2005
COPENHAGEN
OFFSHORE WIND
International Conference & Exhibition

26-28 October 2005
Copenhagen

ForWind
Center for Windenergy Research

Can Jackets and Tripods Compete with Monopiles?

Prof. Peter Schaumann

Dipl.-Ing. Cord Böker

Institute for Steel Construction
University of Hannover

COW'05

27 October 2005, Copenhagen

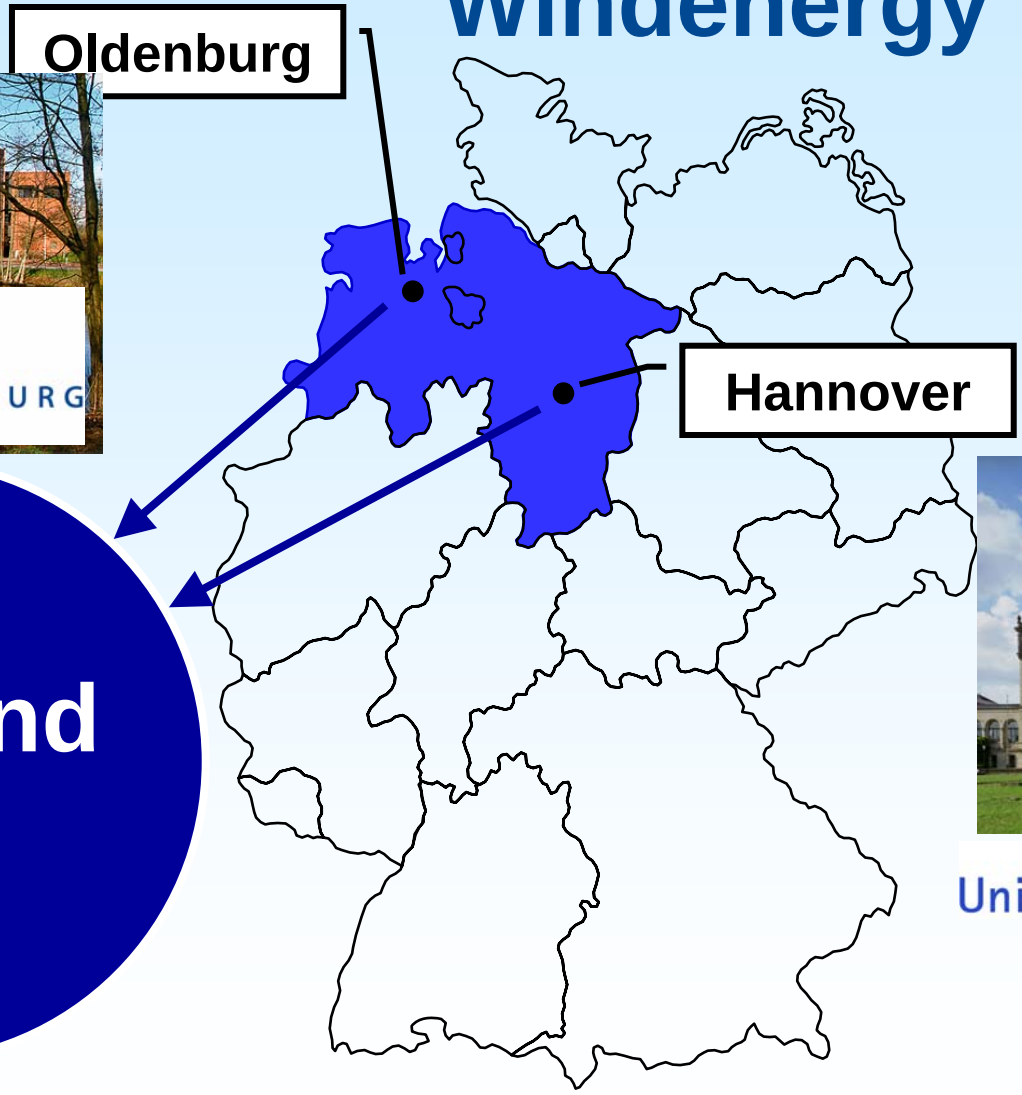
ForWind
Center for Windenergy Research

Assembly in Arklow Bank

Can Jackets and Tripods Compete with Monopiles?

- Introduction
- General Considerations
- Parameter Study
- Summary and Outlook

ForWind Center for Windenergy Research



ForWind
2003

Universität Hannover

Offshore Windenergy Research

at University of Hannover

GIGAWIND-project:

- Fluid Mechanics Institute
- Institute for Structural Analysis
- Institute for Foundation and Soil Mechanics
- Institute for Steel Construction

Aims of the project:

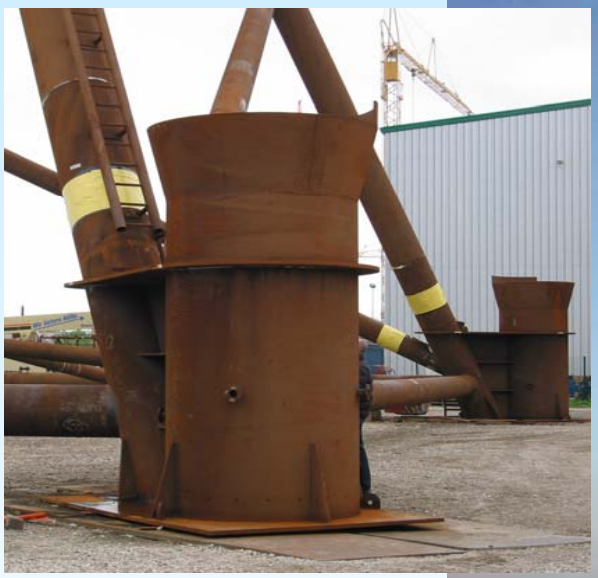
- Development of methods and tools for the design of offshore wind energy converters under ultimate and fatigue loads
- Converter size: up to 5 MW
- Water depth: 20 to 50 m

supported by the German government (2000-2007)

Offshore Windenergy Research

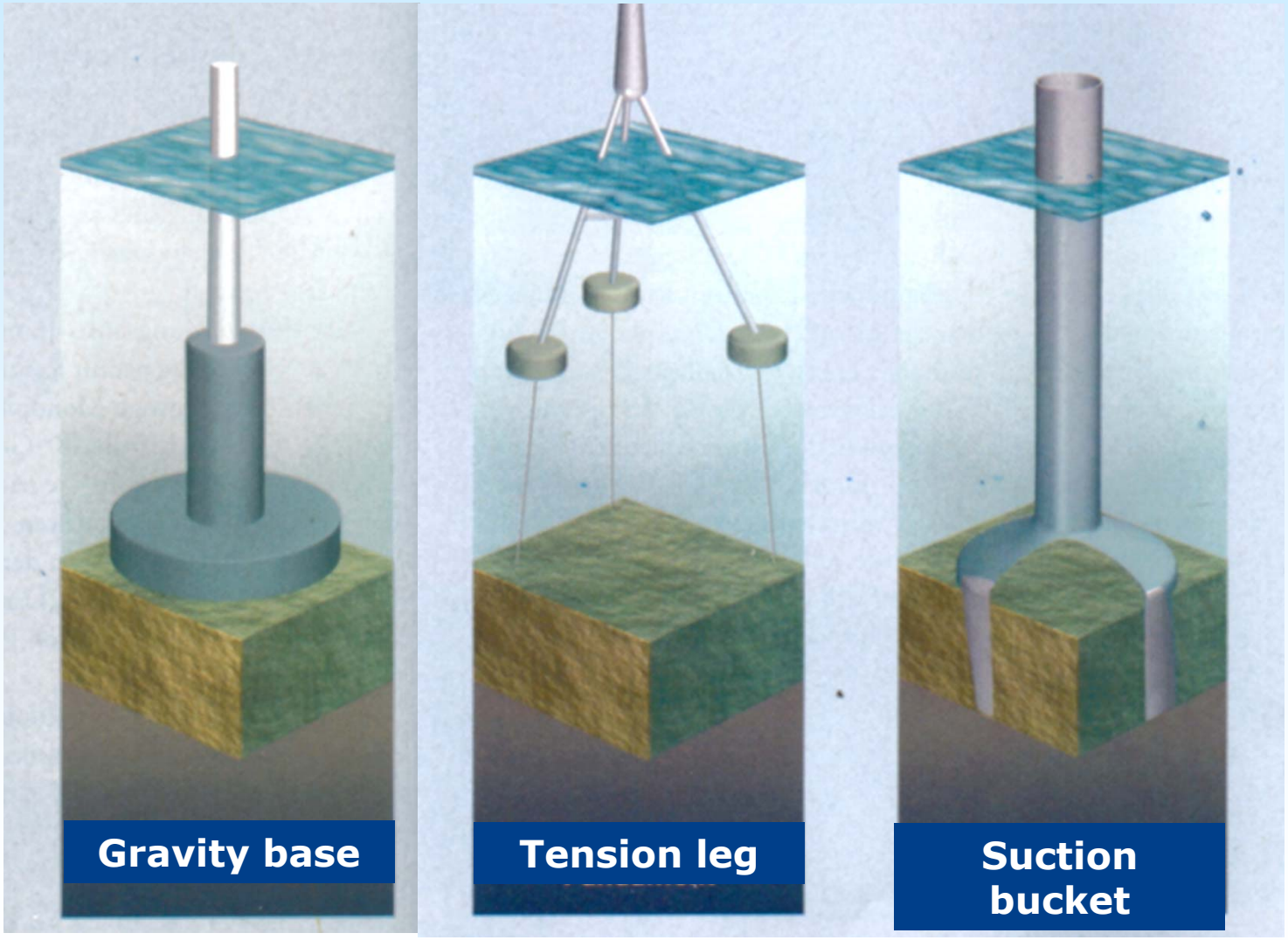
at University of Hannover

- Scour - large wave channel
  Length: 324 m, Width: 5 m
  Wave height: ≤ 2,5 m



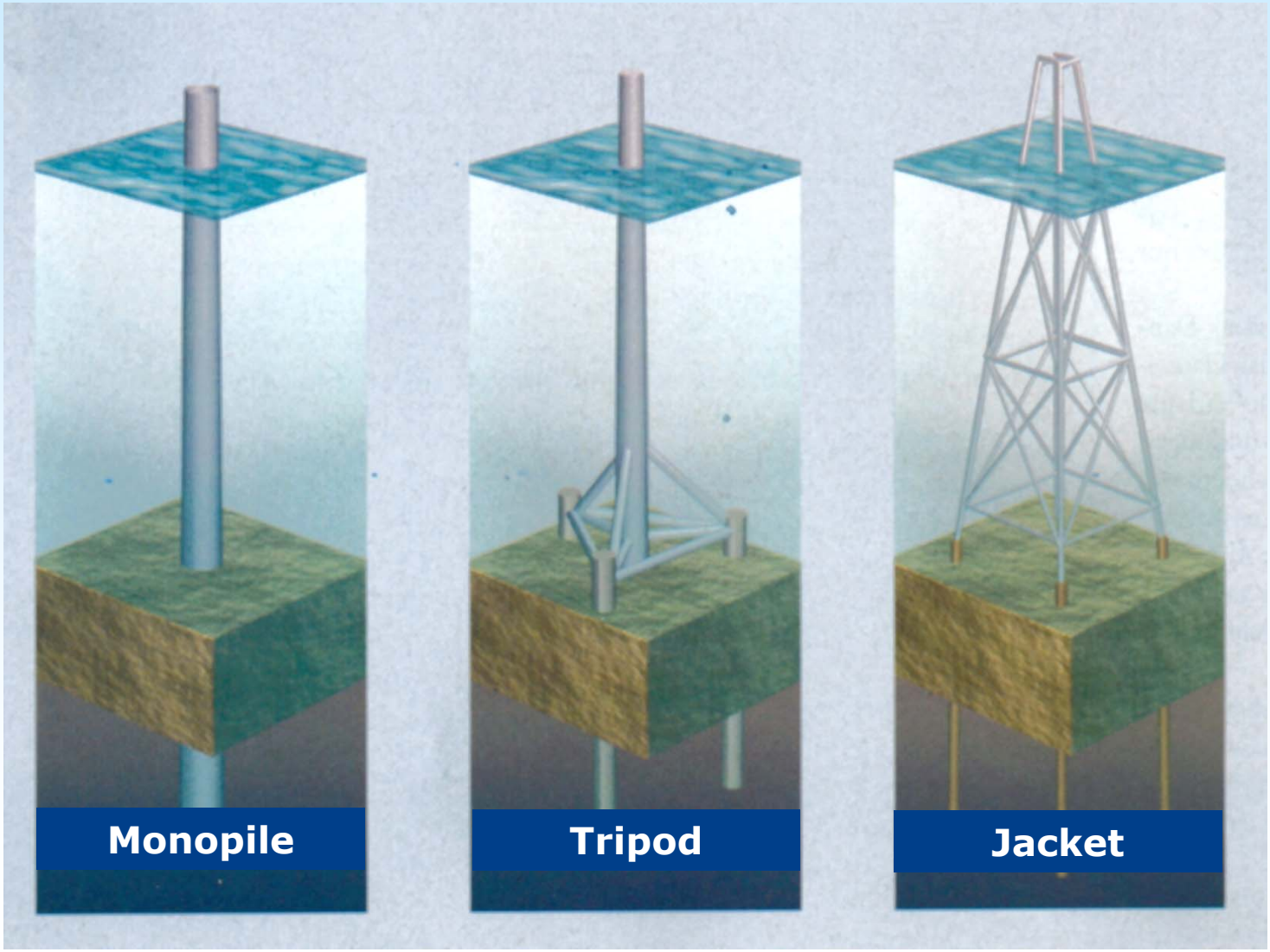
- Validation of fatigue design approaches with FINO 1 data

Types of Support Structures



Picture:
neue Energie

Types of Support Structures



Can Jackets and Tripods compete with Monopiles?

Picture:
neue Energie

Approved Windfarm Projects

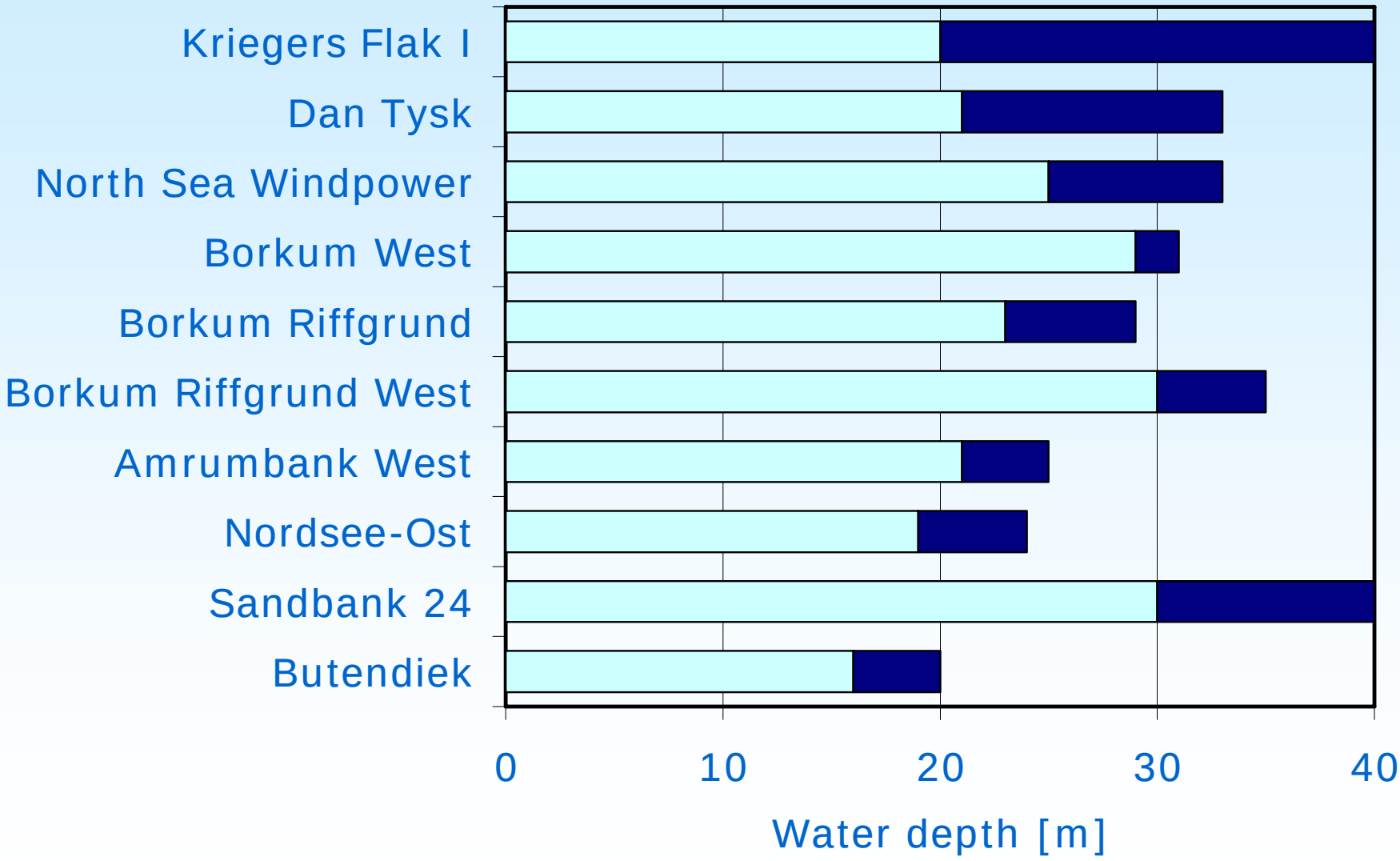
German Exclusive Economic Zone

Project	Area	Water Depth [m]	Distance to Coast [km]	Number of Turbines	Max. Turbine Size [MW]
Butendiek	North Sea	16-20	34	80	3
Sandbank 24	North Sea	30-40	90	80	5
Nordsee-Ost	North Sea	19-24	30	80	5
Amrumbank West	North Sea	21-25	35	80	5
Borkum Riffgrund West	North Sea	30-35	40-50	80	3,5
Borkum Riffgrund	North Sea	23-29	34	77	3
Borkum West	North Sea	30	43-50	220	5
North Sea Windpower	North Sea	25-33	45	48	5
Dan Tysk	North Sea	21-33	70	80	5
Kriegers Flak I	Baltic Sea	20-40	30	80	5

Information taken from www.bsh.de

Approved Windfarm Projects

German Exclusive Economic Zone

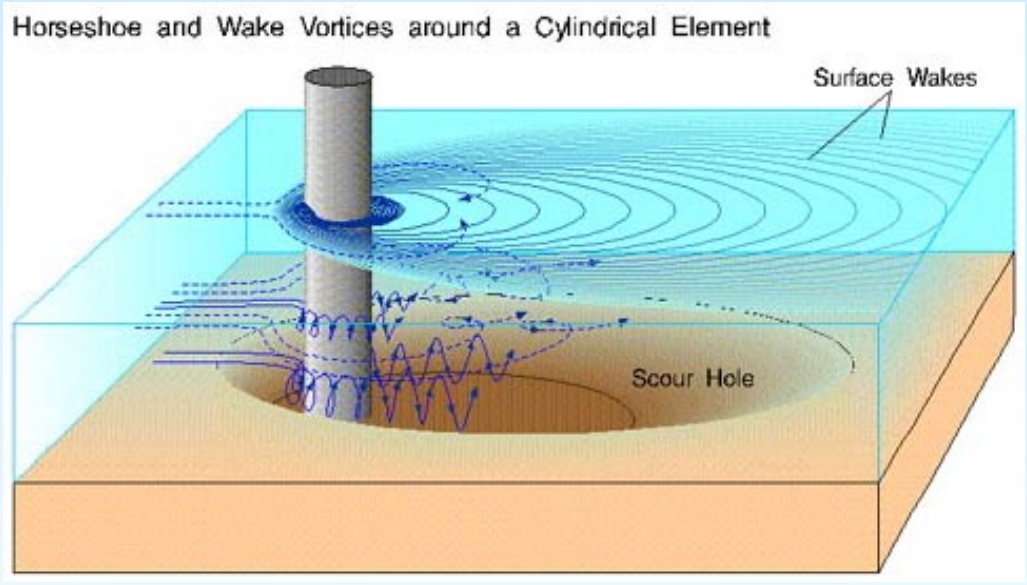


Evaluation of Substructures

- Purpose:
  Evaluation of Monopile, Jacket and Tripod
  with respect to technical and economical feasibility
- Basis:
  Expert´s opinion, interviews, reports, publications,
  presentations, own investigations
- Methodology
  Consideration of 14 features of different importance
  (factor 3=high, 2=medium, 1 low)
  Ranking of the type of substructure
  (3=best, 1=second, 0=last)

Evaluation of Substructures

Features examples – scour (importance 3)

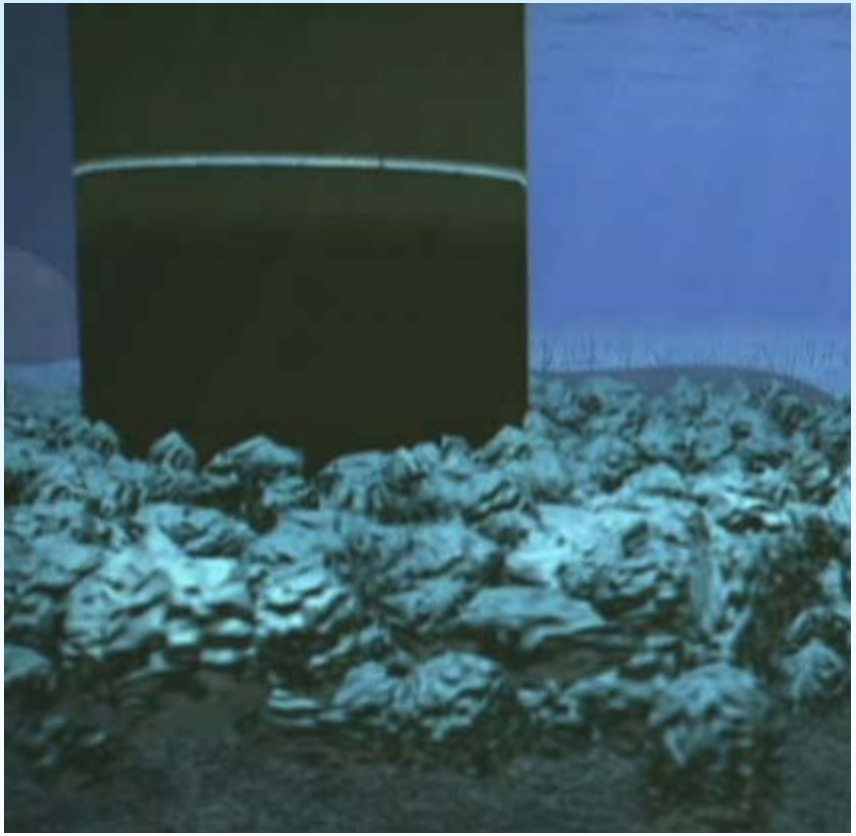


without scour protection:

DNV: $D_{scour} = 1.3 * D_{pile}$

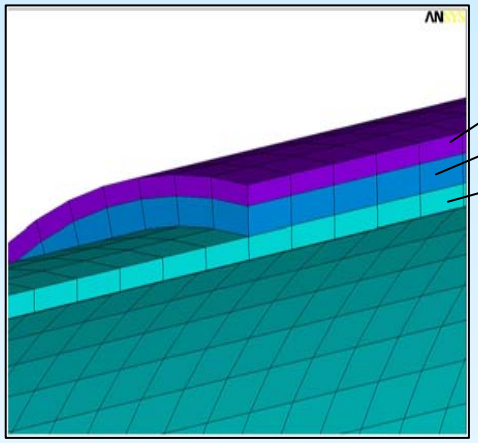
GL: $D_{scour} = 2.5 * D_{pile}$

with scour protection:

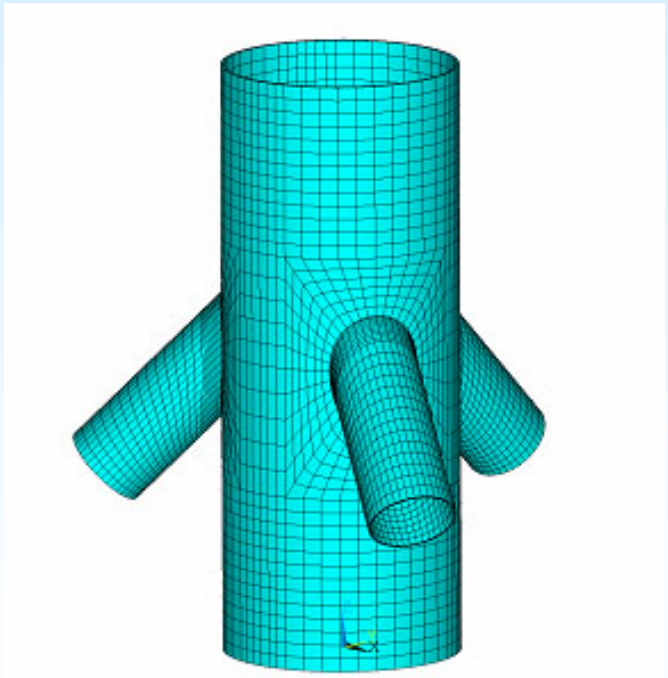


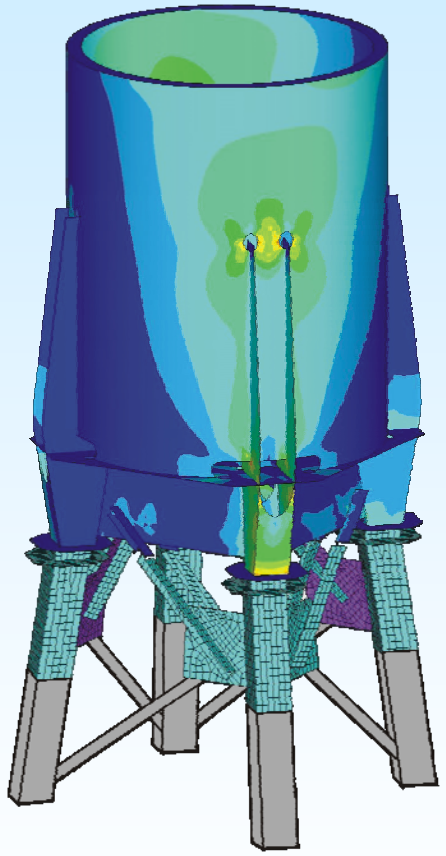
Evaluation of Substructures

Features examples – joints (importance 1)



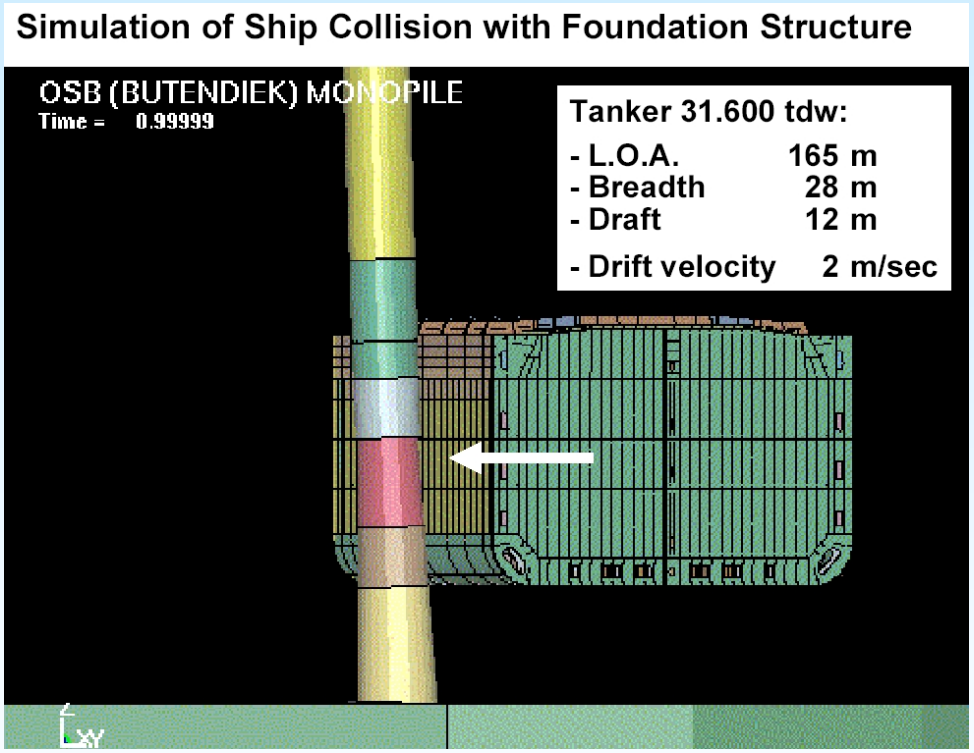
Grouted joint:

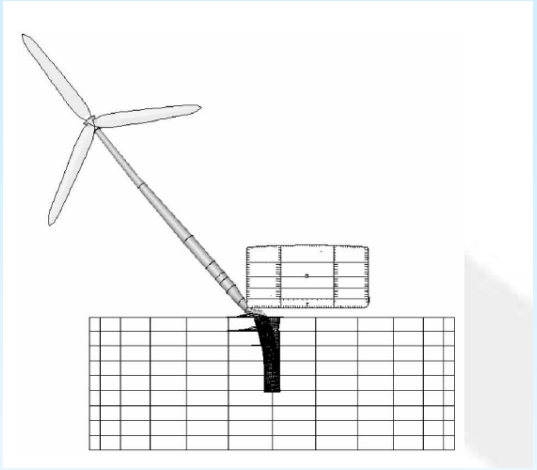


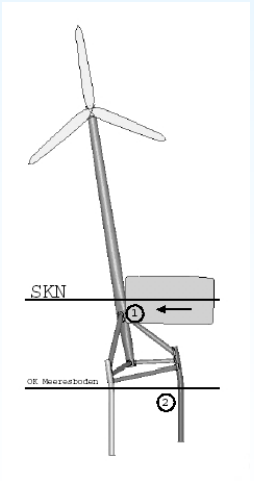


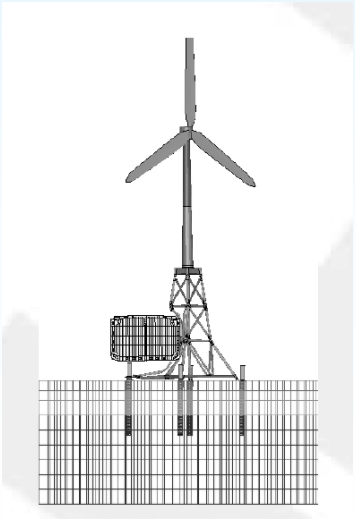
Evaluation of Substructures

Features examples – ship collision (import. 2)





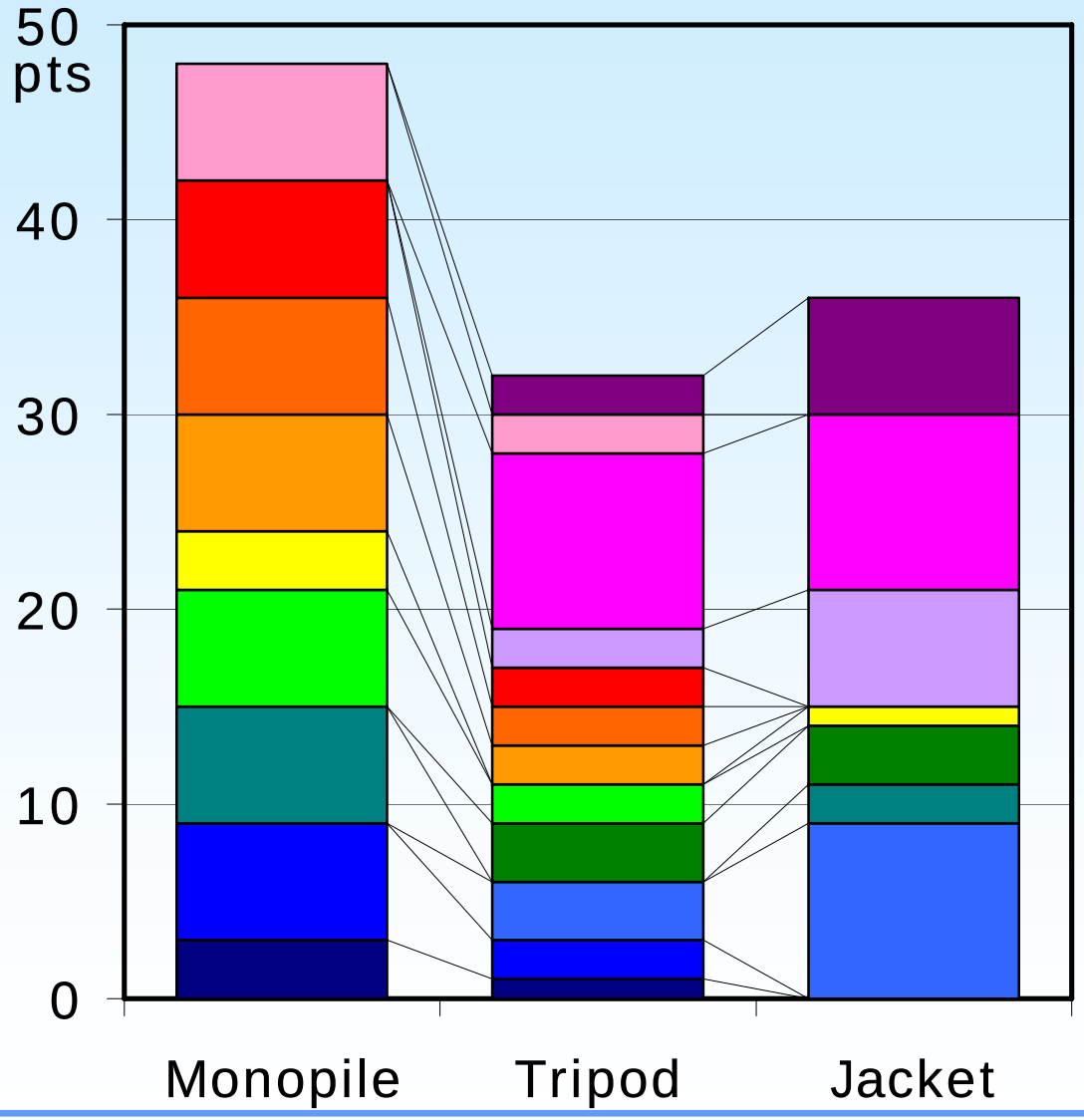




research performed by
Lehmann/Biehl
TU HH, Germany, 2004

Evaluation of Substructures

Results



Which concept is preferable in terms of:

- Overall weight to be expected
- Unit price per tonne of steel
- Dependancy on soil conditions
- Deflection at tower top
- Deconstruction after lifetime
- Installation procedure
- Serial production
- Complexity of joints (fatigue)
- Design experience with OWECS
- Availability of installation equipment
- Ship collision
- Scour
- Corrosion protection / allowance
- Transportability

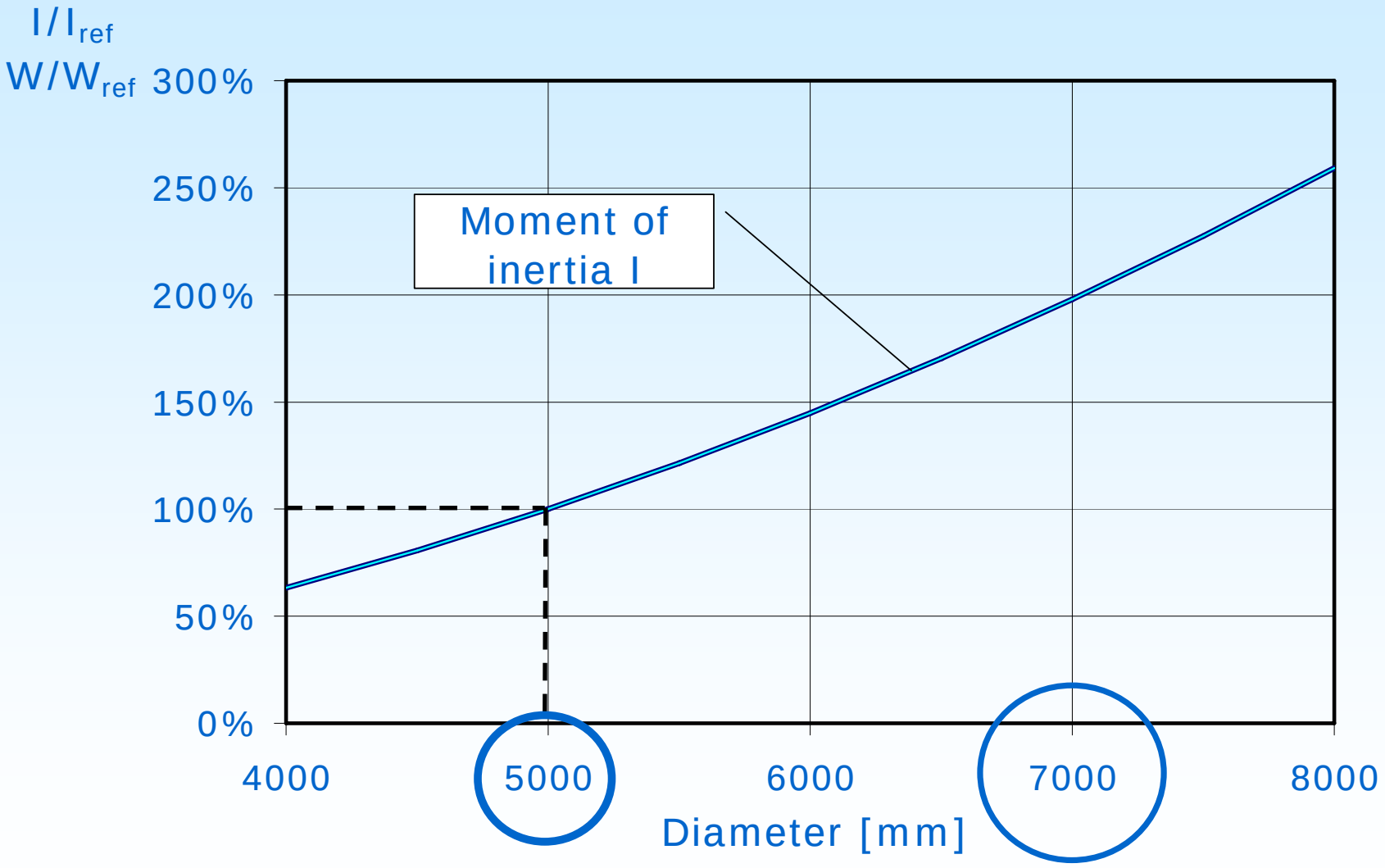
General Considerations

Cross section properties

- Limit states:
  ULS, FLS, SLS
- Basis:
  Monopile cross-section (D, t),
  D_{ref} = 5000mm, t_{ref} = 50mm
  Cross-section area is kept constant
- Investigation consideration considering
  stiffness -> I -> natural frequency (SLS)
  resistance -> W* -> maximum load carrying resistance

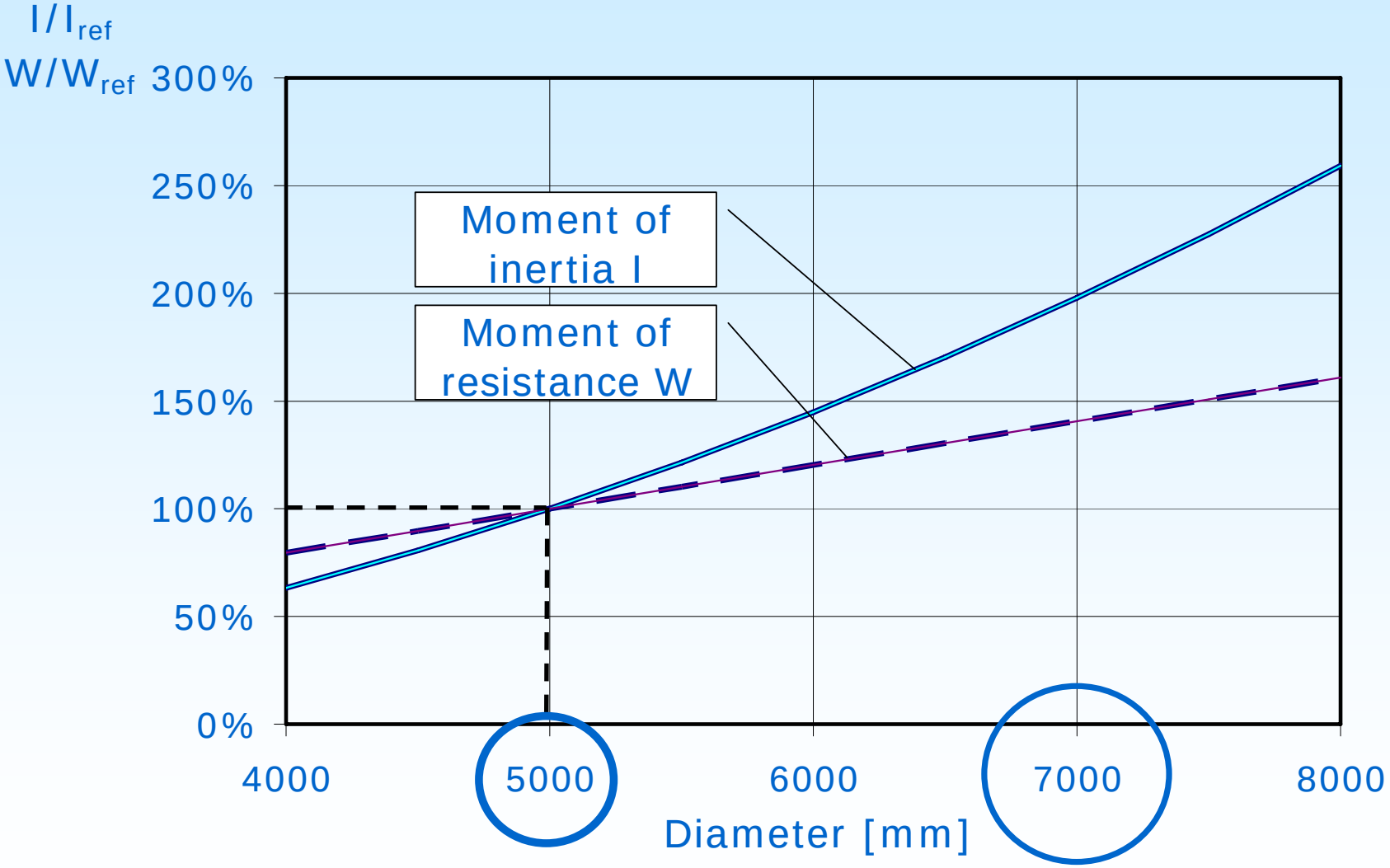
General Considerations

Cross section properties



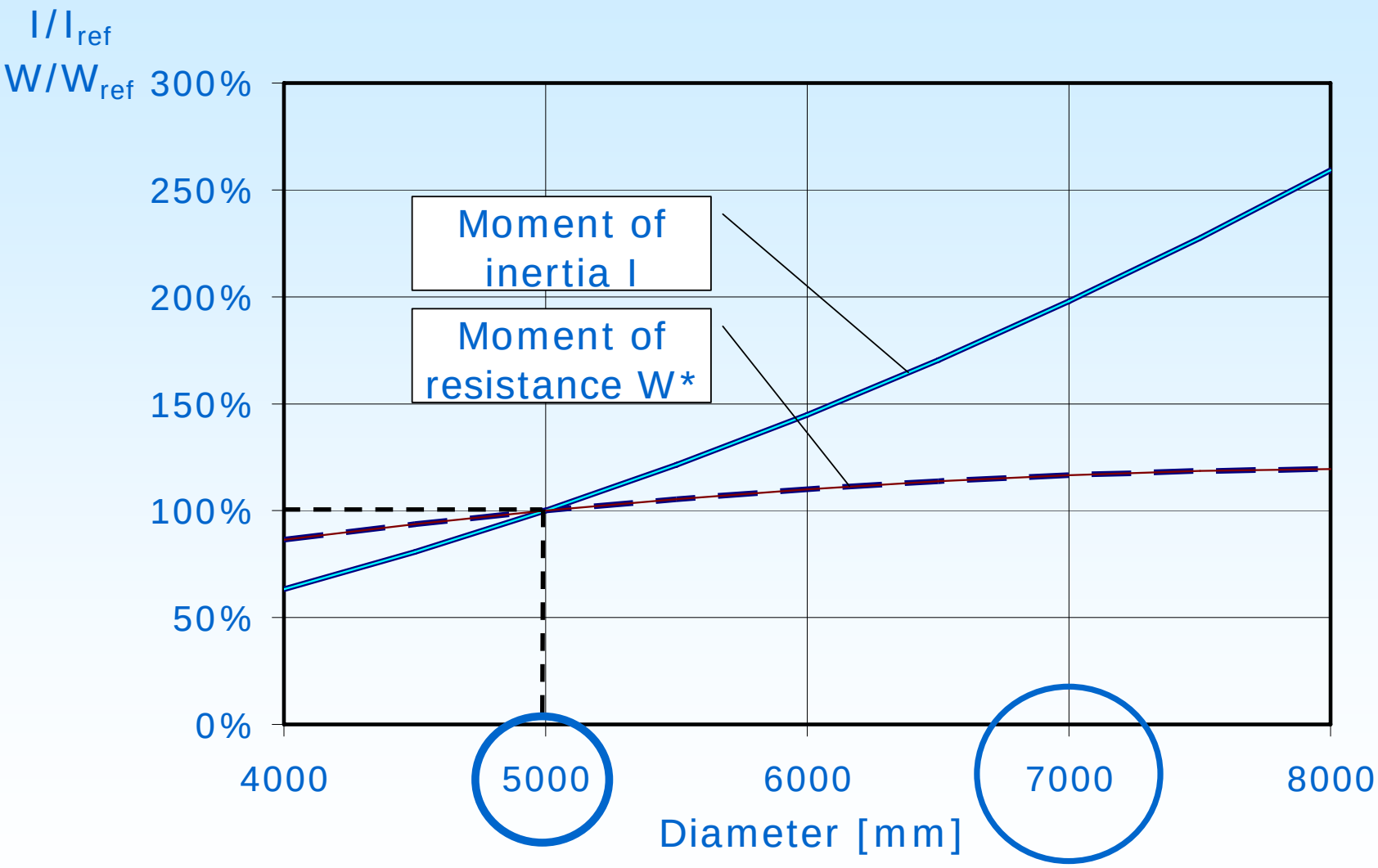
General Considerations

Cross section properties



General Considerations

Cross section properties



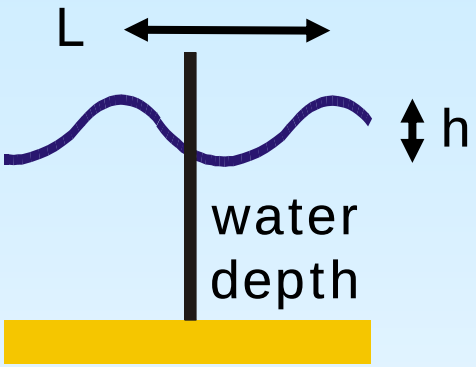
Monopile – Parameter Study

Basic assumptions

- Purpose
  Determination of dimensions and weight of different Monopile substructures
- Parameters
  Turbines: 3 / 5 MW, head mass 280 / 400 t
  water depths from 10 to 50m
  soil conditions: acc. to FINO 1 location
  wave conditions: H_{max}=20m, T_{rel}=16sec
- Methodology
  SLS: target value of 0.28 Hz 1. natural frequency
  ULS: buckling resistance
  FLS: fatigue resistance
  Soil capacity: “no-toe-kick“ criterion

Monopile - Parameter Study

Structural response under wave loadings



real wave

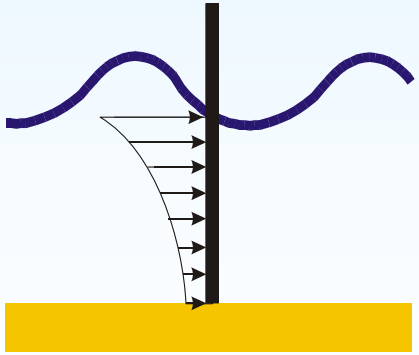
wave theories

different order

kinematics of water particles
- velocity
- acceleration

HanOff

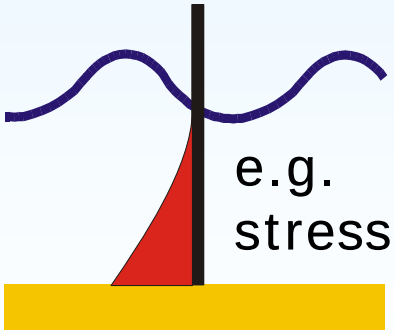
Morison formula



loading of structure

static or dynamic

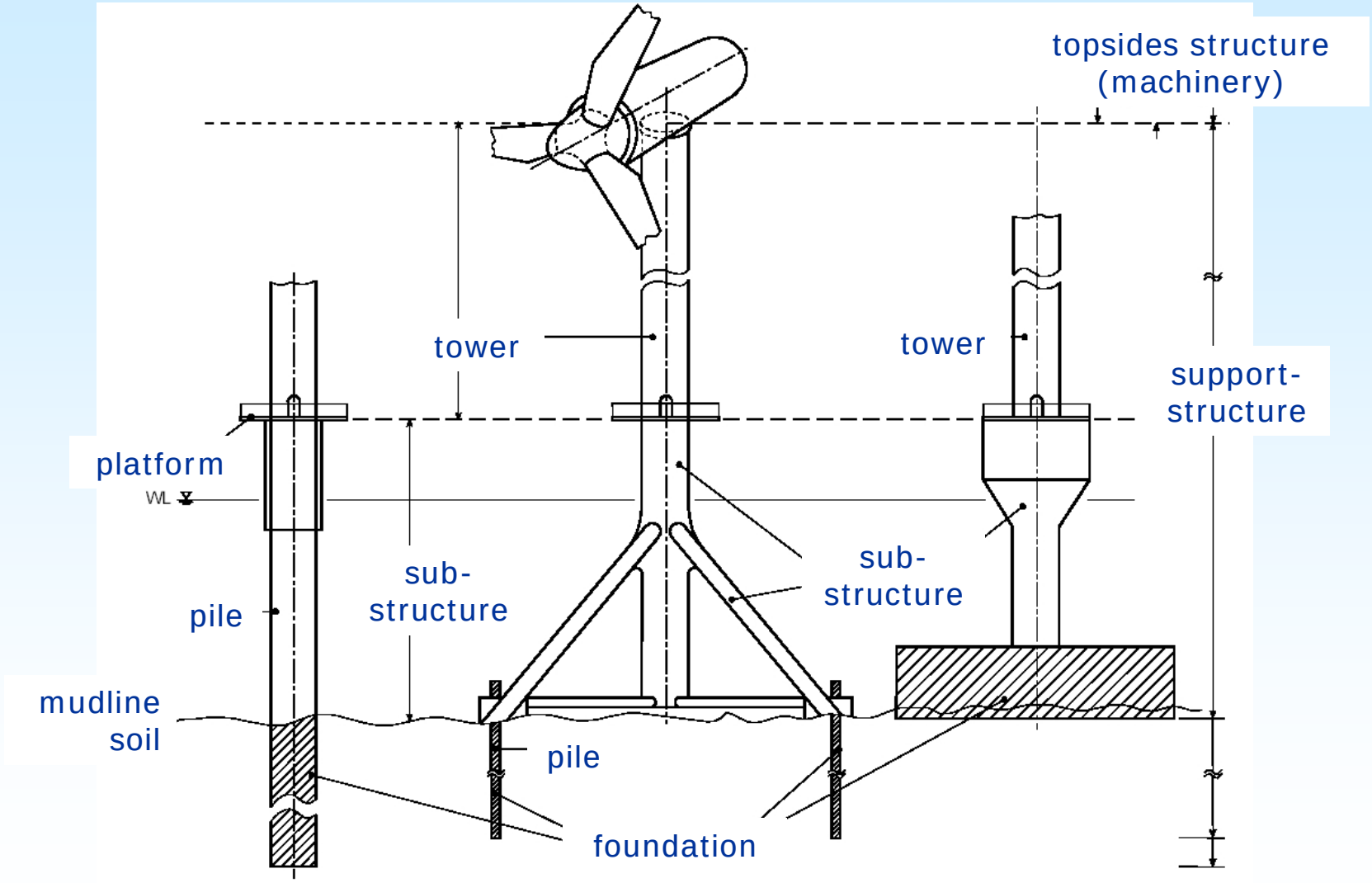
calculation methods
- deterministic approach
- time domain
- frequency domain



reaction of structure

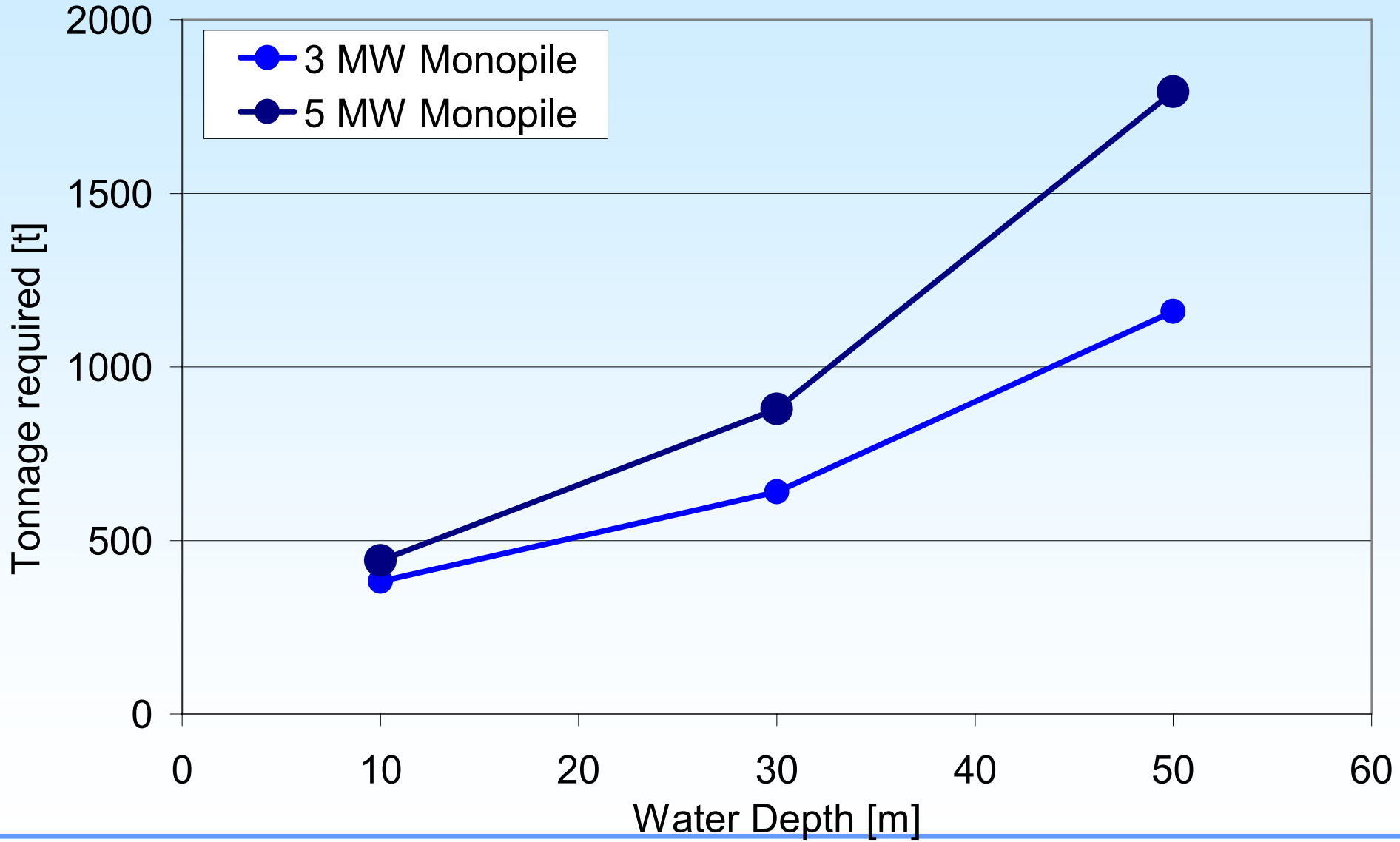
Monopile – Parameter Study

Definitions acc. to GL



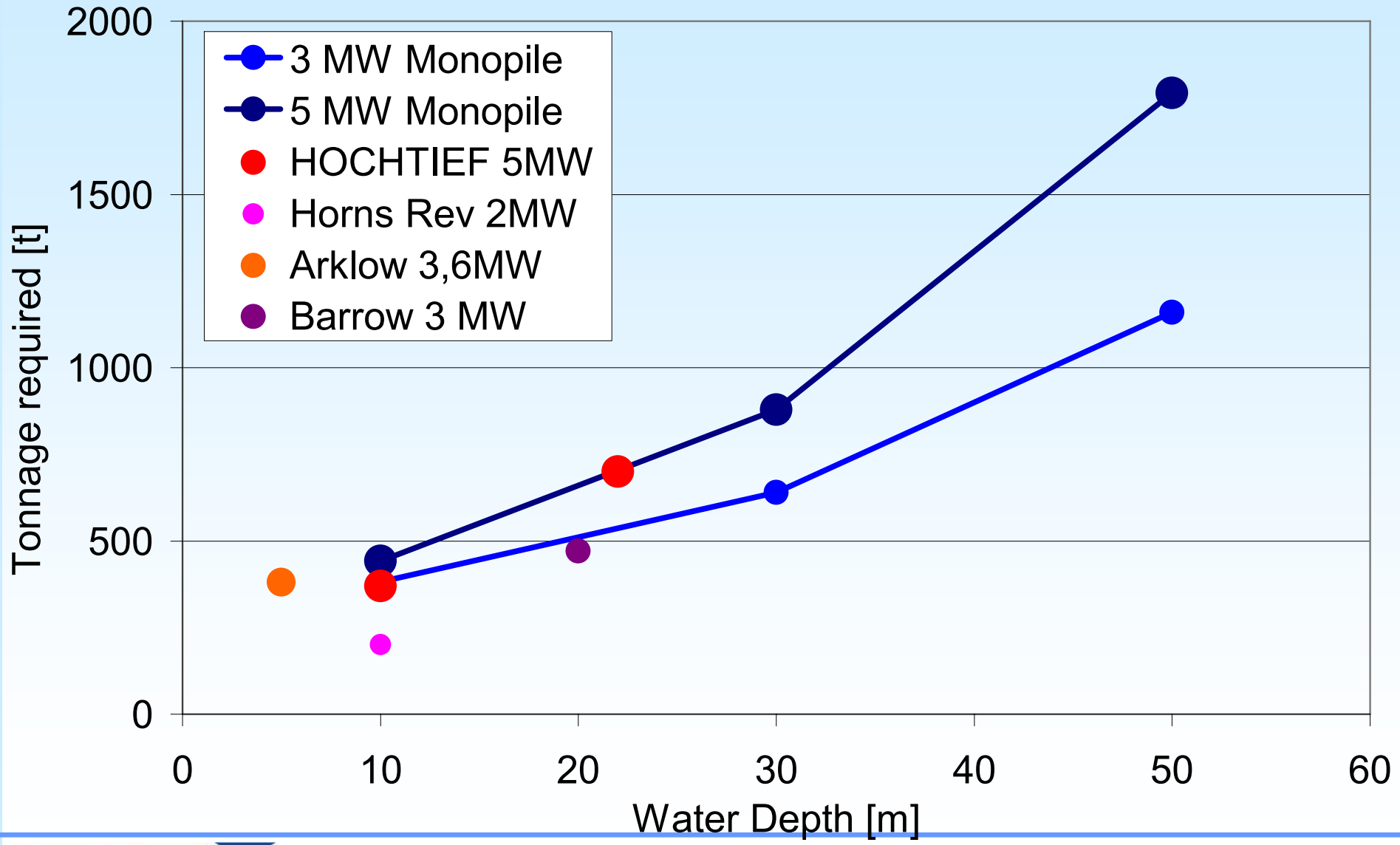
Monopile - Parameter Study

Results



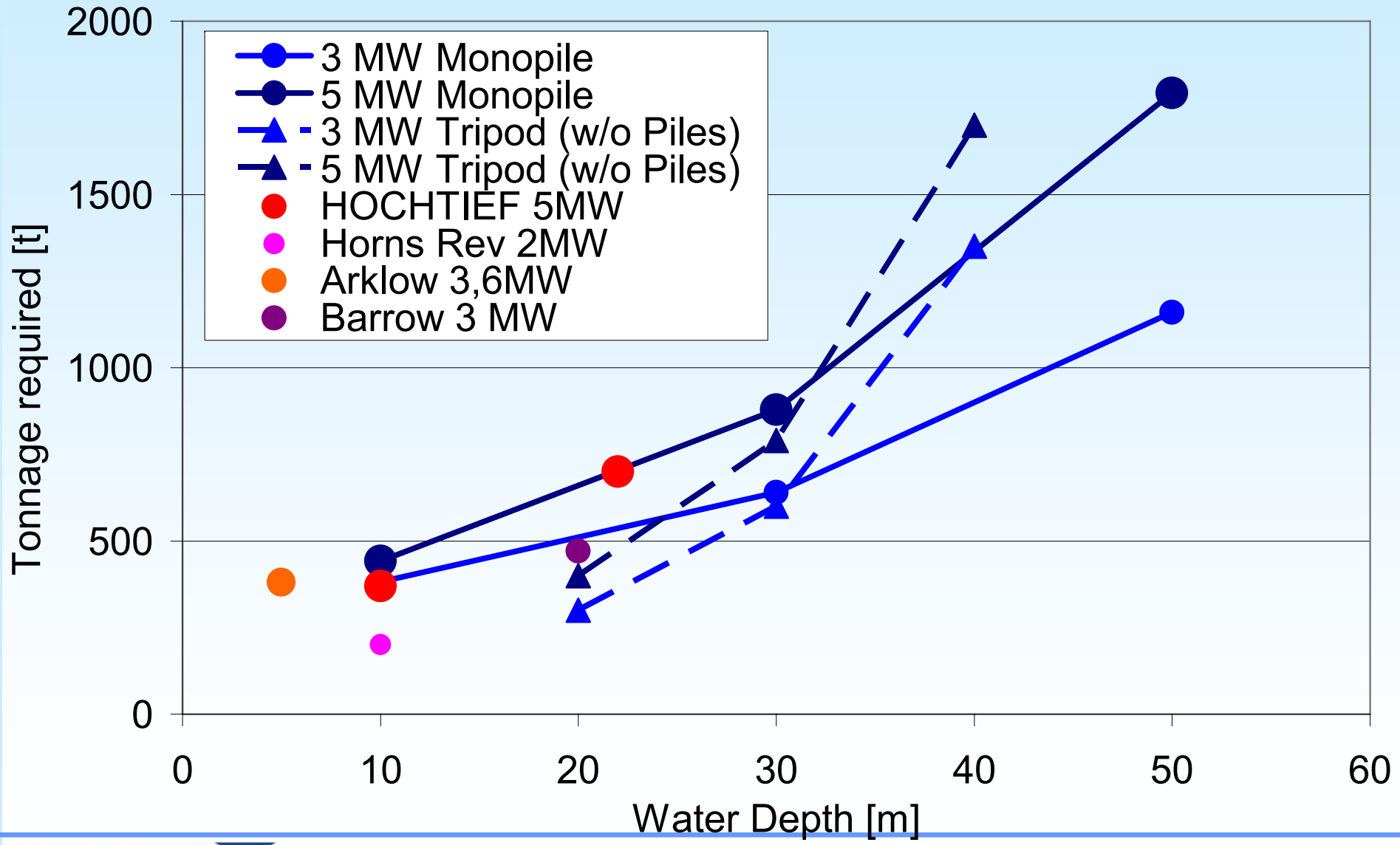
Monopile - Parameter Study

Results



Monopile - Parameter Study

Results

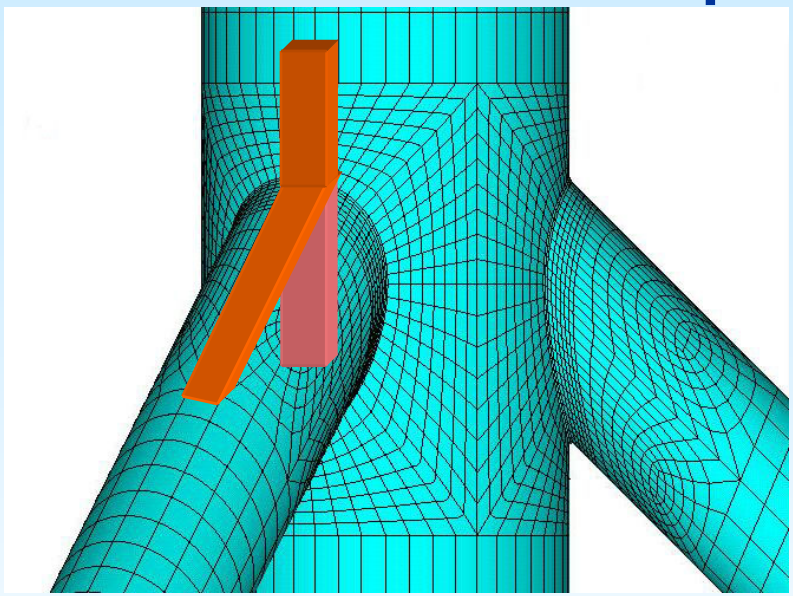


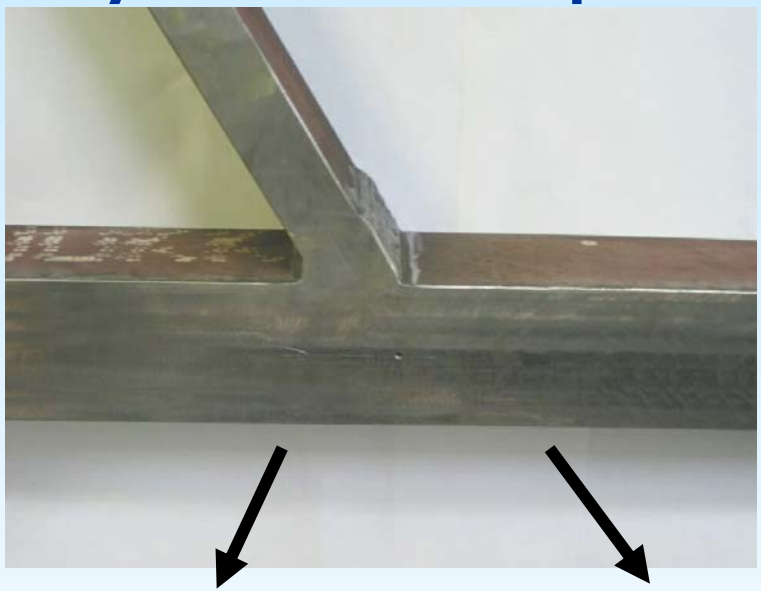
Summary

- **Monopile is the most competitive substructure for Offshore turbines**
- **Application of Monopiles in deep German waters (≤ 40m) is possible**
- **Dynamic and fatigue properties are driving the design**
- **Main technial risk is the long term soil-structure interaction**
- **Technical and economical limits in pile driving and installation set the limits for monopiles**

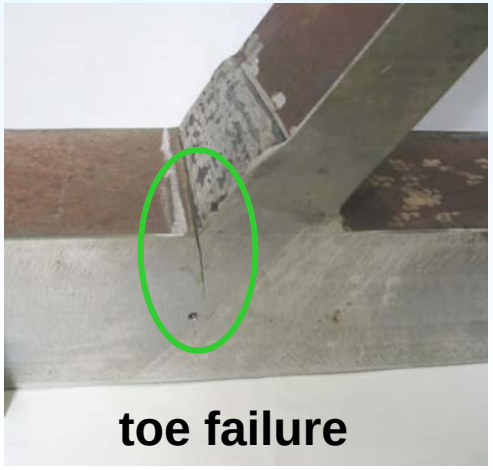
Outlook – Fatigue tests

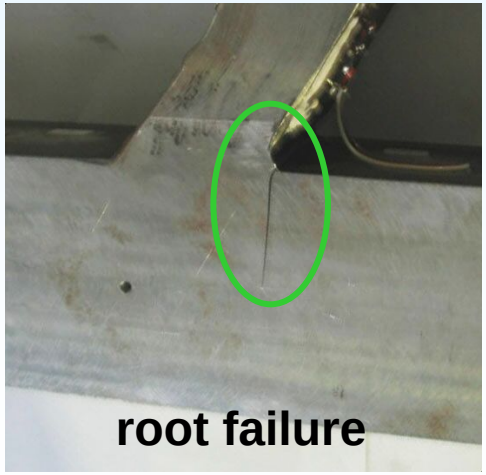
Improvement by PWT on thick plates





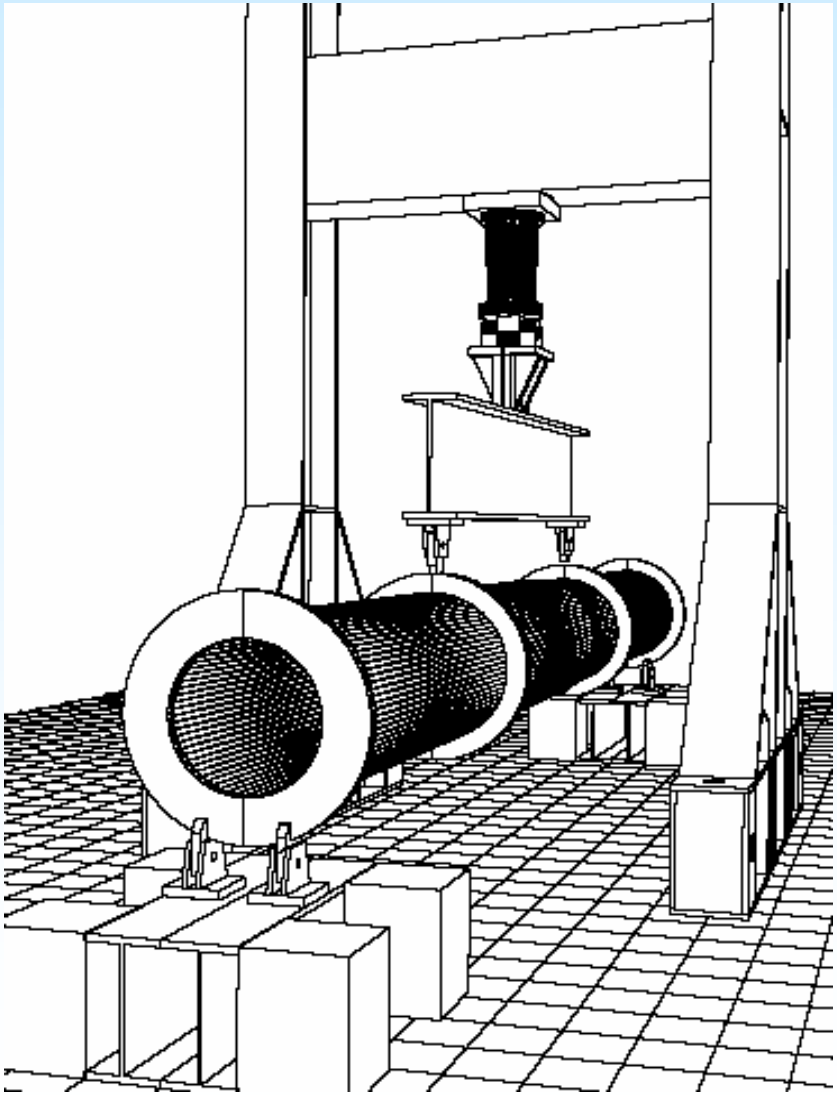
UIT
Ultrasonic
Impact
Treatment





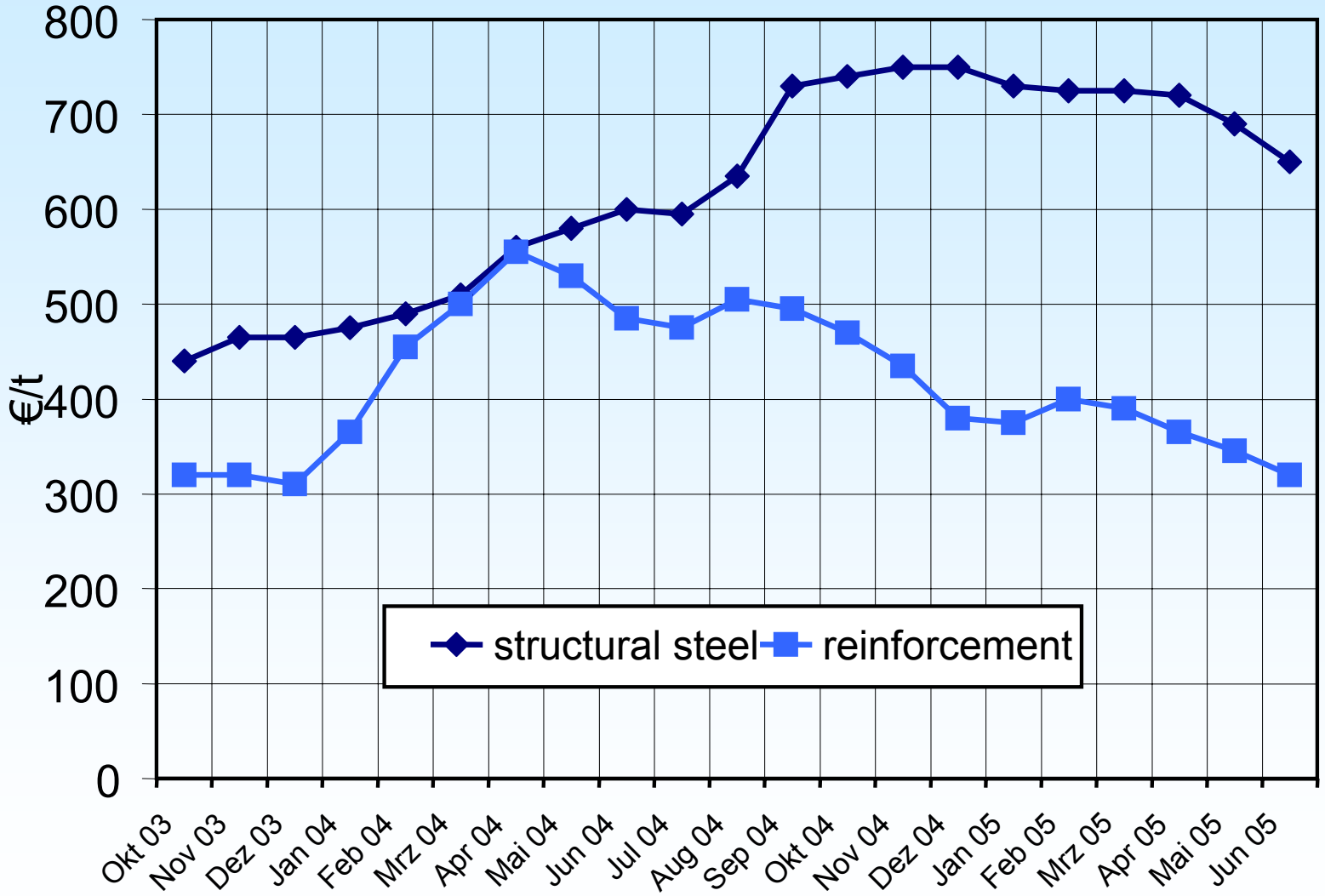
Outlook – New test frame

Tests on "grouted joints"



Outlook – Cost of Steel

Development in Germany



Thank you for your Attention!

www.stahlbau.uni-hannover.de

www.forwind.de

ForWind
Center for Windenergy Research