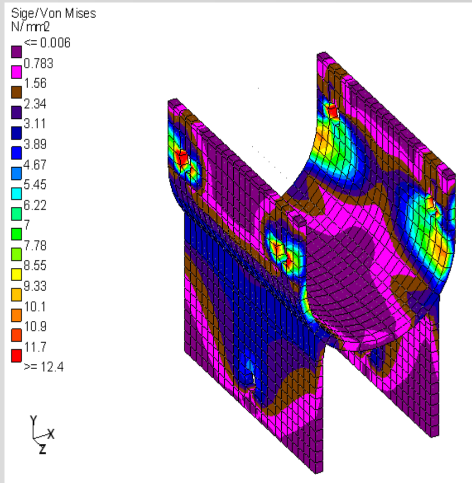
6. Mounting progress of different foundation concepts



7. Conclusions

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






Thanks
for your attention