Institute for
Steel Construction

Leibniz
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Numerical design concept for submerged, axially loaded grouted connections

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ForWind
Center for Wind Energy Research
Bremen
Hannover
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Wind Energy

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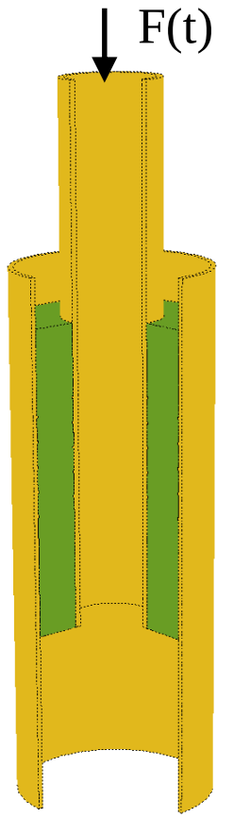
Outline

- Introduction
- Large scale tests
- Numerical design concept
- Summary



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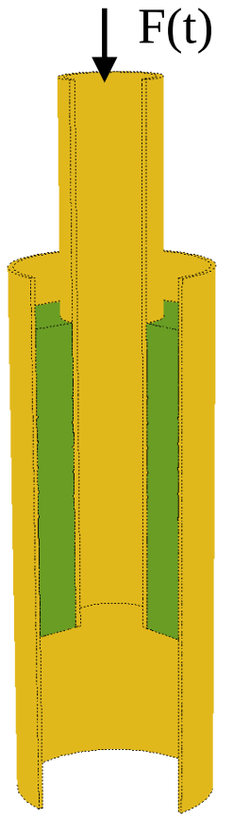
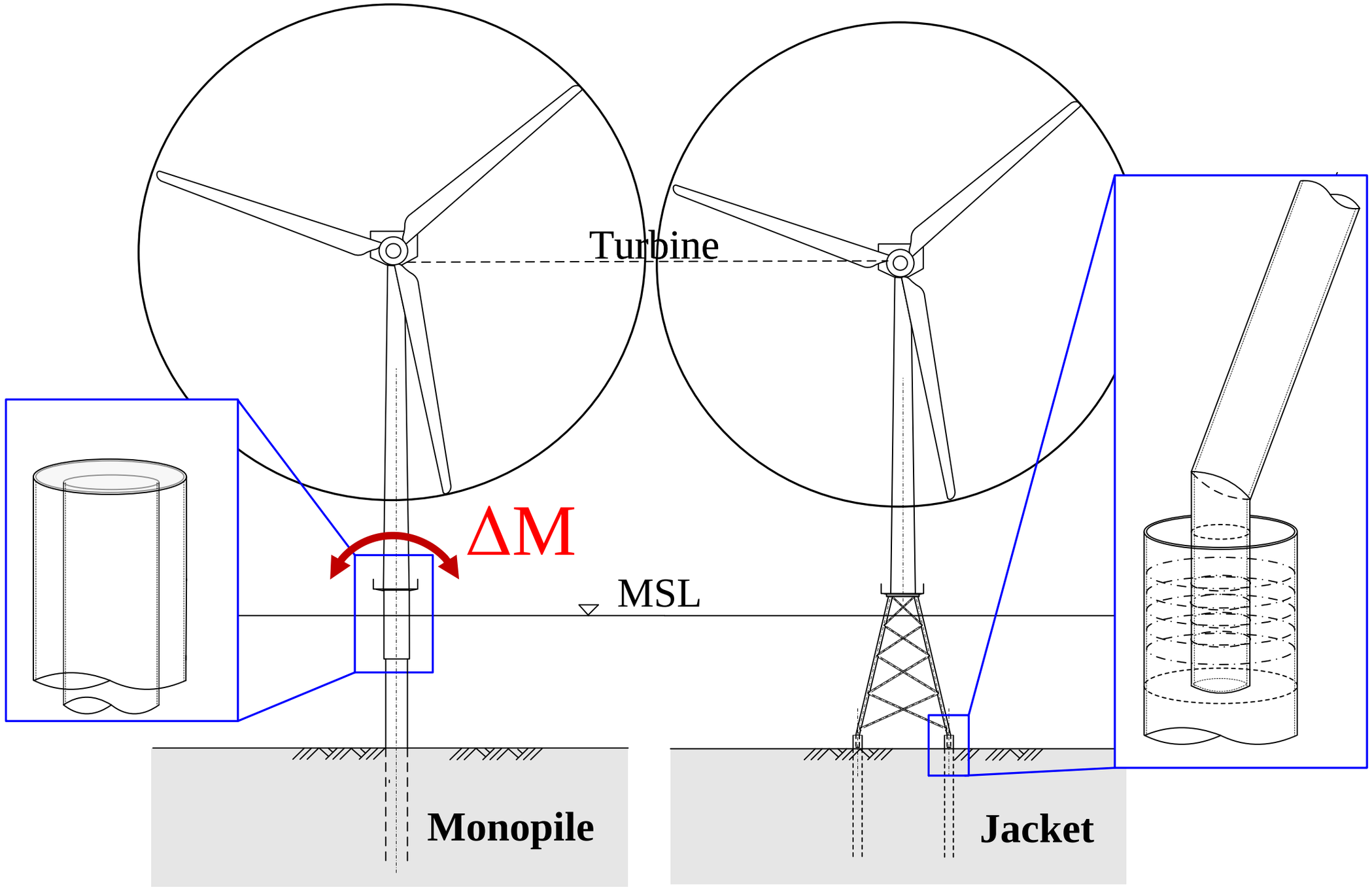


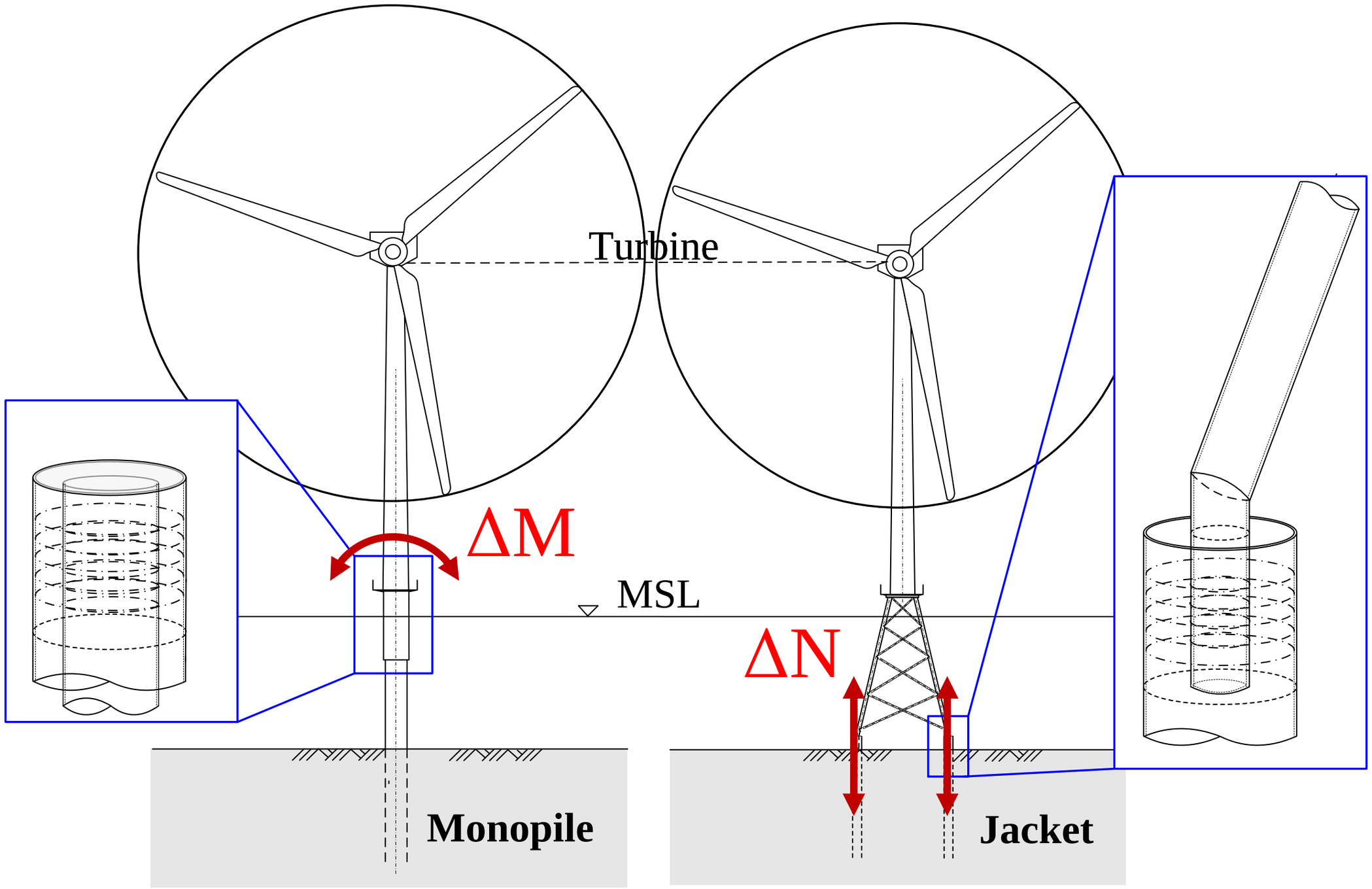
Grouted connections - general

Introduction



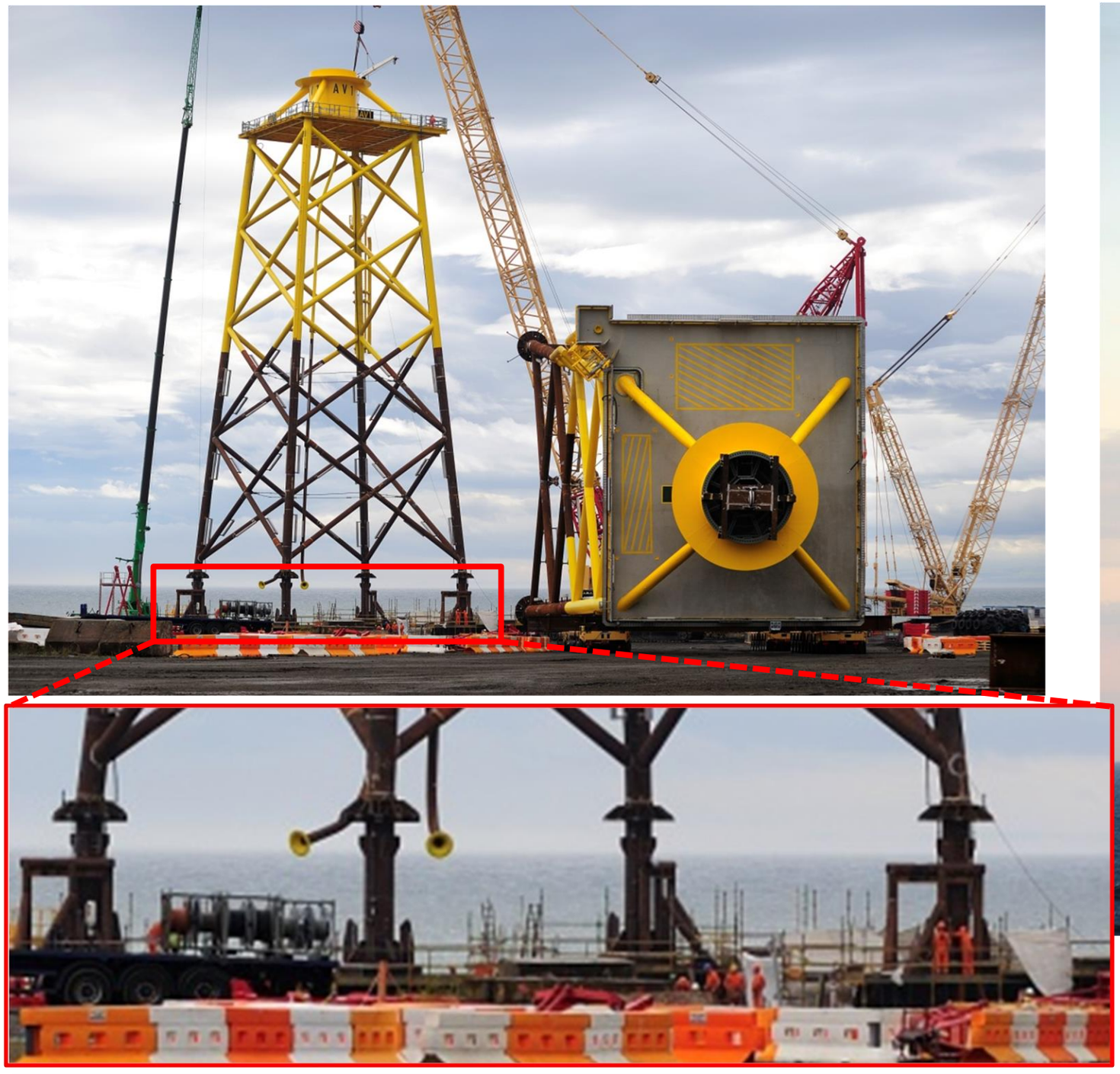
Grouted connections - general

Introduction



Grouted connection of jacket support structure

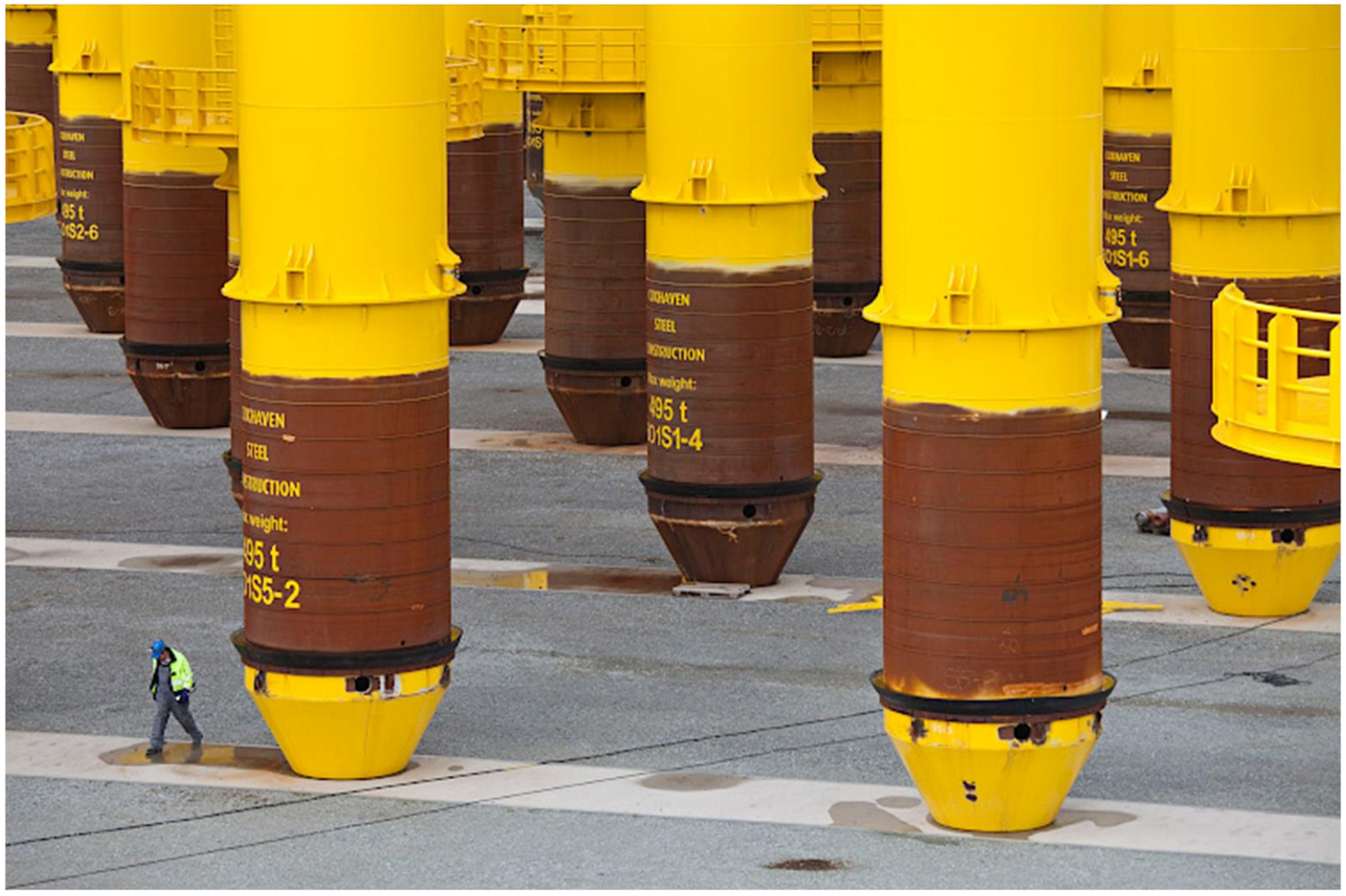
Introduction



© Doti: Offshore Wind Park alpha-ventus, Germany

Grouted connection of tripile support structure

Introduction



picture: www.bard-offshore.de

- Partly submerged ambient conditions
- Axially loaded plus bending

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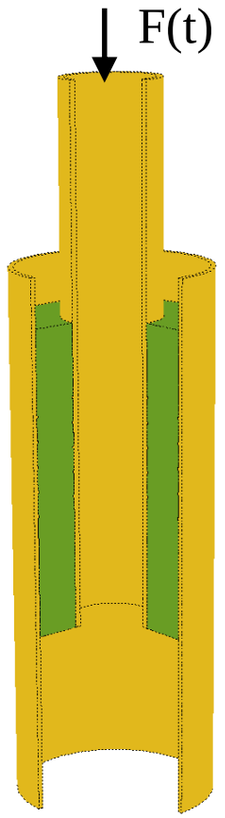
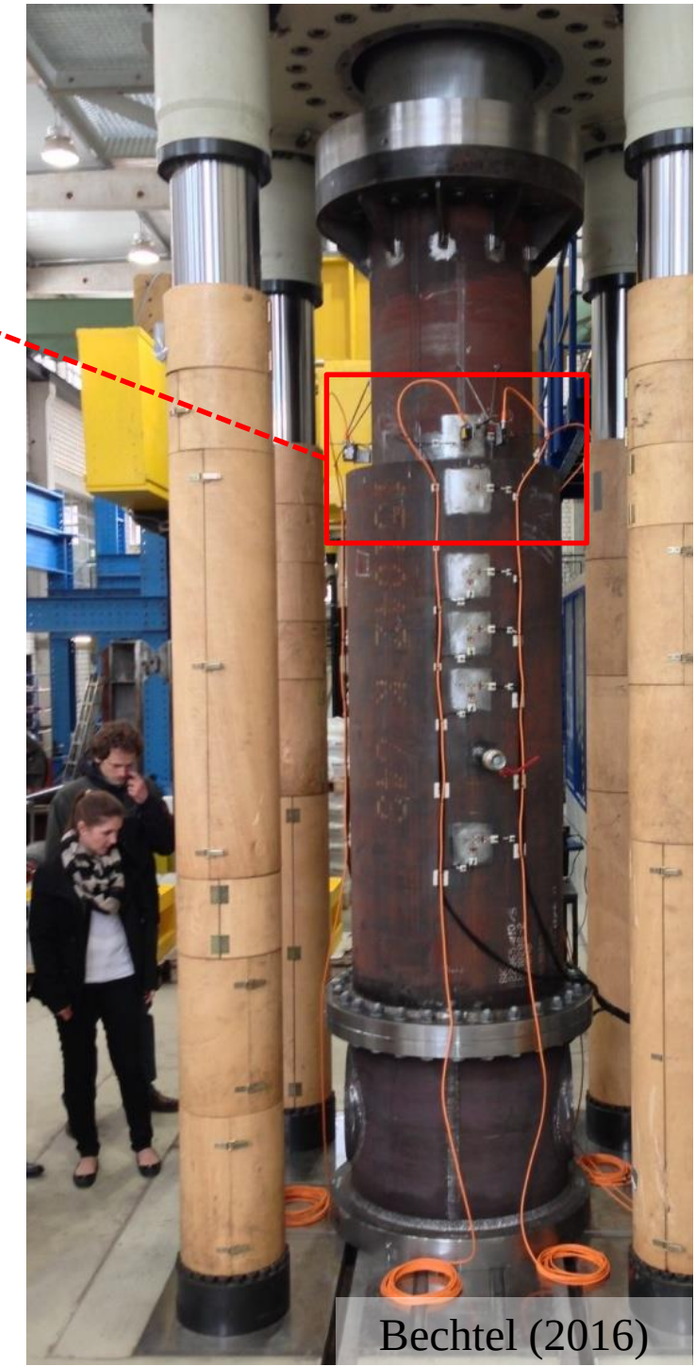
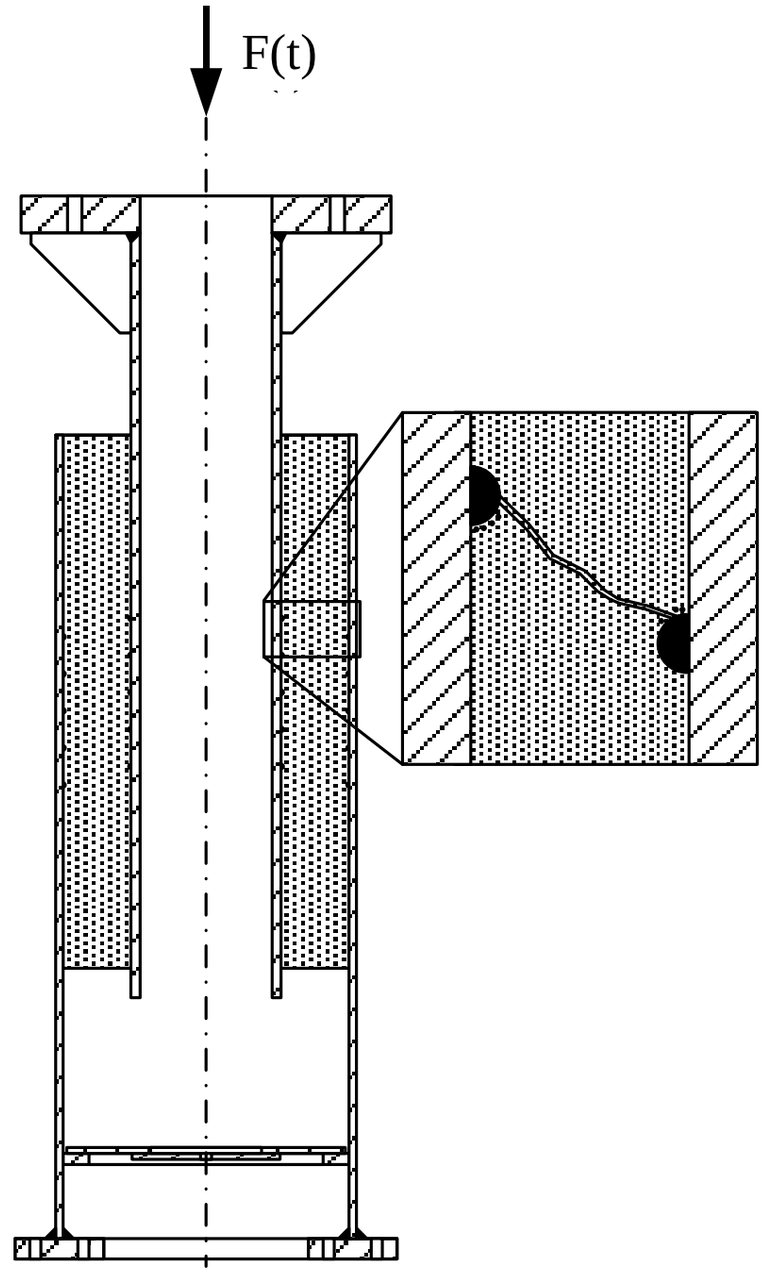


Laboratory tests under dry ambient conditions

Large scale tests



Bechtel (2016)



Current guidelines based on laboratory tests under dry ambient conditions!

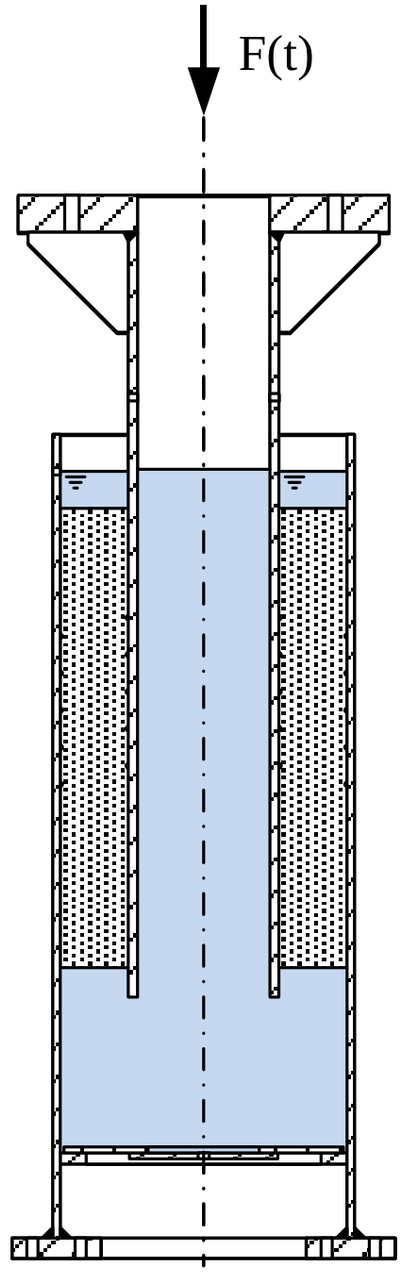
ULS
(FLS)

Failure mechanism:

- Compression strut failure
- (Locally crushed grout)

Laboratory tests under submerged ambient conditions

Large scale tests

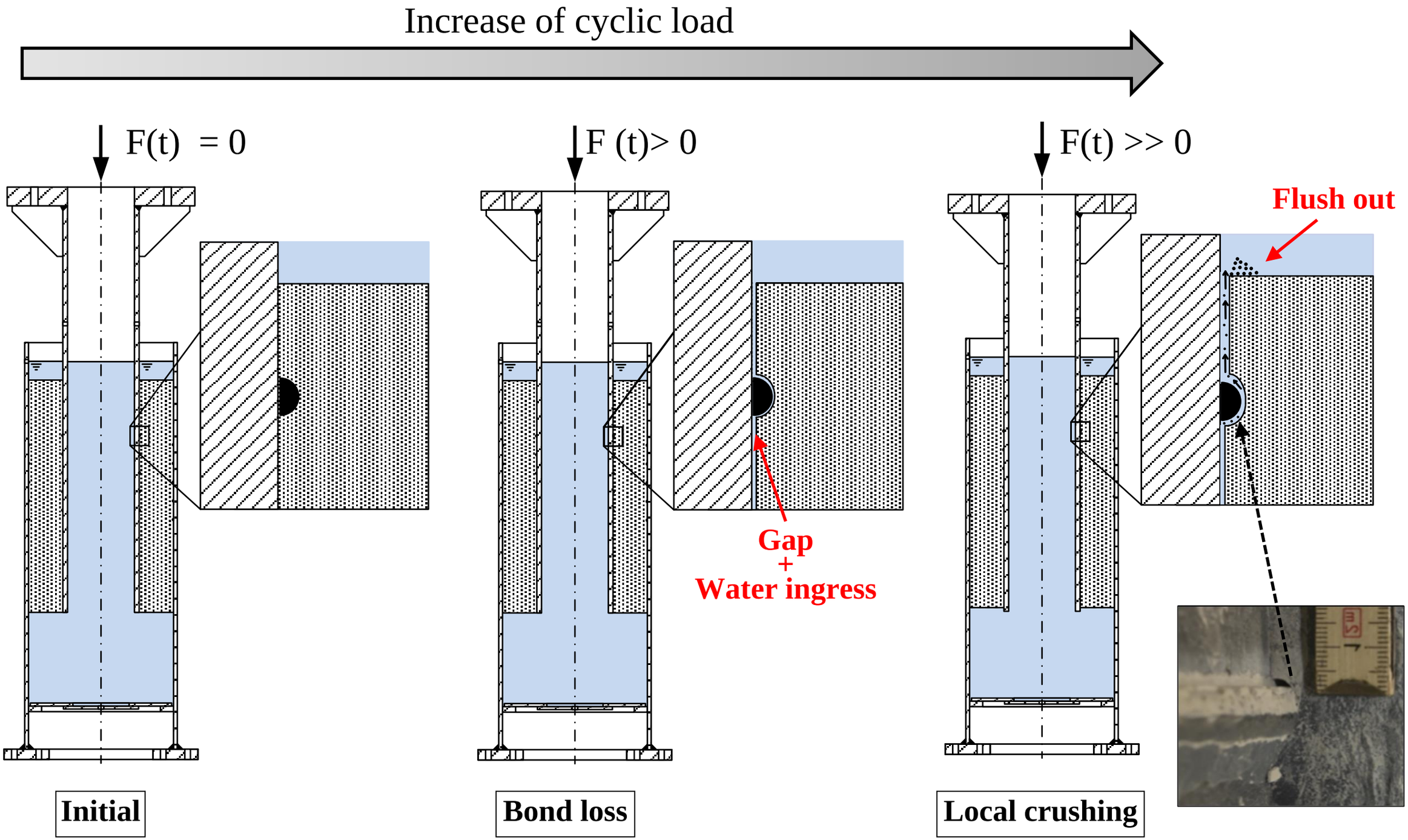


Current guidelines based on laboratory tests under dry ambient conditions!

ULS?
FLS?

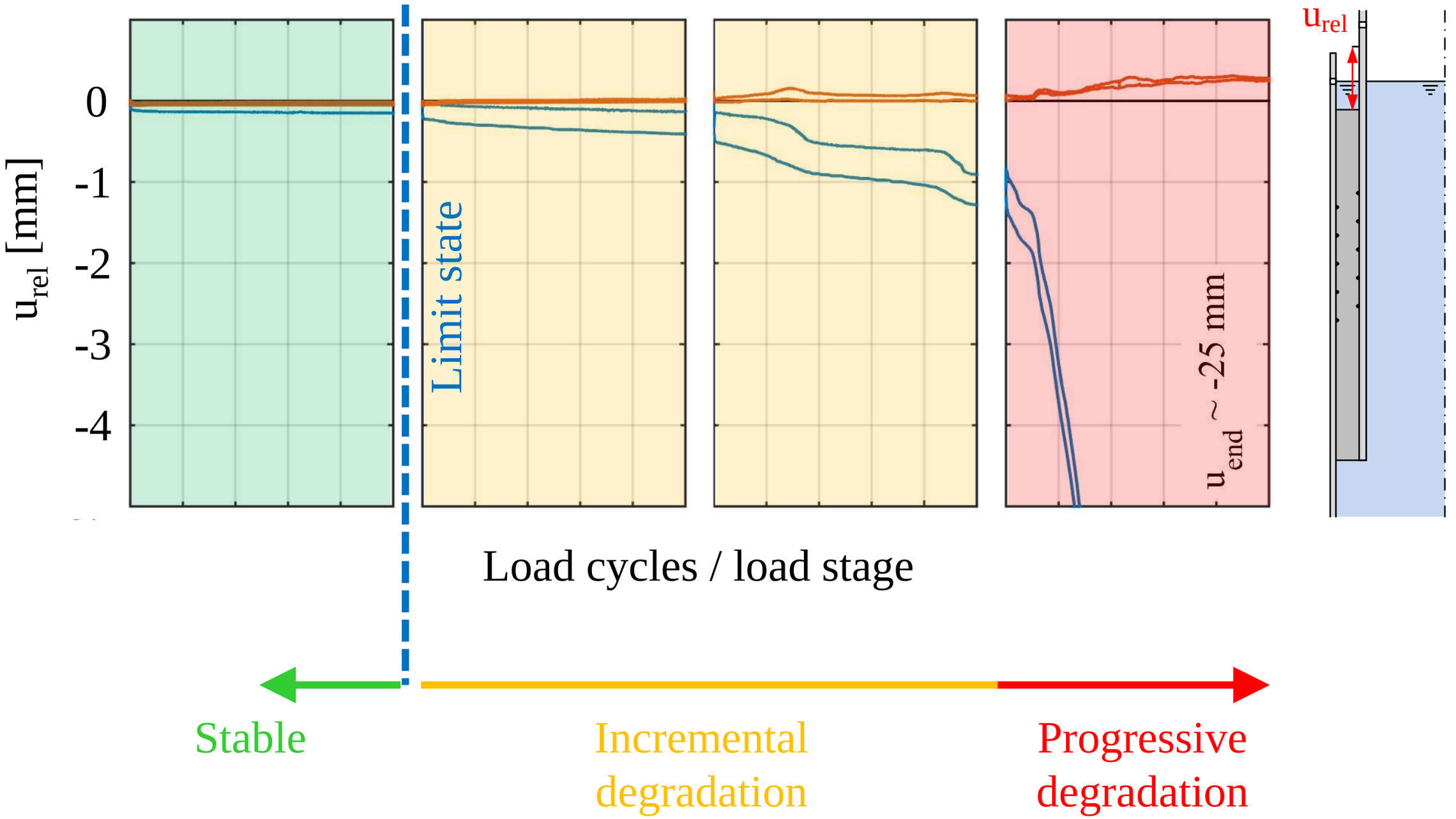
Failure under submerged ambient conditions

Large scale tests



Limit state for numerical concept

Large scale tests



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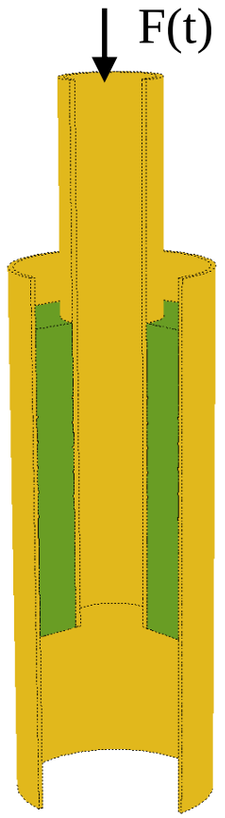
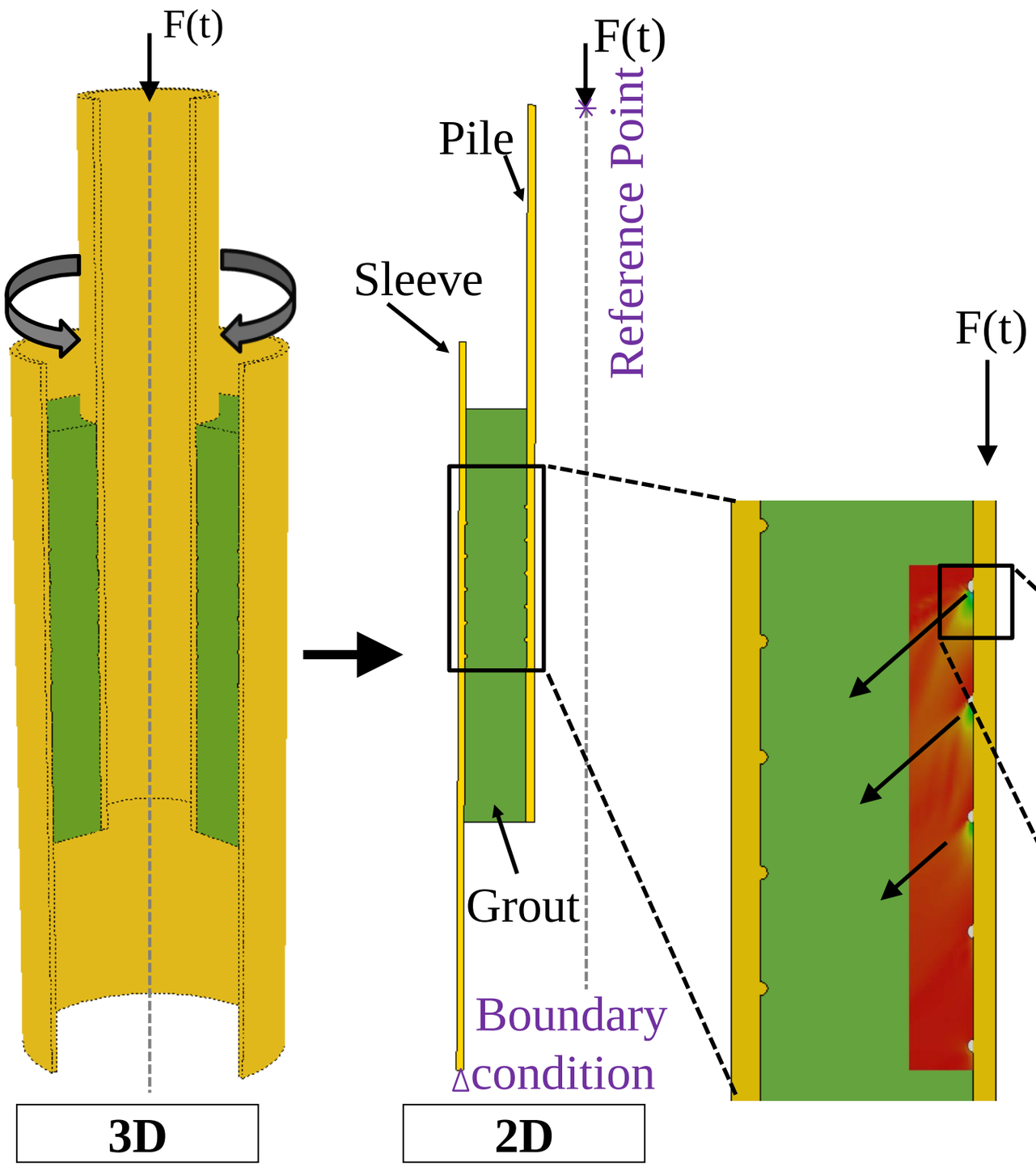


Finite element model

Numerical design concept



- Rotational symmetry

  → reduced FE-model (CAX4)
- Local crushing of grout

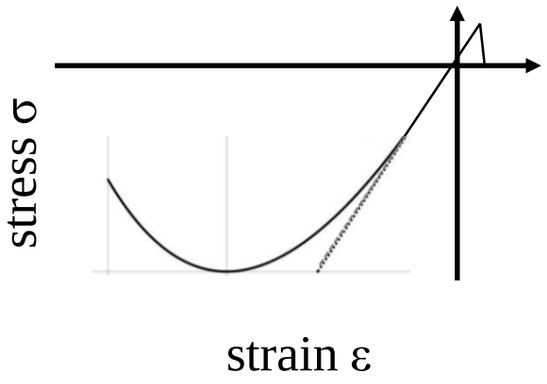
  → Depiction of shear keys
- Stress analysis at shear key interface

  → Very fine mesh

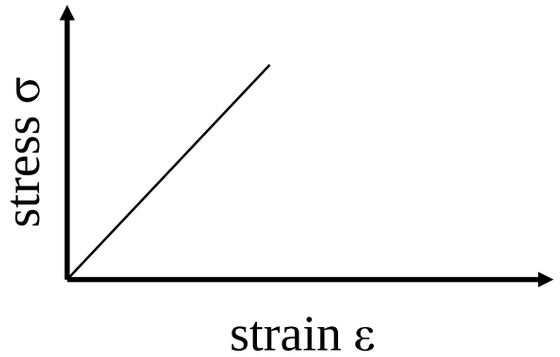
Finite element model

Numerical design concept

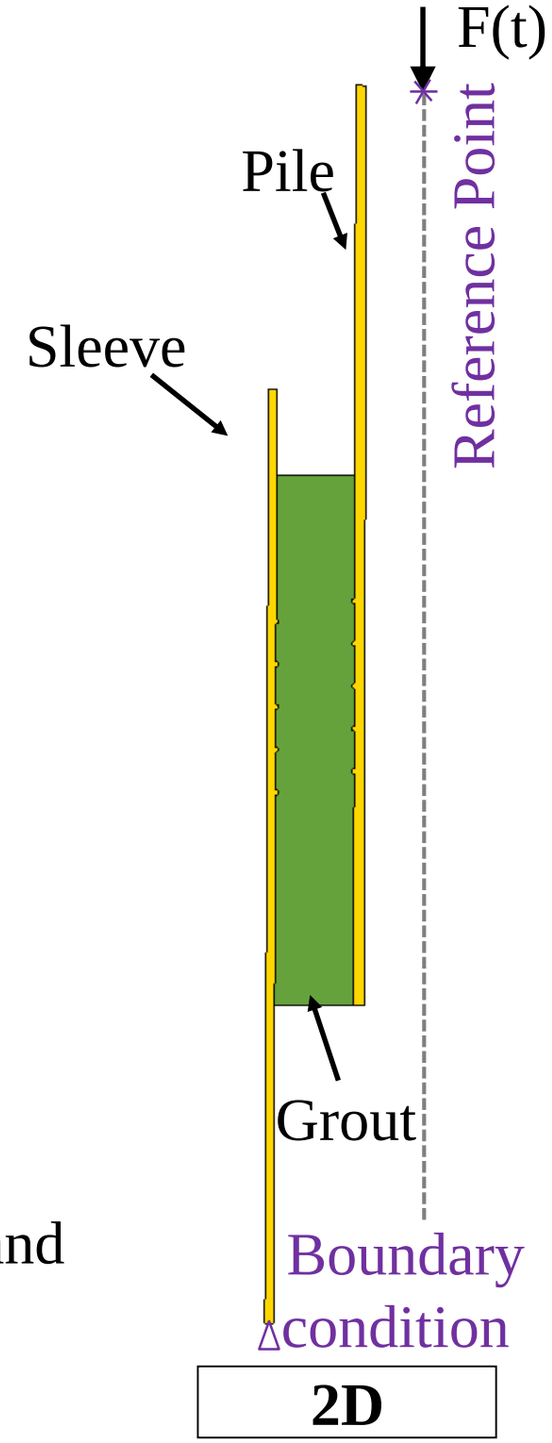
- Displacement controlled simulation (by reference point)
- Modelled tubes -> exclude influence boundary conditions
- Grout: nonlinear (CDP)



Steel: linear elastic

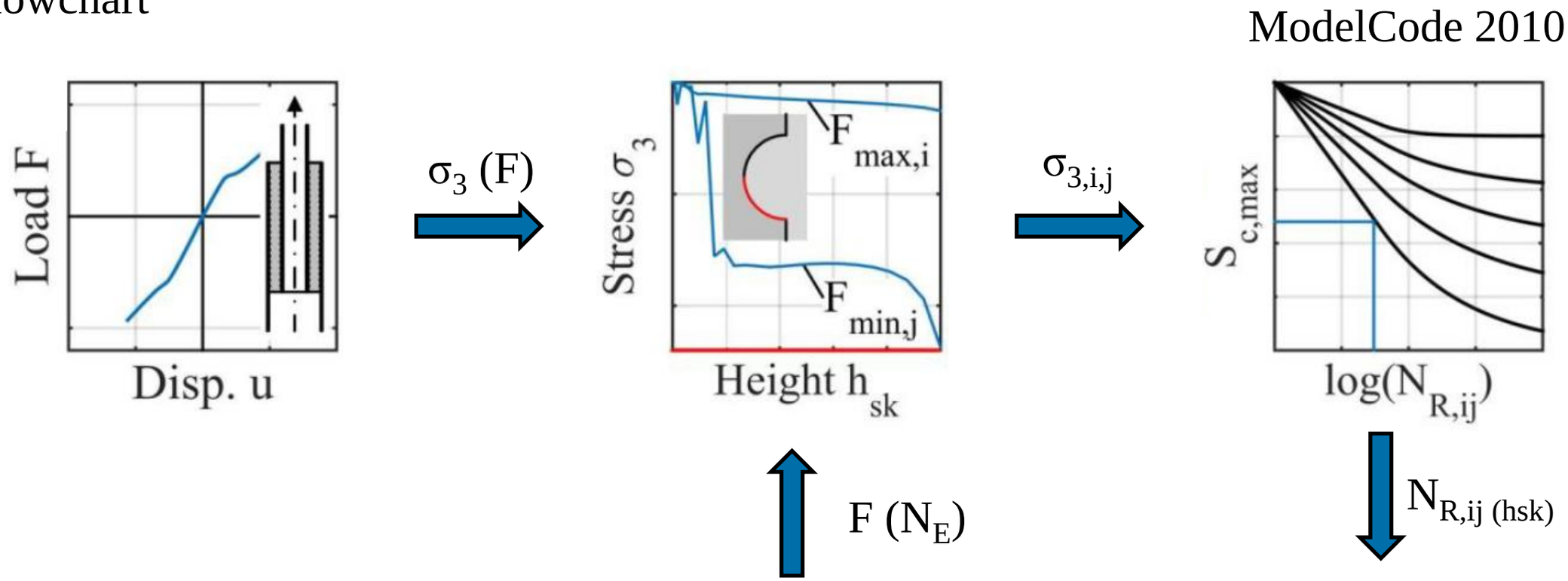


- Interaction: Surface-to-surface
  - Hard contact (normal direction)
  - Penalty μ=0.4 (tangential direction) according to Lotsberg (2013) and Fehling (1990)

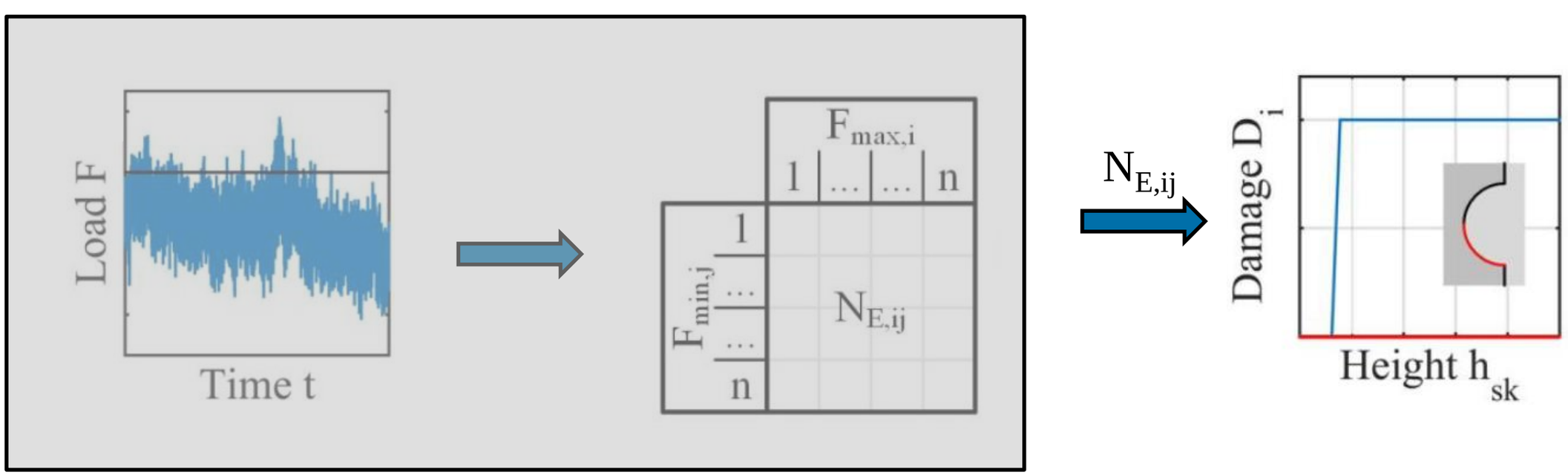


Numerical design concept

Flowchart

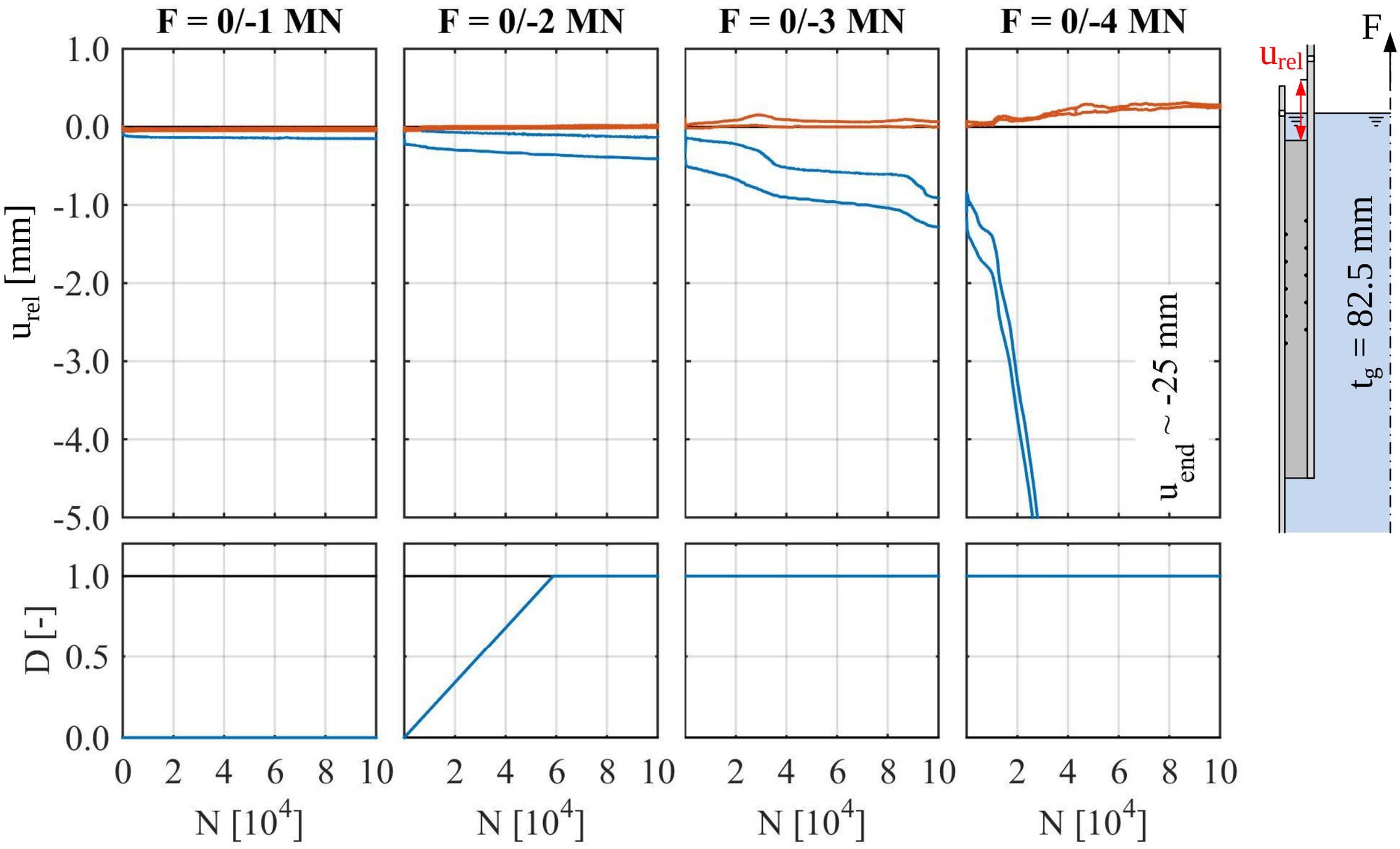


ModelCode 2010



Input of global load simulation

Comparison laboratory test and FE-simulation



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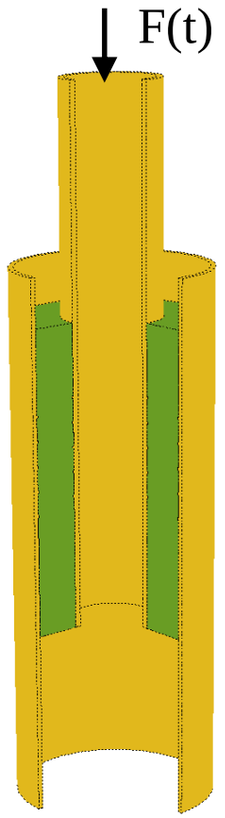
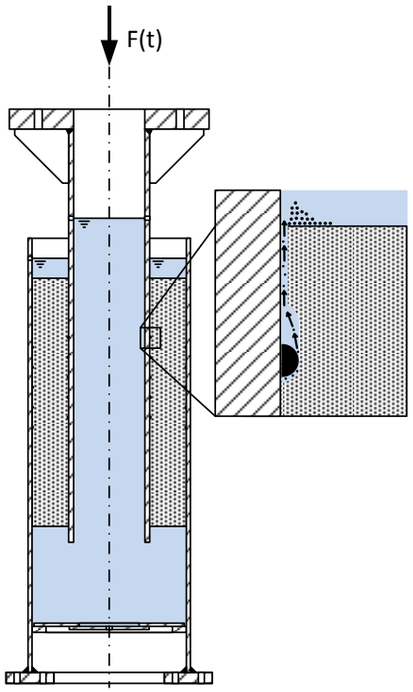
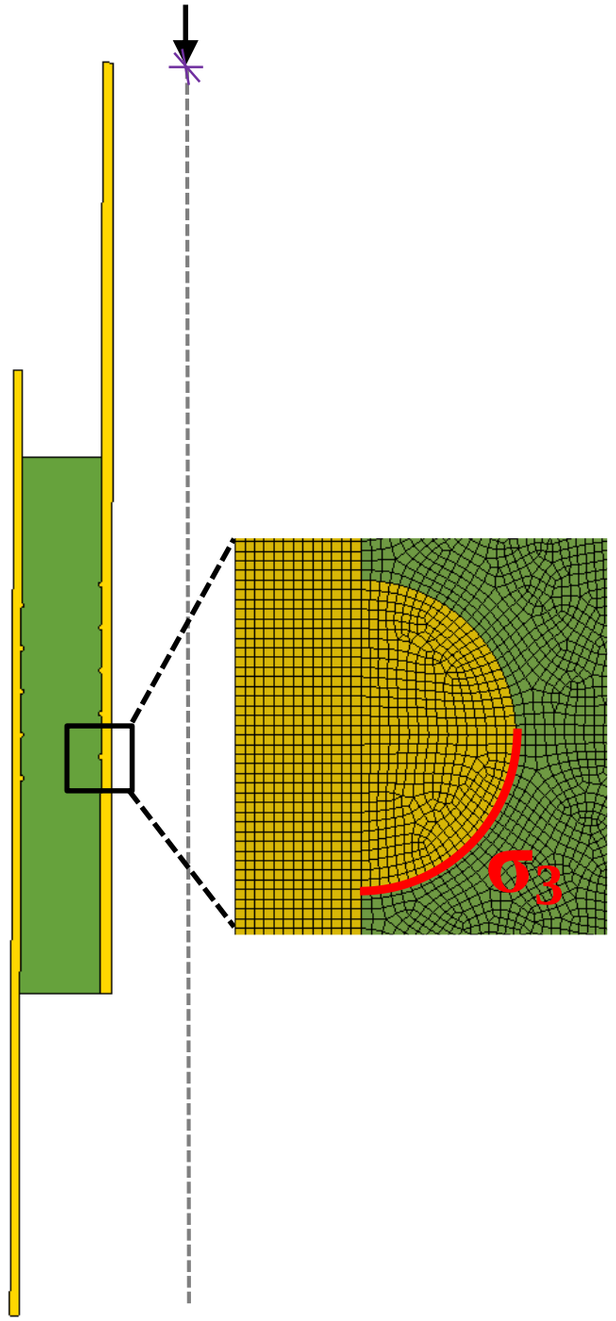


Summary

Design concept for submerged axially loaded grouted connections





<u>Conditions of use</u>

- Submerged ambient conditions

  → different failure mechanism

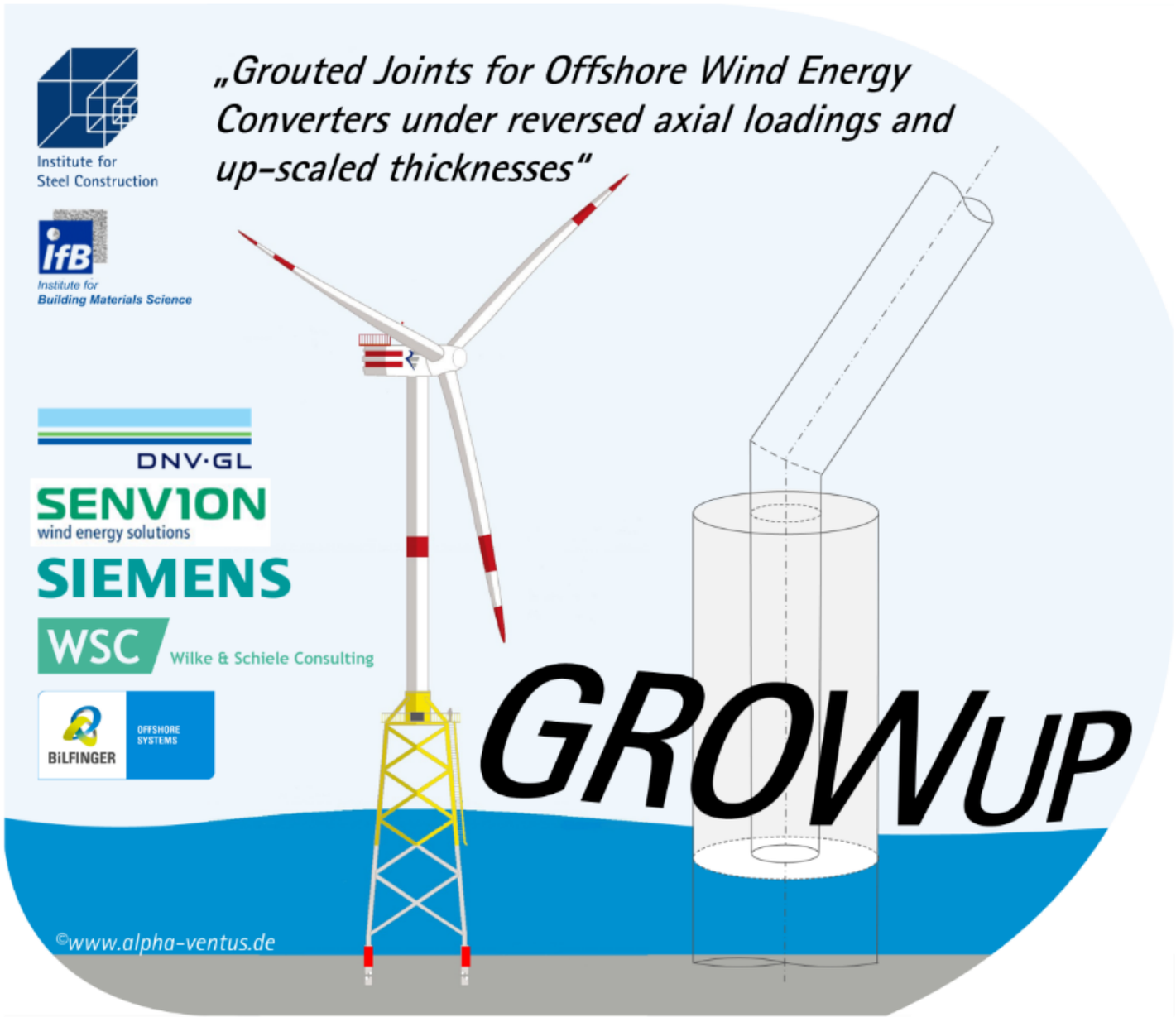
- Predominantly axial loading

<u>Requirements for FE-model</u>

- 2D rotational symmetric FE-model
  - Depiction of shear keys
  - Nonlinear material (e. g. Concrete Damaged Plasticity)
  - Highly discretized mesh
- Local stress analysis of grout material according to ModelCode 2010

Thank you to our project partners and supporters!

Thank you for your attention!



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