ANGELHY supported by European Commission Research Fund for Coal & Steel

Wind Loads on Steel Lattice Towers

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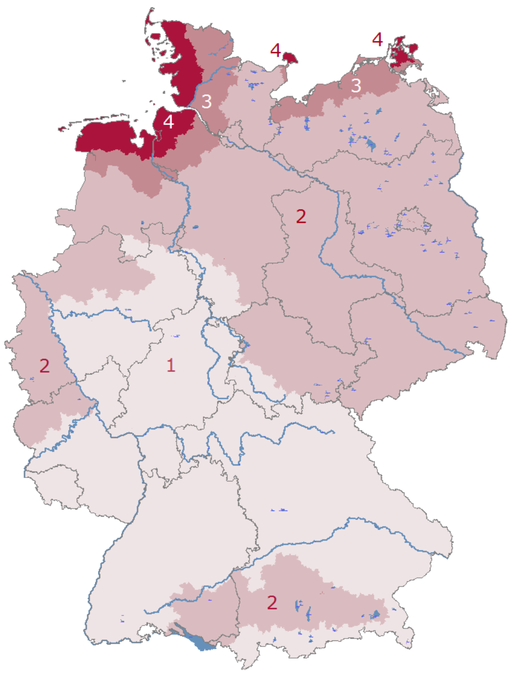
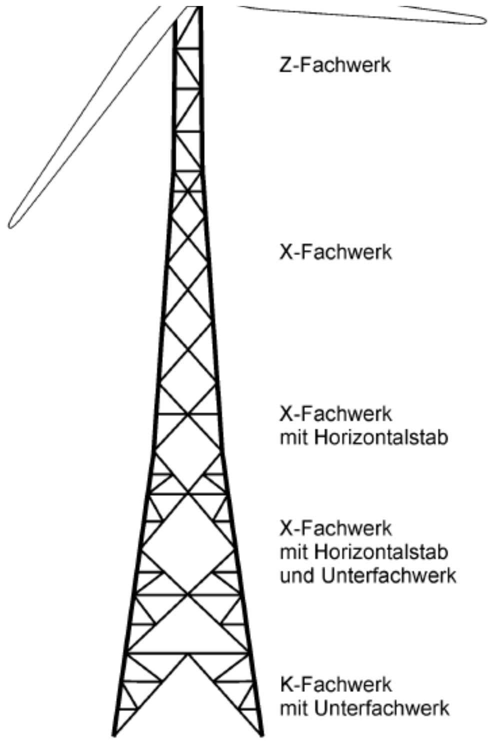
CWE Center for Wind and Earthquake Engineering RWTH AACHEN UNIVERSITY

Influence Parameters for Wind Loading

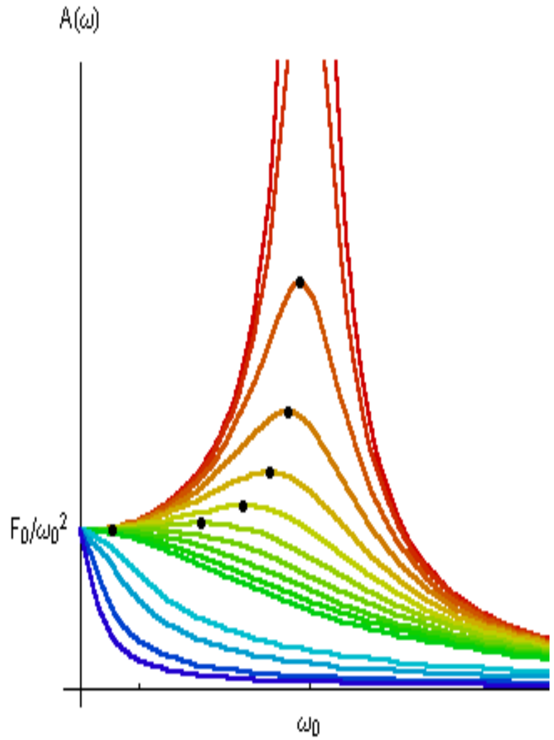
Location



Geometry



Structural Response



Basic Velocity - Gust Velocity

Basic velocity v_b

- Wind Zone Map acc. DIN EN 1991-1-4:2010 (for Germany)
- 10min average - rural terrain - 10m height - 50 years

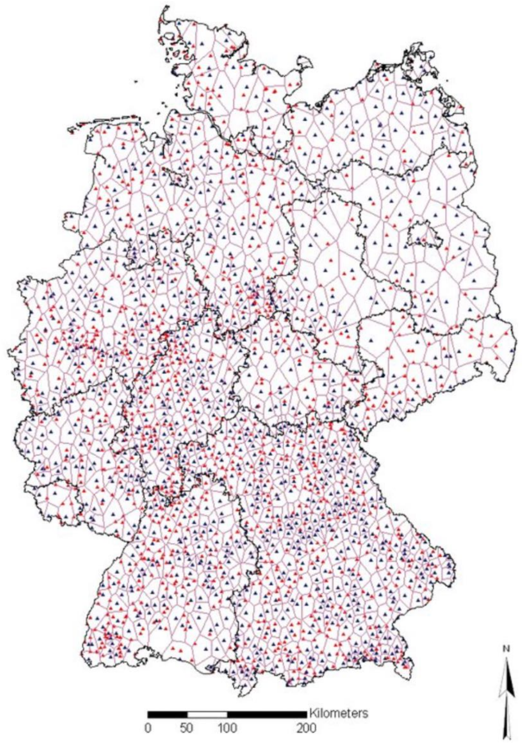
Approach (AiF Project „Wind+Ice“):

Automated analysis:

- Safe values based on weather data
- Full automated data analysis

➢ Directional v_b values

Location

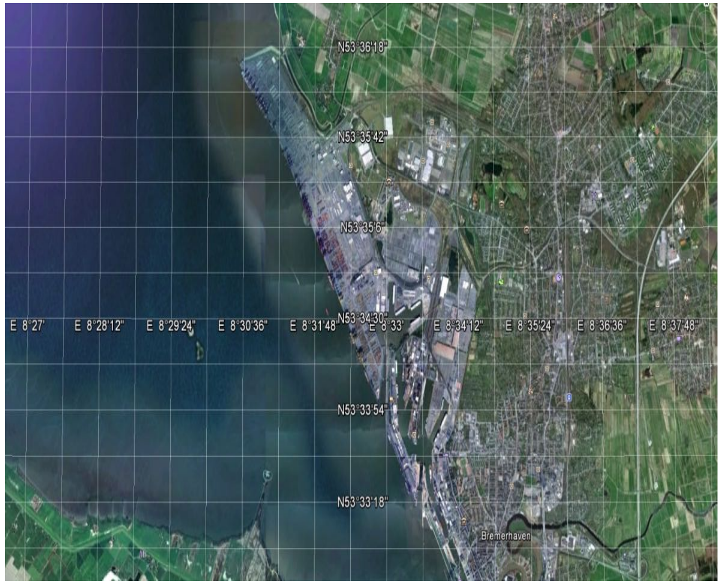


Influence of Terrain Roughness

Gust Velocity Pressure q_p

Location

- Peak values with averaging of T=3s
- Turbulences are decisive
- Terrain roughnes needs to analyzed
- Roughness Categories I-IV
  (satellite photographs by view)



Influence of Terrain Roughness

Location

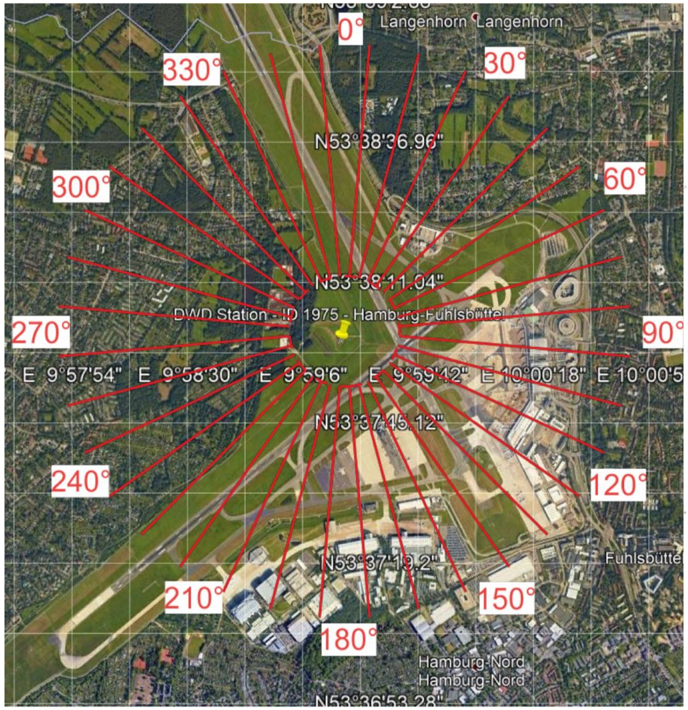
Approach (AiF ZIM Project):

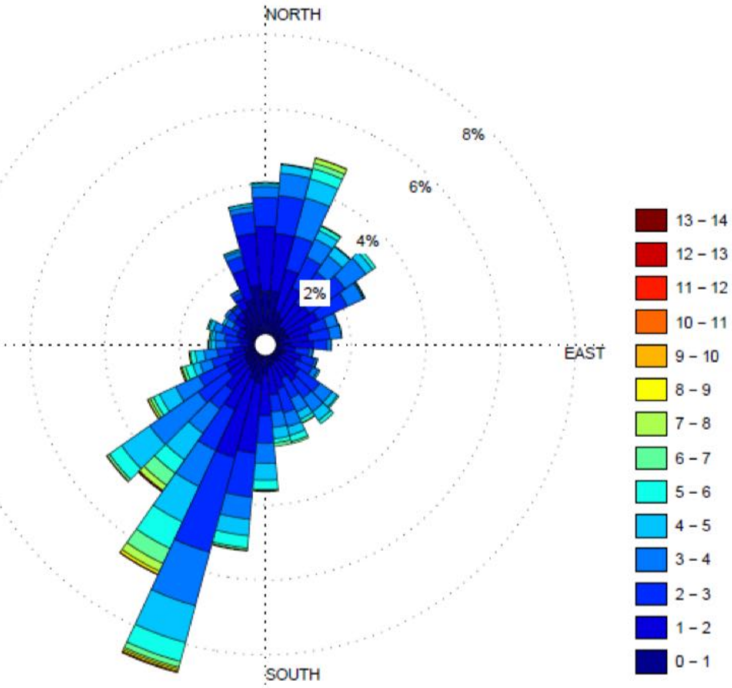
Automated analysis:

- Corine Data Base (GIS)
- Direction dependent analysis of ground usage
- Roughness assesment

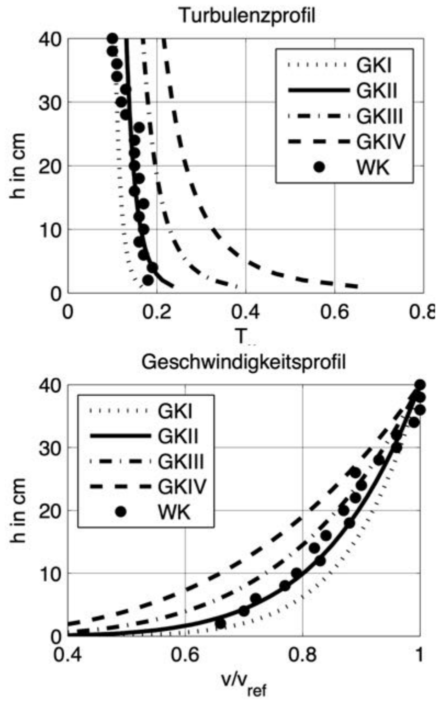
➤ Directional z_0 values

Direction related Wind Velocities





Location

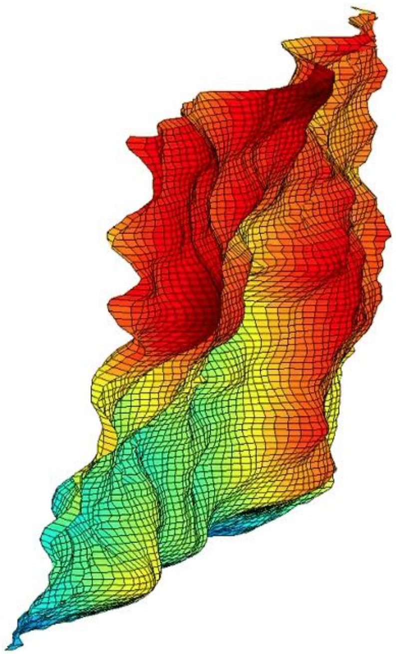


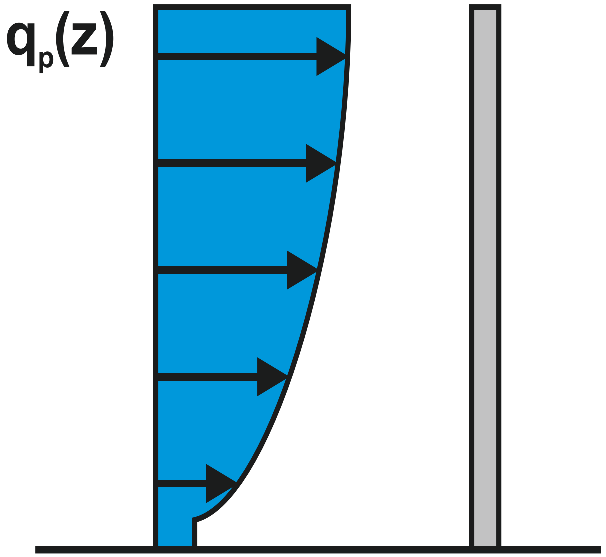
► Directional Gust Velocities

Modeling of Gust Velocity Pressure

Profile of gust velocity pressure q_p

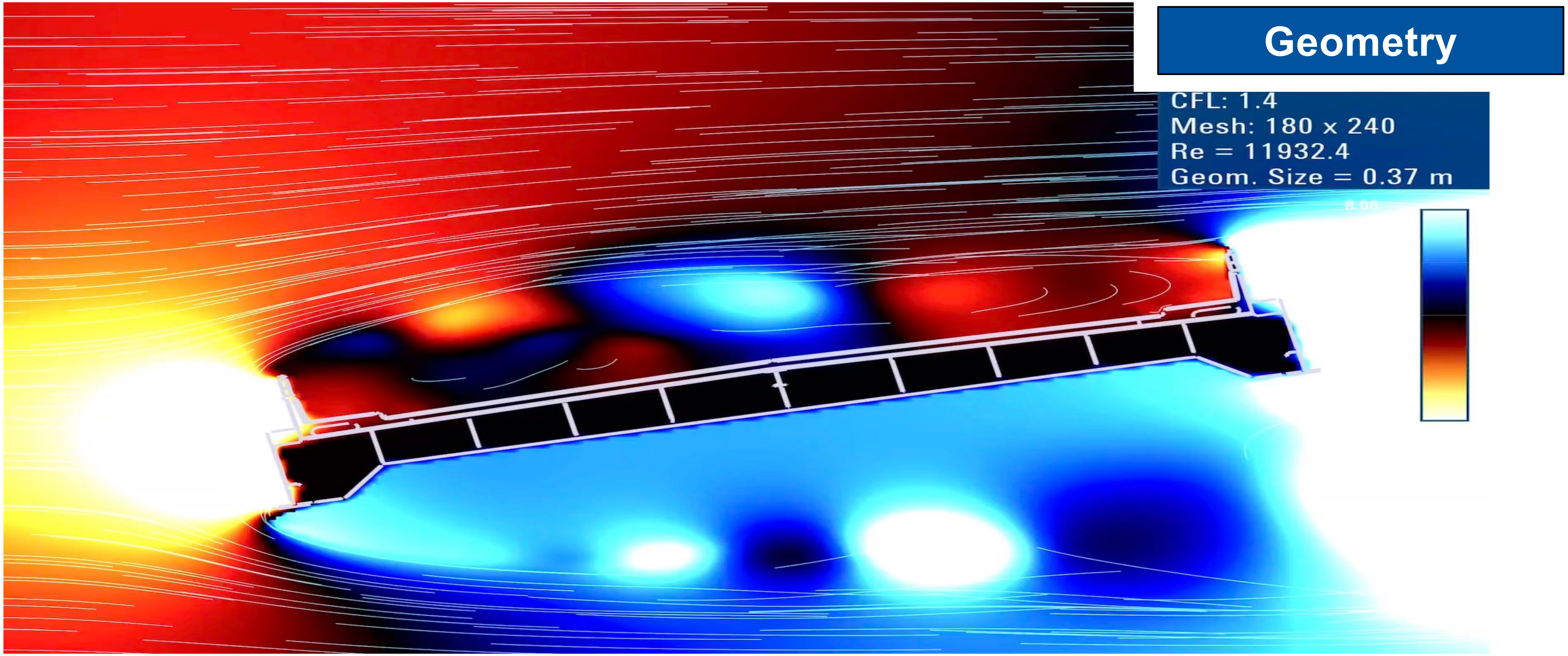
Location





- Return Period 50 years
- Averaging T=3s

Influence of Aerodynamics

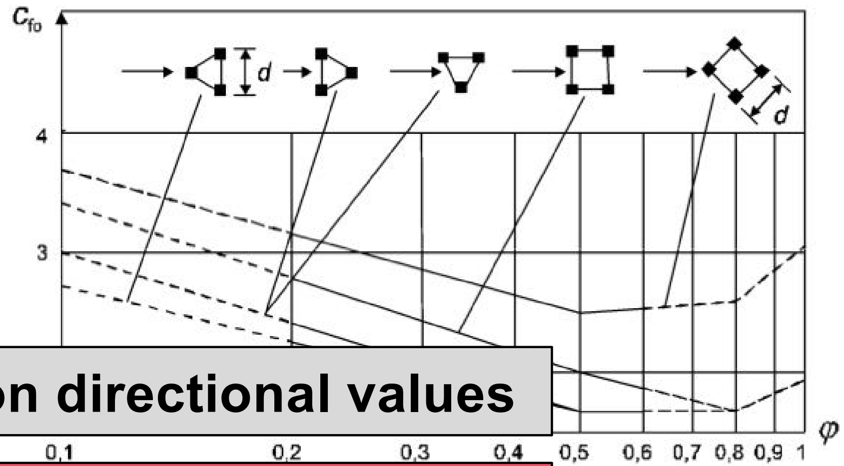


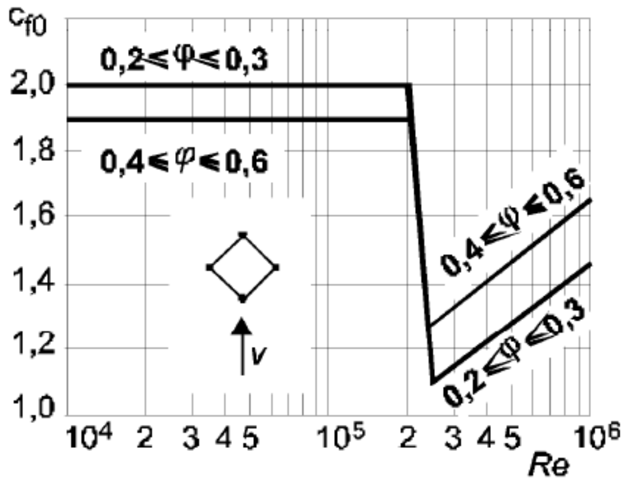
Aerodynamic Coefficients for Lattice Structures

Geometry

According to EN 1991-1-4

- Dependent on Cross-Section and Projection
- Present values for rectangualr and cylindrical cross-sections
- Overall enveloping values





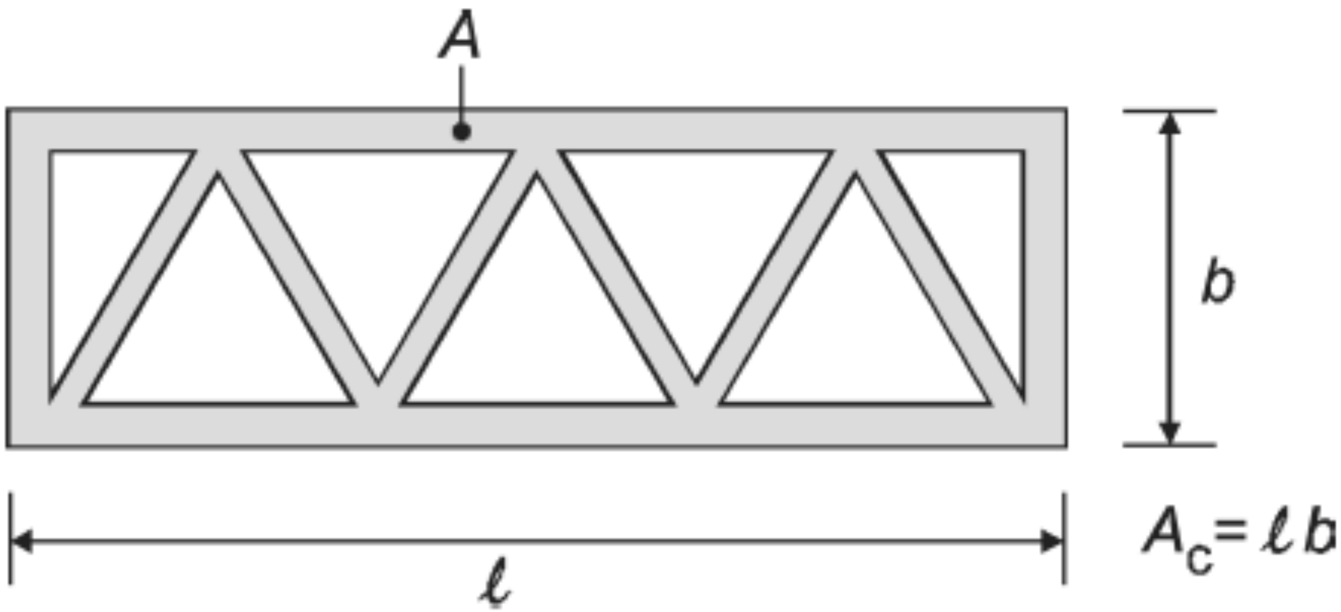
▶ Non directional values

▶ Safe, but not realistic

Aerodynamic Coefficients based on Standards

According to EN 1993-3-1

- Projective areas with φ

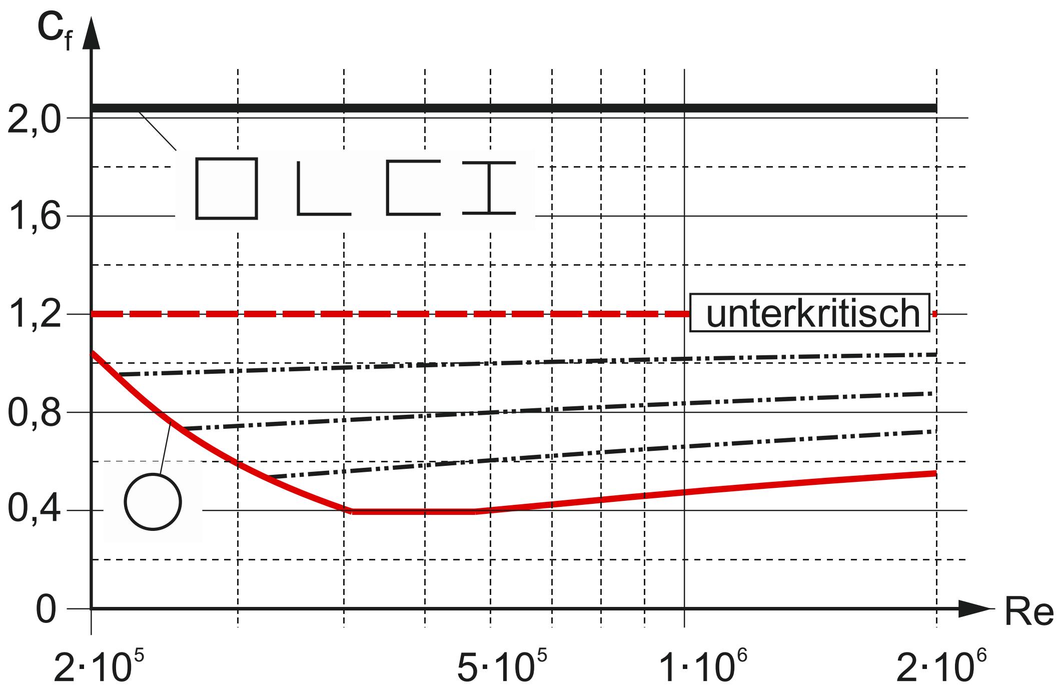


$$c_{f,S} = K_\theta \cdot c_{f,S,0} \cdot \frac{A_S}{\sum A}$$ AC

Aerodynamic Coefficients based on Standards

According to EN 1993-3-1

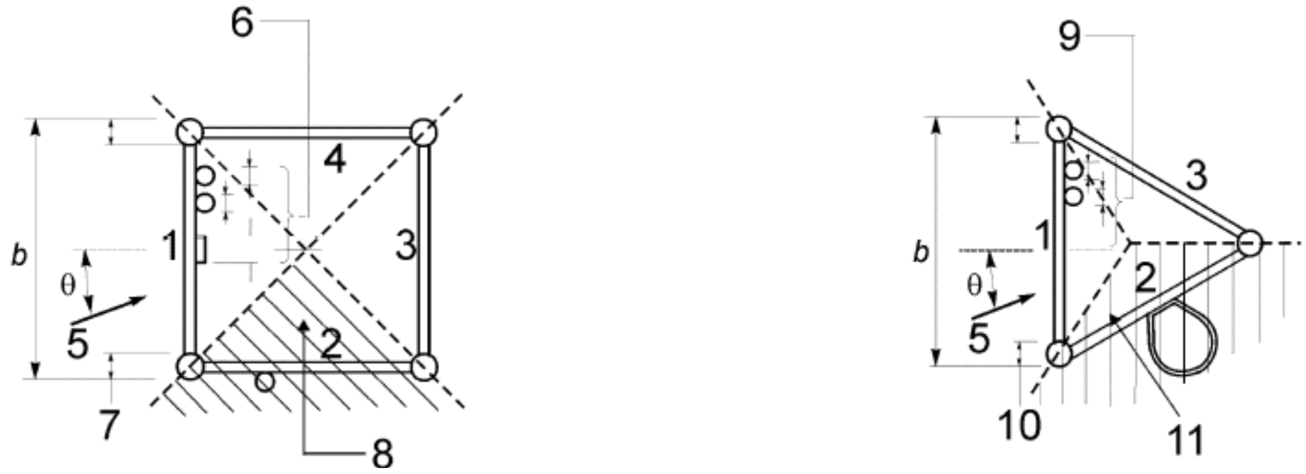
- Weighted sum of $c_{f,s,0}$ dependent on the used cross-sectional types
- Ratio of sharp-edged to rounded cross-sections (A_f/A_s)



Aerodynamic Coefficients based on Standards

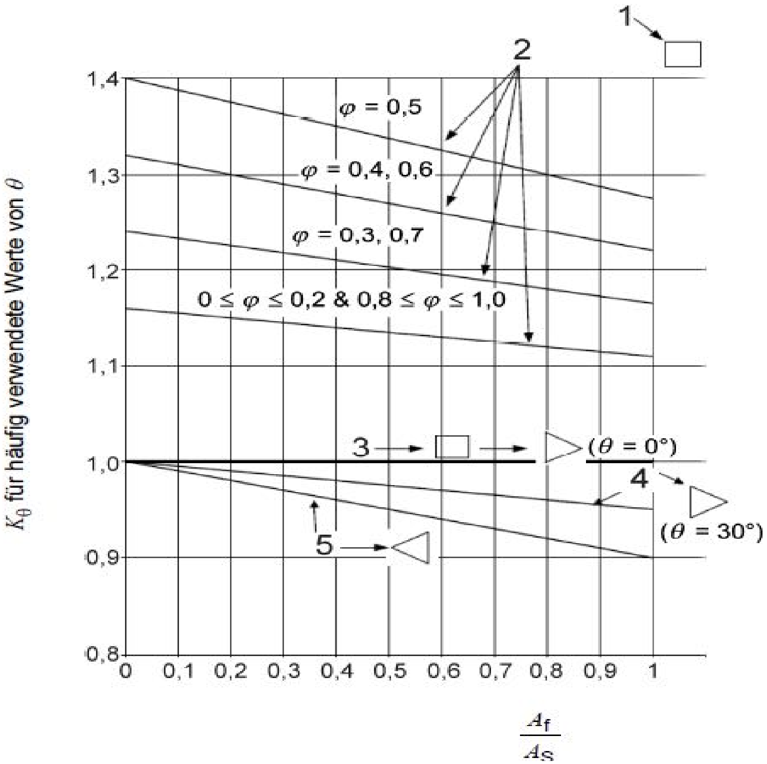
According to EN 1993-3-1

- For coefficients $c_{f,s,0}$ dependent on cross-section
- Ratio of the sharp edged to the rounded cross-sections (A_f/A_s)
- Dependence of base geometry
- Directional influence k_Θ



Aerodynamic Coefficients based on Standards

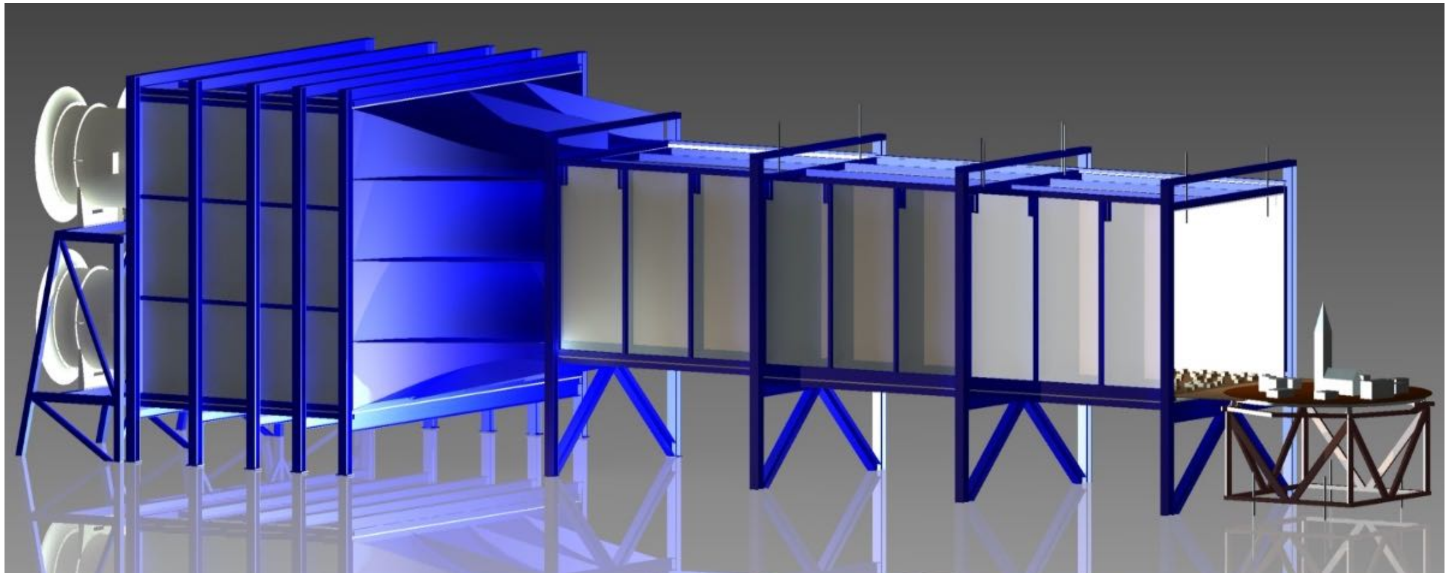
According to EN 1993-3-1

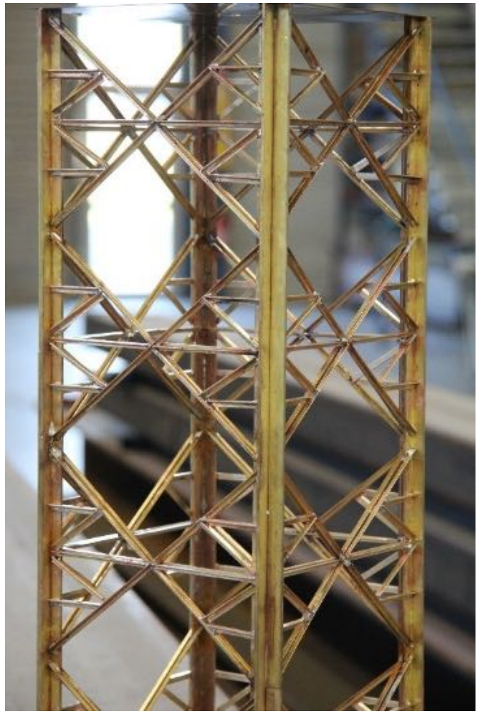


► Directional coefficients

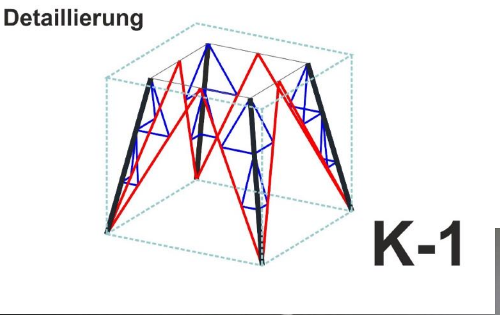
Aerodynamic Coefficients based on Wind Tunnel Measurements

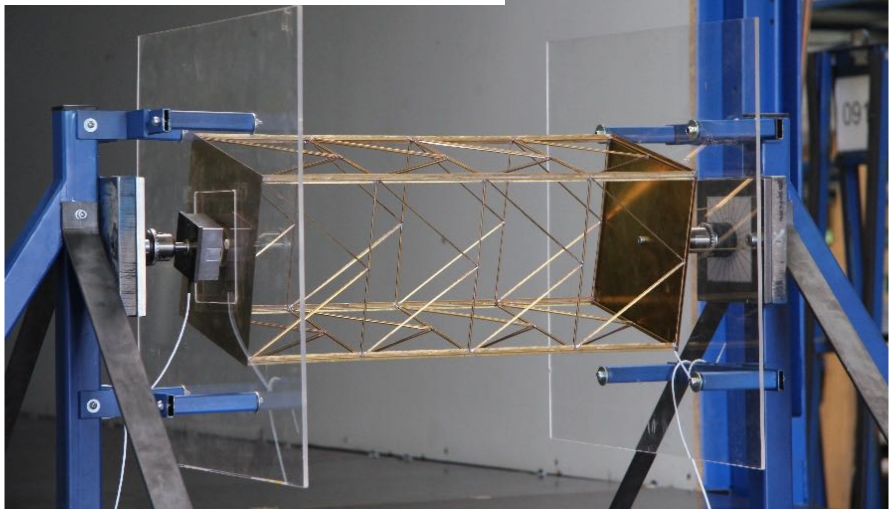
Own investigations (FOSTA Project: OpDiWind)

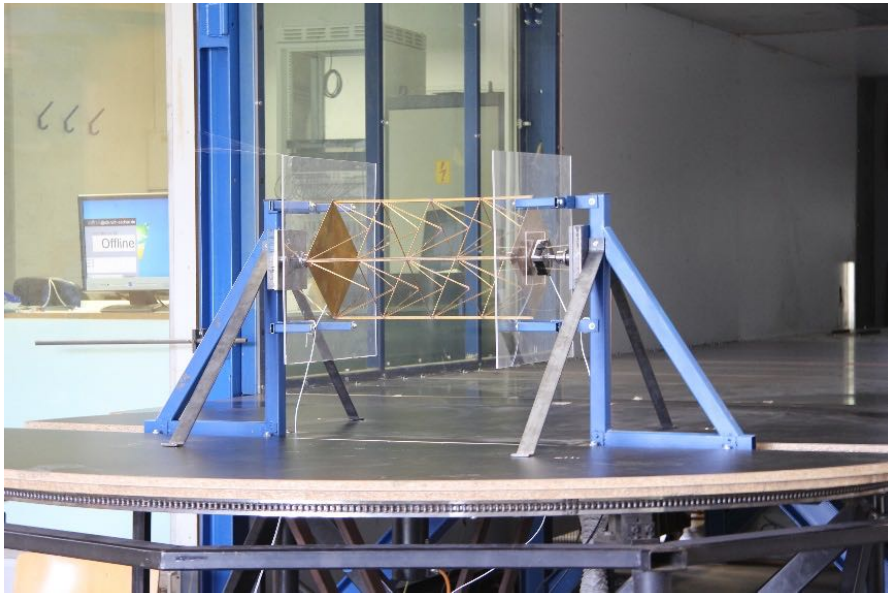




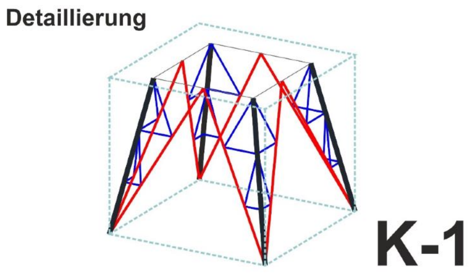
Aerodynamic Coefficients based on Wind Tunnel Measurements

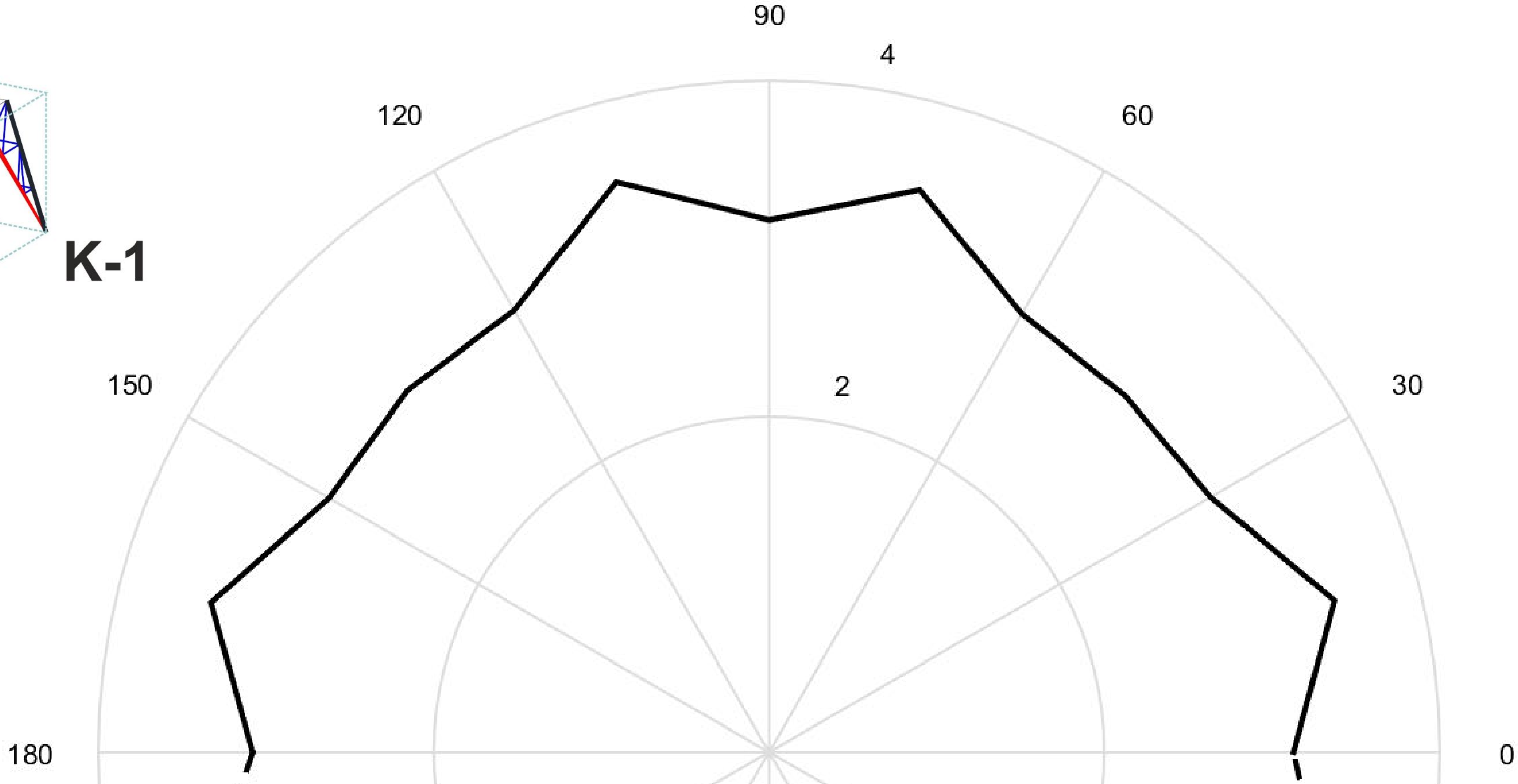






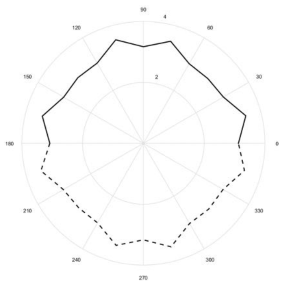
Aerodynamic Coefficients based on Wind Tunnel Measurements



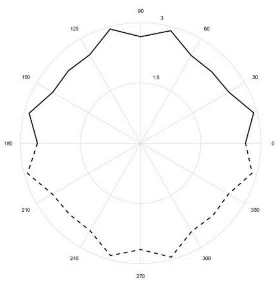


Aerodynamic Coefficients based on Wind Tunnel Measurements

K1



K2



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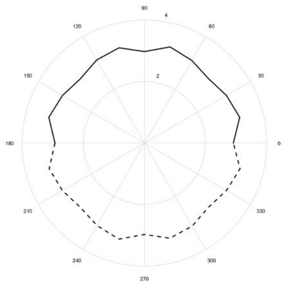
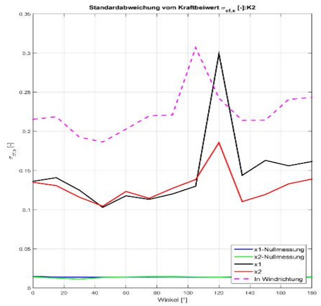
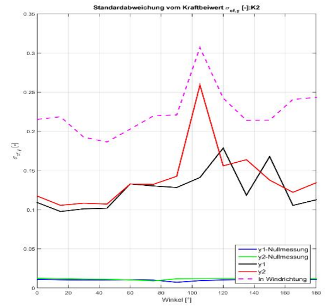
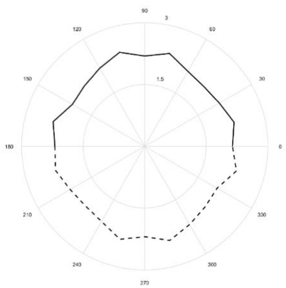


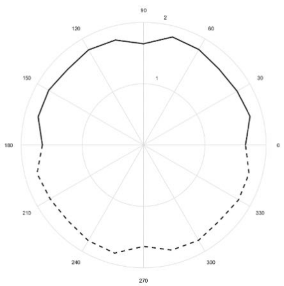




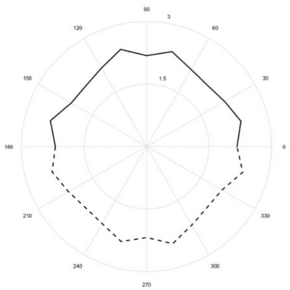
XH1



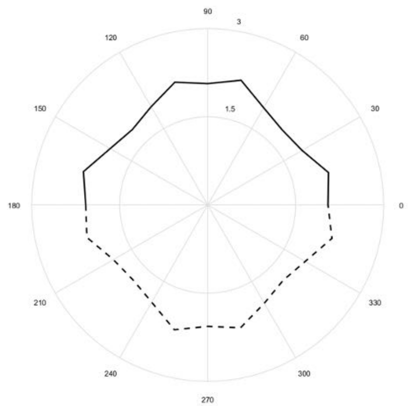
XH2



X1

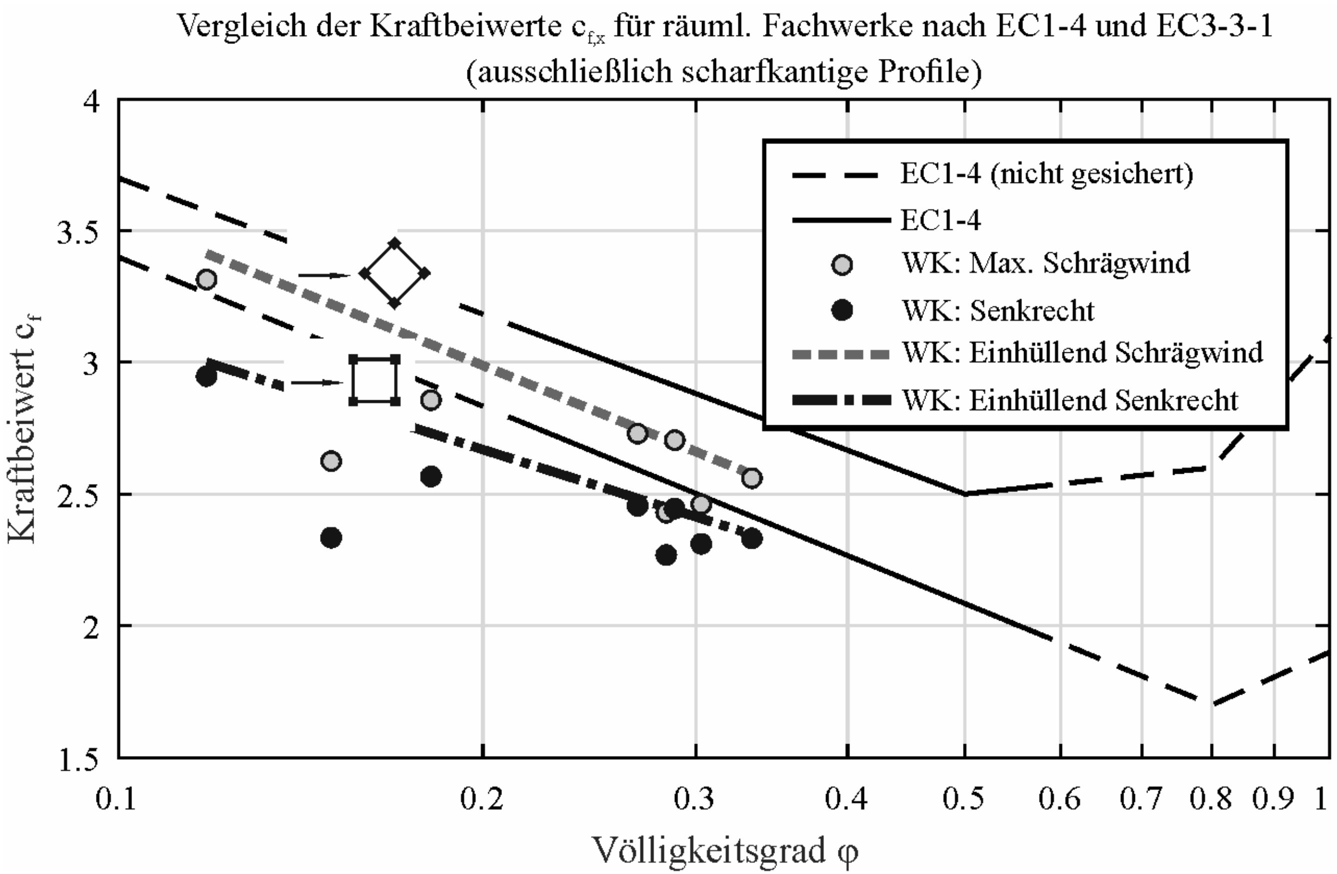


Z1



Z2

Aerodynamic Coefficients based on Wind Tunnel Measurements



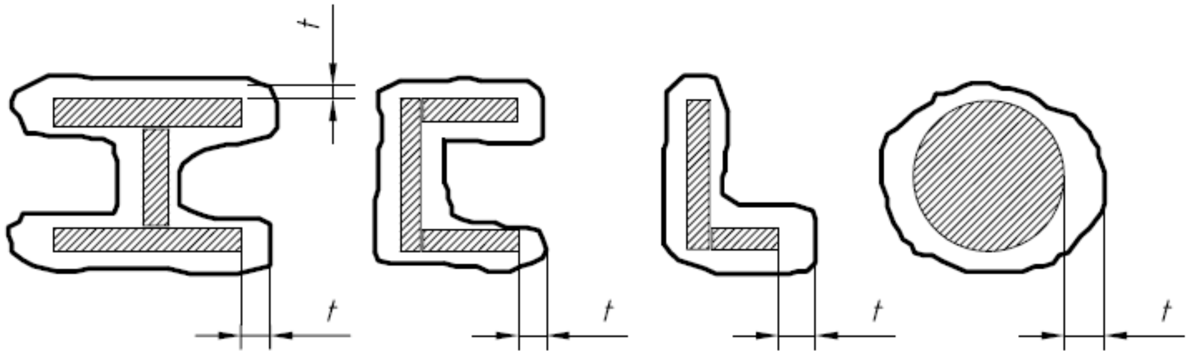
Ice Loading

- In case of icing, the aerodynamic shape is modified
- Furthermore, correlation of wind and ice leads to reduced wind speeds

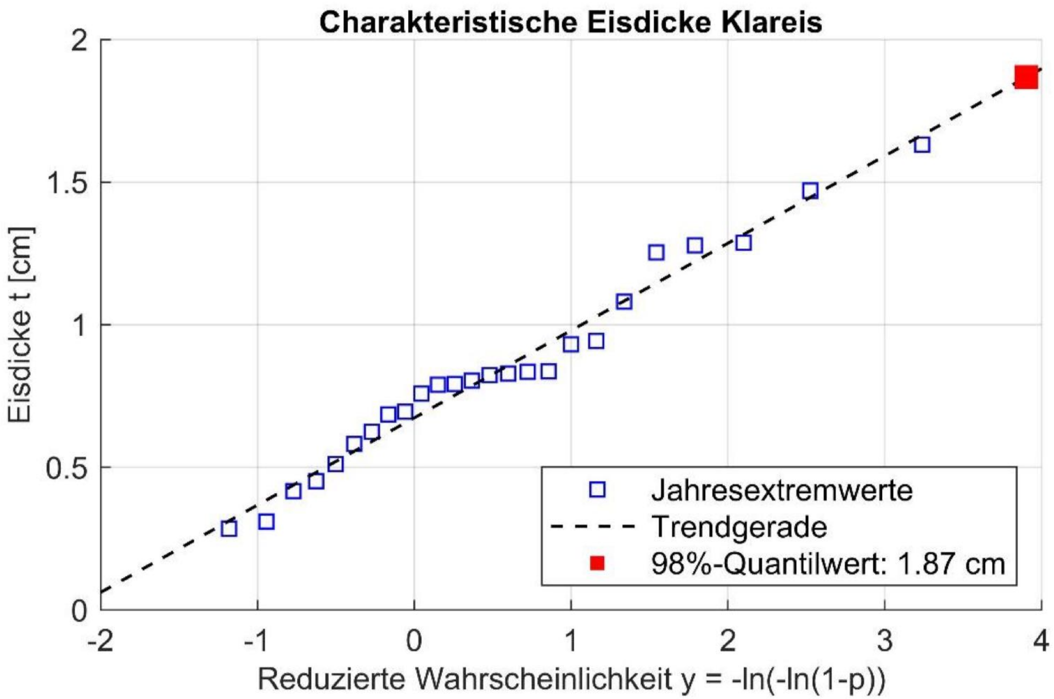
CWE approach:

- Meteorological icing criteria
- Automated analysis of wind speeds considering icing criteria

➢ Reduced wind speeds
➢ Ice attachement



Ice Loading

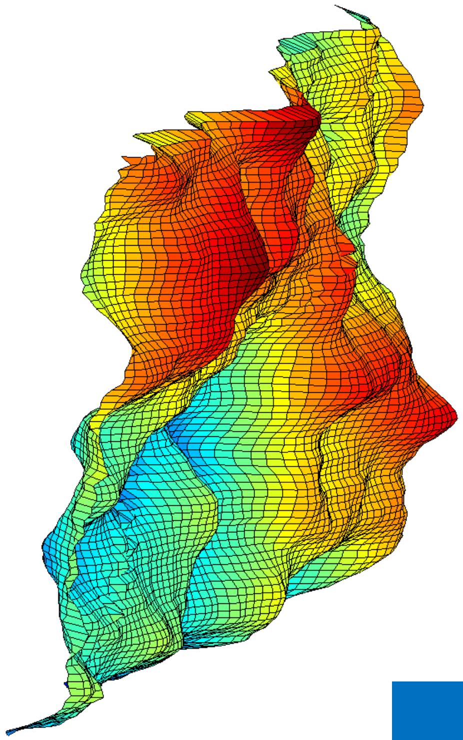


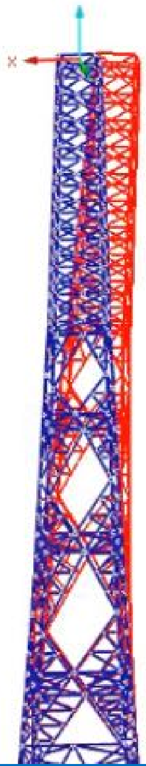
e.g. Recommendation acc. to ISO 12494:

Vereisungsklasse für Klareis: G2

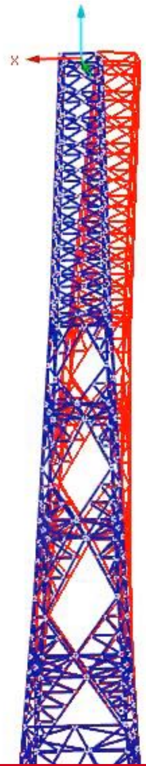
Vereisungsklasse für Raueis: R6

Consideration of structural response





Correlation: Background



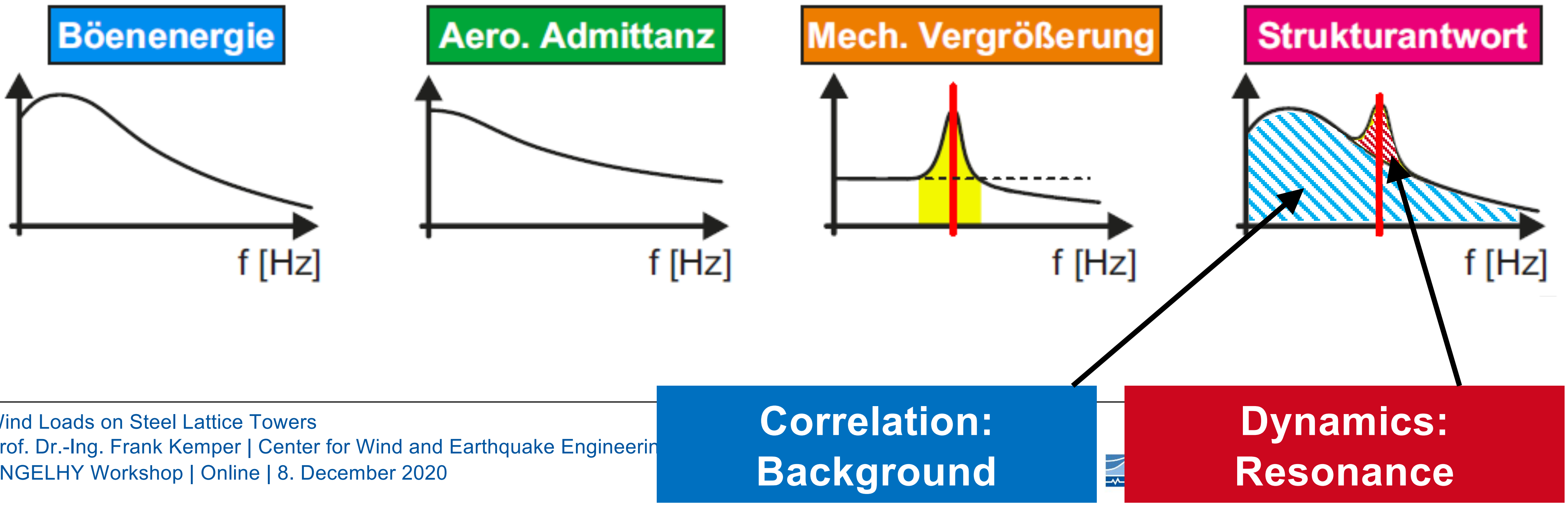
Dynamics: Resonance

Consideration of structural response

Gust induced response

- Influence of turbulence and gust energy
- Structural factor $c_s c_d$

$$c_s c_d = \frac{1 + 2 \cdot k_p \cdot I_v \cdot \sqrt{B^2 + R^2}}{1 + 7 \cdot I_v}$$



Consideration of structural response

Gust induced response

- Simplified check-up, η-values

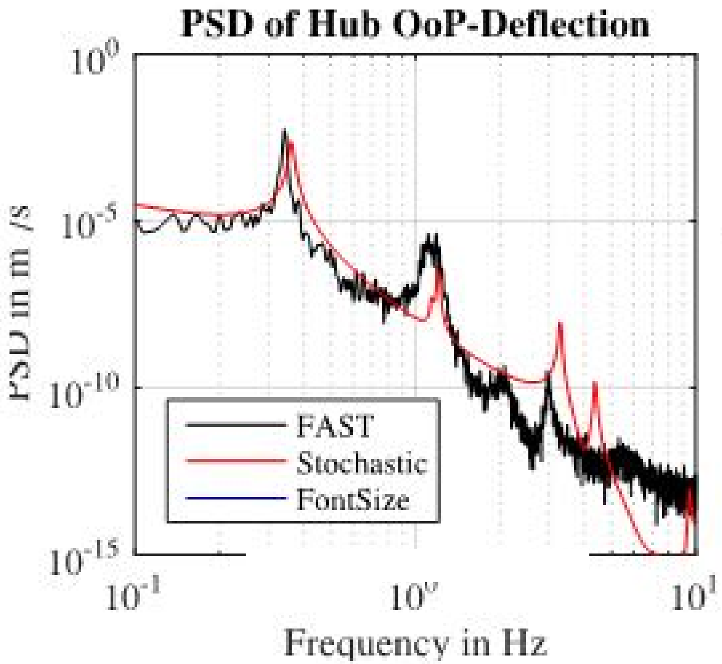
	Geländekategorie			
Windzone	I	II	III	IV
1	232,6	181,8	149,3	128,2
2	149,3	123,5	104,2	90,9
3	119,0	100,0	85,5	75,2
4	114,9	97,1	83,3	73,0

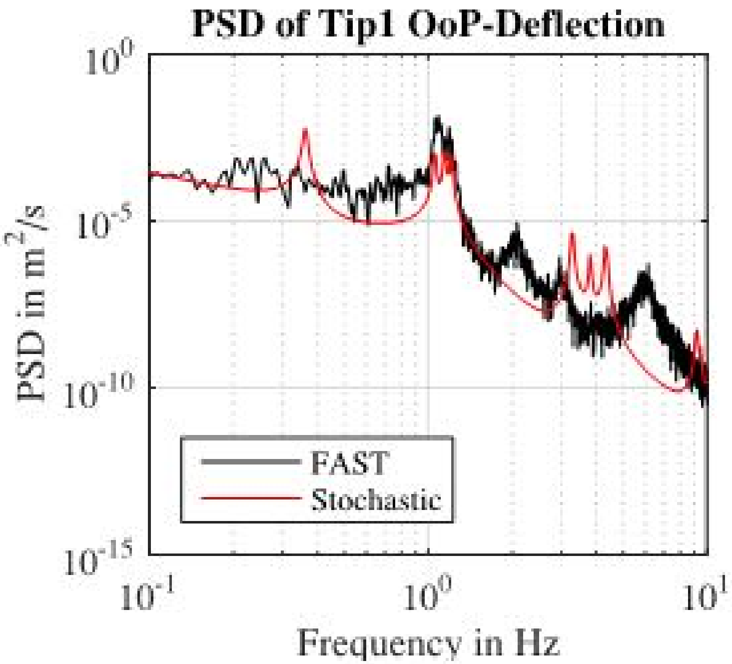
$$c_d(f, \delta) = 1{,}2 + (\eta \cdot \delta \cdot f^{0{,}4})^{-1}$$

Dynamics: Resonance

Consideration of structural response

Complexity of wind turbines (FOSTA project OpDiWind)

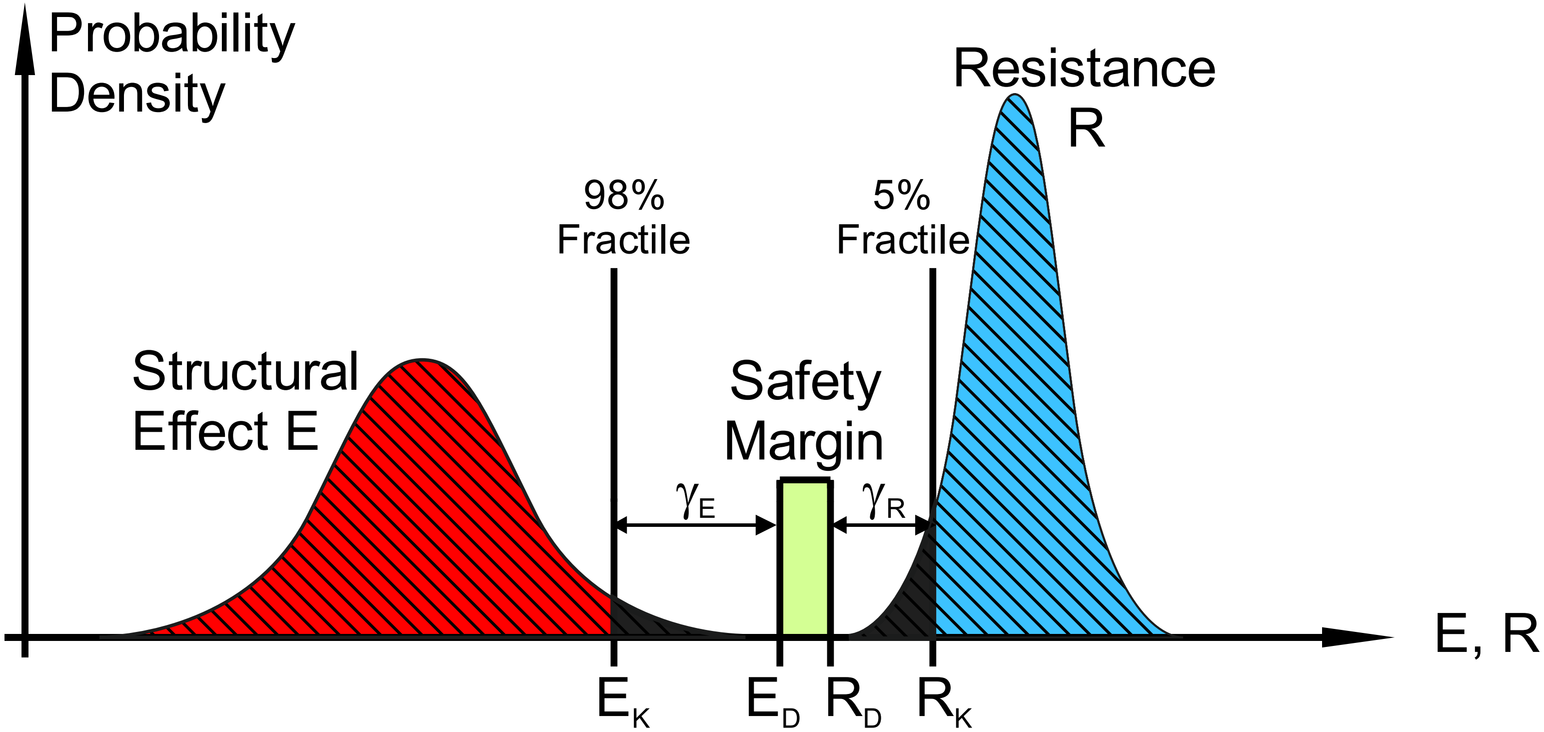




27,5 m/s

Consideration of structural safety

Reliability approach



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Thank you.

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