Leibniz Universität Hannover

Installation and bearing behaviour of suction bucket foundations for offshore wind energy converters

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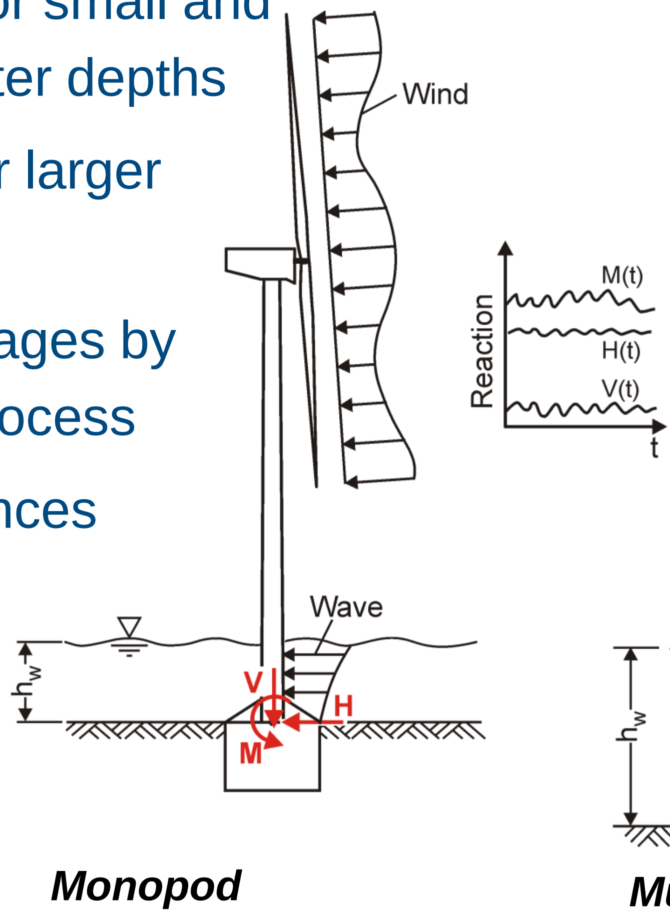
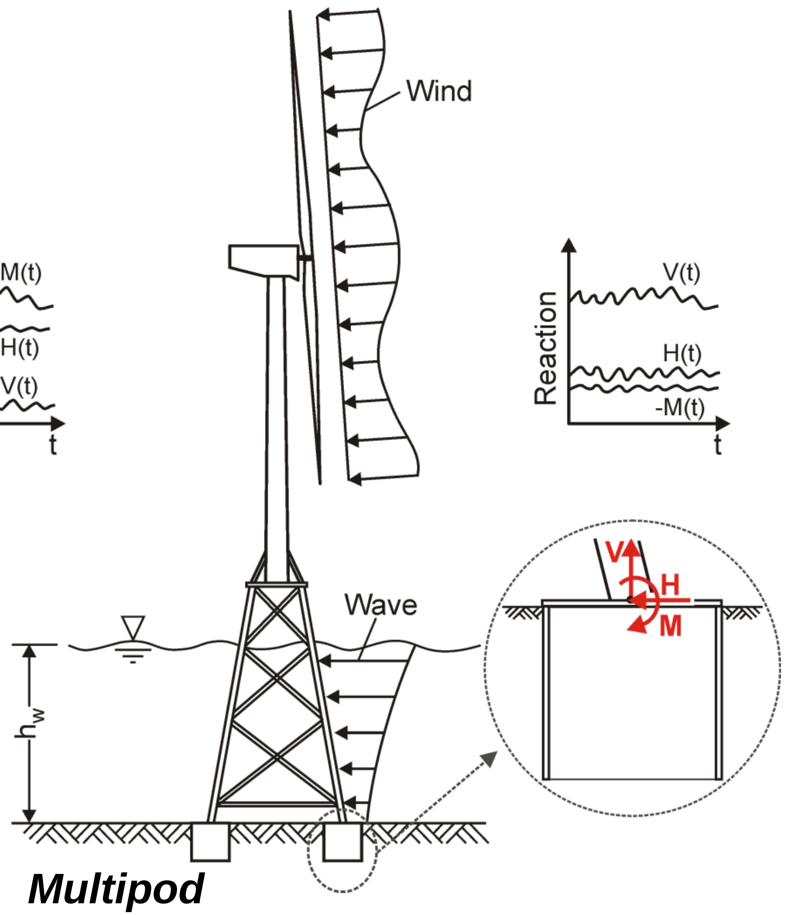
RAVE Conference 2015, Bremerhaven, 13th -14th October 2015

Suction Buckets for OWECs

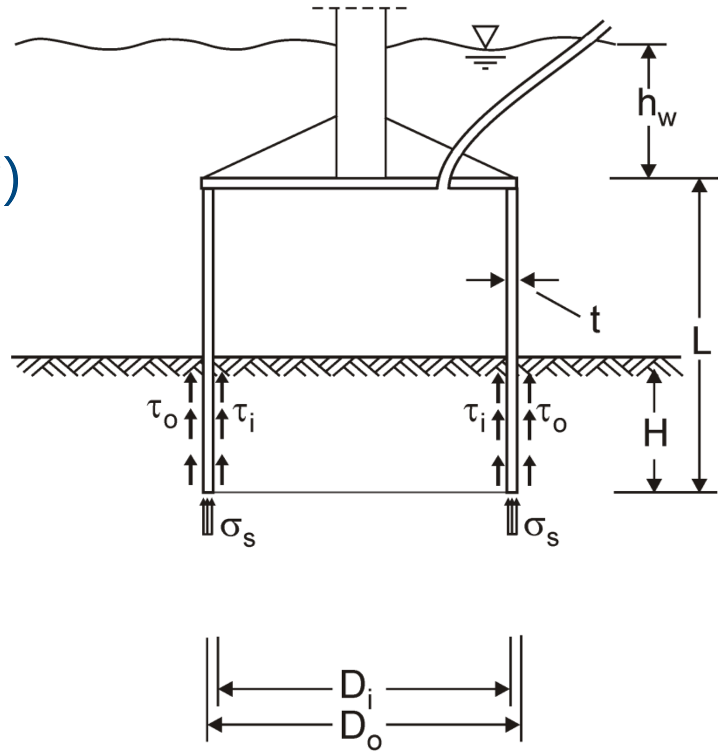
- Two novel foundation concepts using suction buckets
- ***Monopods*** for small and moderate water depths
- ***Multipods*** for larger water depths
- Great advantages by installation process
- Less experiences for design





Installation process

- Suction driven installation process
- Almost no noise emission (no pile driving)
- No need for a transition piece



Source: Foglia, 2014

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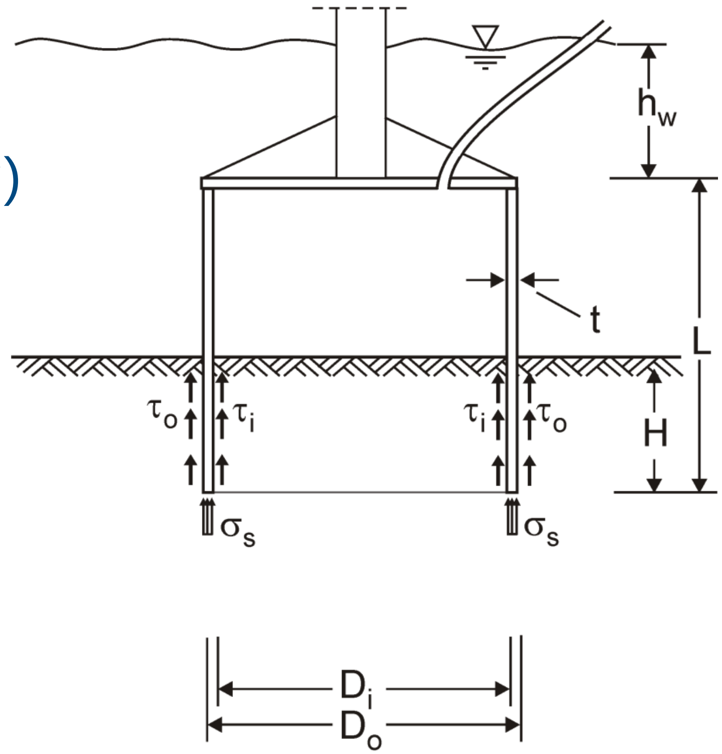

<u>Without applying suction pressure:</u>

$$R_i + R_o + R_{tip} \leq G$$

$$R_i = A_i \cdot \tau_i(z) = k_f \cdot q_c(z)$$

$$R_o = A_o \cdot \tau_o(z) = k_f \cdot q_c(z)$$

$$R_{tip} = A_{tip} \cdot \sigma_{tip} = k_p \cdot q_c(z = H)$$

Installation process

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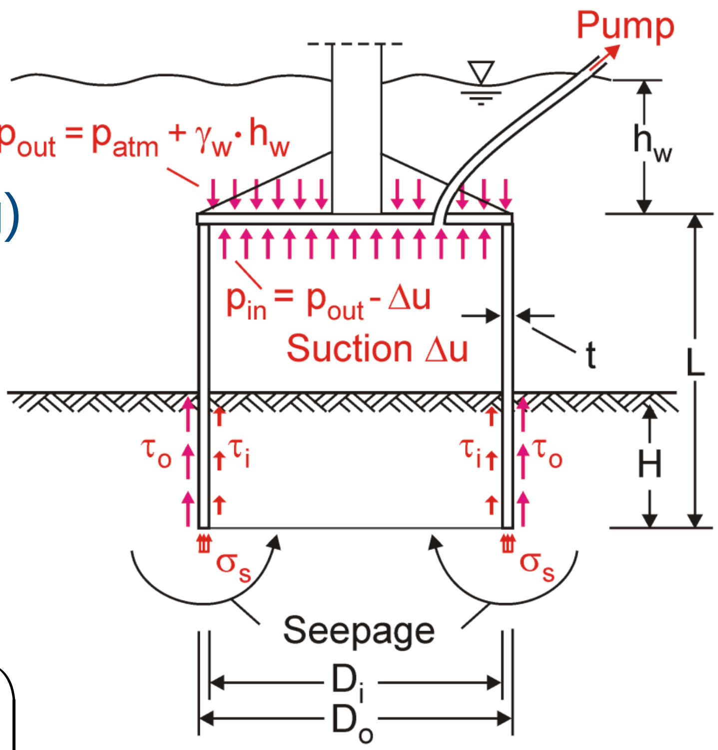


With applying suction pressure:

$$R_i + R_o + R_{tip} \leq G + F_{suc}$$

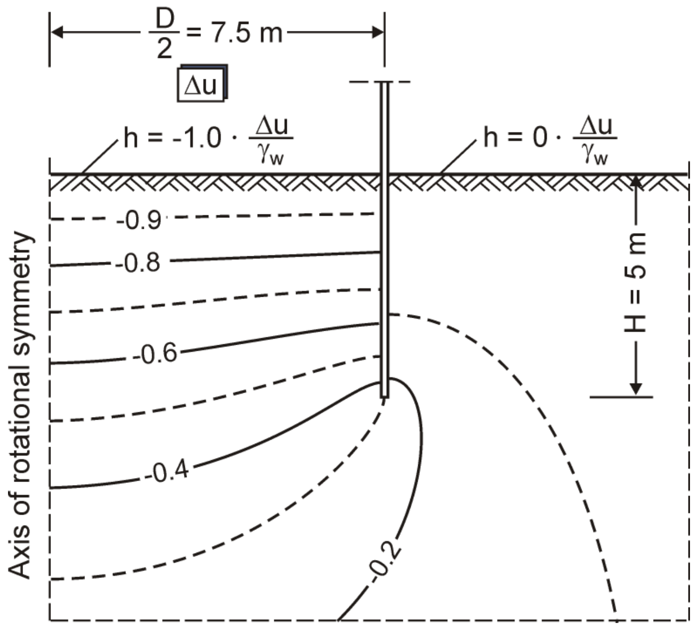
$$R_i = A_i \cdot \tau_i(z) = k_f \cdot q_c(z) \cdot \left(1 - r_i \cdot \Delta u / \Delta u_{hyd}\right)$$

$$R_o = A_o \cdot \tau_o(z) = k_f \cdot q_c(z) \cdot \left(1 + r_o \cdot \Delta u / \Delta u_{hyd}\right)$$

$$R_{tip} = A_{tip} \cdot \sigma_{tip} = k_p \cdot q_c(z = H) \cdot \left(1 - r_t \cdot \Delta u / \Delta u_{hyd}\right)$$

Applicable suction pressure

- Suction pressure is limited by:
  1) Cavitation (absolute pressure > 0)
  2) Buckling failure of the skirt
  3) Hydraulic soil failure inside bucket

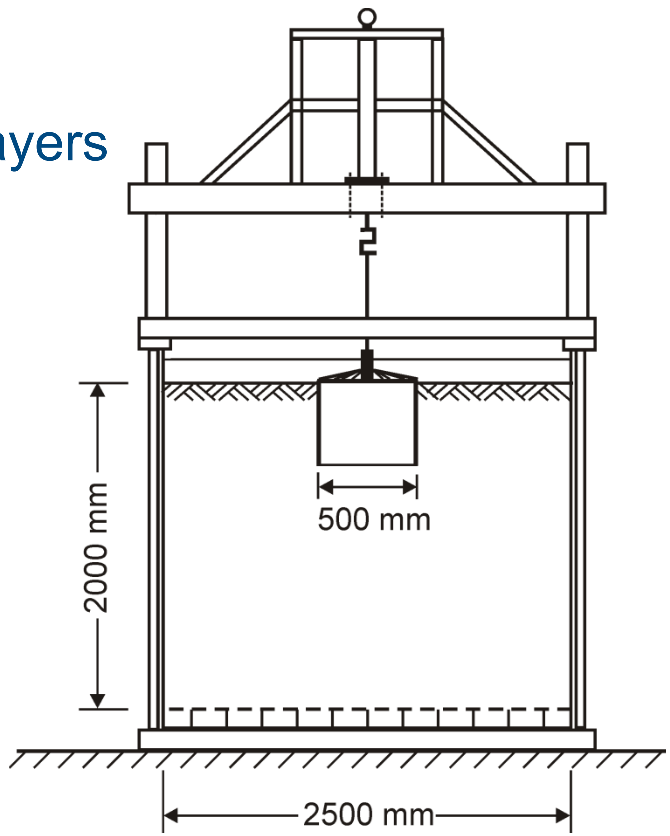


Flow net calculation result

Buckling failure (Monopod)

Installation - Current geotechnical research issues

- Reliable prediction of resistances
  → Great parameter bandwidth / penetration velocity
- Control of layered subsoil
  → Plug heave / sealing by cohesive layers
- Control of soil heterogeneities
  → Risks of bucket tilting
- Safety against buckling
  → Realistic soil resistances
- Effect of installation on the soil
  → Loosening due to upwards directed seepage



IGtH test facility

Installation - Current geotechnical research issues

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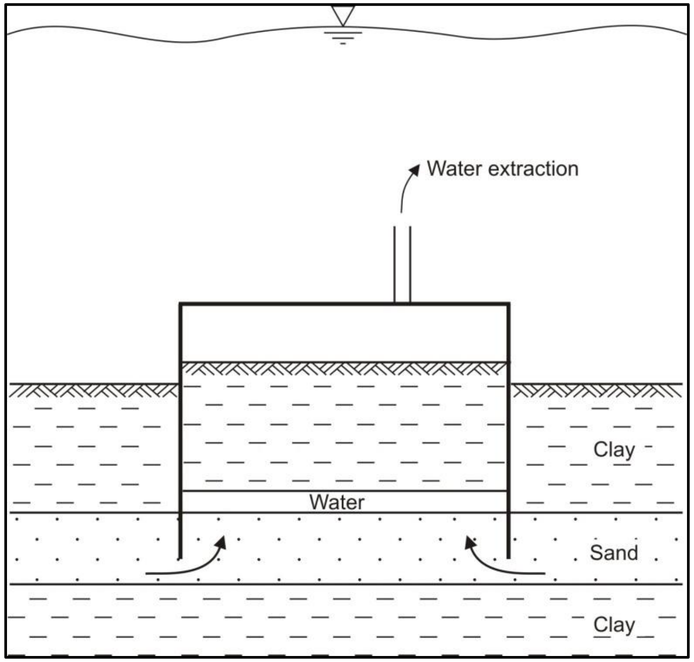

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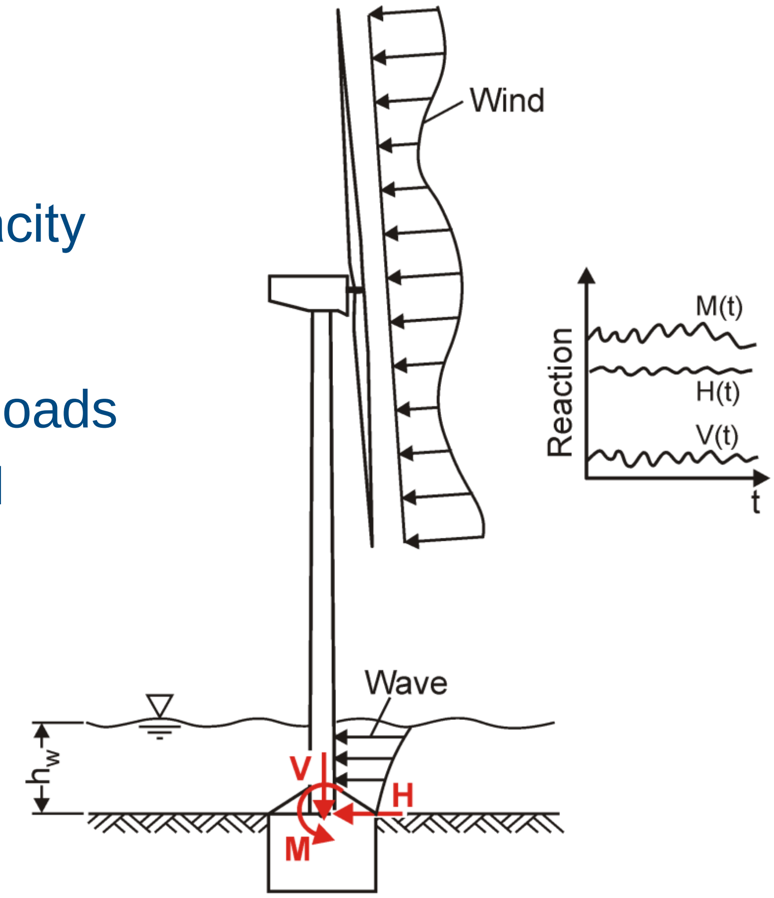
Monopod - Current geotechnical research issues

- Behaviour under monotonic loads (H; M)
  → Reference values
- Effects by long-term cyclic loading
  → Degradation of ultimate capacity
  → Accumulation of rotations
- Foundation stiffness due to repeated loads
  → Input data for integrated load simulations



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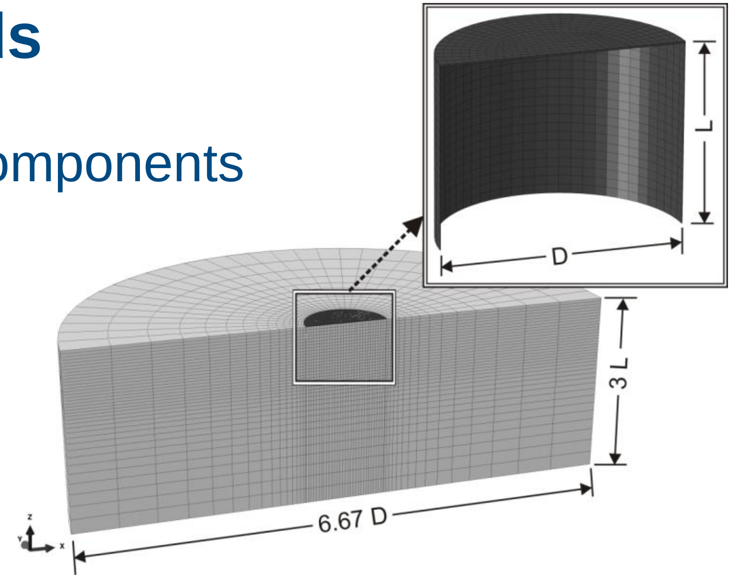
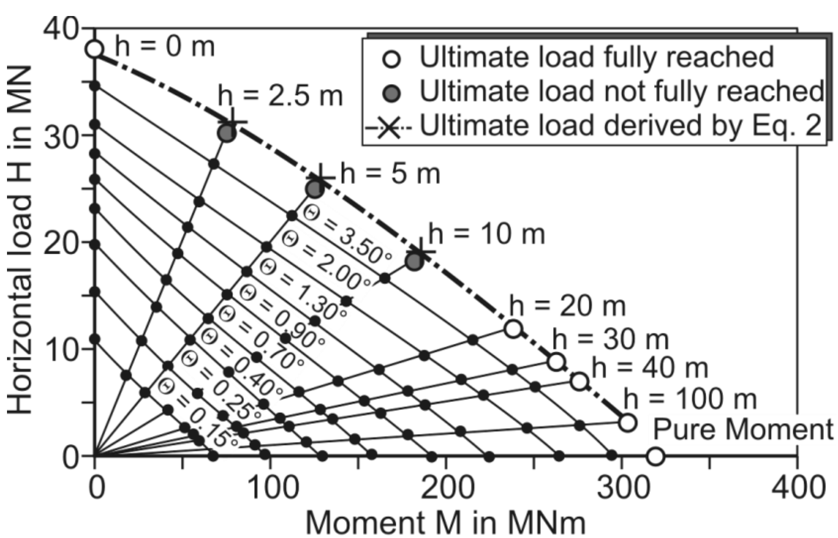
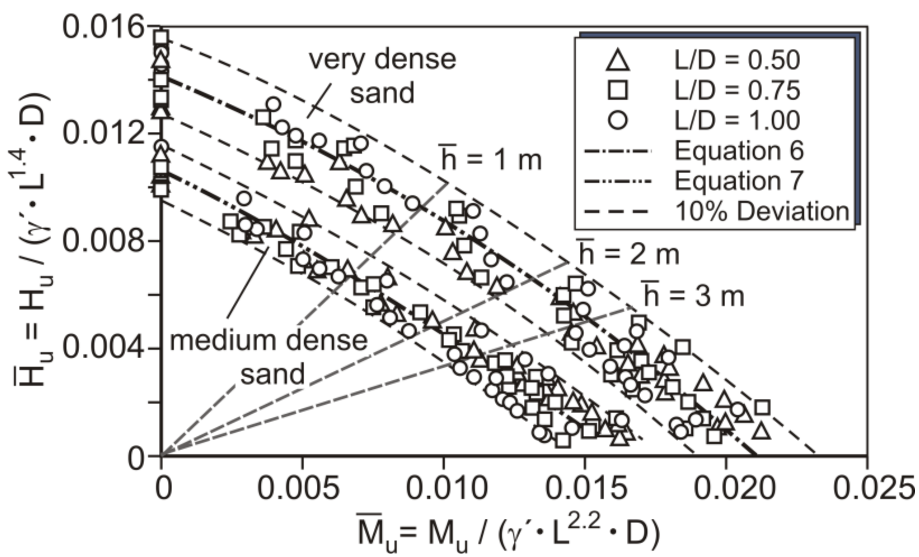
Behaviour under monotonic loads

- Complex interactions between bucket components
- Interaction diagrams (H / M)
- General expressions for bucket's bearing behaviour



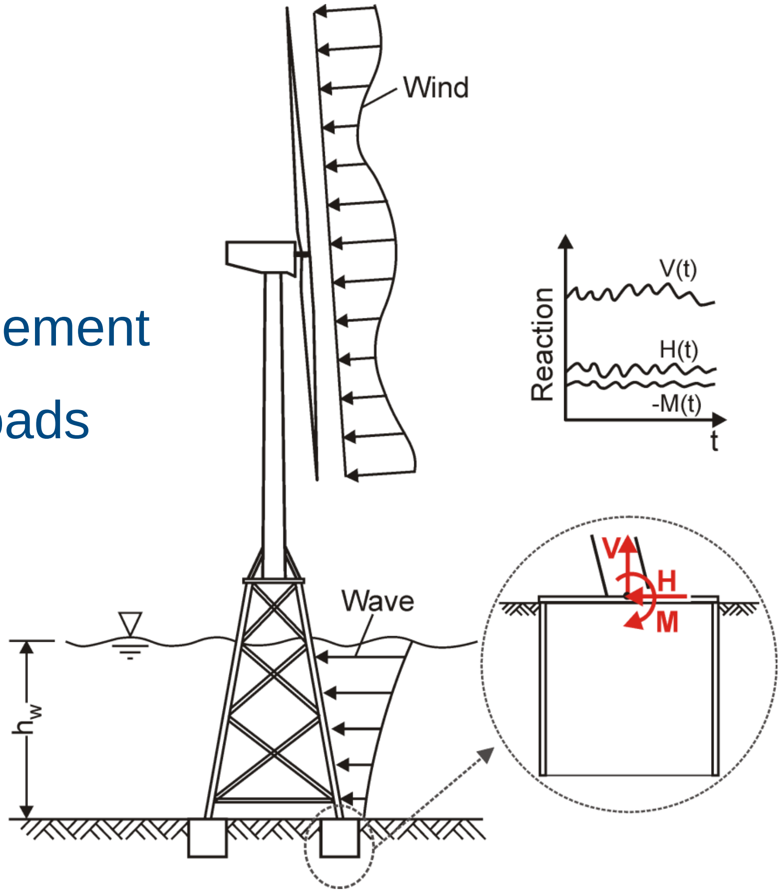




Multipod - Current geotechnical research issues

- Behaviour under monotonic loads (V; H; -M)
  → Complex interactions between bucket components
- Partial drained tensile resistance
  → Increase of tensile capacity
- Effects by cyclic loading (long-term)
  → Accumulations of heave / settlement
- Foundation stiffness due to repeated loads
  → Input data for integrated load simulations

→ **Next presentation**



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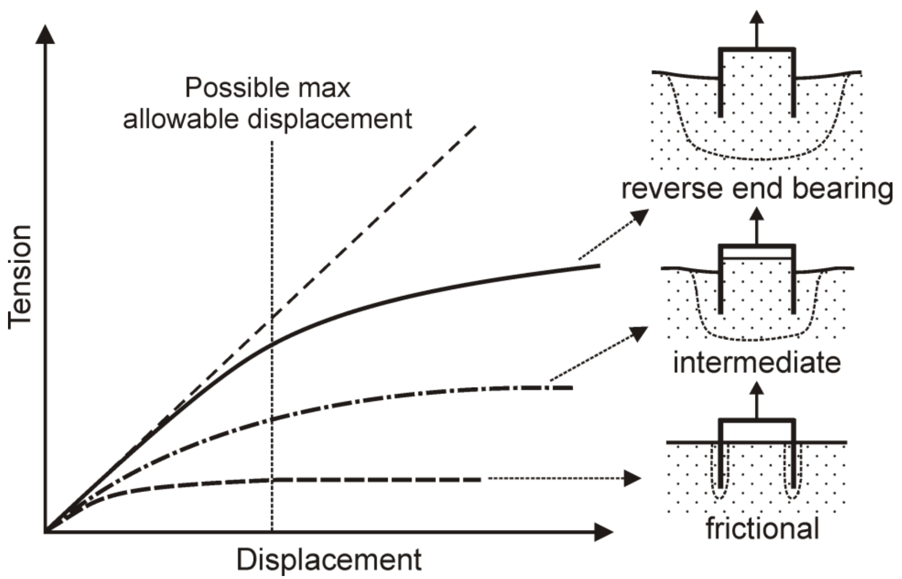
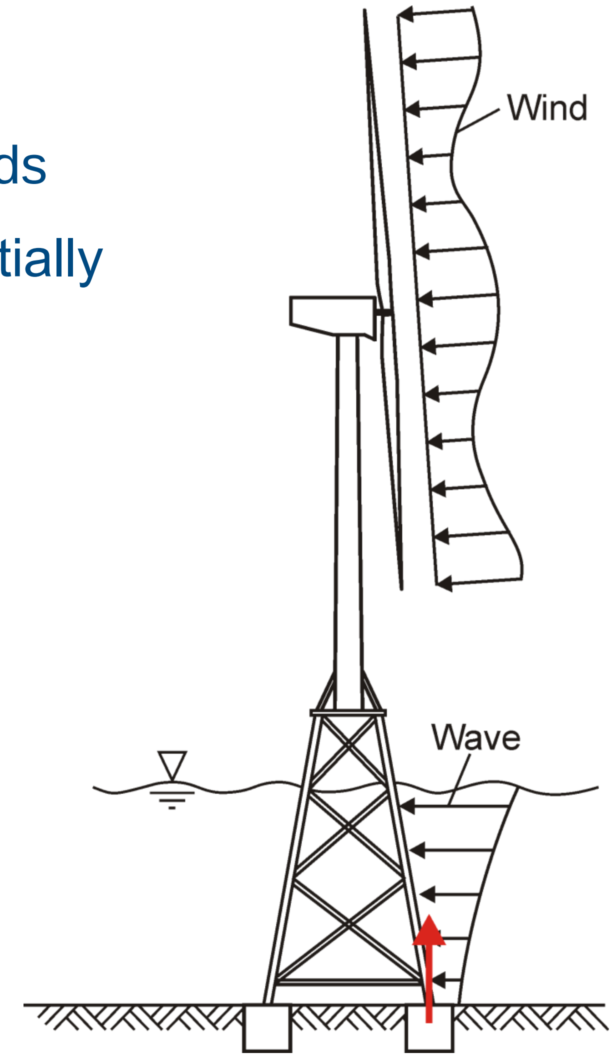
Partially drained tensile resistance

- Drained behaviour for small loading rates
- Suction pressure due to transient tensile loads

  → Actual bearing behaviour under partially drained conditions

  → Effect of repeated loads





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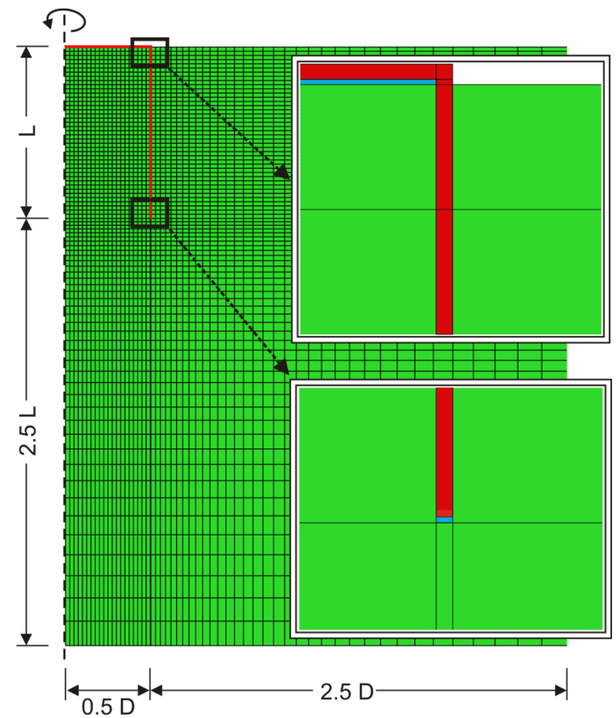
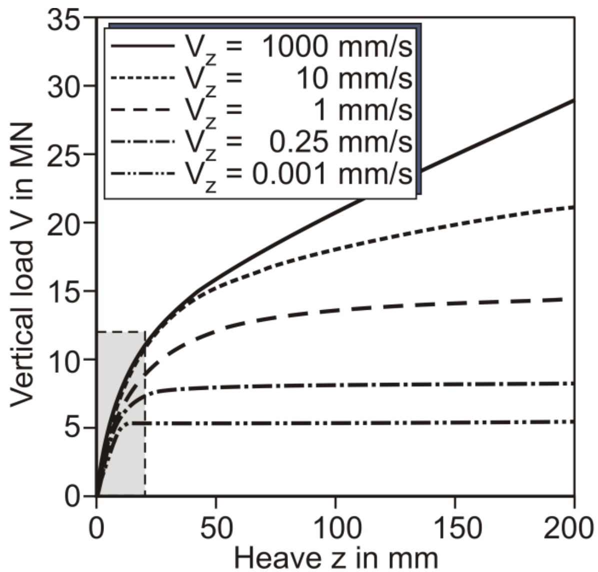
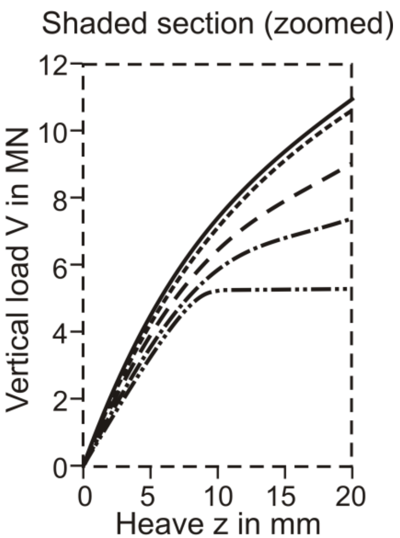
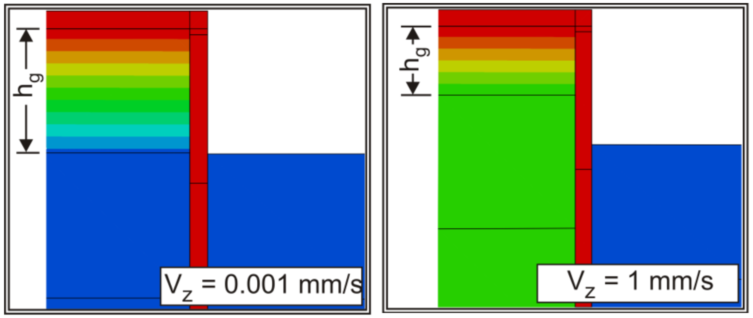
Partially drained tensile resistance - Simulations

- H-M coupling for soil
- Hypoplastic constitutive law
- Void ratio dependent permeability
- Special 'water elements' below bucket lid and skirt tip









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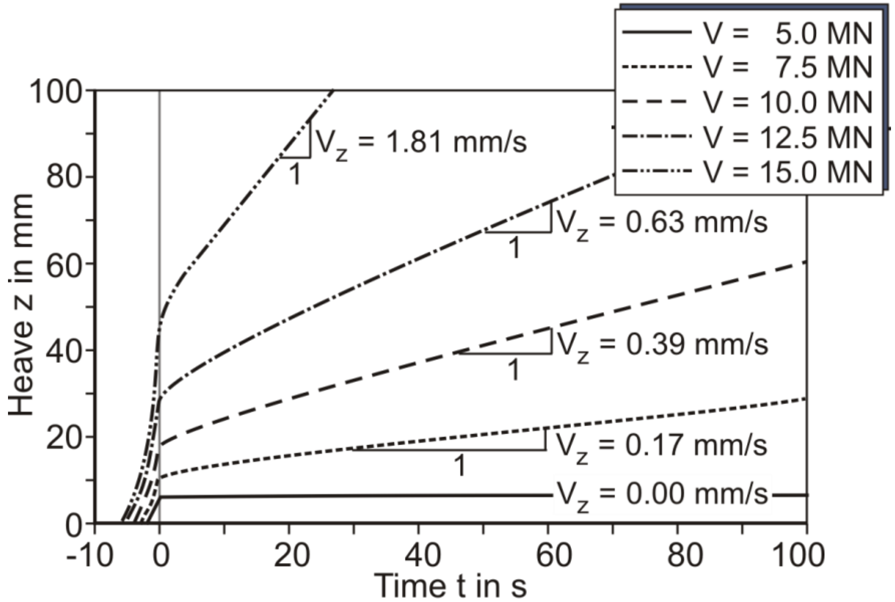
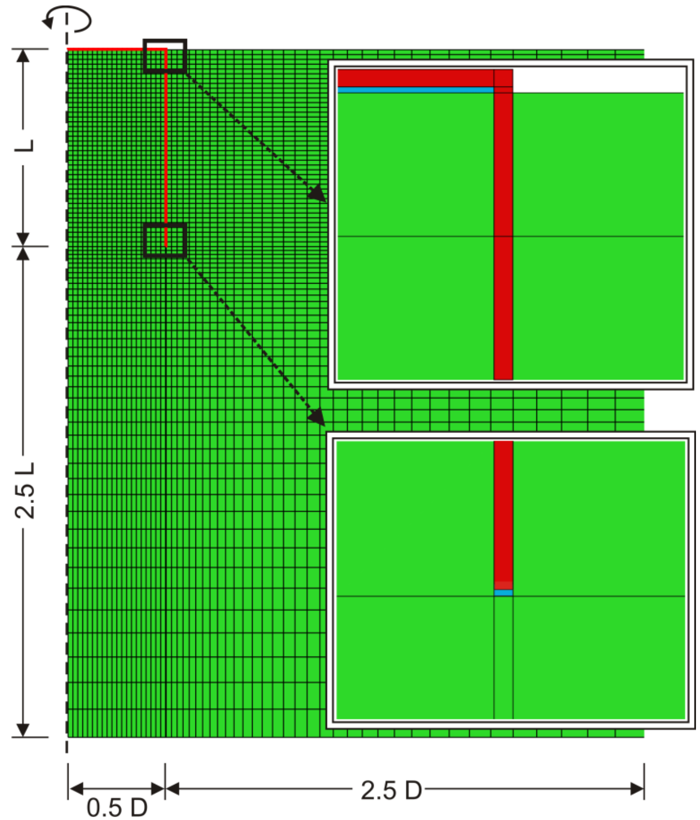
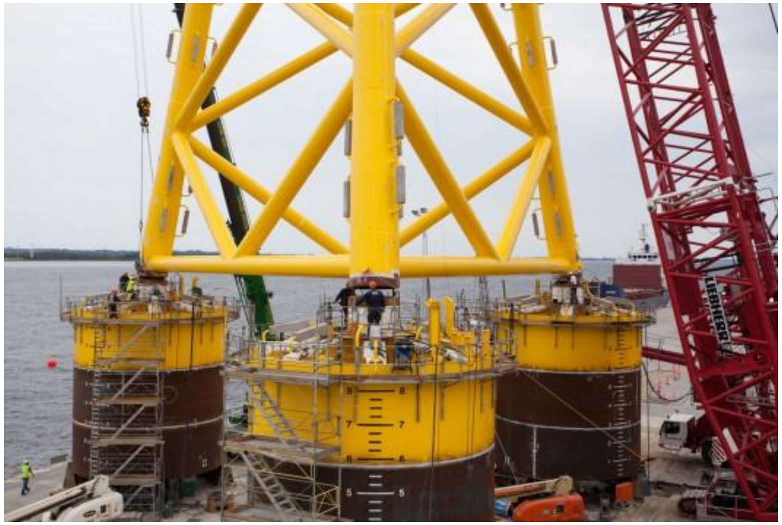




Demo Project - Suction Bucket Jacket (SBJ)

- Prototype installed at the Borkum Riffgrund 1 wind farm
- Development of reliable models and validation by field measurements



Source: DONG Energy

Thank you for your attention!

Special thanks to:

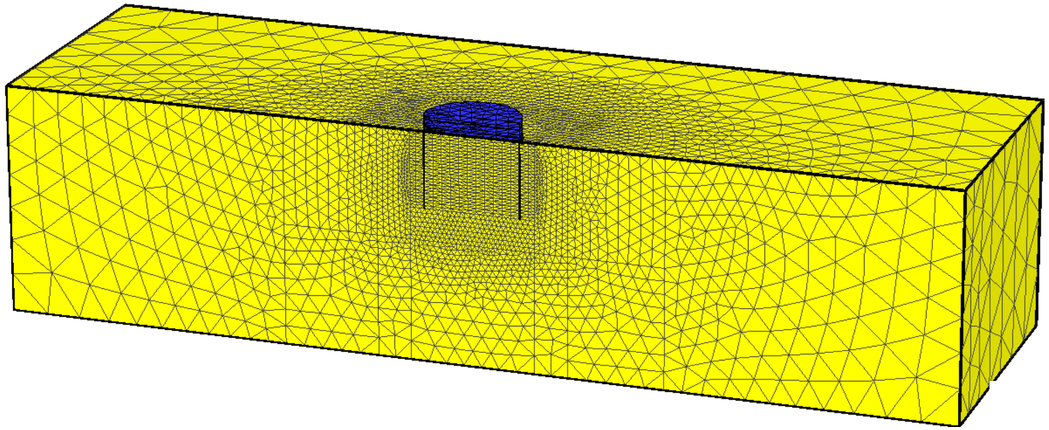
Federal Ministry
for Economic Affairs
and Energy (BMWI)

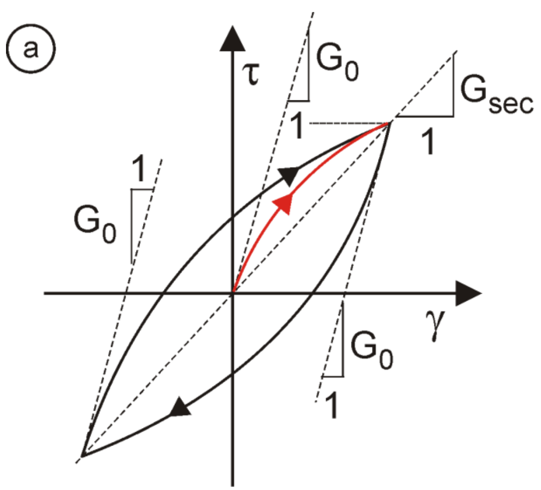
RAVE
RESEARCH AT ALPHA VENTUS

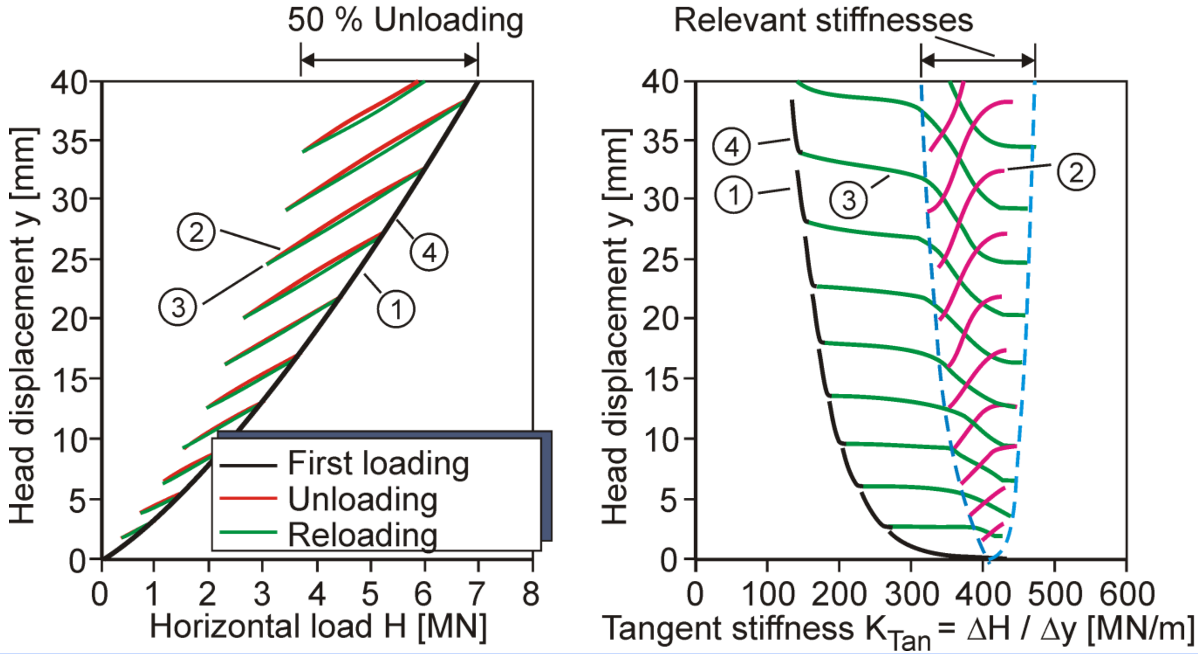
ForWind
Zentrum für Windenergieforschung

Foundation stiffness due to repeated loads

- Integrated load simulation
- Un- and reloading stiffness
- Bandwidth of foundation stiffnesses occurring







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