EERA DeepWind'2017

Fatigue behaviour of grouted connections at different ambient conditions

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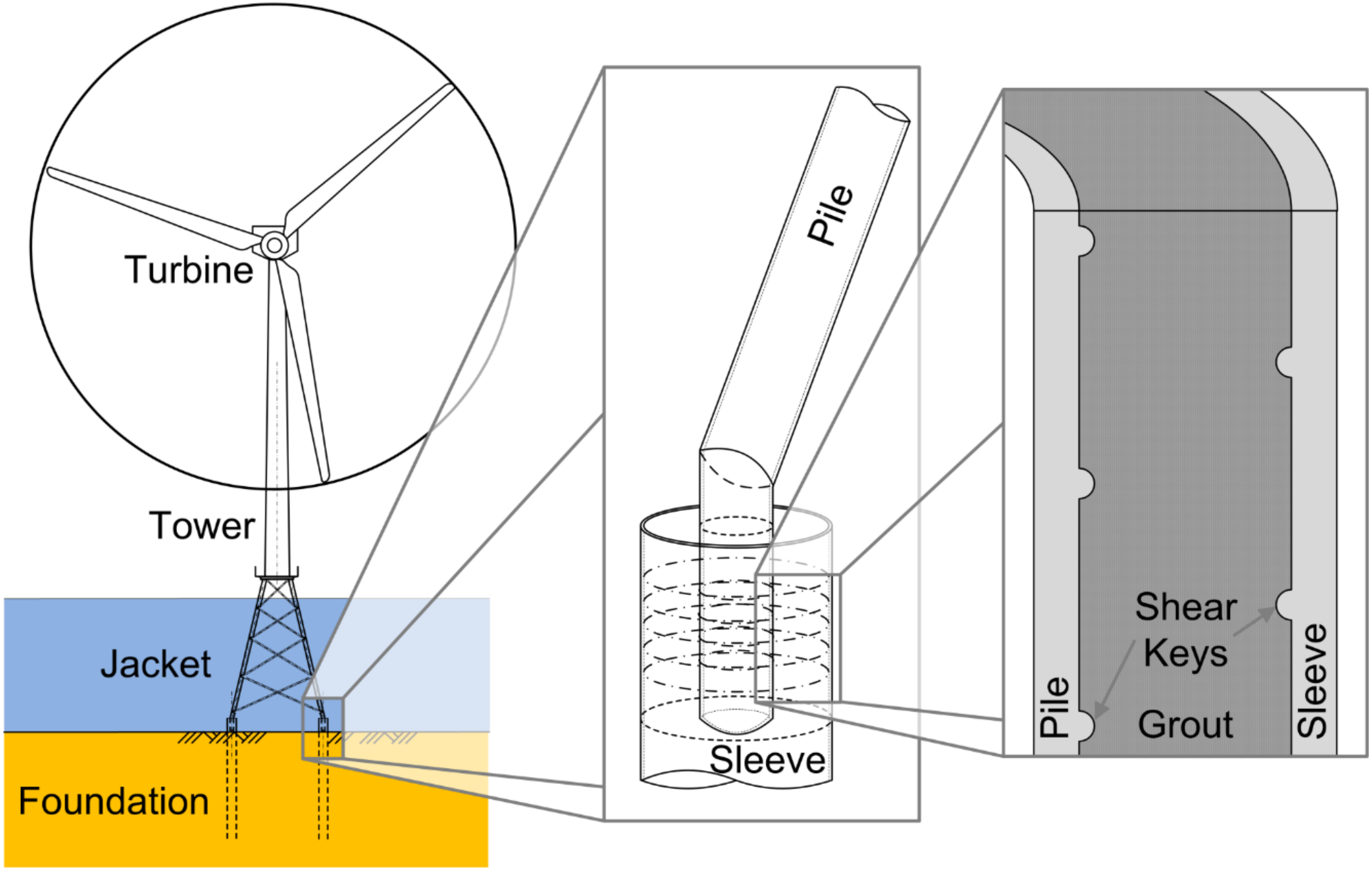
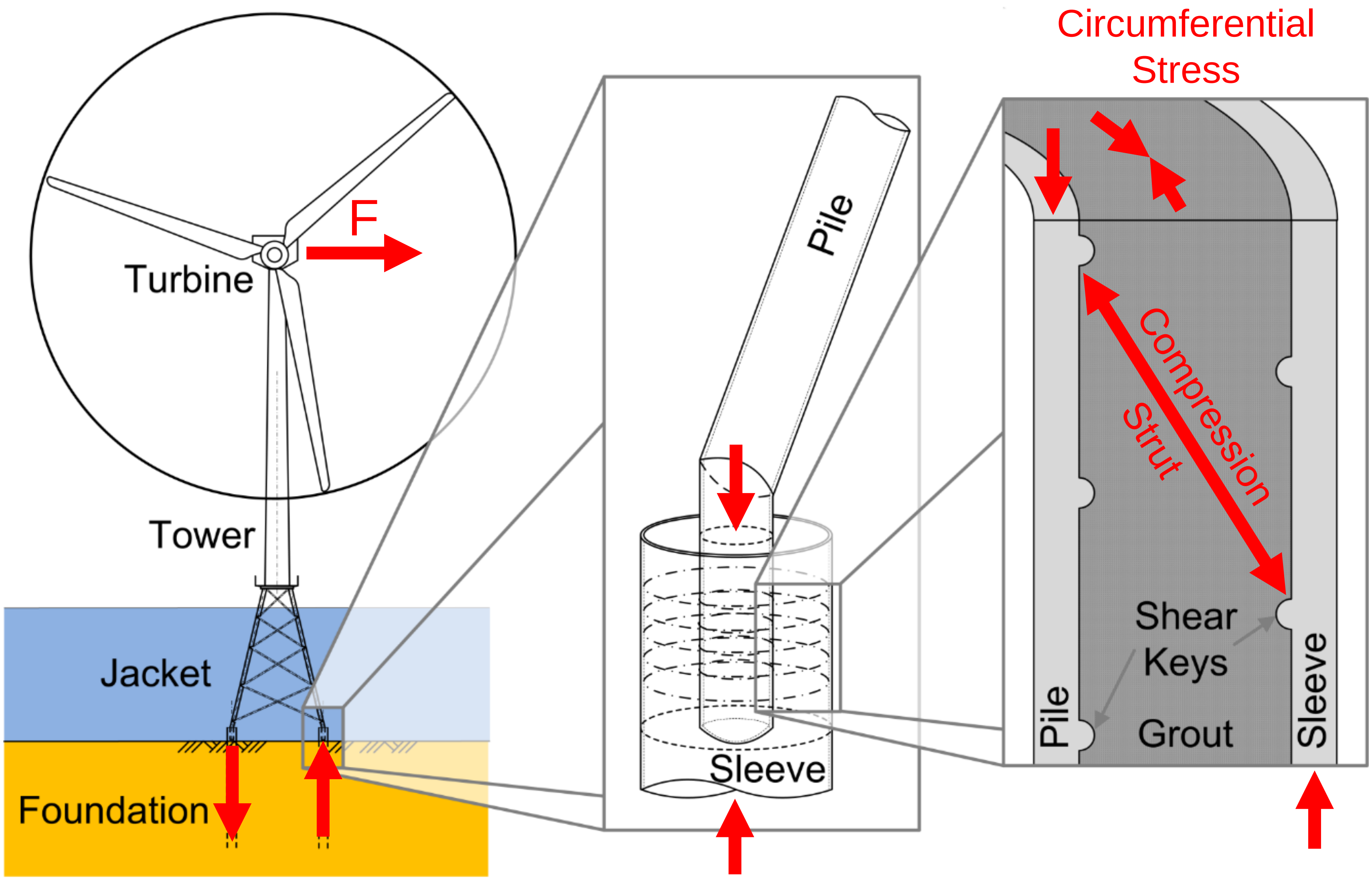
Outline

- Grouted connections
- Submerged fatigue tests
  - Small-scale
  - Large-scale
- Damage mechanisms
- Summary and Outlook

Grouted connections



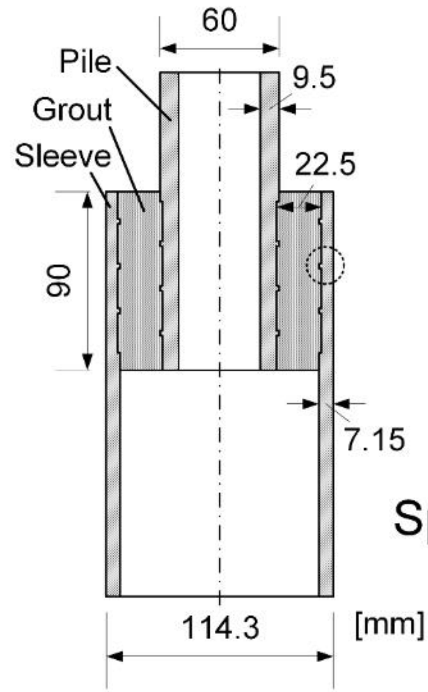
Grouted connections



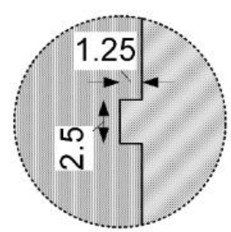
Small-scale tests – setup

- 1 Geometry
- 2 Grout materials
  - f_c = 90 N/mm² / 140 N/mm²
- 2 Load levels
  - constant amplitude
  - F_{max} = 50% F_{ULS} / 20% F_{ULS}
  - R = 20
- 2 Ambient conditions
  - dry / wet
- 5 Loading frequencies
  - 0.3 – 10 Hz

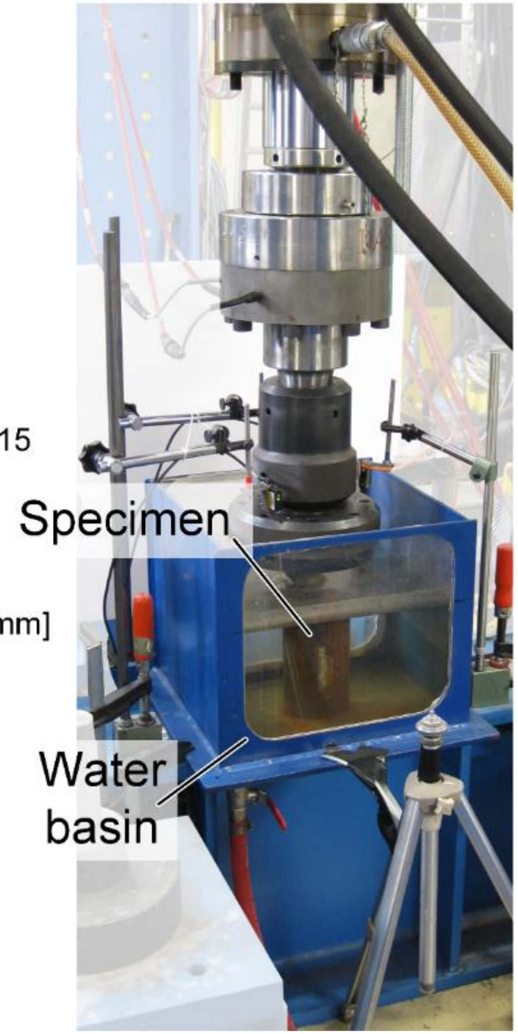
Geometry



Shear key

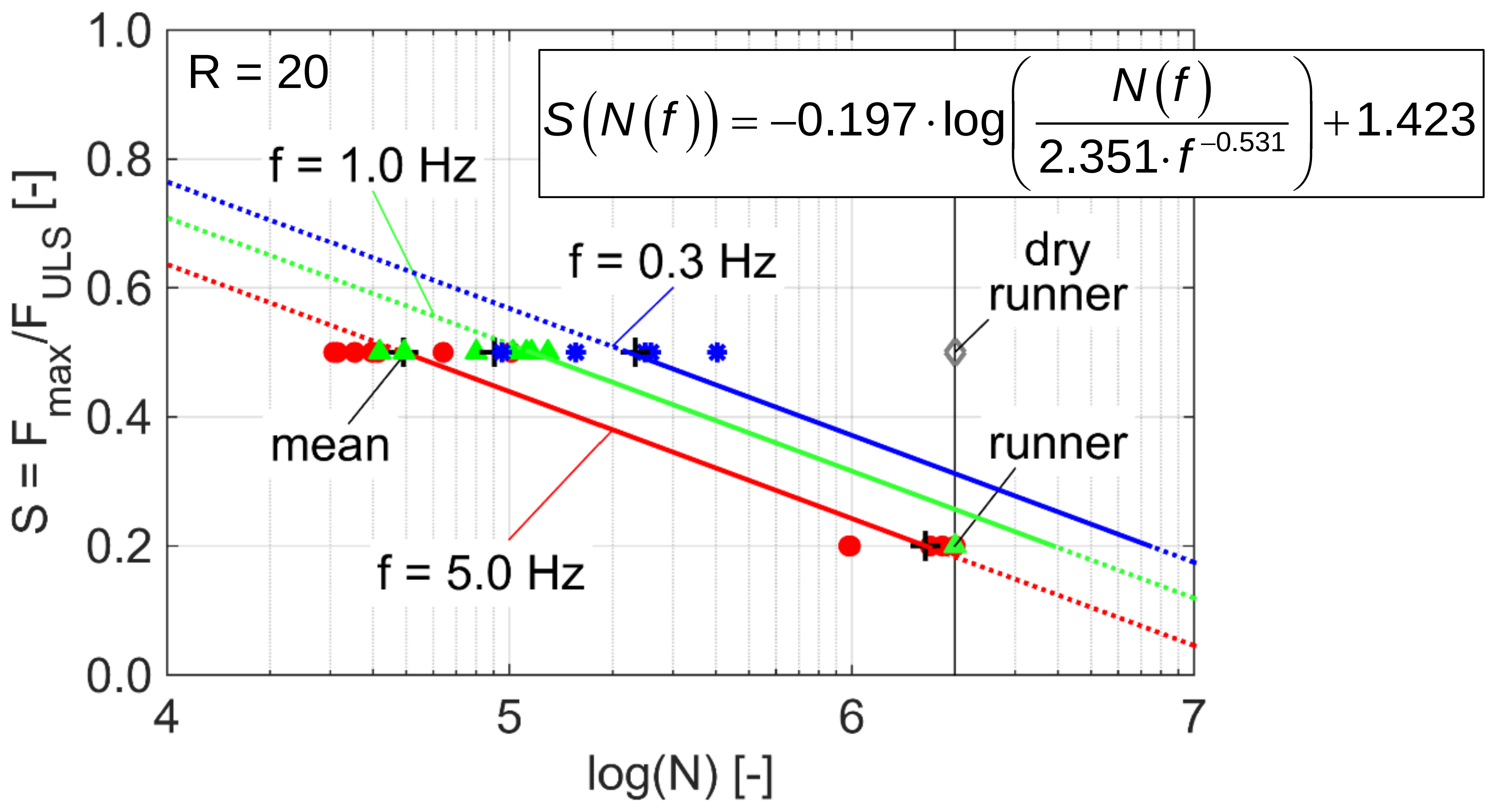


MFL – Test-Rig



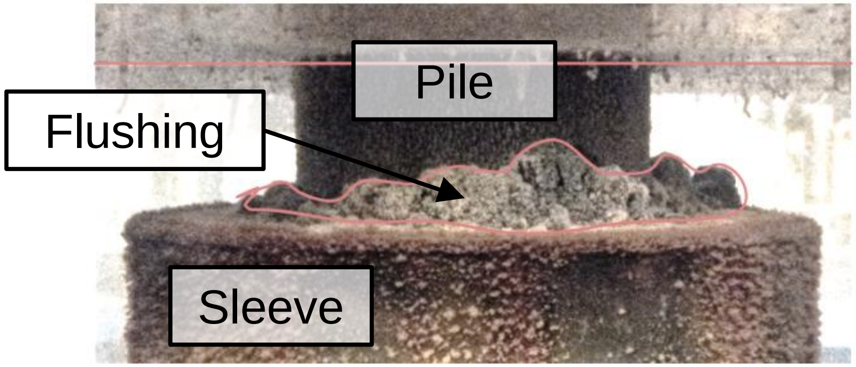
Small-scale tests – endurable load cycles

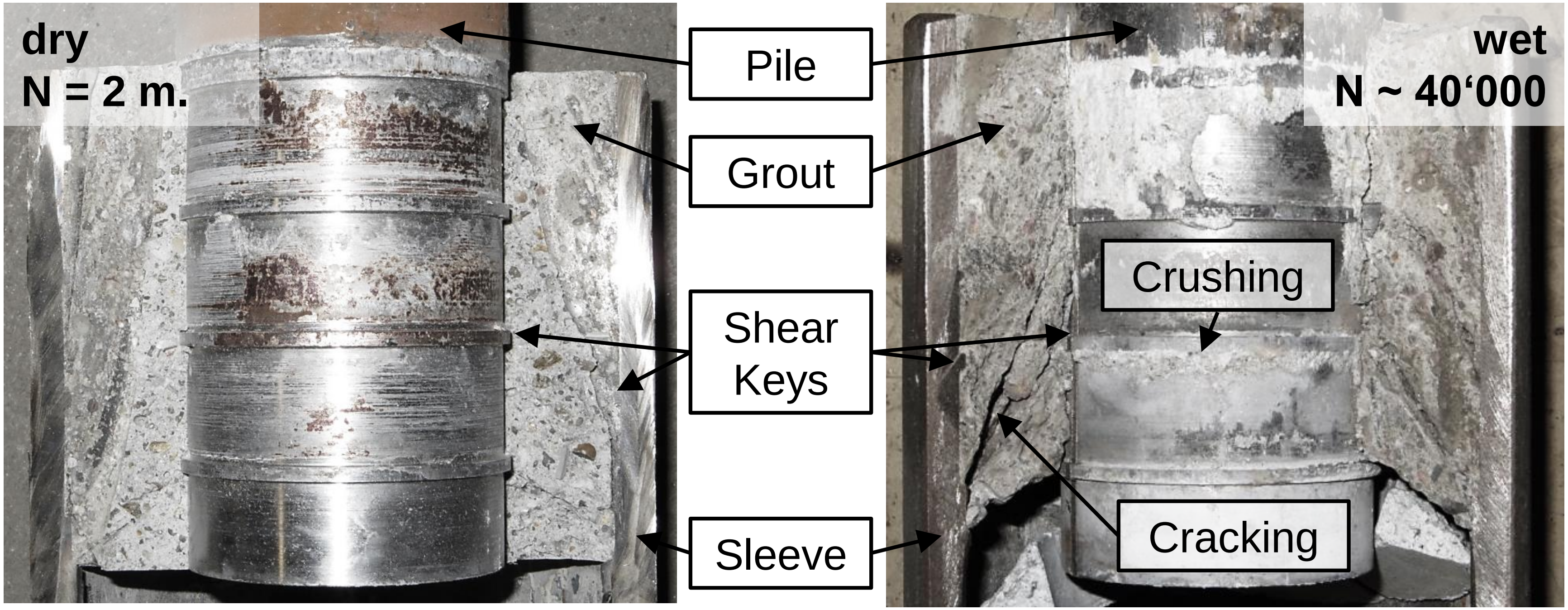
- Water leads to significant reduction of N
  N_{dry} = 2 m. (runner) N_{wet} ~ 50'000 N_{dry}/N_{wet} = 40
- Lower loading frequency increases N



Small-scale tests – damage patterns

- Water introduces
  - Grout flushing
  - Early stage cracking

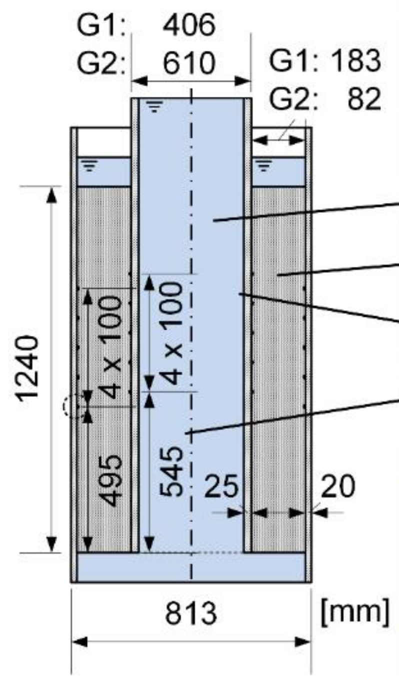




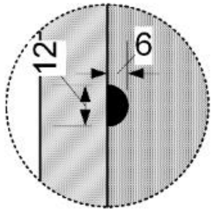
Large-scale tests – setup

- 2 Geometries
  - G1: t_g = 183 mm
  - G2: t_g = 82 mm
- 1 Grout-Material
  - f_c = 140 N/mm²
  - f_t = 8.6 N/mm²
  - E = 50‘900 N/mm²
- 2 Loading scenarios
  - R = -1 / R = ∞
- 2 Ambient conditions
  - dry / wet

Geometry



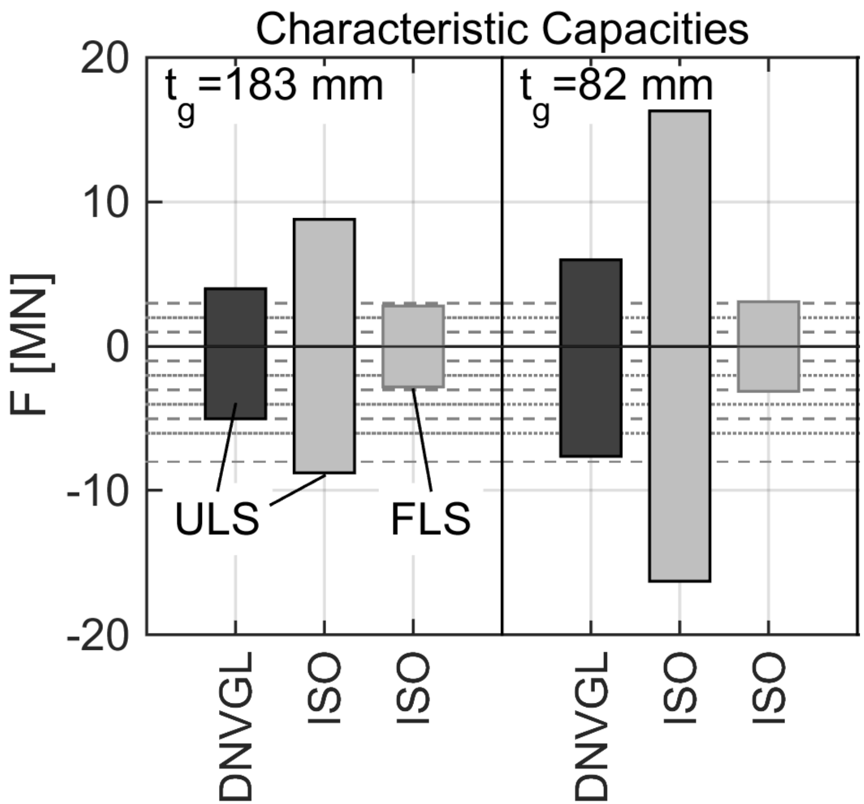
Shear key



IST – 10 MN Rig

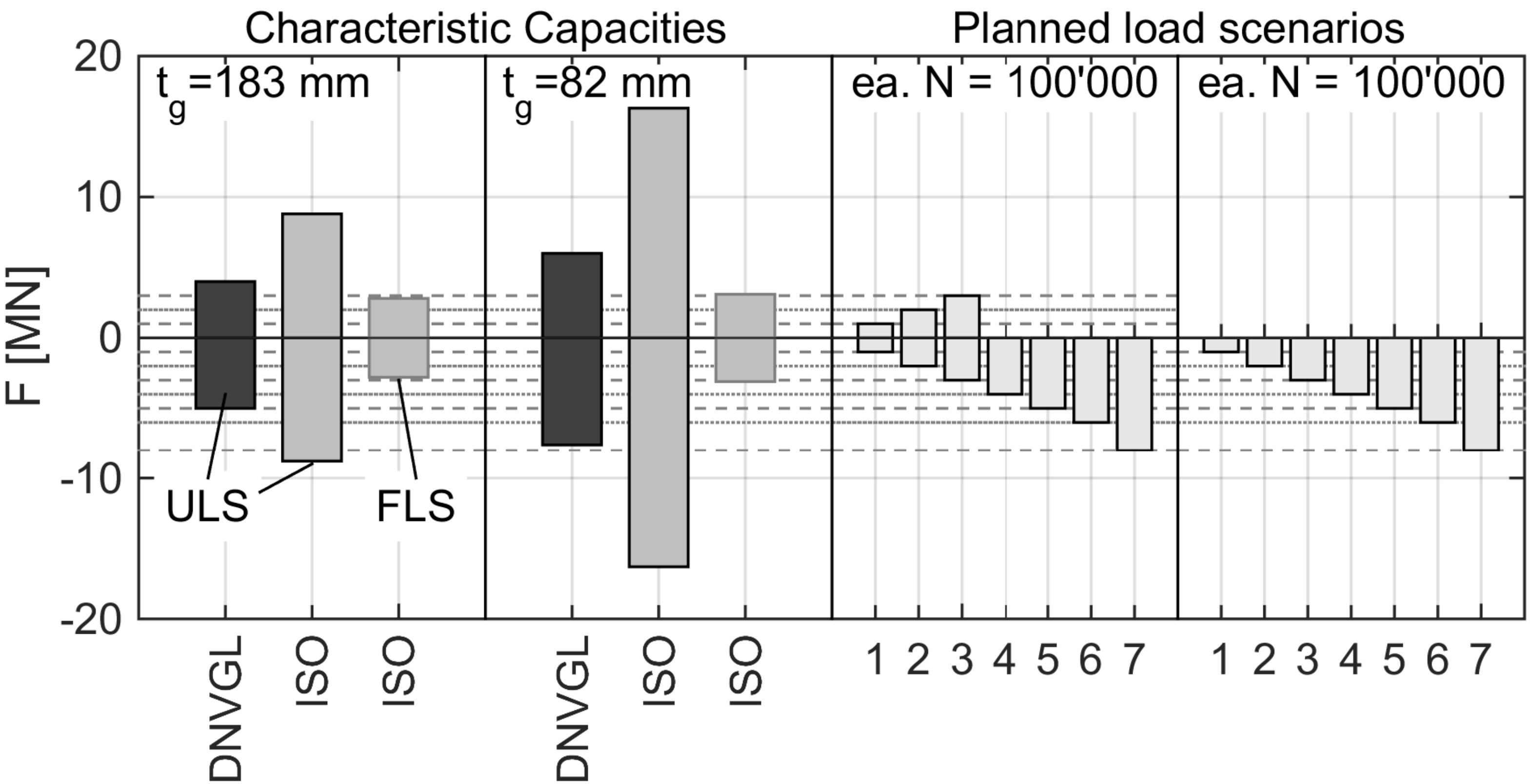
Large-scale tests – load scenarios

- Objective: fatigue damage
  - F_{max} < F_{FLS} (ISO 19902) < F_{ULS} (ISO 19902, DNVGL-ST-0126)



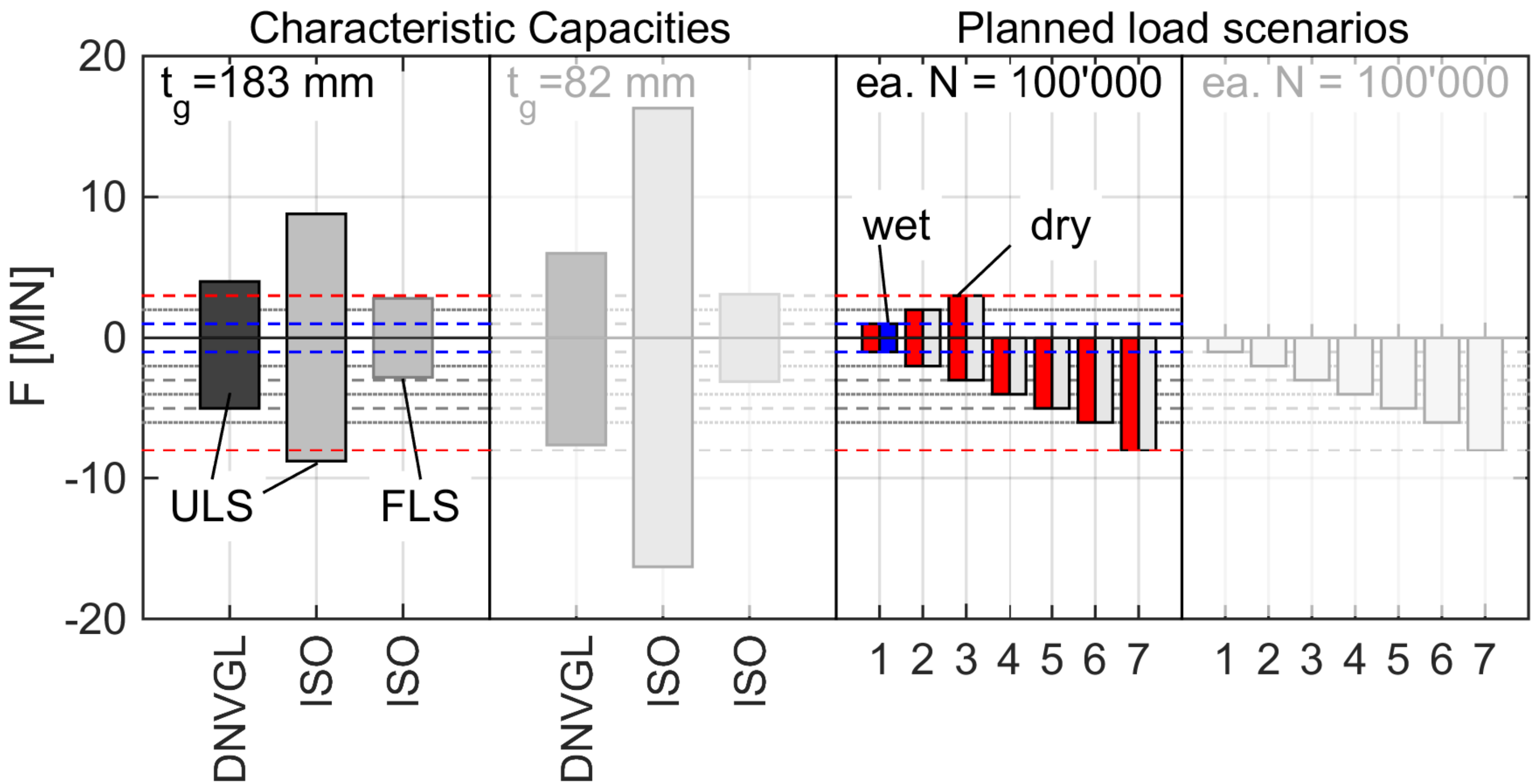
Large-scale tests – load scenarios

- Objective: fatigue damage
  - $F_{max} < F_{FLS}$ (ISO 19902) $< F_{ULS}$ (ISO 19902, DNVGL-ST-0126)
  - Damage expected $\geq$ LS 3



Large-scale tests – endurable load cycles

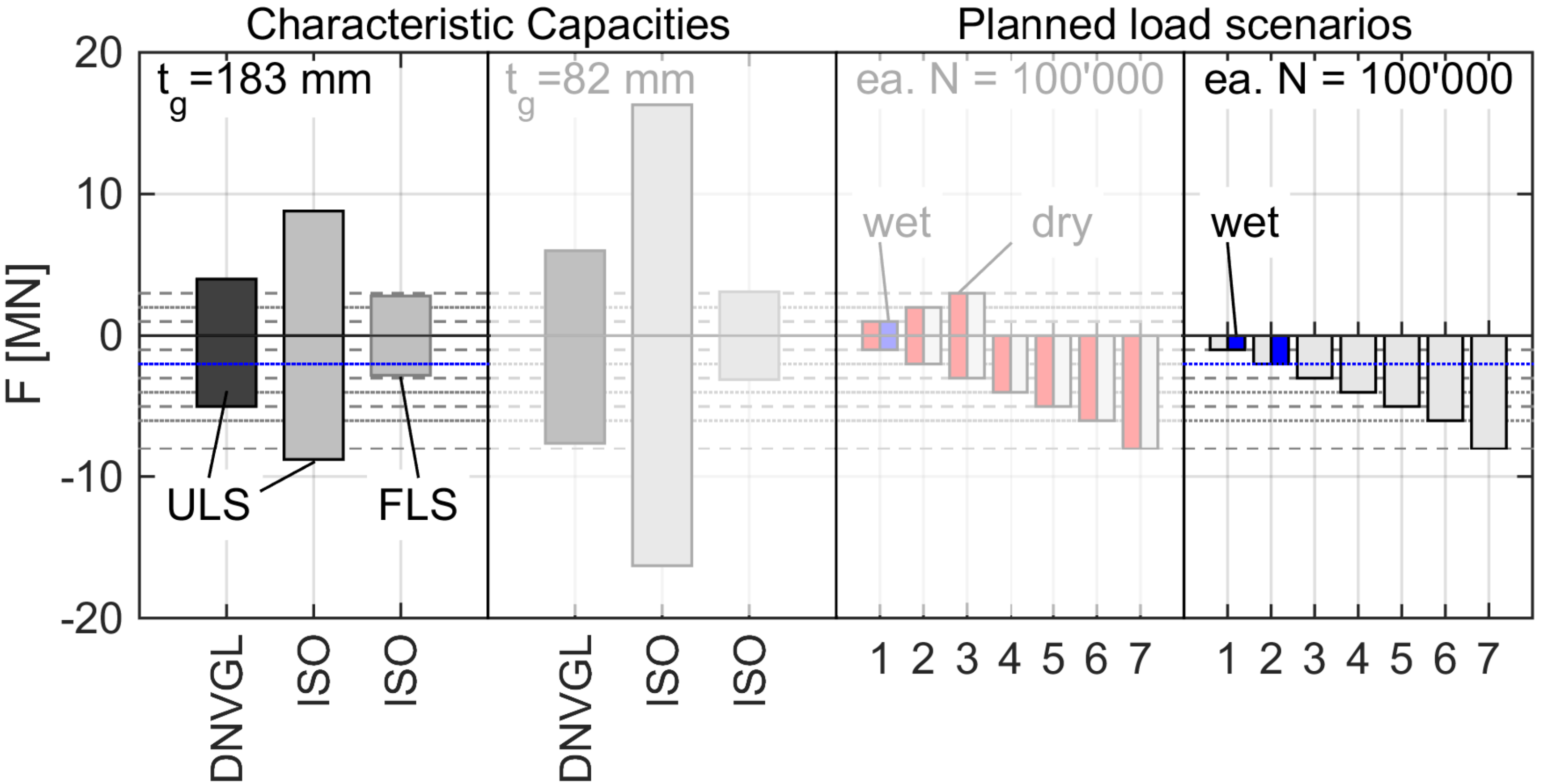
- Failure t_g = 183 mm D1 (R = -1 / dry) LS7 (N ~ 200)
  W1 (R = -1 / wet) LS1 (N ~ 95‘000)



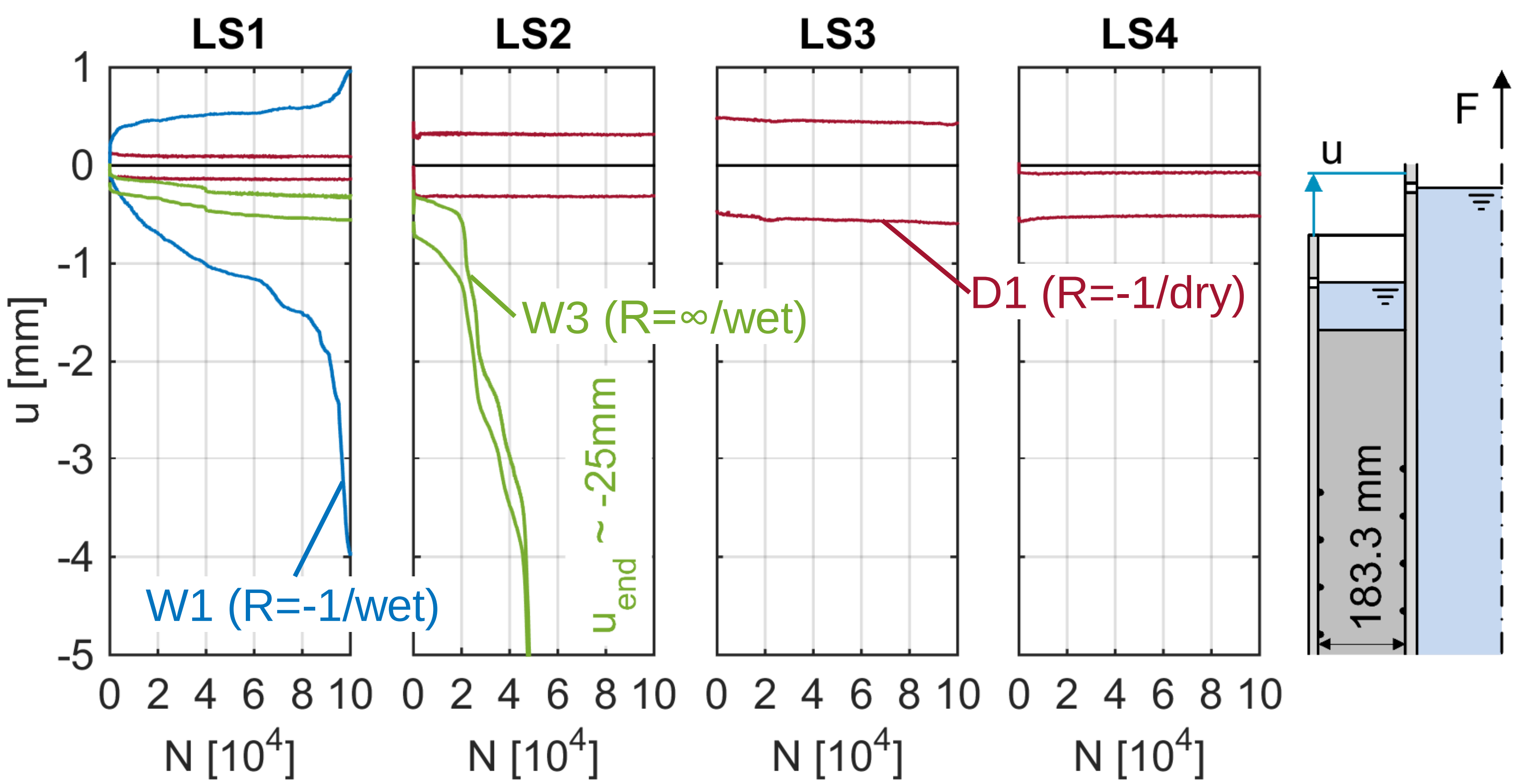
Large-scale tests – endurable load cycles

- Failure t_g = 183 mm

D1 (R = -1 / dry)	LS7 (N ~ 200)
W1 (R = -1 / wet)	LS1 (N ~ 95‘000)
W3 (R = ∞ / wet)	LS2 (N ~ 45‘000)



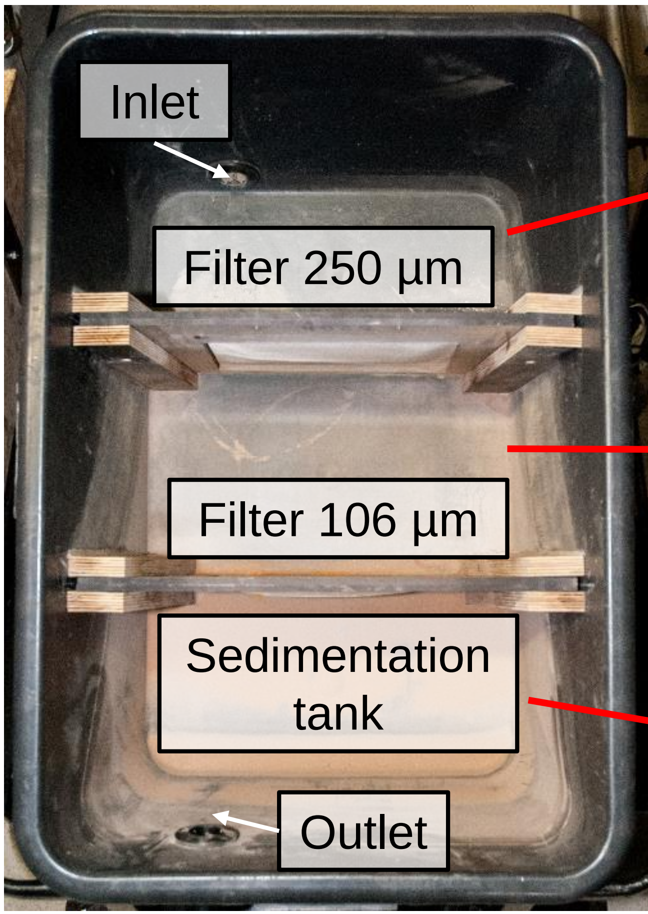
Large-scale tests – deformation behaviour t_g = 183 mm

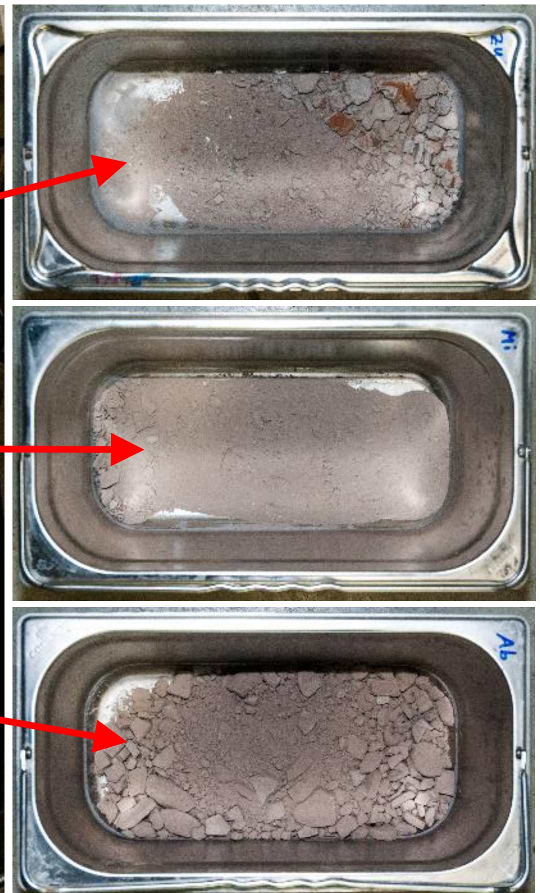


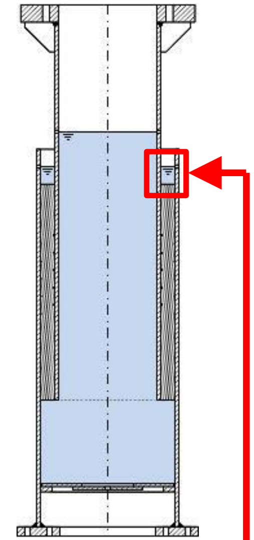
- Water provokes instable load bearing behaviour

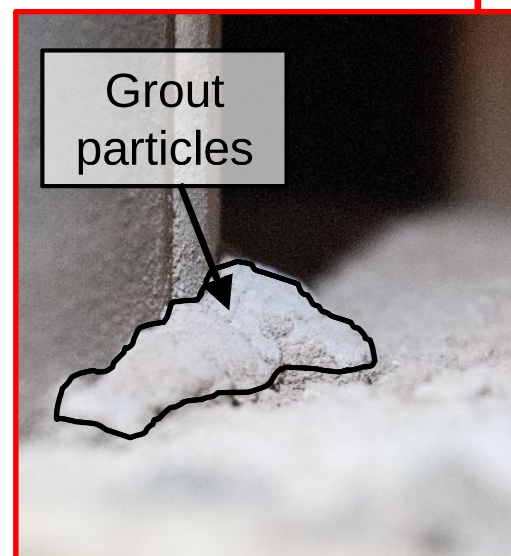
Large-scale tests – flushing

- Filterbasin to detect flushing and particle sizes





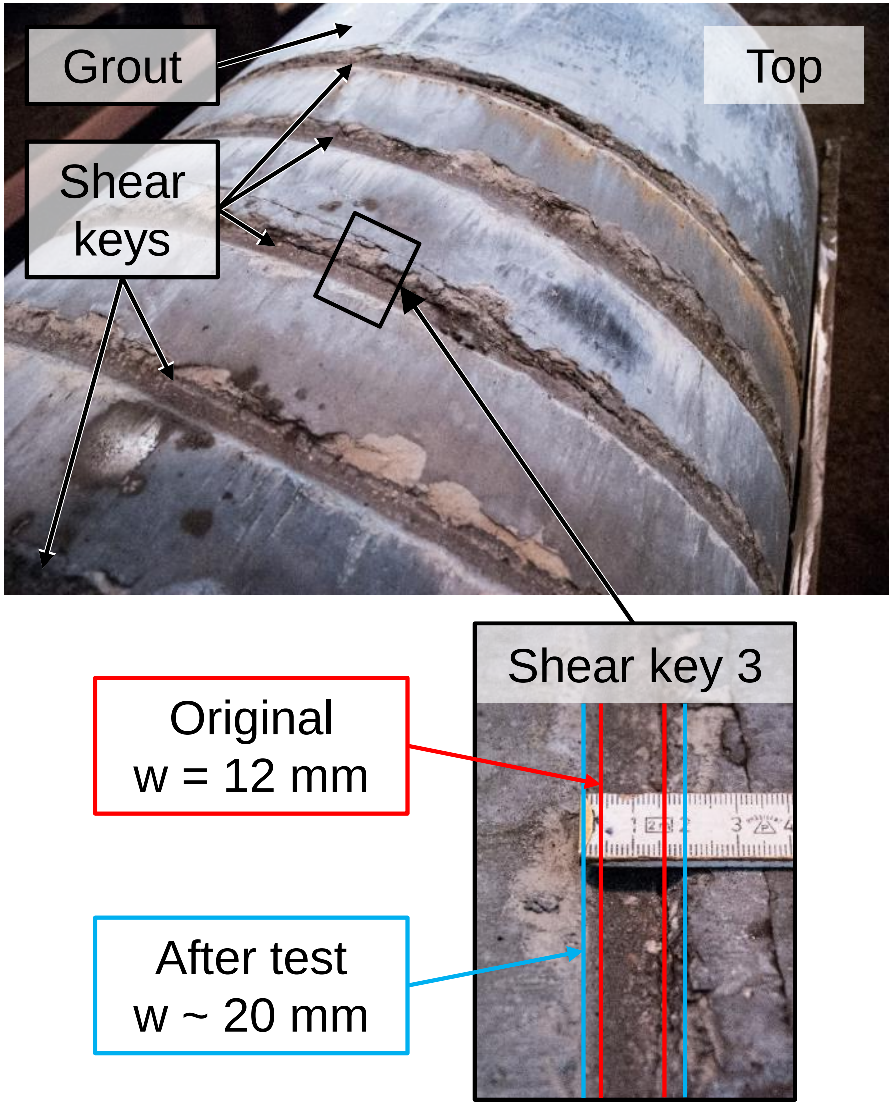


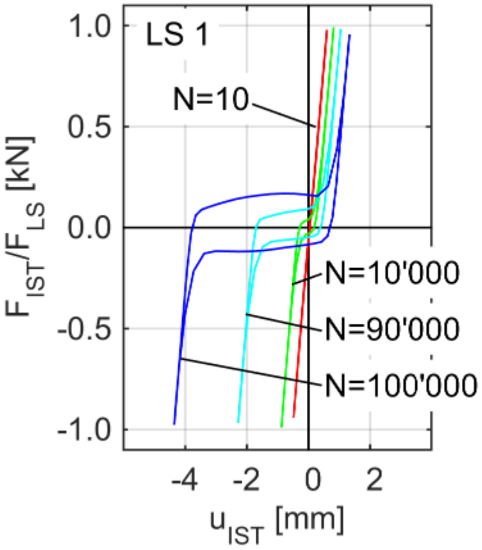


Large-scale tests – dismantling

Large-scale tests – damage patterns t_g = 183 mm (W1)

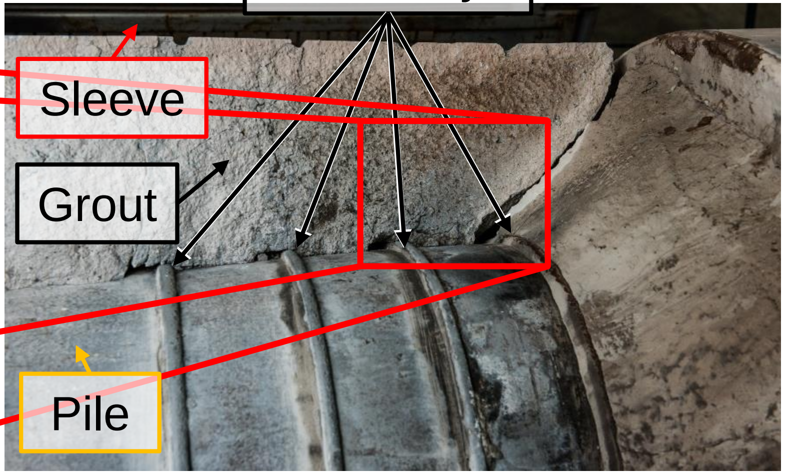
- Grinding marks on grout
- Connection backlash established during test
- Grout crushing around shear keys (sleeve-grout)





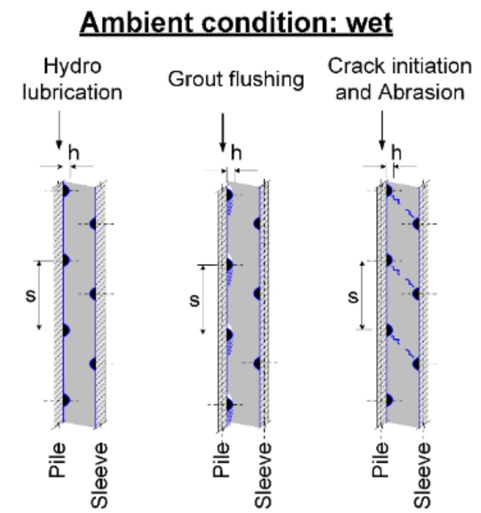
Large-scale tests – damage patterns t_g = 183 mm (W3)

- Compression strut cracking
- Grout crushing around shear keys
- Water passages
- Flushed grout particles



Summary and Outlook

- Parameter influence
  - AC wet → N ↘
  - Load ↘ → N ↗
  - Load ratio R > 0 → N ↗
  - Loading frequency ↘ → N ↗
  - Grout annulus t_g ↘ → N ↗



- Additional damage mechanisms
  - Grout crushing and flushing
  - Early stage cracking
- Comparable results for small- and large-scale tests

Summary and Outlook

- Parameter influence
  - AC wet → N ↘
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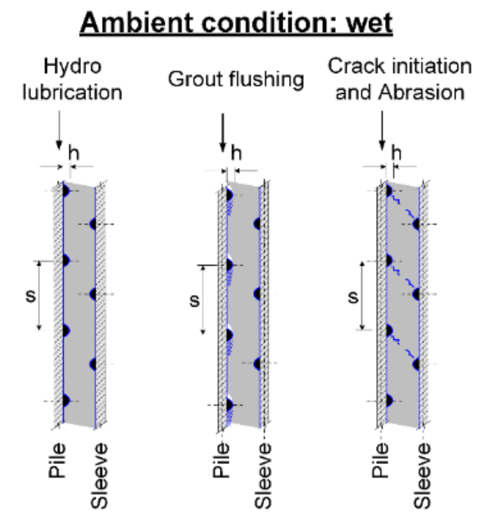
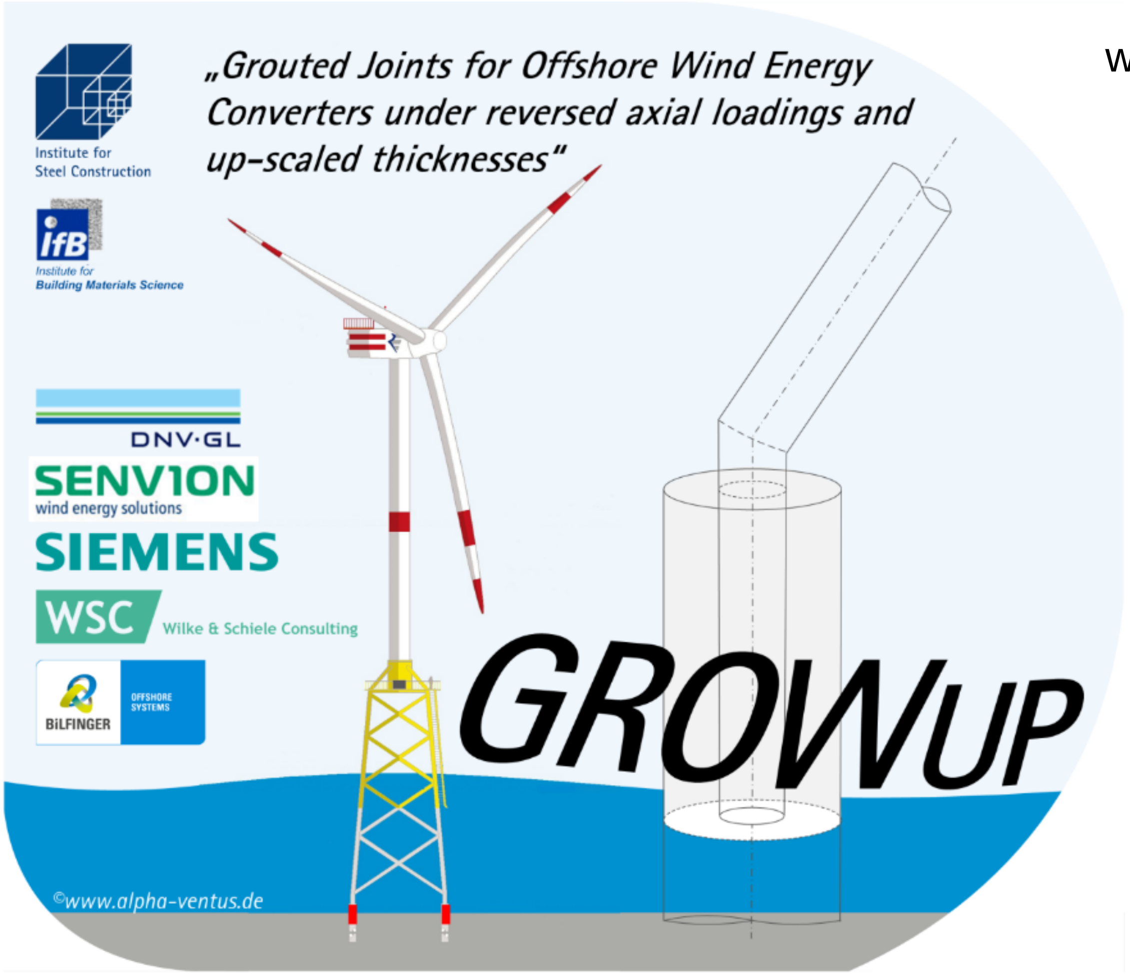


- Additional damage mechanisms
  - Grout crushing and flushing
  - Early stage cracking
- Comparable results for small- and large-scale tests
- Future tests with OPC in preparation

Thank you to our project partners and supporters!

Thank you for your attention!



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