Fatigue behaviour of grouted connections at different ambient conditions

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Trondheim, 19/01/2017
Outline

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

Raba – Fatigue behaviour of grouted connections at different ambient conditions and loading scenarios
Grouted connections

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Small-scale tests – setup

- 1 Geometry
- 2 Grout materials
  - $f_c = 90 \text{ N/mm}^2 / 140 \text{ N/mm}^2$
- 2 Load levels
  - constant amplitude
  - $F_{\text{max}} = 50\% \ F_{\text{ULS}} / 20\% \ F_{\text{ULS}}$
  - $R = 20$
- 2 Ambient conditions
  - dry / wet
- 5 Loading frequencies
  - 0.3 – 10 Hz
Small-scale tests – endurable load cycles

- Water leads to significant reduction of $N$
  $N_{\text{dry}} = 2 \text{ m. (runner)}$  $N_{\text{wet}} \sim 50'000$  $N_{\text{dry}}/N_{\text{wet}} = 40$

- Lower loading frequency increases $N$

$$S(N(f)) = -0.197 \cdot \log \left( \frac{N(f)}{2.351 \cdot f^{-0.531}} \right) + 1.423$$
Small-scale tests – damage patterns

- Water introduces
  - Grout flushing
  - Early stage cracking

N = 2 m. (dry)
N ~ 40’000 (wet)
Large-scale tests – setup

- **2 Geometries**
  - G1: \( t_g = 183 \) mm
  - G2: \( t_g = 82 \) mm

- **1 Grout-Material**
  - \( f_c = 140 \) N/mm\(^2\)
  - \( f_t = 8.6 \) N/mm\(^2\)
  - \( E = 50'900 \) N/mm\(^2\)

- **2 Loading scenarios**
  - \( R = -1 / R = \infty \)

- **2 Ambient conditions**
  - dry / wet
Large-scale tests – load scenarios

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

- \( F_{\text{max}} < F_{\text{FLS}} \) (ISO 19902) < \( F_{\text{ULS}} \) (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)
  - W1 (R = -1 / wet)
  - W3 (R = ∞ / wet)

- LS7 (N ~ 200)
- LS1 (N ~ 95,000)
- LS2 (N ~ 45,000)
Large-scale tests – deformation behaviour $t_g = 183\, \text{mm}$

- Water provokes instable load bearing behaviour
Large-scale tests – flushing

- Filter basin to detect flushing and particle sizes
Large-scale tests – dismantling

Raba – Fatigue behaviour of grouted connections at different ambient conditions and loading scenarios
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)

![Image of test results and damage patterns](image-url)
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 $\rightarrow$ N
  - Load $\downarrow$ $\rightarrow$ N
  - Load ratio $R > 0$ $\rightarrow$ N
  - Loading frequency $\downarrow$ $\rightarrow$ N
  - Grout annulus $t_g$ $\downarrow$ $\rightarrow$ N

- **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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