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SCHLETTER GmbH

Session 6: Designing trough to installation

Structural analyses as precondition for safe mounting systems

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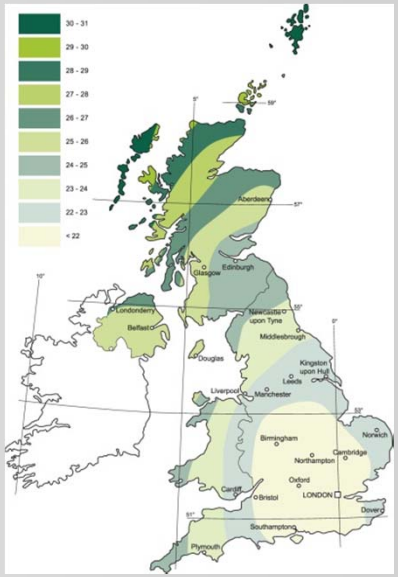
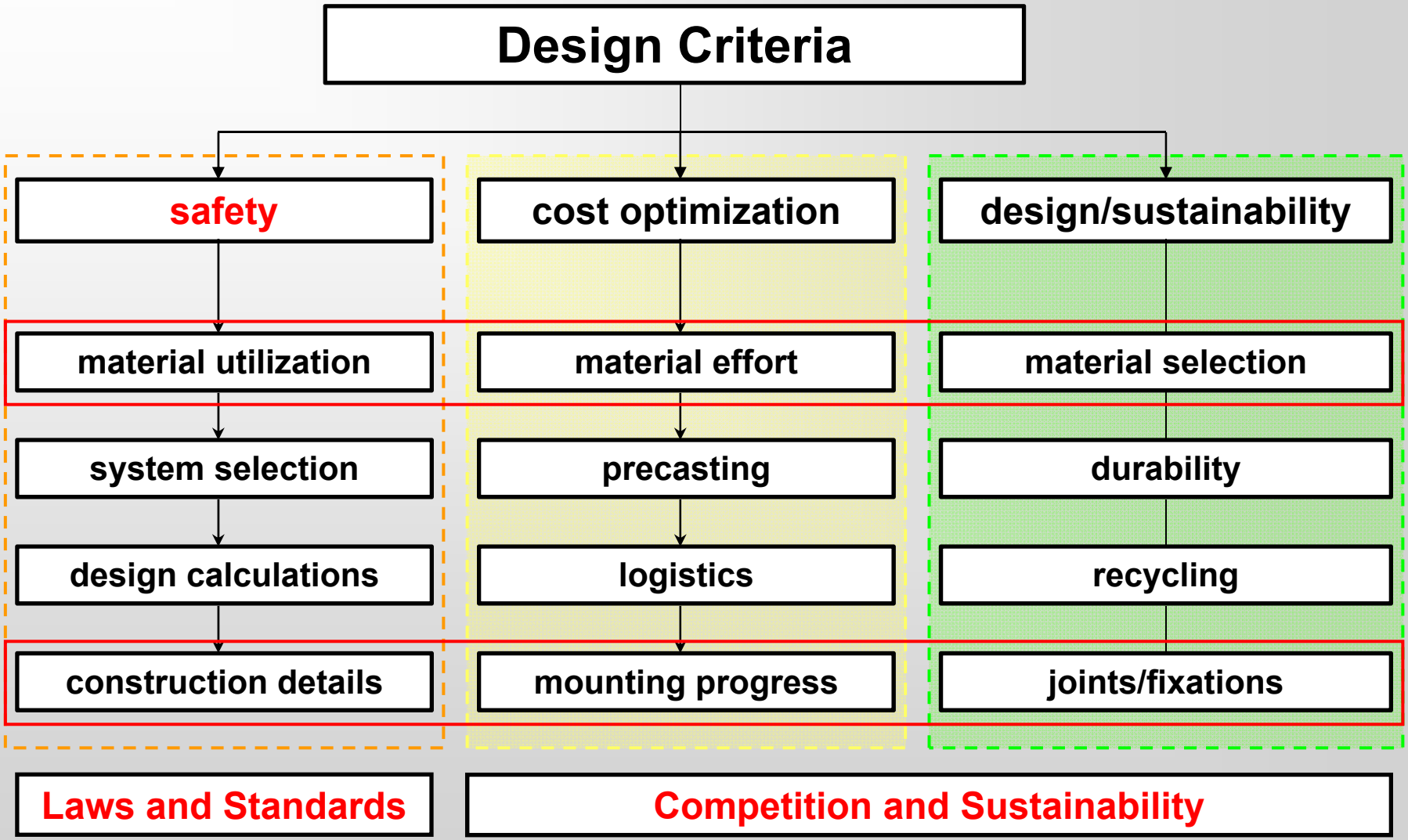
Solar Industy Summit UK 2011 12-13 May, London

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



Types of PV-Plants

Pitched roof

Flatroof (tilted)

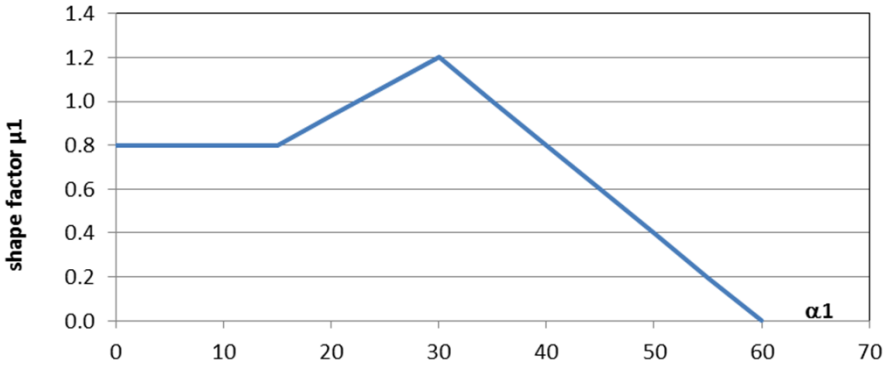
Aerodynamic optimized

Ground mounted

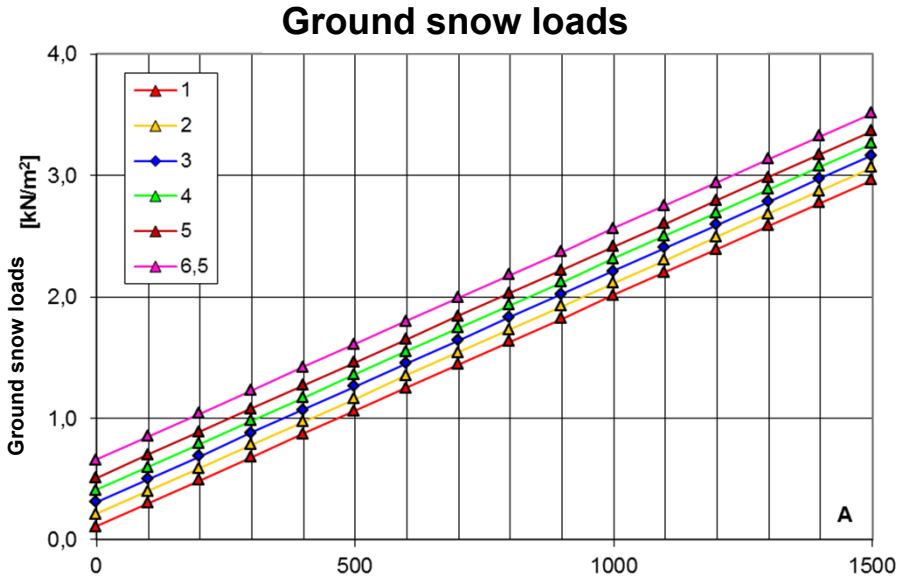
Carport systems Park@Sol

2. Load actions BS EN 1991-1-3/NA June 2007

Snow Loads



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



European wind zone map according to Eurocode 1

Basis:

Measurements (188 in D)

10-minutes median in

10 m height above ground

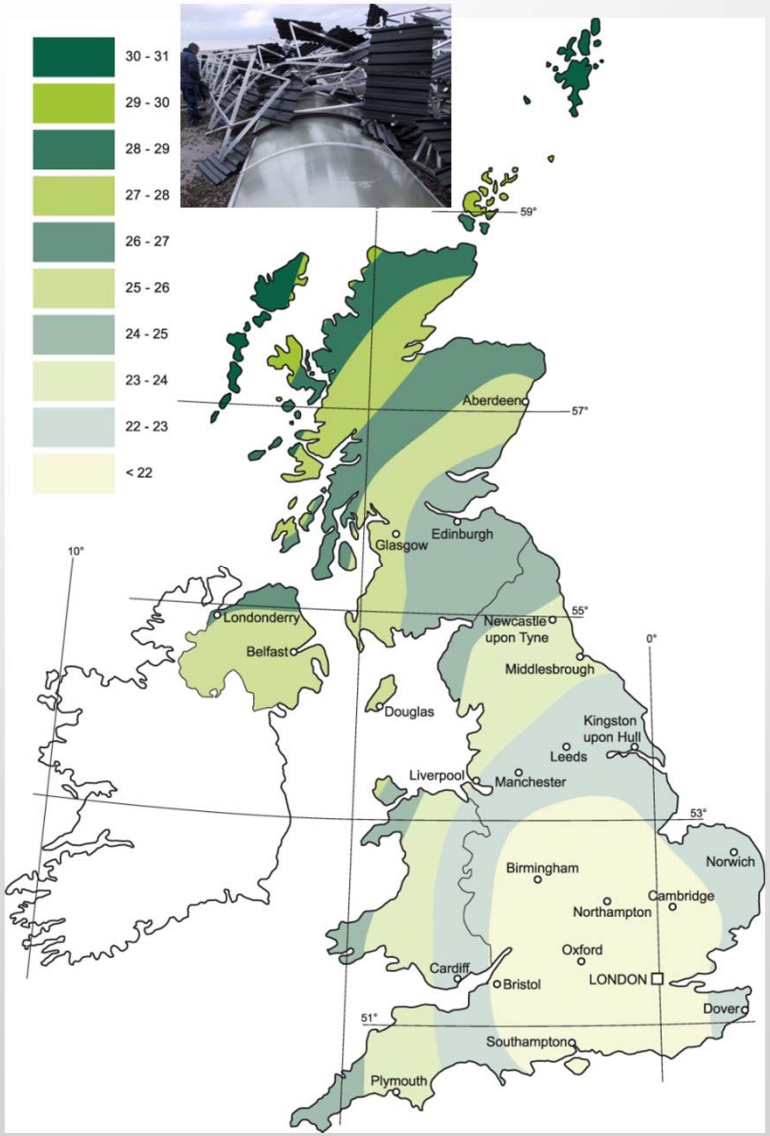
that occurs once every 50 years

observation period: 40-107 years

contains no gusts

applicable for flat, even terrain

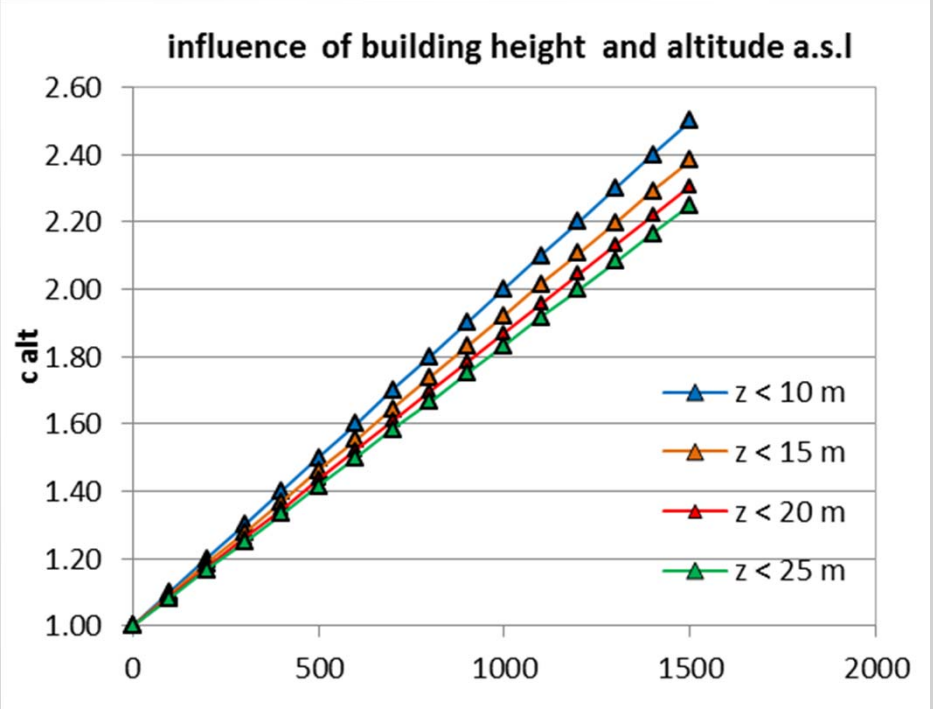
Wind loads BS EN 1991-1-4/NA Sep. 2009



Wind load

Influence of height above mean sea level

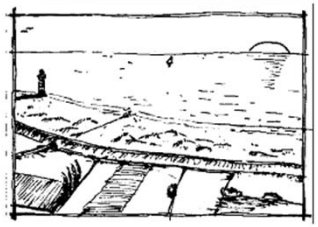
$$v_{b,0} = v_{b,map} \cdot c_{alt}$$



Terrain categories according to Eurocode 1

Terrain category 0

Sea, coastal area exposed to the open sea

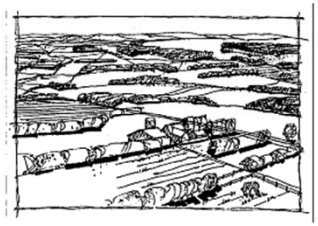


Terrain category I

Lakes or area with negligible vegetation and without obstacles

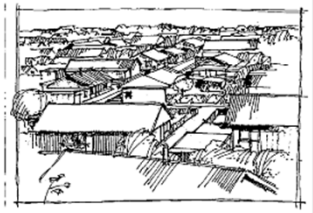
Terrain category II

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



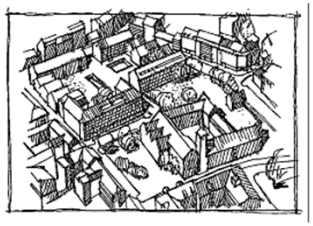
Terrain category III

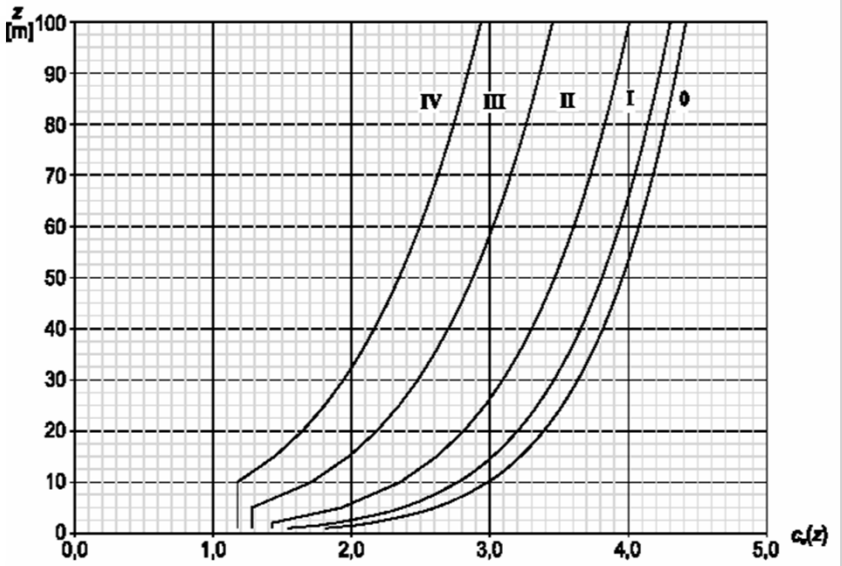
Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)



Terrain category IV

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





Basis:

$q_b = {}^1/_2 \cdot \rho \cdot v_{b,0}^2$ (basic pressure)

ρ weight of air (1,25 kg/m²)

Peak velocity pressure

$q_b(z) = C_e(z) \cdot q_b$

3. Design calculations for PV systems

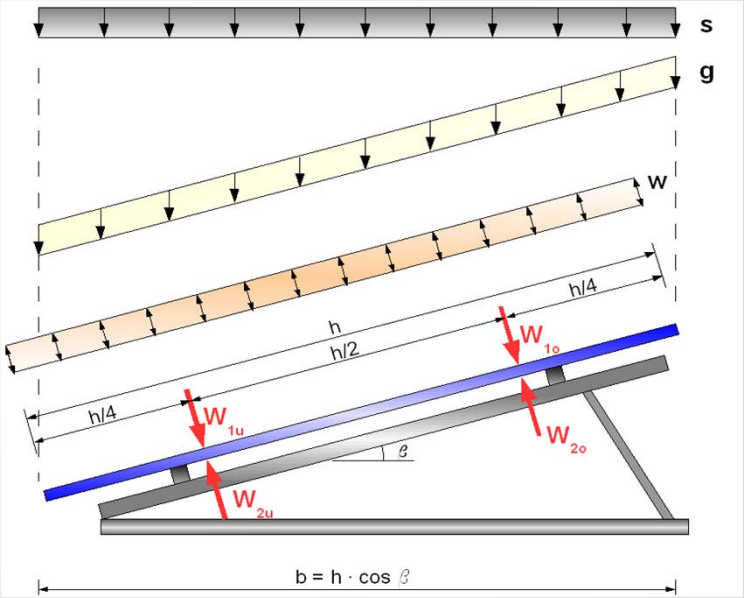
Load combinations

LC 1: 1,35·g + 1,5·s + 0,6·1,5·w

LC 2: 1,35·g + 0,5·1,5·s + 1,5·w

LC 3: 0,9·g + 1,5·w

(uplift)



Verifications

- tilting
- dragging
- uplift

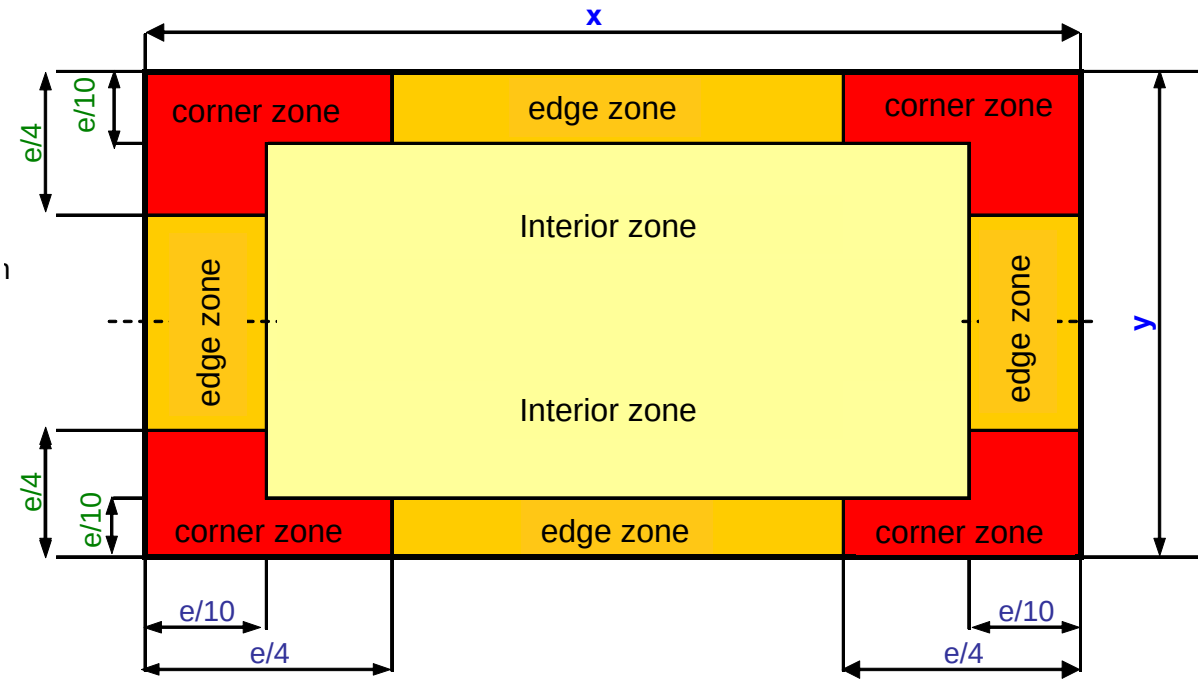
Net pressure factures for pitched roffs

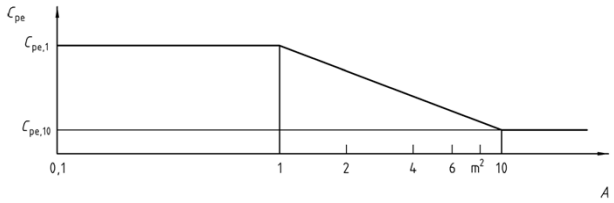
Complex rules can be transmitted in a simplified system

- **corner zones**
- **edge zones**
- **interior zone**

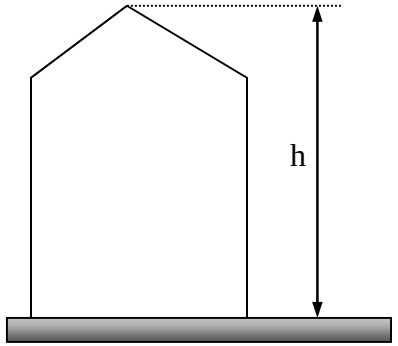
	Saddle roof				Shed roof			
α	Zone F c_{p10}	Zone G c_{p10}	Zone H c_{p10}	Druck	Zone F c_{p10}	Zone G c_{p10}	Zone H c_{p10}	Druck
0	-2.00	-1.25	-0.70	0.20	-1.80	-1.20	-0.80	0.20
5	-1.70	-1.30	-0.70	0.20	-2.30	-1.80	-0.80	0.20
15	-1.30	-1.30	-0.60	0.20	-2.50	-1.90	-0.80	0.20
30	-1.10	-1.40	-0.80	0.40	-2.10	-1.50	-1.00	0.40
45	-1.10	-1.40	-0.90	0.60	-1.50	-1.40	-1.00	0.60
60	-1.10	-1.20	-0.80	0.70	-1.20	-1.20	-1.00	0.70
75	-1.10	-1.20	-0.80	0.80	-1.20	-1.20	-1.00	0.80

parallel to the roof





Load influence areas

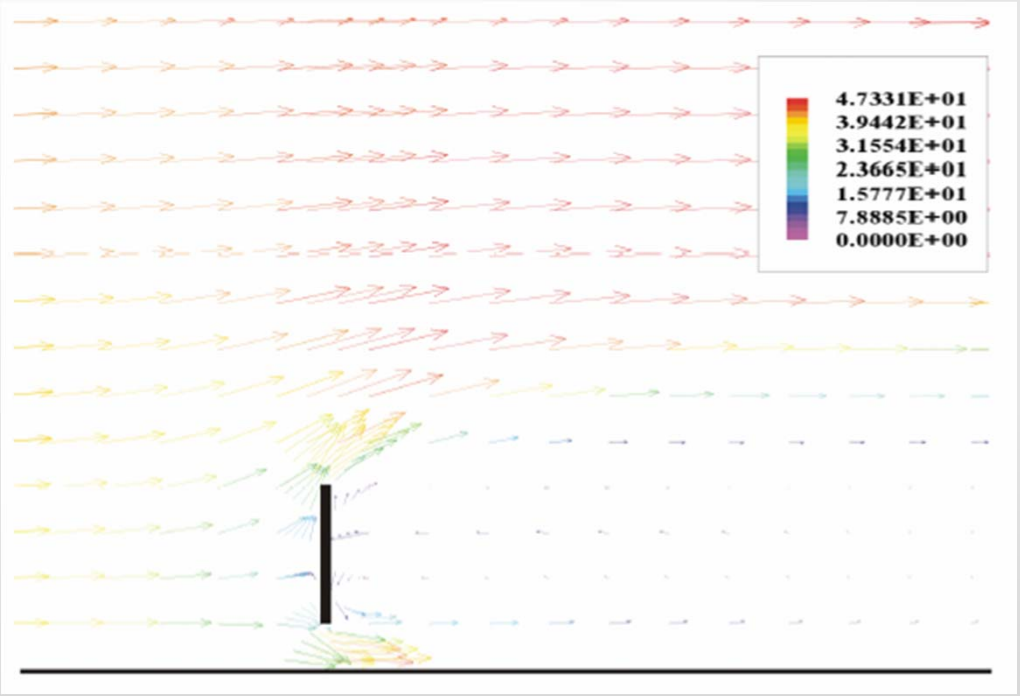


e = Min (x, y oder 2h)

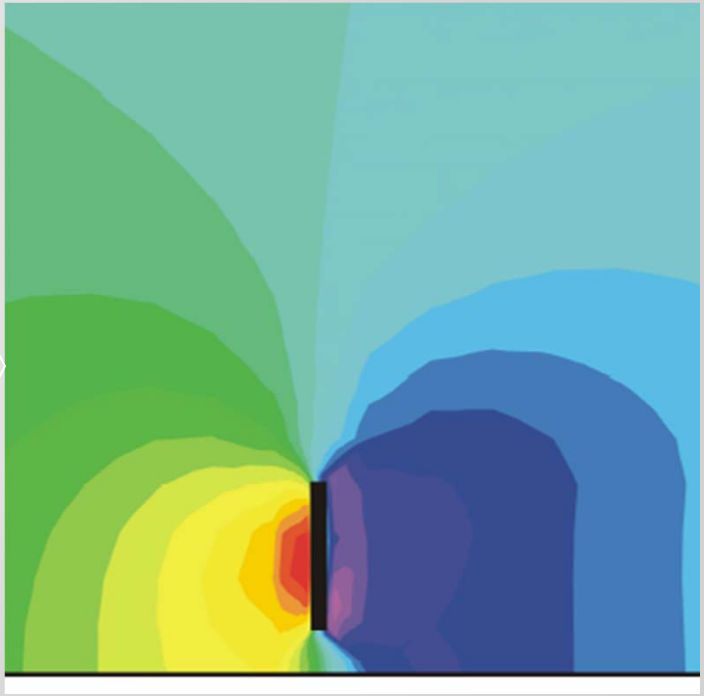
Aerodynamic characteristics

Pressure field if a vertical flow impacts the screen

Wind flow velocity



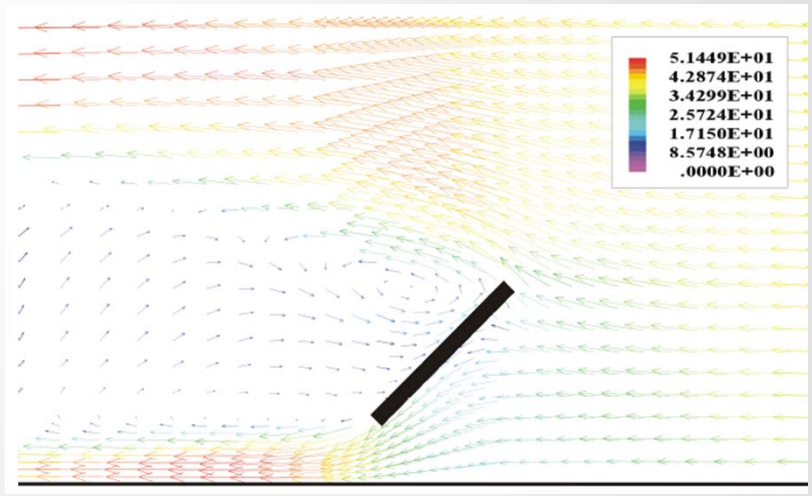
Pressure field (qualitative)

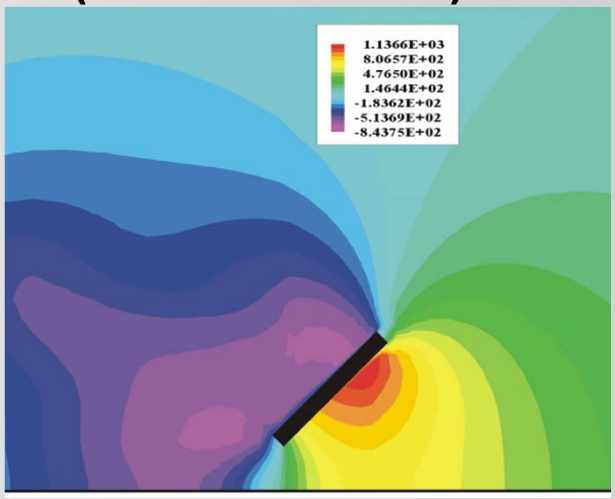


Source: Final report 0327229 A, patronized by the Federal Ministry of Economy and Technology

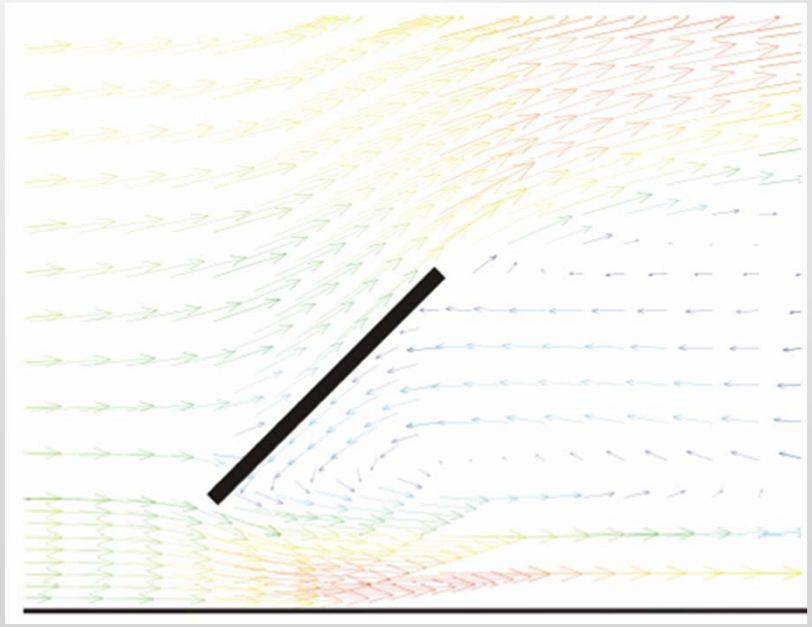
Aerodynamic correlations

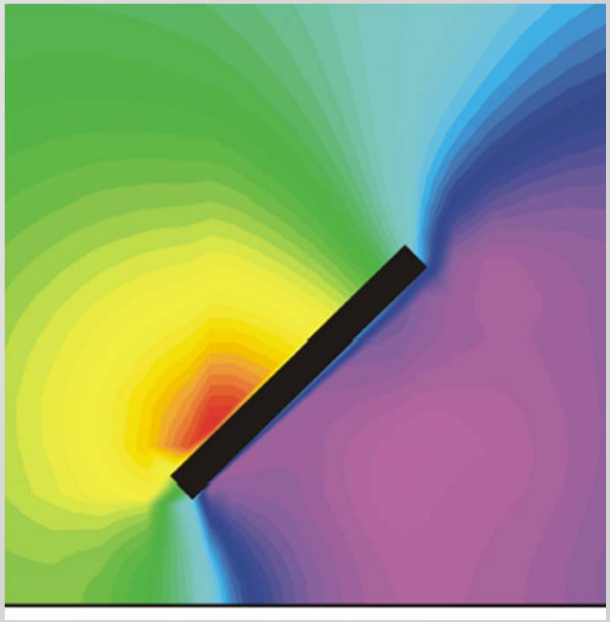
(45° inclination)





Wind direction

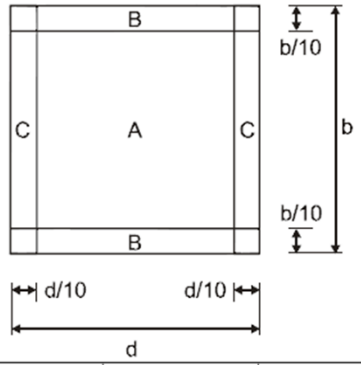




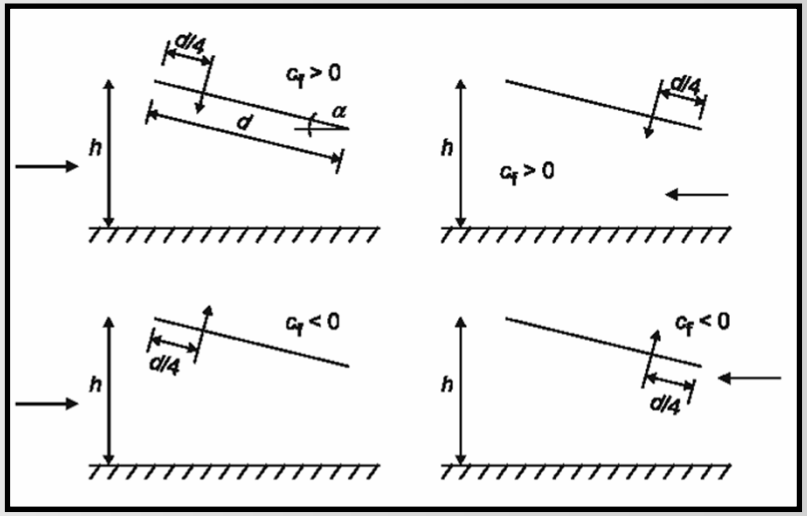
Pressure and Force Coefficients (BS EN 1991-1-4)

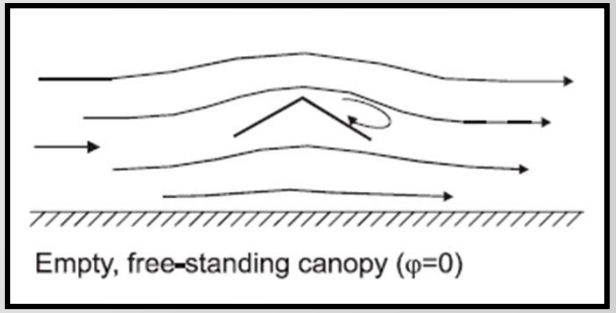
Net Pressure coefficients $c_{p,net}$

Key plan

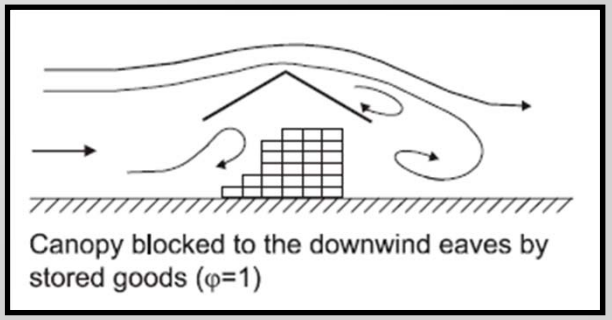


Roof angle α	Blockage φ	Overall Force Coefficients c_f	Zone A	Zone B	Zone C
0°	Maximum all φ	+ 0,2	+ 0,5	+ 1,8	+ 1,1
	Minimum φ = 0	- 0,5	- 0,6	- 1,3	- 1,4
	Minimum φ = 1	- 1,3	- 1,5	- 1,8	- 2,2
5°	Maximum all φ	+ 0,4	+ 0,8	+ 2,1	+ 1,3
	Minimum φ = 0	- 0,7	- 1,1	- 1,7	- 1,8
	Minimum φ = 1	- 1,4	- 1,6	- 2,2	- 2,5
10°	Maximum all φ	+ 0,5	+ 1,2	+ 2,4	+ 1,6
	Minimum φ = 0	- 0,9	- 1,5	- 2,0	- 2,1
	Minimum φ = 1	- 1,4	- 2,1	- 2,6	- 2,7
15°	Maximum all φ	+ 0,7	+ 1,4	+ 2,7	+ 1,8
	Minimum φ = 0	- 1,1	- 1,8	- 2,4	- 2,5
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
20°	Maximum all φ	+ 0,8	+ 1,7	+ 2,9	+ 2,1
	Minimum φ = 0	- 1,3	- 2,2	- 2,8	- 2,9
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
25°	Maximum all φ	+ 1,0	+ 2,0	+ 3,1	+ 2,3
	Minimum φ = 0	- 1,6	- 2,6	- 3,2	- 3,2
	Minimum φ = 1	- 1,4	- 1,5	- 2,5	- 2,8
30°	Maximum all φ	+ 1,2	+ 2,2	+ 3,2	+ 2,4
	Minimum φ = 0	- 1,8	- 3,0	- 3,8	- 3,6
	Minimum φ = 1	- 1,4	- 1,5	- 2,2	- 2,7



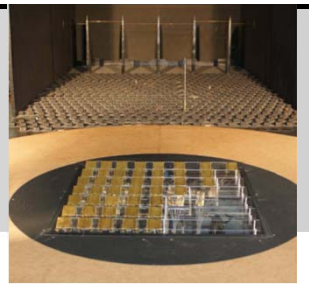


Empty, free-standing canopy (φ=0)

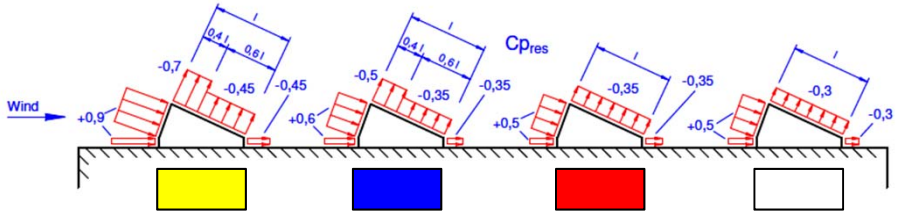


Canopy blocked to the downwind eaves by stored goods (φ=1)

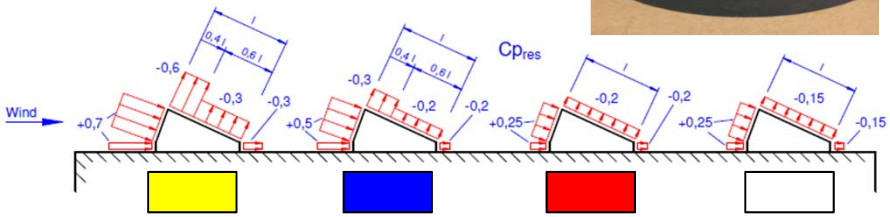
4. Weight optimized systems (AluLight 12°)



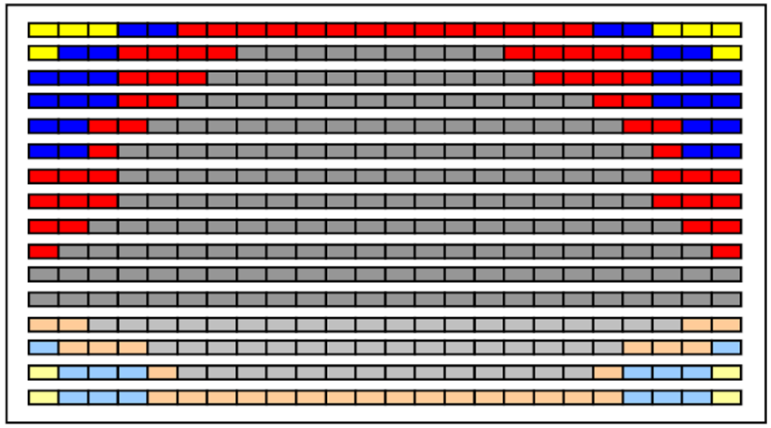
Performed by wind tunnel tests

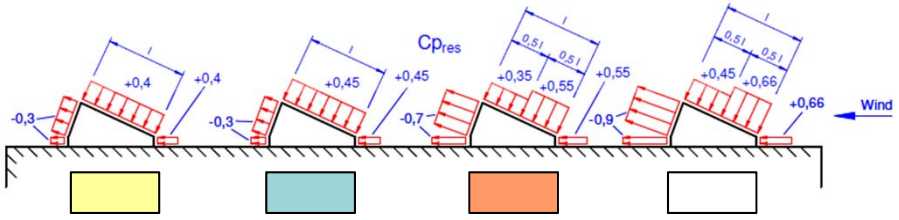


stationary, north wind

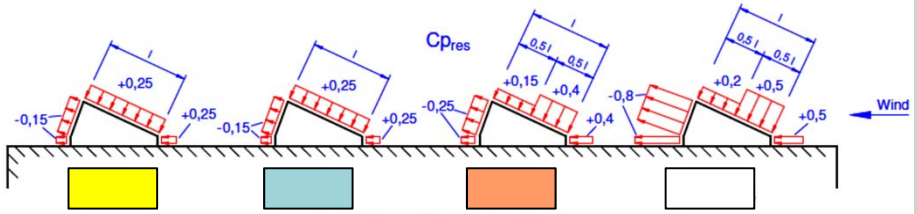


instationary, north wind





stationary, south wind



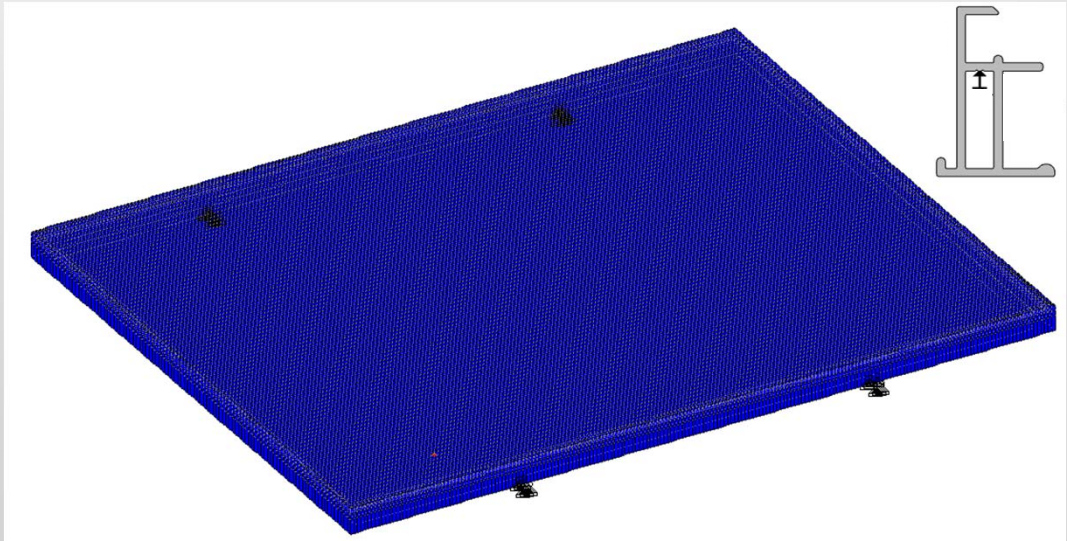
instationary, south wind

5. Numerical simulations

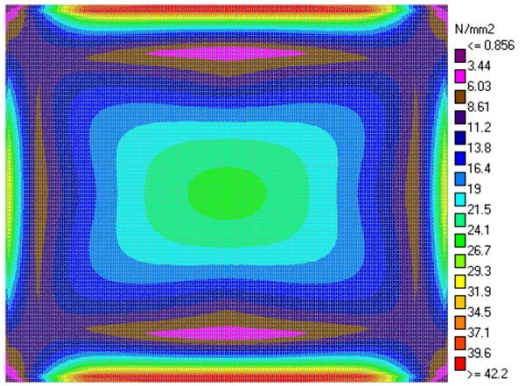
Module design

20.000 Shell elements per panel
- PVB Encapsulant 0,76 mm
- 1300x1100; Frame 50 mm
- Load 2.400 Pa (IEC 61646)

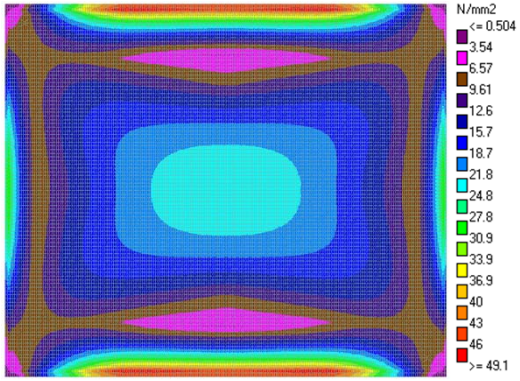
→ **Influence of clamp position**



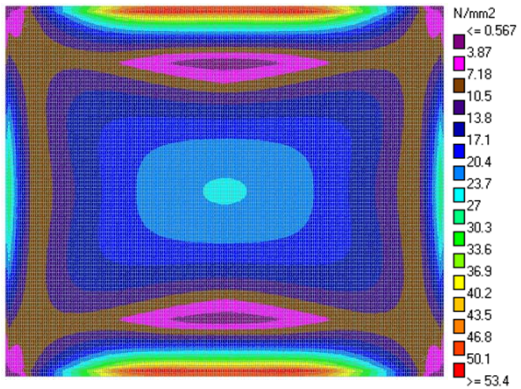
2 x
3,2 mm
14 %



2 x
3,2 mm
22 %

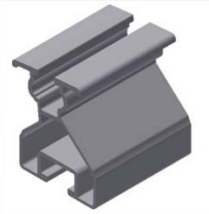


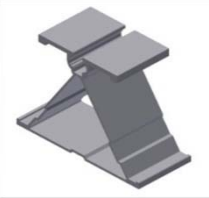
2 x
3,2 mm
30%

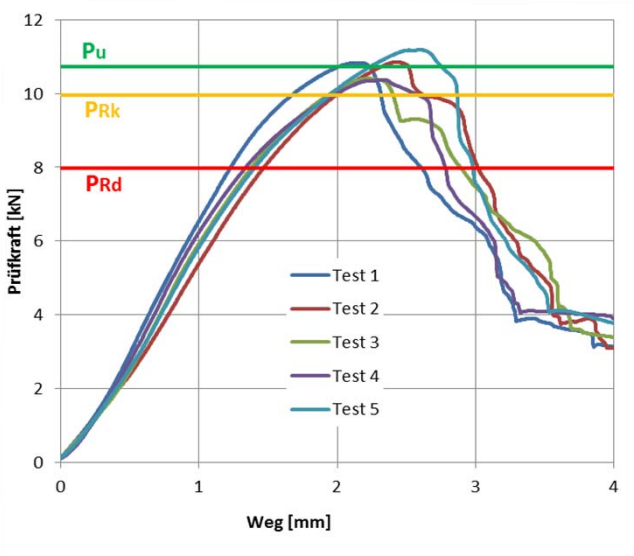


6. Testing procedures

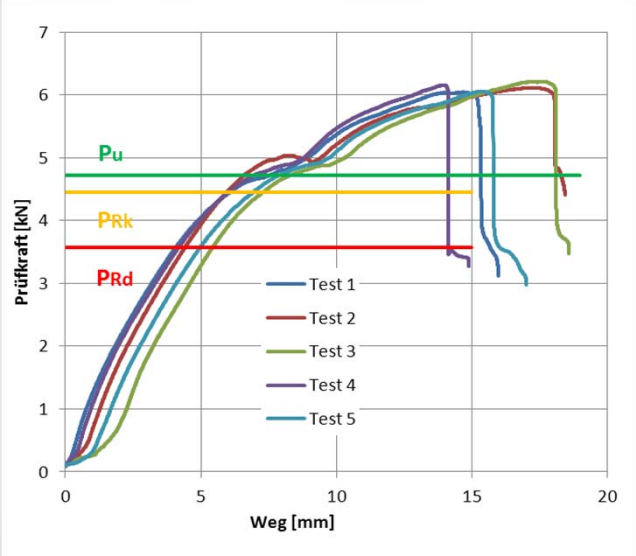
Module clamps





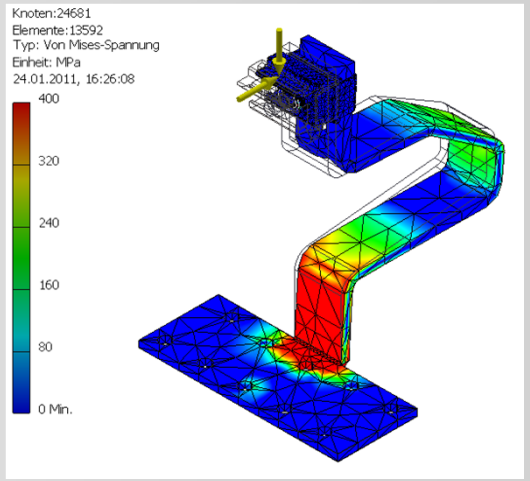


Profile cross connectors



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
  - Maintenace over life time
- Wind tunnel optimized systems for roofs with limited rest bearing capacity



Thanks for your attention

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