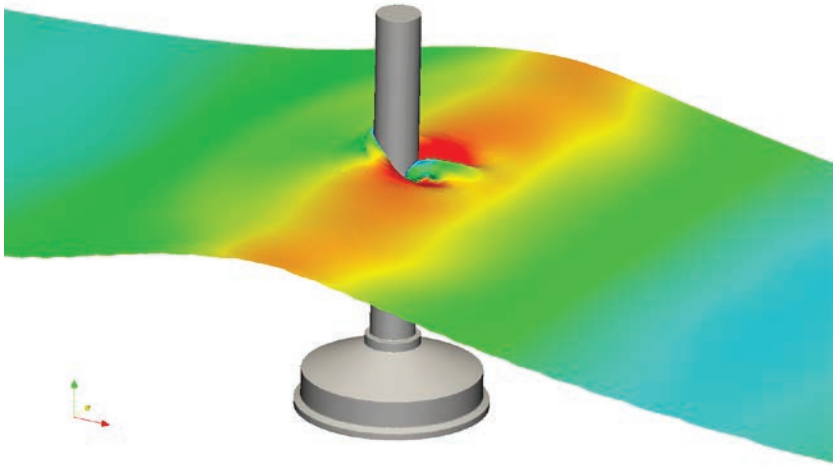
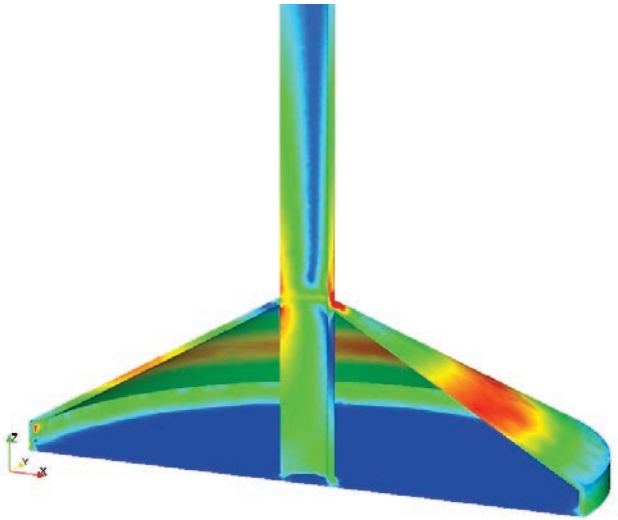
Concepts for gravity base foundations





Motivation

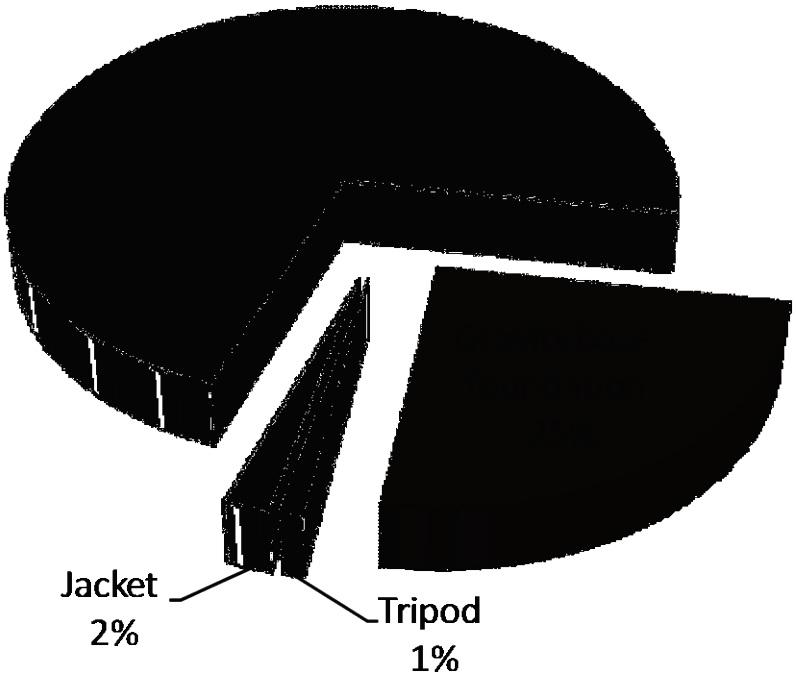
- Cost effective production
- Capacities are available
- Local manufacturing
- Suitability for sandy and rocky soils
- Avoiding acoustic emission

Content

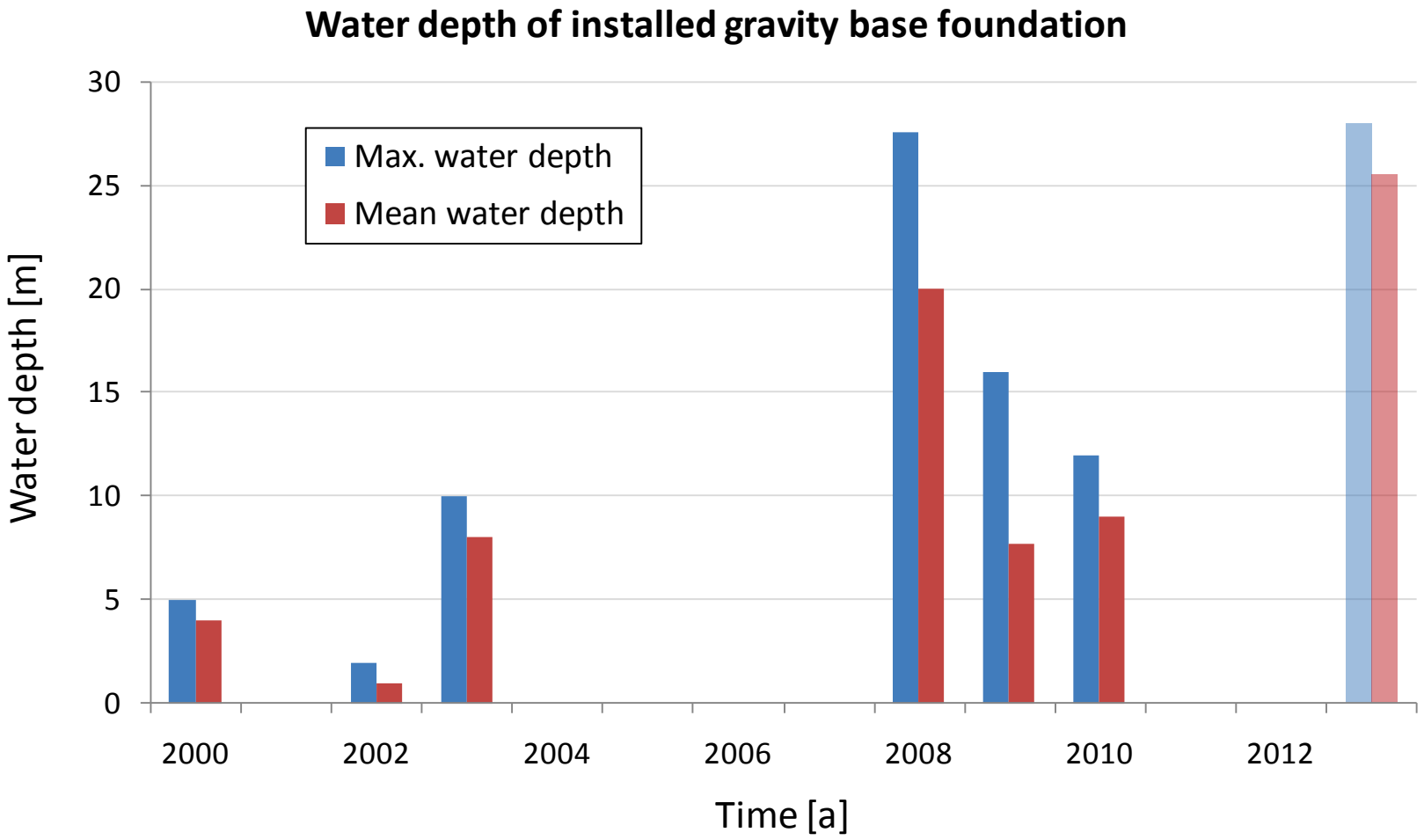
- Comparison of concepts
- Criteria for economic (gravity base) foundation
- Structural behavior
- Conclusion and future development

Current concepts of offshore foundations

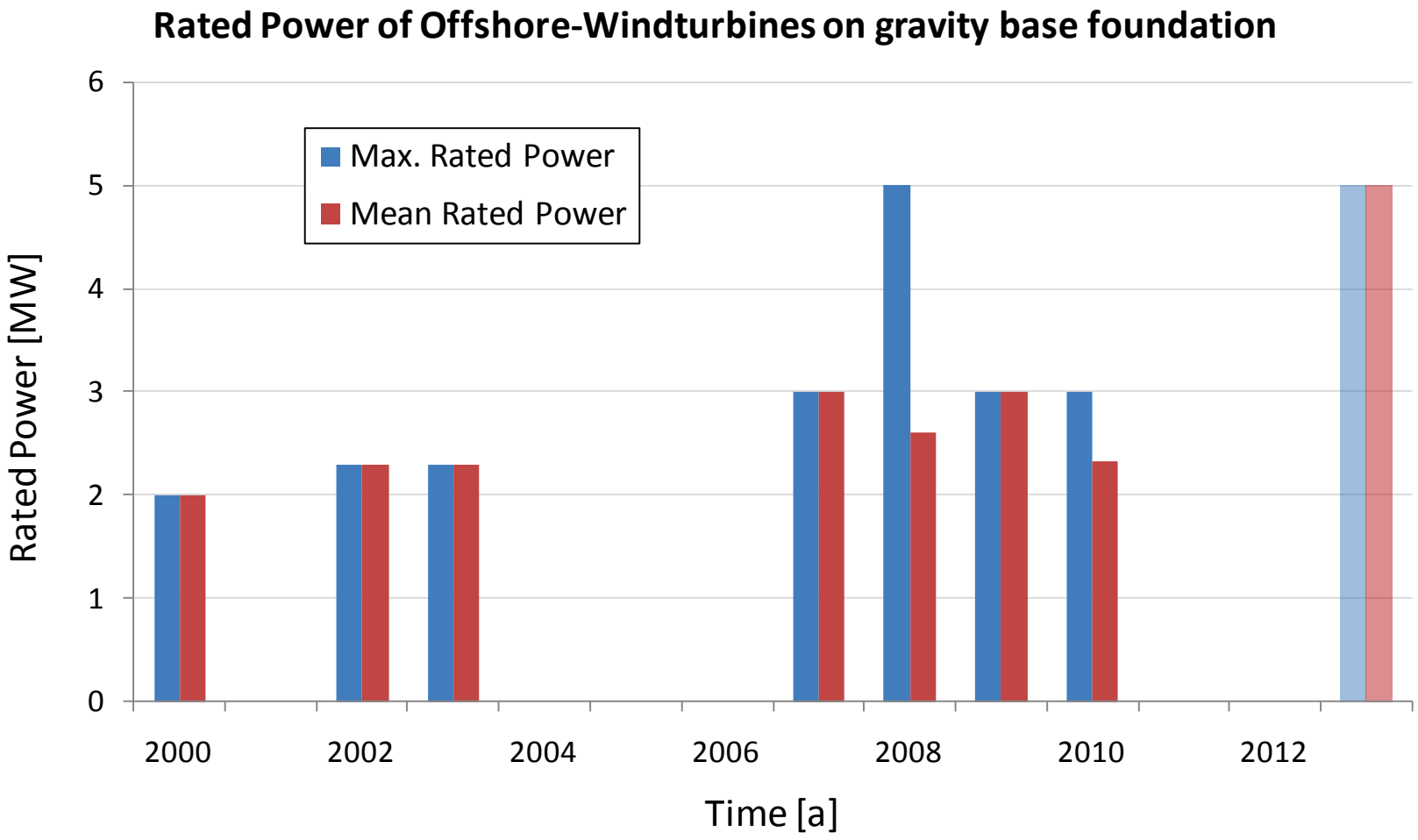
- Monopile/Gravity base foundation mainly in water depths < 10 m
- Greater water depths possible
- All turbine sizes possible



Current concepts of offshore foundations



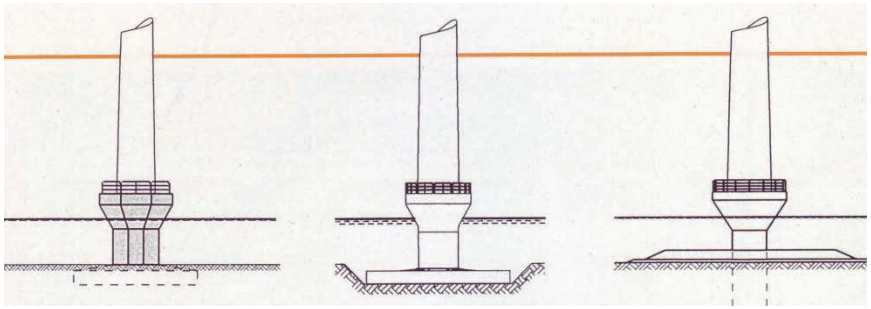
Current concepts of offshore foundations



Criteria for economic foundations

Manufacturing

- Onshore prefabrication
- Serial production
- Cost advantages of concrete



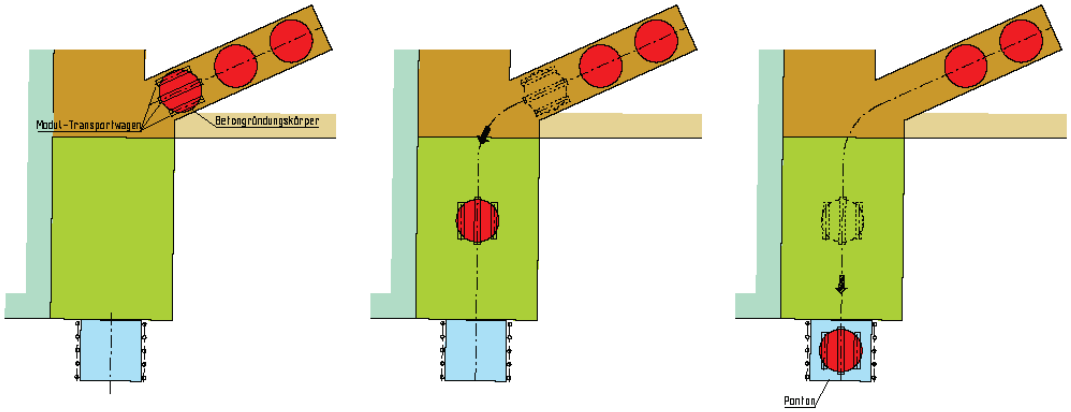
Steel-Caisson 380.000 €
Concrete structure 315.000 €
Monopile 420.000 €

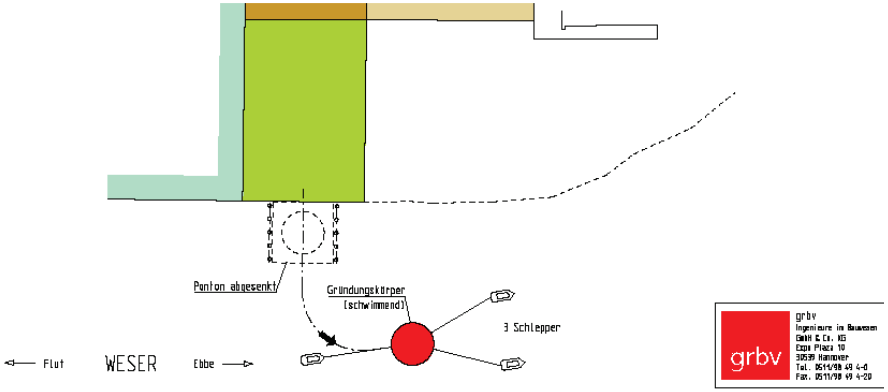
Price comparison according to [1]

[1] Sorensen et al.: Middelgrunden 40 MW offshore wind farm, a prestudy for the danish offshore 750 MW wind program

Criteria for economic foundations

Serial Production and preperation for transport





Criteria for economic foundations

Transport

- Transport of individual components
- Transport of complete Offshore-Windturbines
- Floating/Transport on pontoons

Criteria for economic foundations

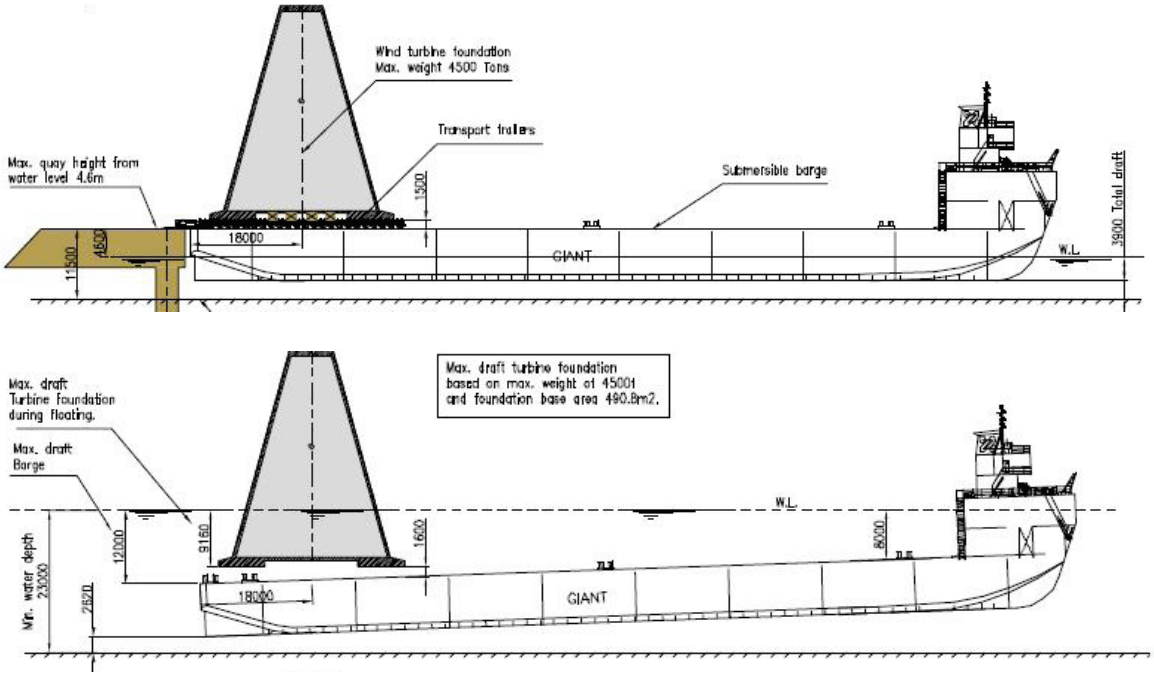
Transport

- Transport of individual components
- Transport of complete Offshore-Windturbines
- Floating/Transport on pontoons

Criteria for economic foundations

Transport

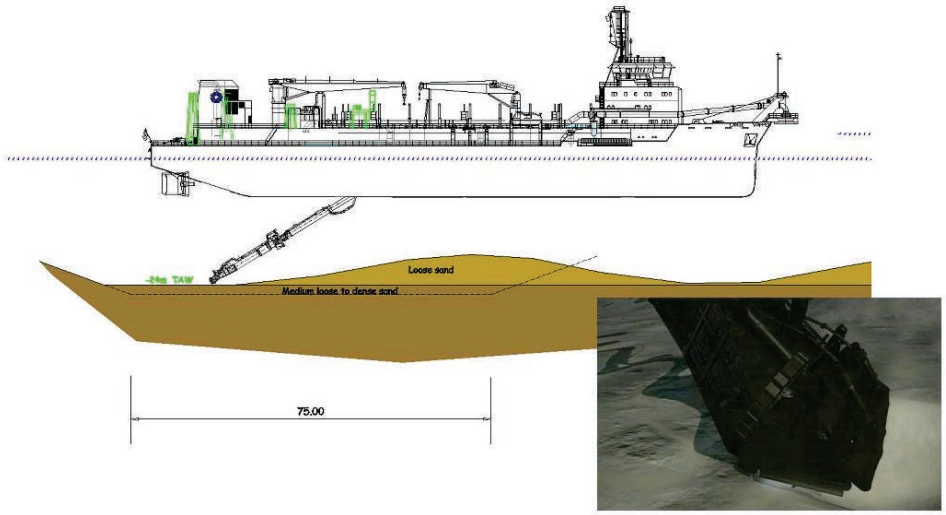
- Cost advantages by lightweight constructions
- Submersible barge

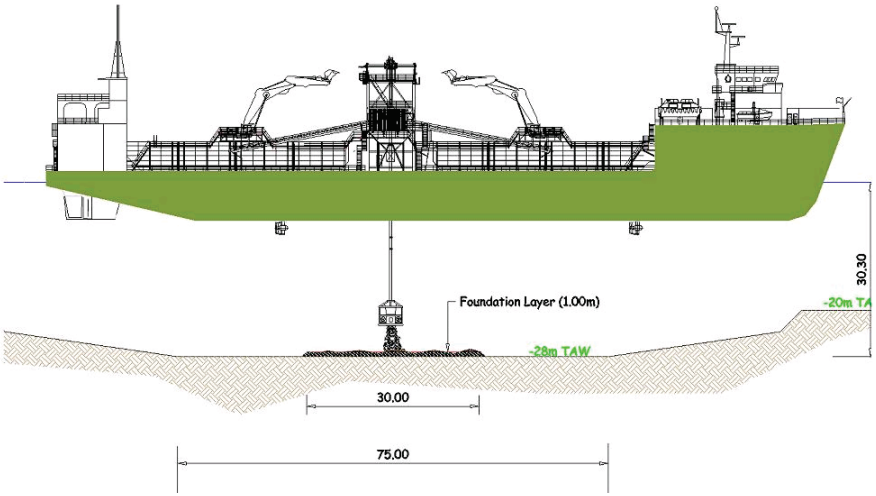


Criteria for economic foundations

Soil preparation

- No inhibit time (rammed structures), but preparation of the soil





Criteria for economic foundations

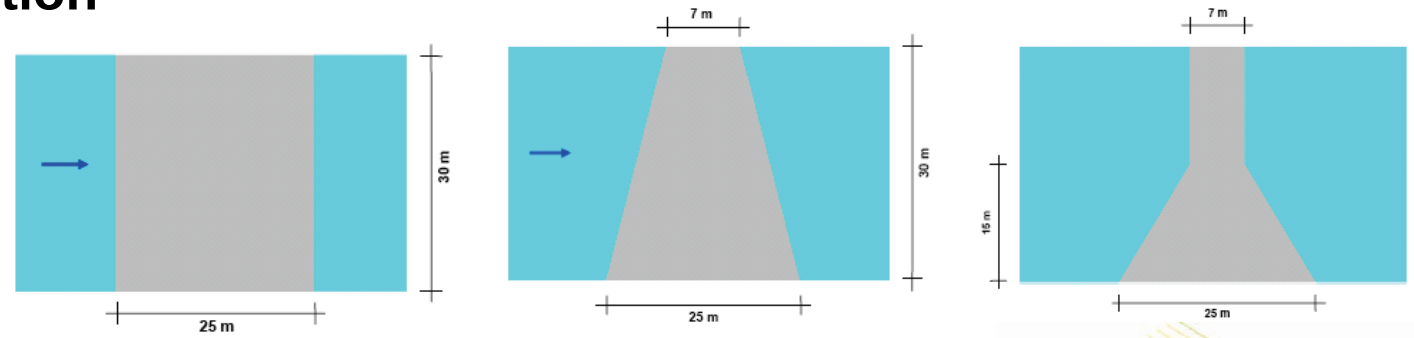
Limited time window

Significant wave height Threshold value [m]	Period of time		Duration [d]			
			1	2	3	4
1			Number of weather window's			
	Year	Jan - Dec	132	52	23	12
	Summer	Apr - Sep	89	37	18	11
	Winter	Oct - Mar	43	15	5	1
2			Number of weather window's			
	Year	Jan - Dec	276	128	77	53
	Summer	Apr - Sep	161	77	49	34
	Winter	Oct - Mar	115	51	28	19
3			Number of weather window's			
	Year	Jan - Dec	334	161	103	74
	Summer	Apr - Sep	178	87	57	42
	Winter	Oct - Mar	156	74	46	32

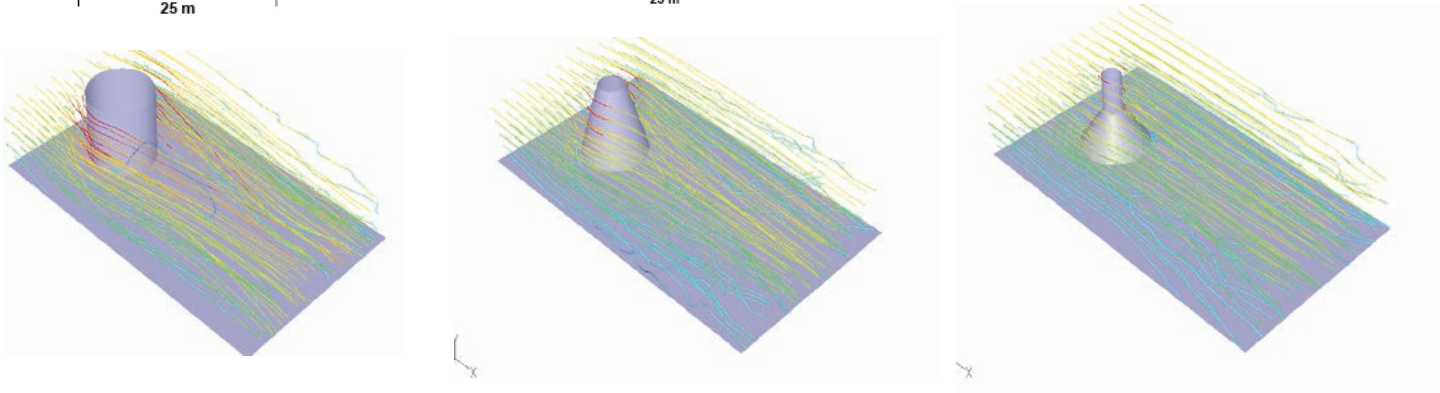
Criteria for economic foundations

Scour protection

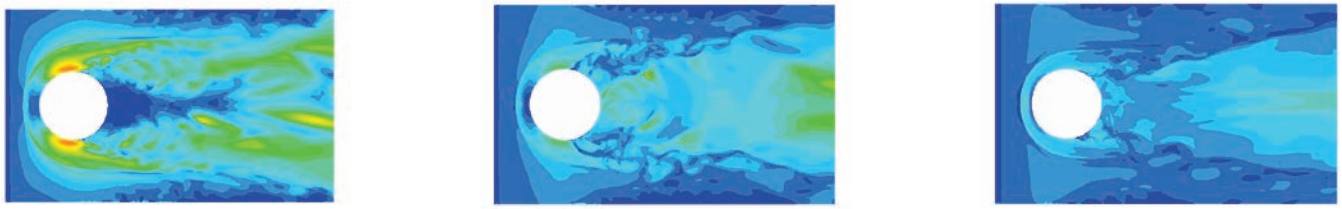
Geometry:



Flow velocities:

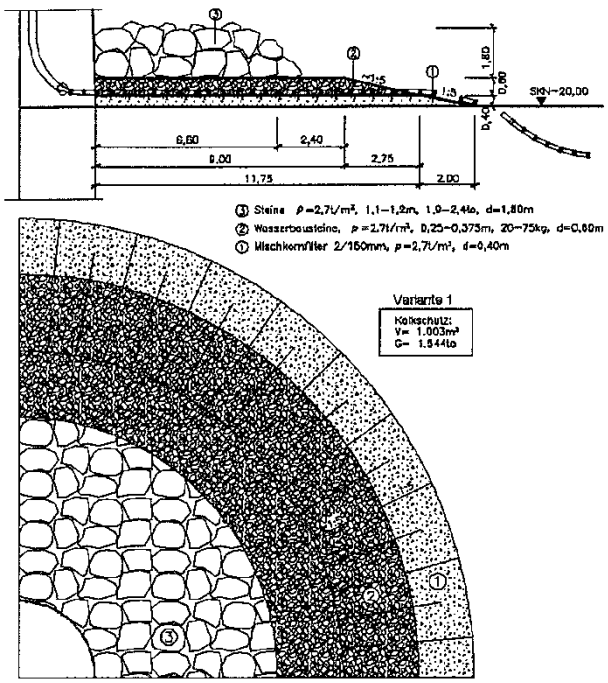


Shear stress
at the bottom:

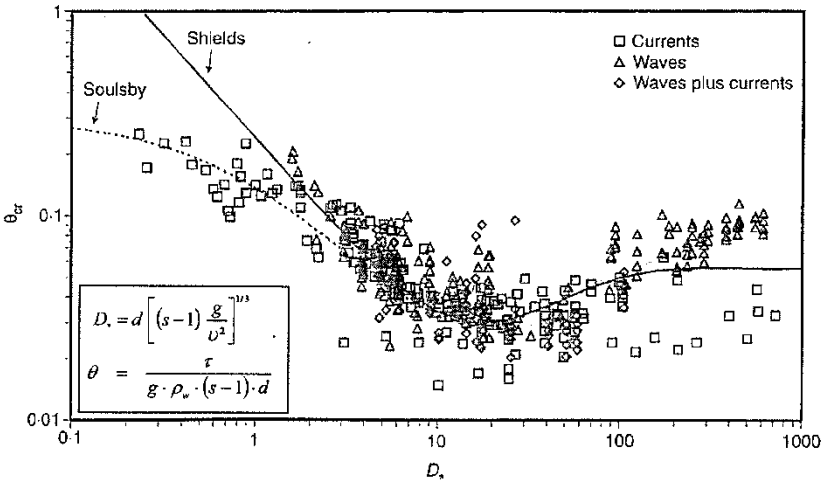


Criteria for economic foundations

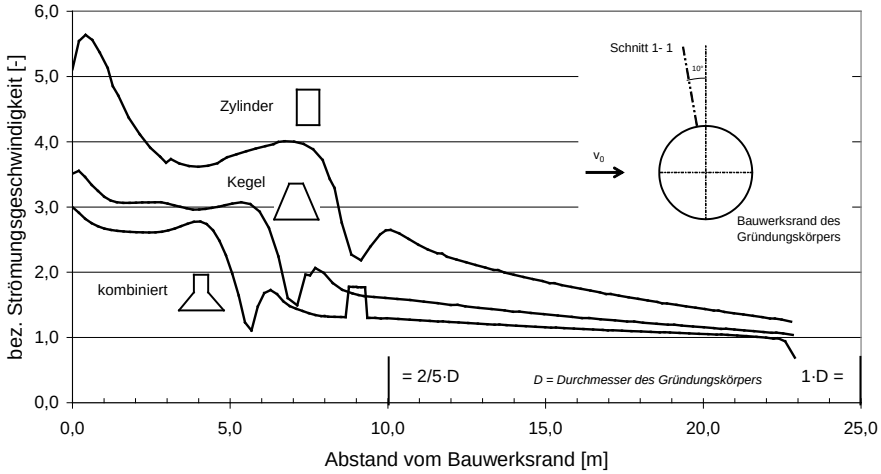
Scour protection



Construction of a scour protection [2]



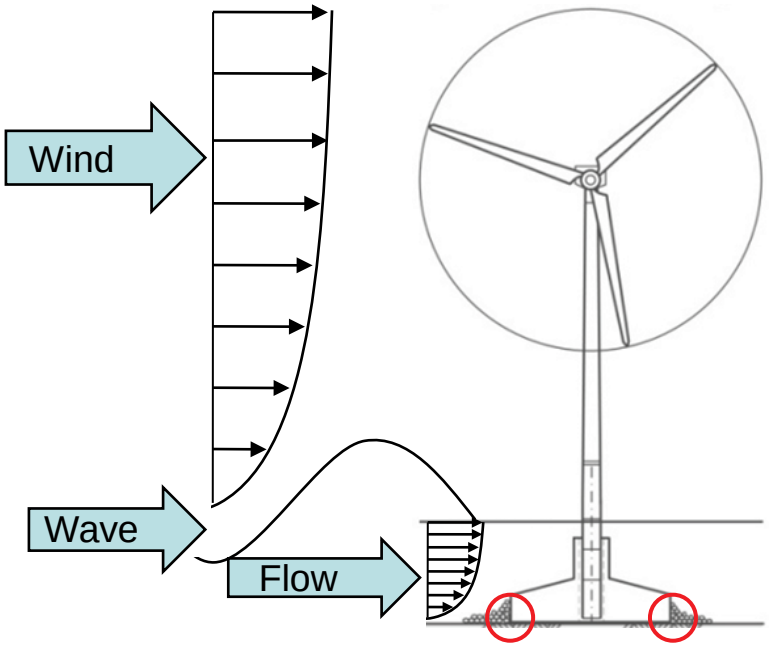
Limit shear stress according to the grain size [2]



[2] Tagungsband 5. FZK – Kolloquium, 8.3.2005

Structural behavior of gravity base foundation

Design loads on gravity base foundation

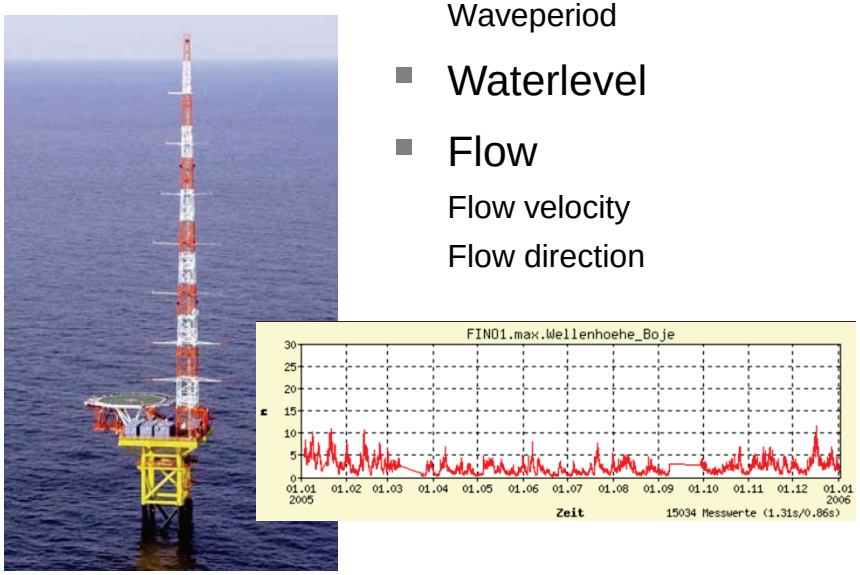


Detailed knowledge of the loads must be available to determine the structural behavior

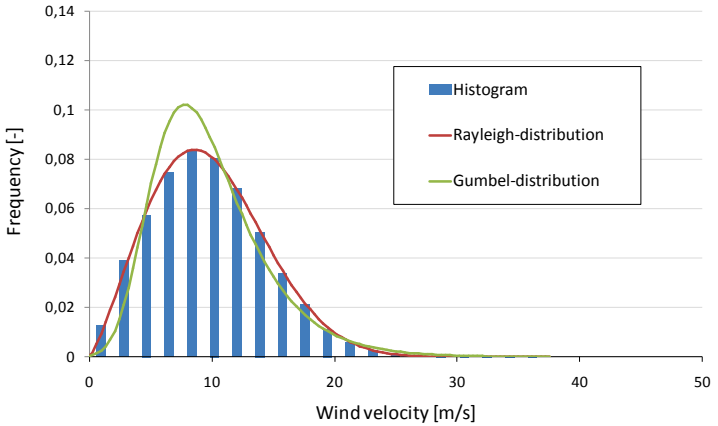
Structural behavior of gravity base foundation

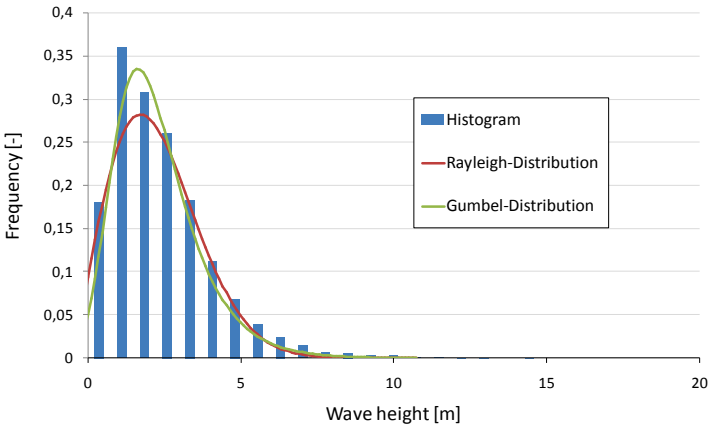
Action effects on foundations

- Wind data
  - Wind velocity
  - Wind direction
- Wave data
  - Wave height
  - Waveperiod
- Waterlevel
- Flow
  - Flow velocity
  - Flow direction



PDF of action effects





Structural behavior of gravity base foundation

Action effects on foundations

- Wind data
  - Wind velocity
  - Wind direction
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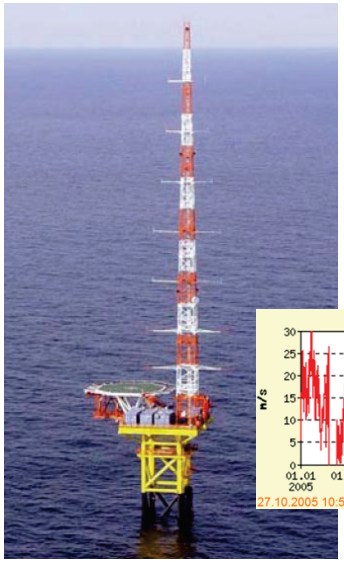
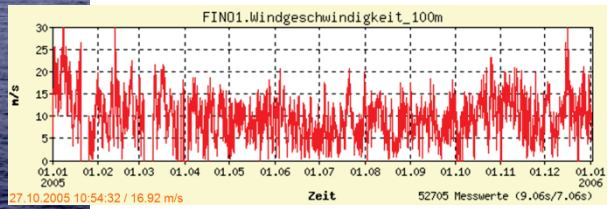
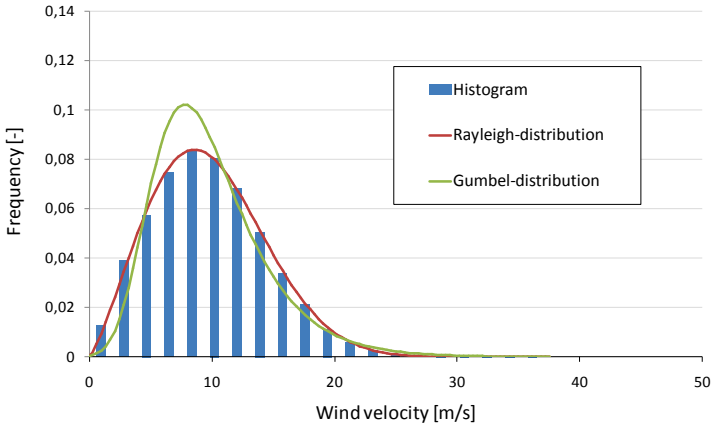
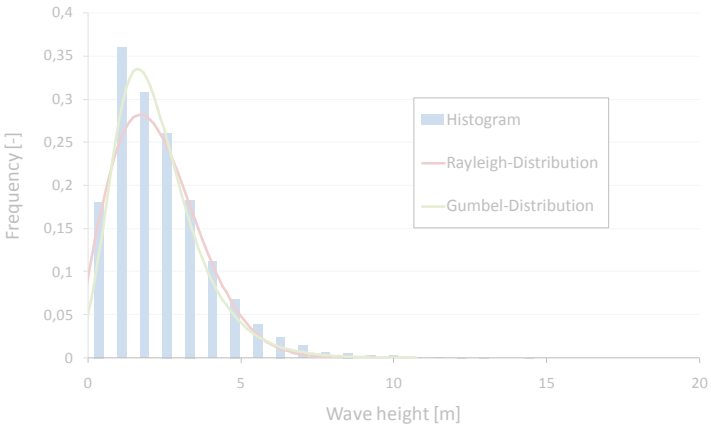
  - Wave height
  - Waveperiod
- Waterlevel
- Flow
  - Flow velocity
  - Flow direction





PDF of action effects

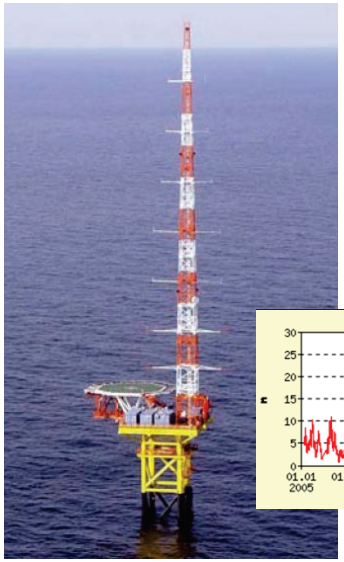


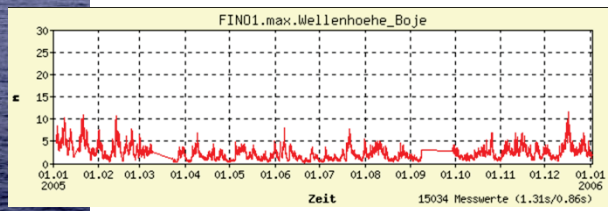


Structural behavior of gravity base foundation

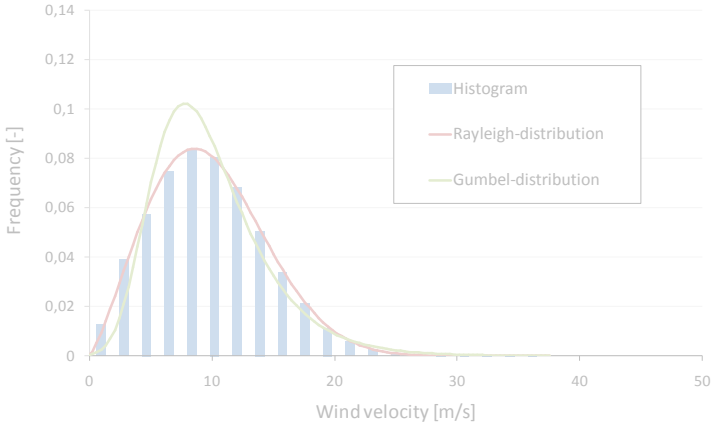
Action effects on foundations

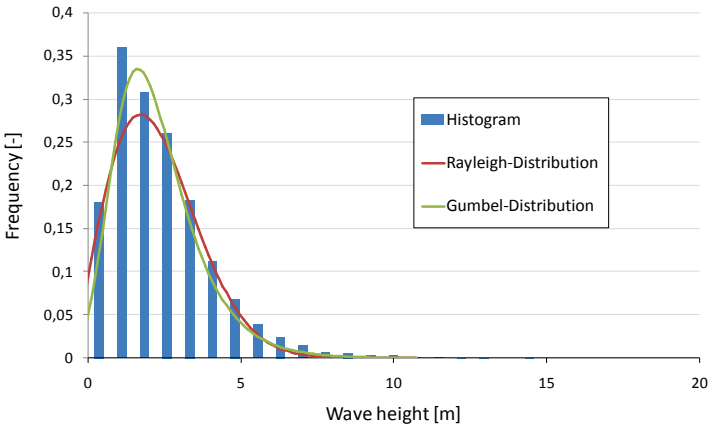
- Wind data
  - Wind velocity
  - Wind direction
- Wave data
  - Wave height
  - Waveperiod
- Waterlevel
- Flow
  - Flow velocity
  - Flow direction





PDF of action effects

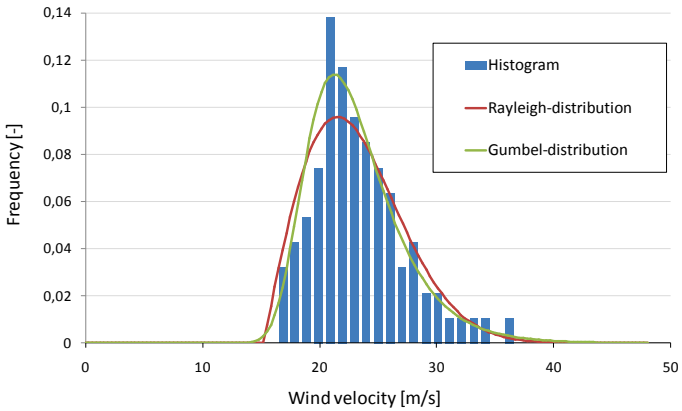


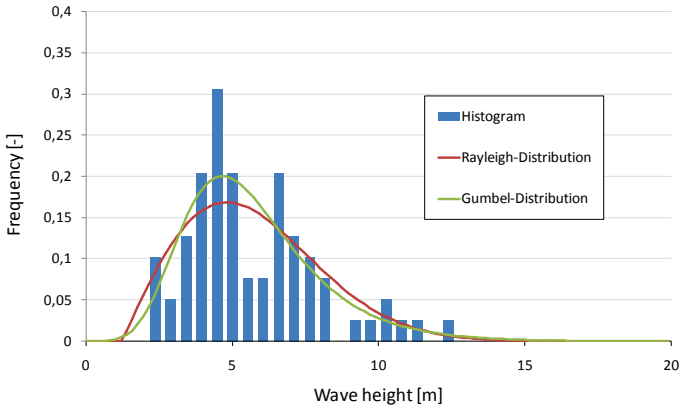


Structural behavior of gravity base foundation

Action effects on foundations

PDF of extreme action effects

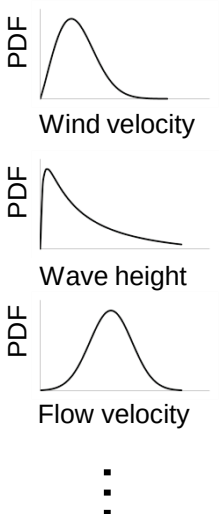




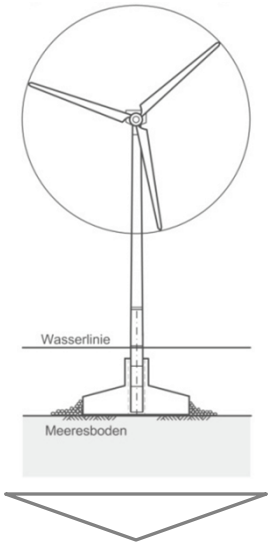
- Fractiles
  - $H_{max,50}$ = 19,01 m
  - V_{ref} = 42,06 m/s
- Statistical values of action effects
  - Mean value
  - Standard deviation
- Consideration of scattering loads

Structural behavior of gravity base foundation

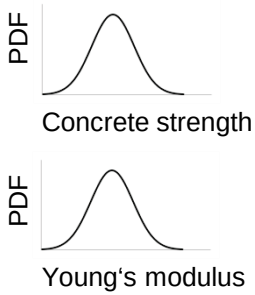
Scattering action effects

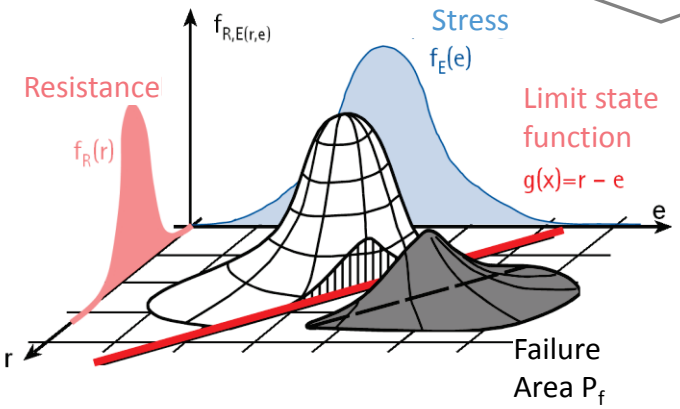


Calculation model



Scattering resistance effects





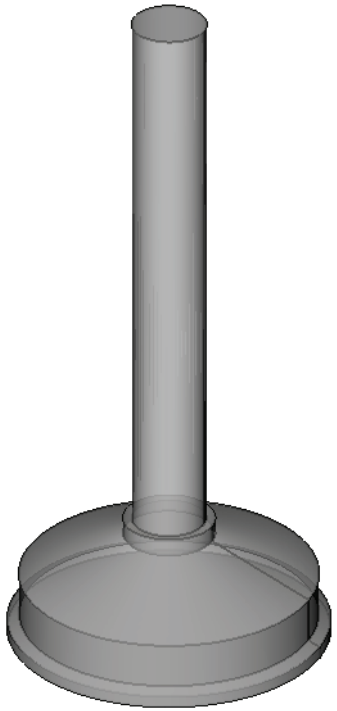
Failure area according to [3]

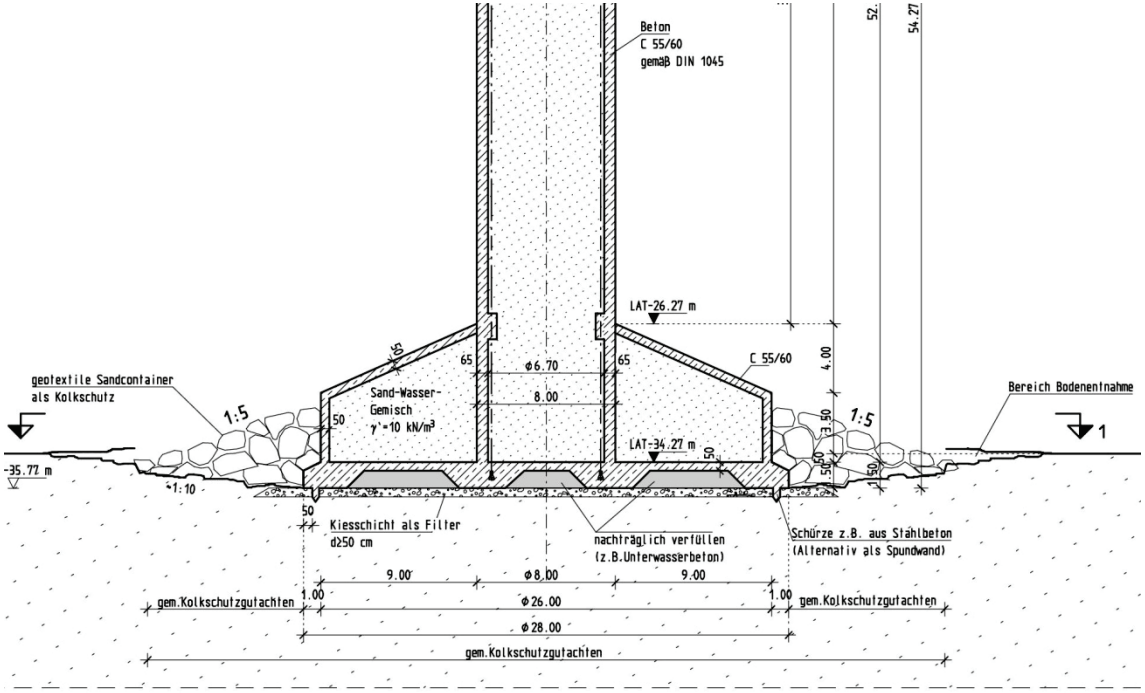
- Probability of failure
- Sensitivities
- Optimization of the foundation

[3] Hansen, M.: *Zur Auswirkung von Überwachungsmaßnahmen auf die Zuverlässigkeit von Betonbauteilen*

Structural behavior of gravity base foundation

Axial symmetric gravity base foundation (predesign)

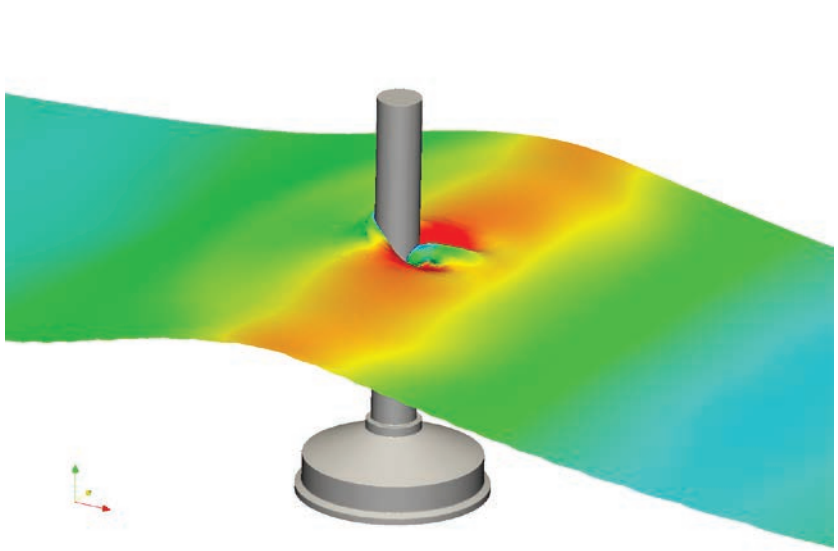


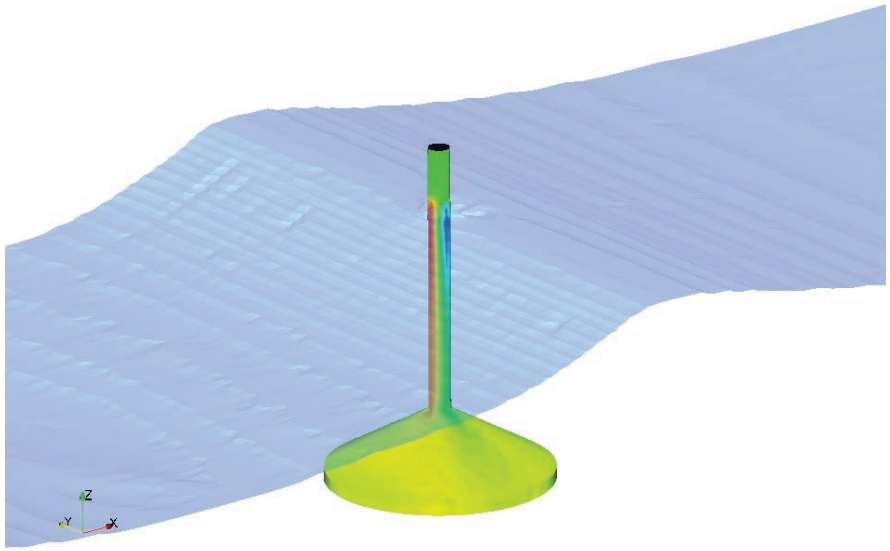


Structural behavior of gravity base foundation

Wave simulation

- Three-dimensional Reynolds-averaged Navier-Stokes equations
- Turbulence closure model: k-omega SST
- Wave generated by stream function theory

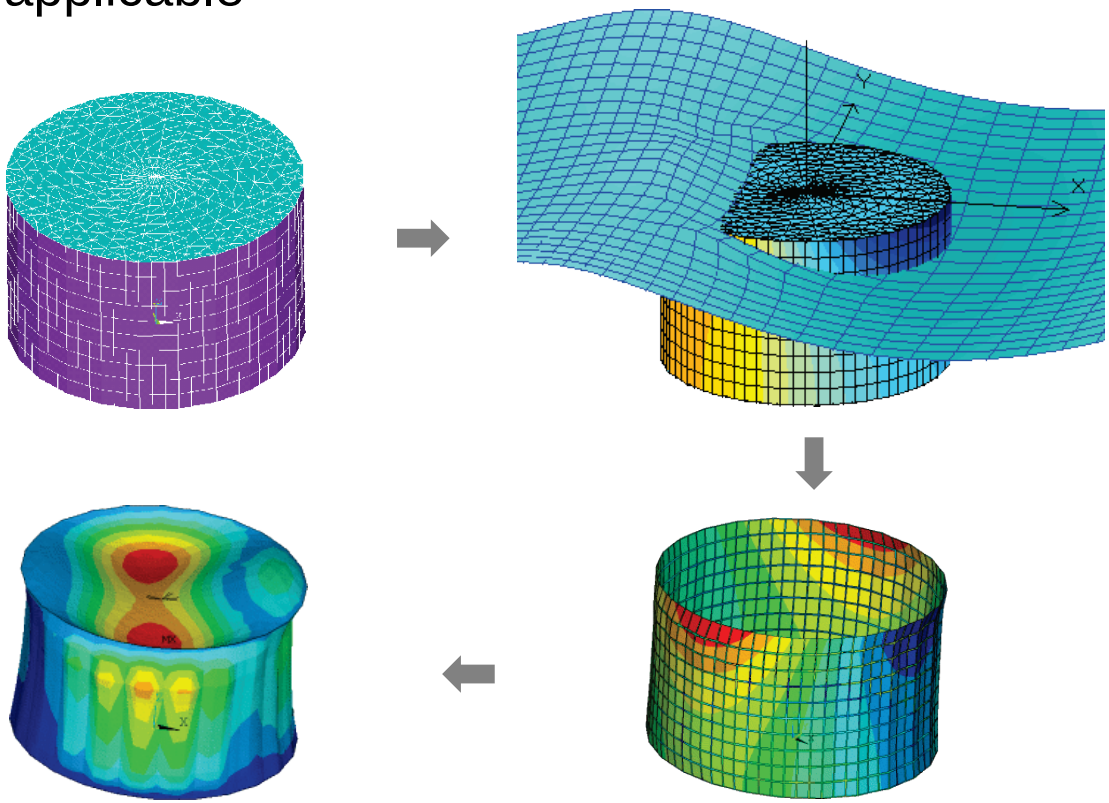




Structural behavior of gravity base foundation

Wave simulation

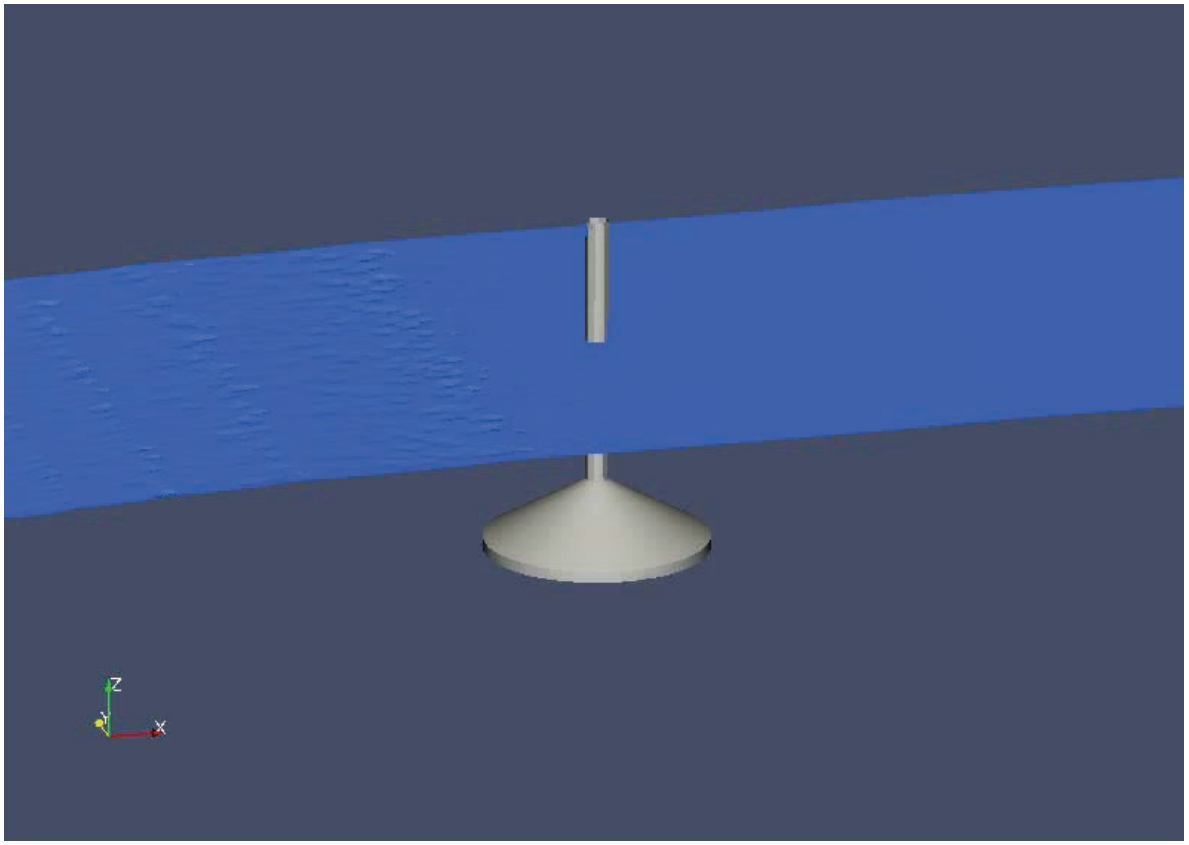
- For gravity base foundations the Morison equation is not always applicable



- Numerical simulation of wave or tide induced flow around the structure with a CFD model
- Project the resulting pressure on the mesh of a numerical mechanical model of the foundation
- Calculate stress and deformation with a suitable constitutive model

Structural behavior of gravity base foundation

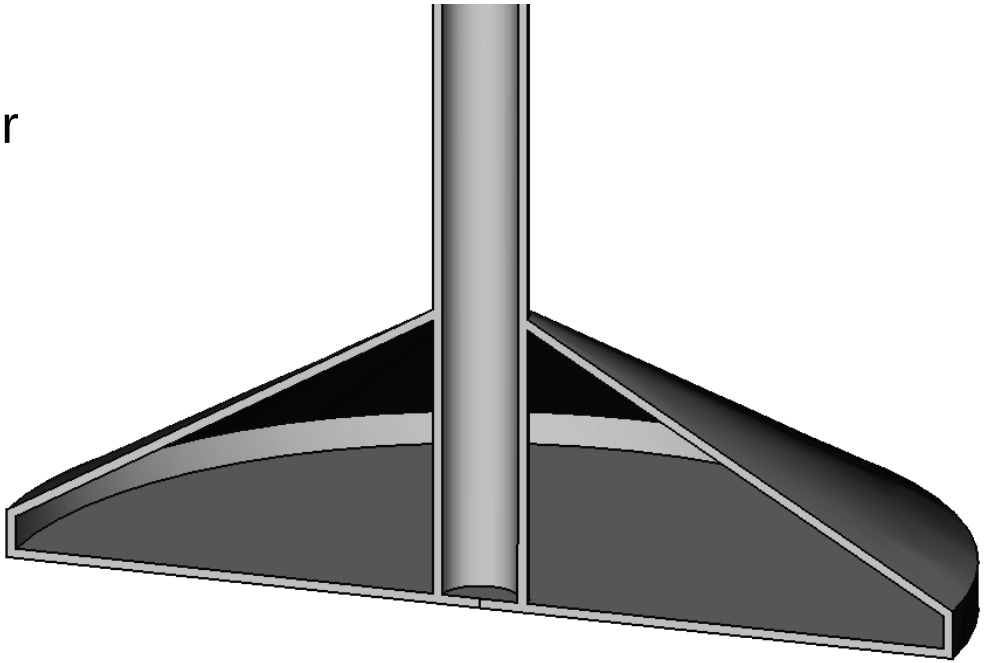
Wave simulation



Structural behavior of gravity base foundation

Structural mechanical model

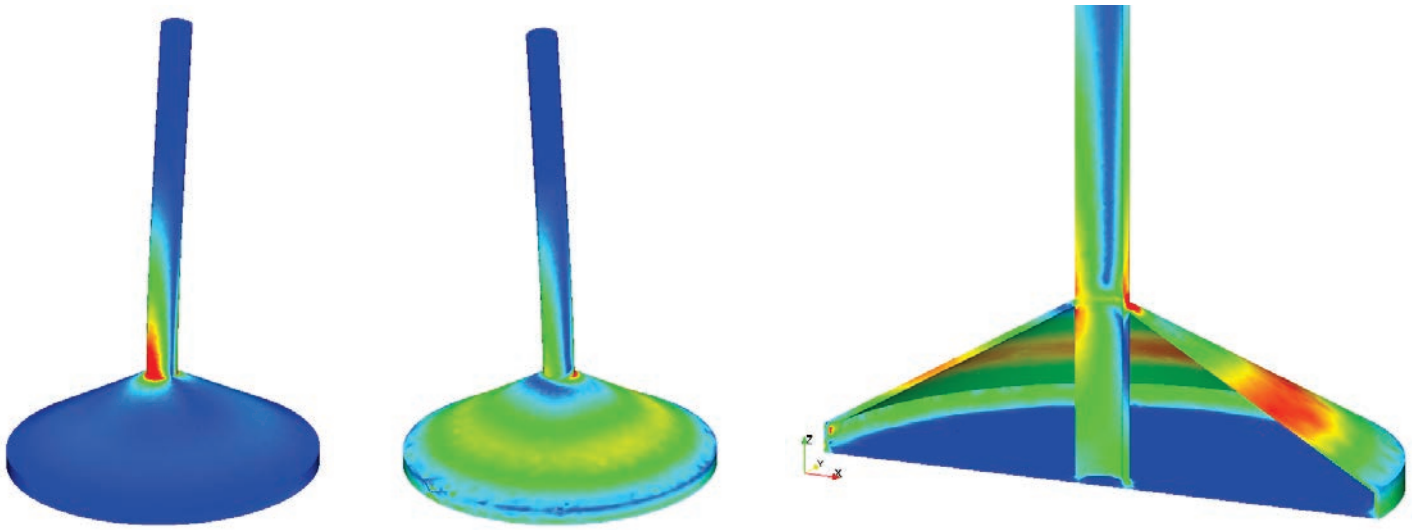
- Three-dimensional geometry of the foundation is taken into account
- Linear elastic approach for first assessment



Structural behavior of gravity base foundation

Structural mechanical model

- Results of stress and deformation at different wave positions



Conclusion

- 3D-CFD-Model
- Economic foundation design
- This requires a precise knowledge of the loads
- Integrated design

Future development

- Concepts for fatigue design under wave loads
- Coupling of soil and the structural mechanical model
- Transient analyses under wave loads

Thank you for your attention!