In situ test of steel core piles in limestone bedrock in Sweden

- Purpose of presentation
  - Illustrate some, for Sweden, special geological conditions
  - Difficulties we had to judge the quality of sedimentary rock and how we should use it for piling

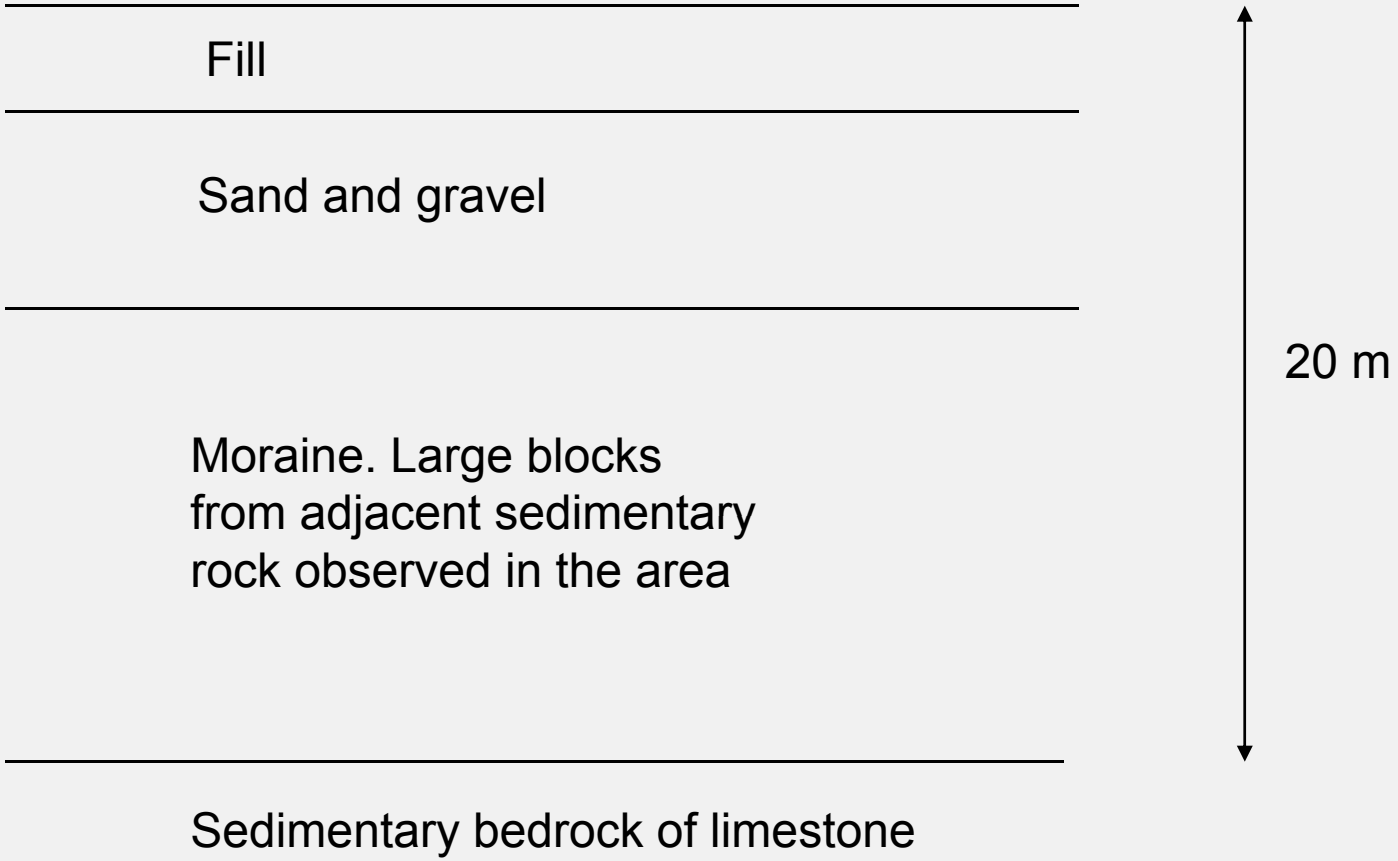
In situ test of steel core piles in limestone bedrock in Sweden

- Background
- Geotechnical conditions
  - Geology
  - Soundings and samples
  - Study of core of rock
- Test
  - Purpose
  - Piles
  - Compression tests
  - Tension tests
- Conclusions

Background

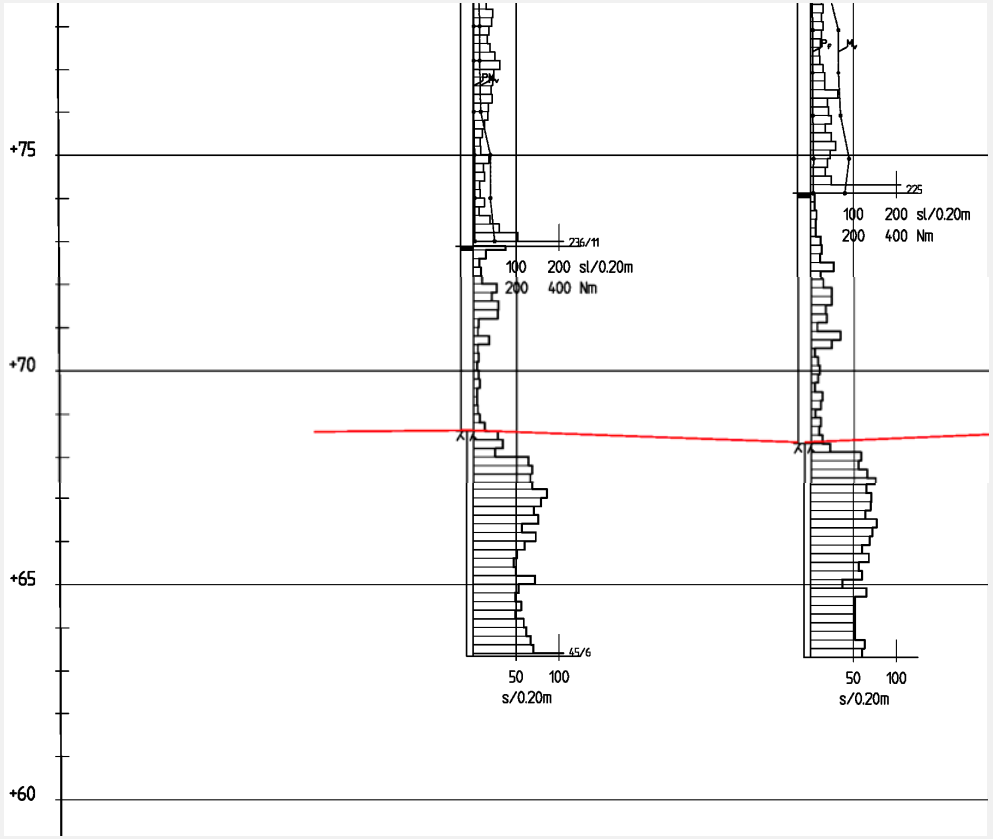
- Replace bridge from 1870
- Canal Göta kanal
  - Started 1808
  - Assistance from Thomas Telford
  - Cultural heritage
- Care for embankments of Göta kanal and foundations of old bridge:
  - Steel-core-piles

Geotechnical conditions – geology



Geotechnical conditions – soundings and samples

- Soil-Rock-Soundings
  - Push-force,
  - Pressure on hammer,
  - Pressure driving rotation-motor
  - Pilot bit 57 mm
  - Confirmed bedrock horizontal surface at 20 m of depth



Geotechnical conditions – soundings and samples

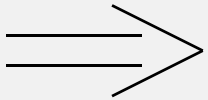
- Upcoming flush during case boring (for rock core)
  - 10 m thick broken down block of limestone overlying moraine
- Boring for casing to steel-core-pile
  - Rock indication a few meters above anticipated bedrock-surface
  - Continued boring indicated gravel below and level of bedrock-surface as anticipated
  - Variation of quality of rock

Study of core of rock

- Observation
  - Limestone with horizontal layers 0,2 m thick
  - In between: 1 cm thick layers of shale
  - Vertical cracks
- Conclusion
  - E- modulus (for shaft bearing): 0,2 to 0,4 GPa,
  - Low E-modulus means constant distribution of tension along shaft
  - Bond to rock along shaft: 300 kPa in shearing capacity

Test - background

- Good experience of limestone in other parts of Sweden
- Effect of weak layers and cracks difficult to assess
- Large pile group – reduce grouted lengths and use end-bearing possible?



- Full scale tests!

Test - piles

- Steel-core-piles 120 mm, 355 MPa
- API threaded joints tightened with 700 kNm with a capacity of 1690 kN

Test - compression

- Endbearing expected (Bredenberg (2000)): 60 MPa
- PDA 2 points, 1 m and 5 down
- 1940 to 2730 kN, 7 to 3 mm pile toe compression

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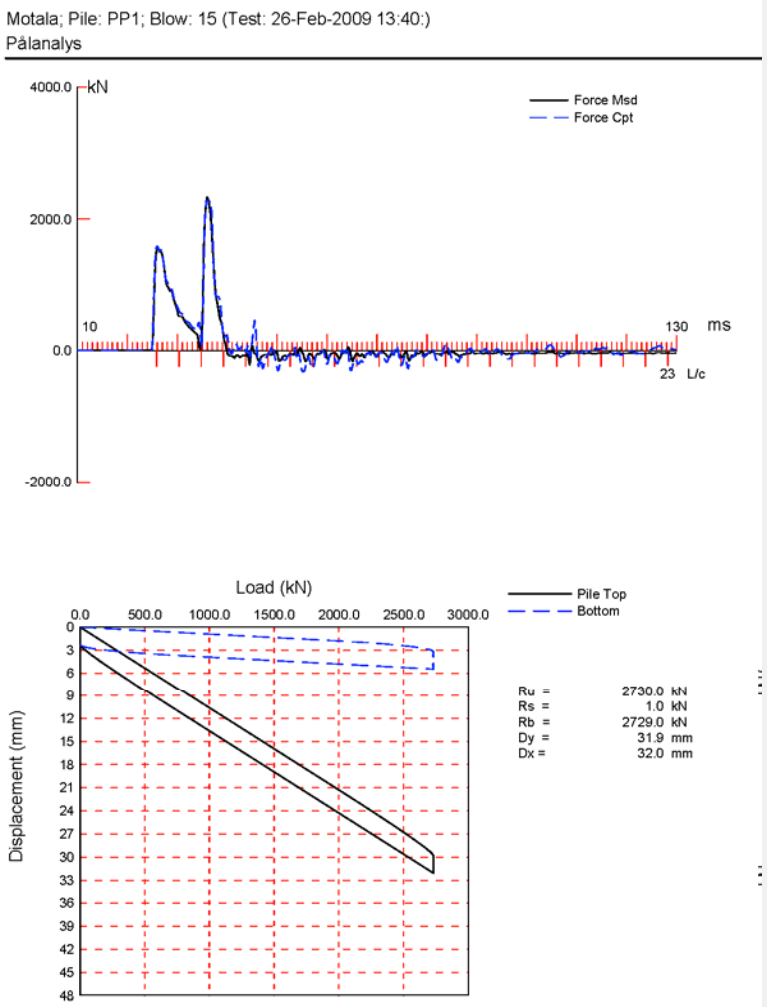
- Endbearing around 45 MPa – as expected
- Endbearing Rd 1200 kN



Test - tension

- Bond shearing capacity according to study of core would lead to long grouting lengths
- Piles grouted 5 m in bedrock
- Stepwise loading
  - 15 min duration of step (EN1537: 30 min to 60 min)
  - Up to 1400 kN
- First pullout test
  - At W402: 1400 kN during 5 minutes, total creep 2 mm (?)
  - At W403: 1200 kN during 9 minutes, total creep 4 mm (?)
  - Large settlements of supports: uncertain creep values

Test - tension

- Second pullout test
  - At W402: 1400 kN without any measurable creep

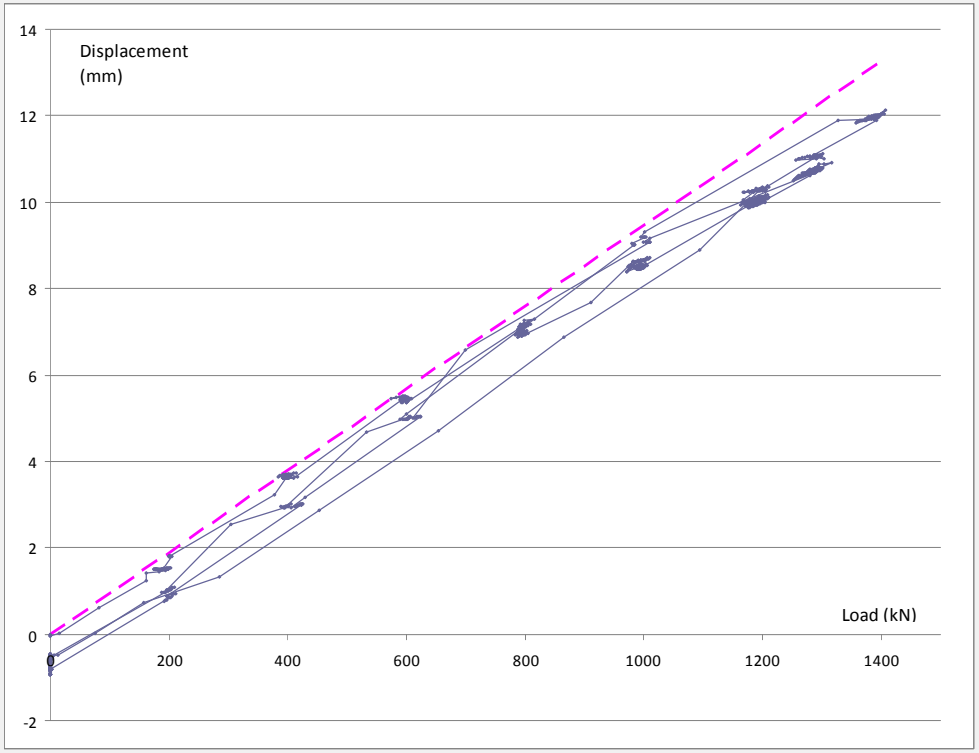


Figure. Displacement as a function of load. Red line is displacement owing to elasticity within free length

Test

- Shear-strength at bond between rock and grout
  - In hard layers at points for PDA (calculated from PDA end bearing): 2250 kPa
  - Minimum average over 5 m depth confirmed by tension tests: 540 kPa

Conclusions

- Influence of cracks and weak layers was overestimated
- Hard layers for end-bearing can be found with careful boring
- If a low average E-modulus (expected from core-study) can be verified, than the end-bearing (PDA) and shaft bearing can be combined for compression