Bridge Foundations at Large Water Depths

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Content

• Research topic
• Macro model describing non-linear foundation behaviour (Soil Structure Interaction)
• Rock Anchor research – cyclic loads
• Practical application
Research topic

- Bridge foundations at large water depths
  - The foundation structure connecting the suspension- or floating bridge and a fixed bridge towards the shoreline
Macromodel

• What is a macromodel?
  – The foundation and soil is represented by a single element in the structural analysis. This element describes the elasto-plastic foundation behavior

• Motivation:
  – Major advantage: Capability to describe complex interactions between the various degrees of freedom in a relatively simple manner. = time and cost saving
Macromodel - Yield surface

\[ F = H_F^2 + M_F^2 - N_F^2 - V_F^2 = 0 \]

\[ H_F^2 = \left( \frac{H}{h_0 \cdot V_0} \right)^2 \cdot \left( \frac{\mu_m}{\mu_h} \right)^2 \cdot \left( \frac{V}{V_0} \right)^{2(\beta_{1m} - \beta_{1h})} \cdot \left( 1 - \frac{V}{V_0} \right)^{2(\beta_{2m} - \beta_{2h})} \]

\[ M_F^2 = \left( \frac{M / B}{m_0 \cdot V_0} \right)^2 \]

\[ N_F^2 = \frac{2 \cdot a \cdot H \cdot M / B}{h_0 \cdot m_0 \cdot V_0^2} \cdot \frac{\mu_m}{\mu_h} \cdot \left( \frac{V}{V_0} \right)^{(\beta_{1m} - \beta_{1h})} \cdot \left( 1 - \frac{V}{V_0} \right)^{(\beta_{2m} - \beta_{2h})} \]

\[ V_F^2 = \mu_m^2 \left( \frac{V}{V_0} \right)^{2\beta_{1m}} \cdot \left( 1 - \frac{V}{V_0} \right)^{2\beta_{2m}} \]

\[ \mu_h = \left[ \frac{(\beta_{1h} + \beta_{2h})^{(\beta_{1h} + \beta_{2h})}}{\beta_{1h}^{\beta_{1h}} \cdot \beta_{2h}^{\beta_{2h}}} \right] , \quad \mu_m = \left[ \frac{(\beta_{1m} + \beta_{2m})^{(\beta_{1m} + \beta_{2m})}}{\beta_{1m}^{\beta_{1m}} \cdot \beta_{2m}^{\beta_{2m}}} \right] \]

\[ V_0 = \kappa \cdot V_{\text{max}} \]
Calculation example

- Anchor block
- \( L \times B = 100\text{m} \times 50\text{m} \)
- Self weight = 2GN (200 000 tons!)
- 40m waterdepth
- Cable pull 500 MN
- 50m dense sand over bedrock
Calculation result

Model
Plaxis
Macromodel – further work:

- Paper issued and presented, SEMC (Conference on Structural Engineering, Mechanics and Computation), Cape Town.
- Modify to accommodate cyclic/dynamic loads
- Sand-bin prototype testing
Macromodel, sand-bin
Rock Anchors

- Rock Anchors purpose:
  - increase foundation capacity
- Wire strands or bars
- Passive or pre-stressed anchor
- Retaining walls, tall-rise buildings, mining and tunneling industry
- Hardangerbrua: «End-anchored» rock anchors. Mechanical fixation – can be inspected
Rock anchors - Hardangerbrua

- ANCHORAGE UNIT
  Anchors strand of 528 wires

- PEH tube
- Injected cement mortar
- 38 prestressing strands, tension in strand 5,235 kN

- PRESTRESSING STRAND
  Ø 200 mm
  38 strands per splay chamber

- ANCHORAGE BLOCK
  Section A-A

- ANCHORAGE PLATE
- ANCHORAGE CHAMBER

- CABLE ANCHORAGE
  Formwork: 3,400 m² x 6,800 m² = 22,880 m²
  Walls and roof
  Concrete: 2,000 m³ B45 SV-40
  Concrete: 4,000 m³ B35 low heat concrete in anchorage block and plate
  Reinforcement: 1,000 tonnes
  Prestressing steel: 33,600 MN
  Bore hole Ø 200 mm: 4,400 metres
  Borehole liner: 5,080 metres
Rock Anchor research

- Topic: Cyclically loaded rock anchors and failure propagation / post cyclic capacity
  - Laboratory testing on prototypes (passive anchors)
  - Numerical model for prediction of rock anchor capacity
Laboratory test

• Test set-up
Cycling at 75% of static capacity

- Laboratory test results will be used as input in a numerical model
Rock anchor research application

- Innovative research
- Knowledge on failure propagation for rock anchors subjected to cyclic loads
- Improved knowledge might allow for extended use of rock anchors
  - Passive rock anchors vs. end-anchored rock anchors
  - Potential for significantly reduced material cost
  - Schedule impact (positive)

- Application for ferry-free E39:
  - Any foundation expected to experience tension/moment loads;
    - Anchor blocks (for main cables)
    - Anchors for floating suspension bridge towers
    - Anchors for submerged tunnel
    - Floating bridge abutments
Thank you for your attention!