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HIGH CAPACITY MICROPILES IN WEAK DOLOMITIC LIMESTONE FOR CRANE FOUNDATION SUPPORT

A Case History in Temporary Foundations

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Outline

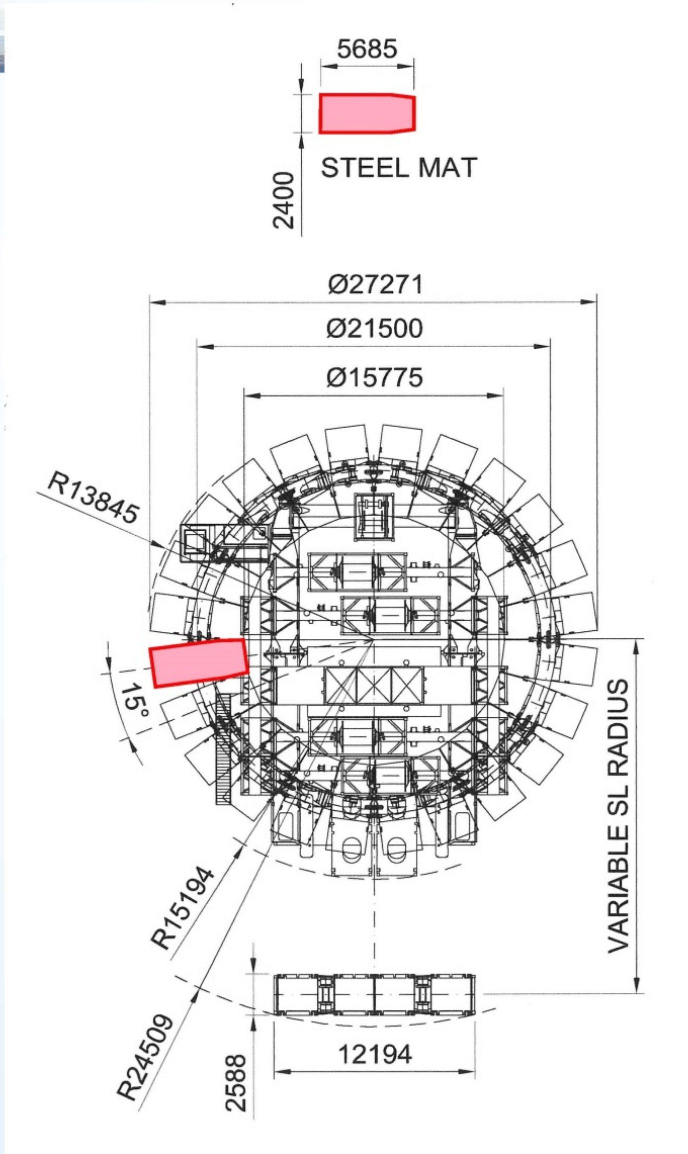
- Introduction
- Ring Crane Support Requirements
- Development of Constructible Solutions
- Design of Micropile Support
- Load Testing
- Production Pile Installation/Challenges
- Performance of the Ring Crane Foundation

Introduction (Now that's a big crane!)

- Emission and SCR upgrades at major S.E. U.S. combined nuclear and coal-fired plant
- Congested environment – large, long-radius crane picks
- 1800 metric tonne PTC ring crane, 27 m outside ring diameter
- Tremendous number of partially mapped subsurface utilities

Photo of typical usage and setup for a Mammoet PTC35 ring crane (photo courtesy of Mammoet)

Ring Crane Support Requirements



Crane layout and dimensions (in mm) for a PTC35 ring crane (image courtesy of Mammoet).

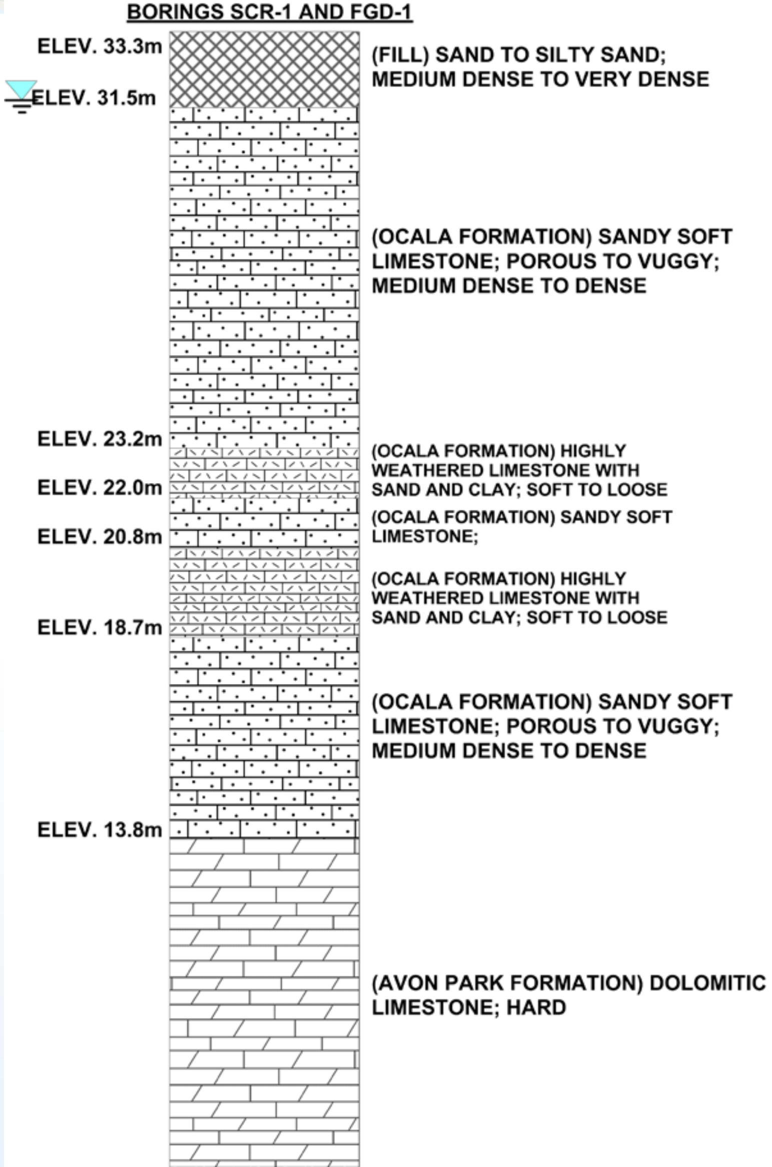
- Largest crane pick = 230 tonnes
- Dedicated, high performance foundation required for support
- 24 steel mats with distributed load of 4.0 MN/ea., total vertical load of 96.5 MN

Development of Constructible Solutions

- Original design by Owner's consultant was 38, 0.91 m dia. drilled shafts in underlying "limestone"
- Topics not considered in original design
  - Utilities and lack of understanding of locations
  - Limited access for large drilling equipment
  - Poor recent experience with drilled shaft construction adjacent to crane location
- Owner very amenable to value engineered solution
  - 2 to 1 substitution of micropiles for drilled shafts
  - Reduction of pile cap thickness from 1.52 m to 1.22 m

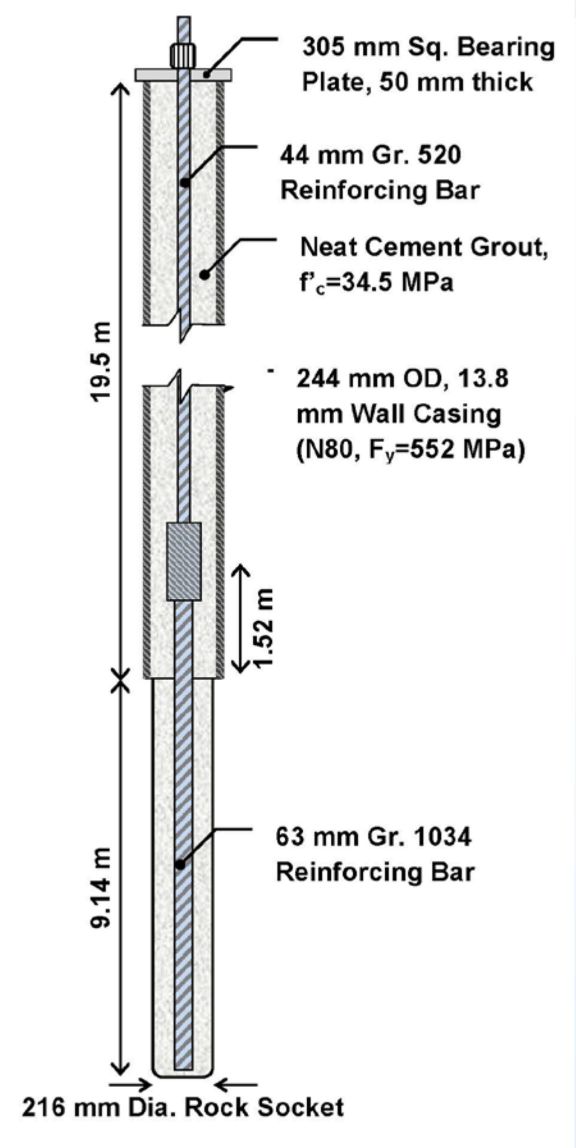
Development of Constructible Solutions

- Bypass weak Ocala Limestone Formation
- Bond zone in Avon Park dolomitic limestone
- 1.78 MN working loads for micropiles
  - 62 minimum piles



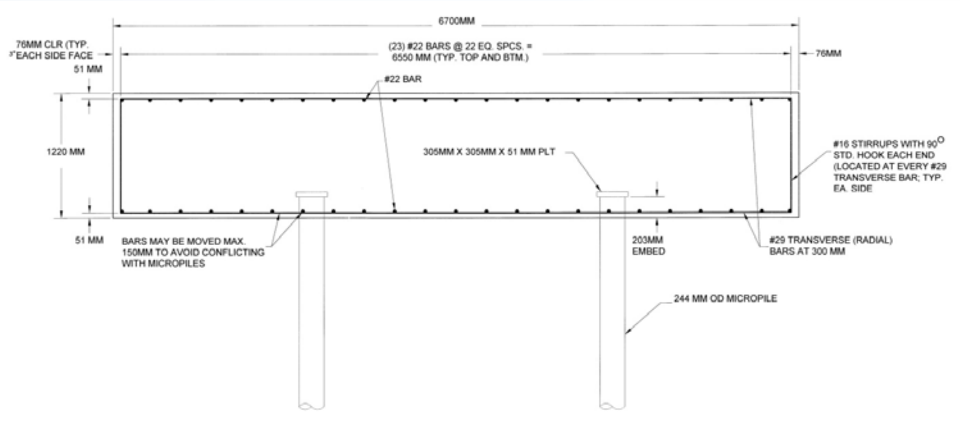
Design of Micropile Support

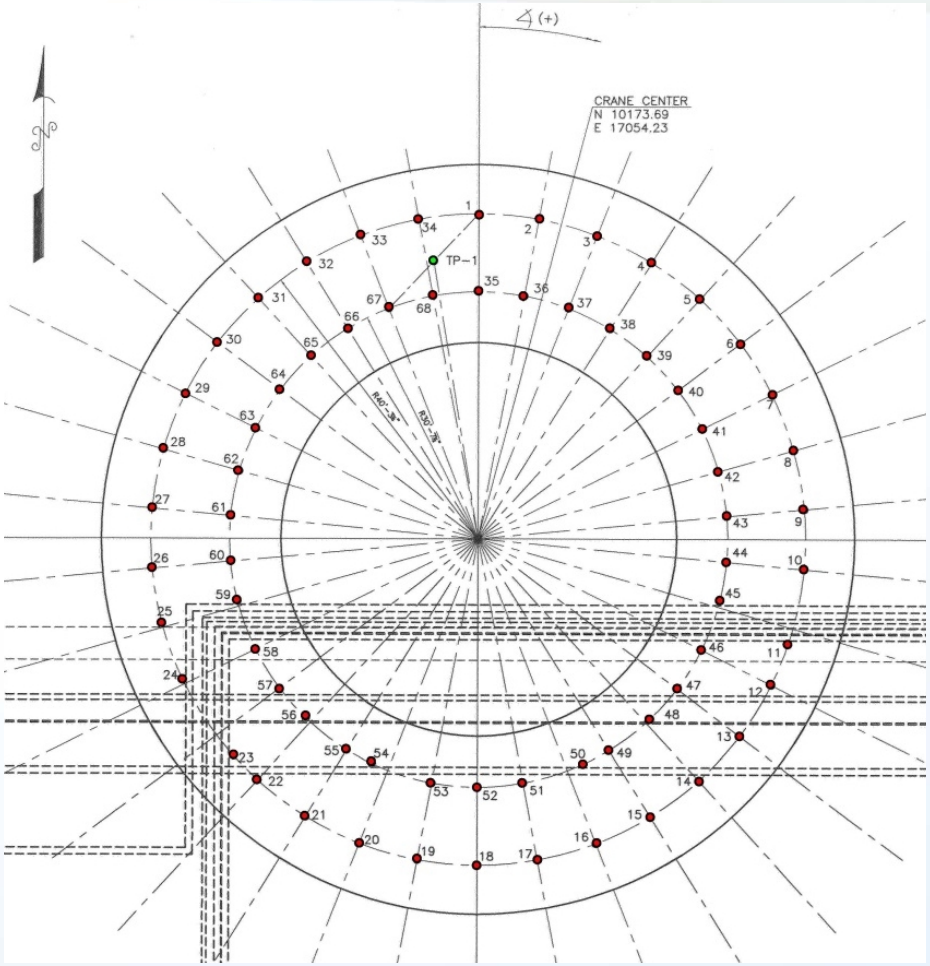
- Structural
  - Allowable stress design
  - Gr. 1034 reinforcing bar with higher allowable stress (0.50 F_{ult})
- Geotechnical
  - Ultimate bond stress of 690 kPa, developed from previous unfailed tension tests (conservative)



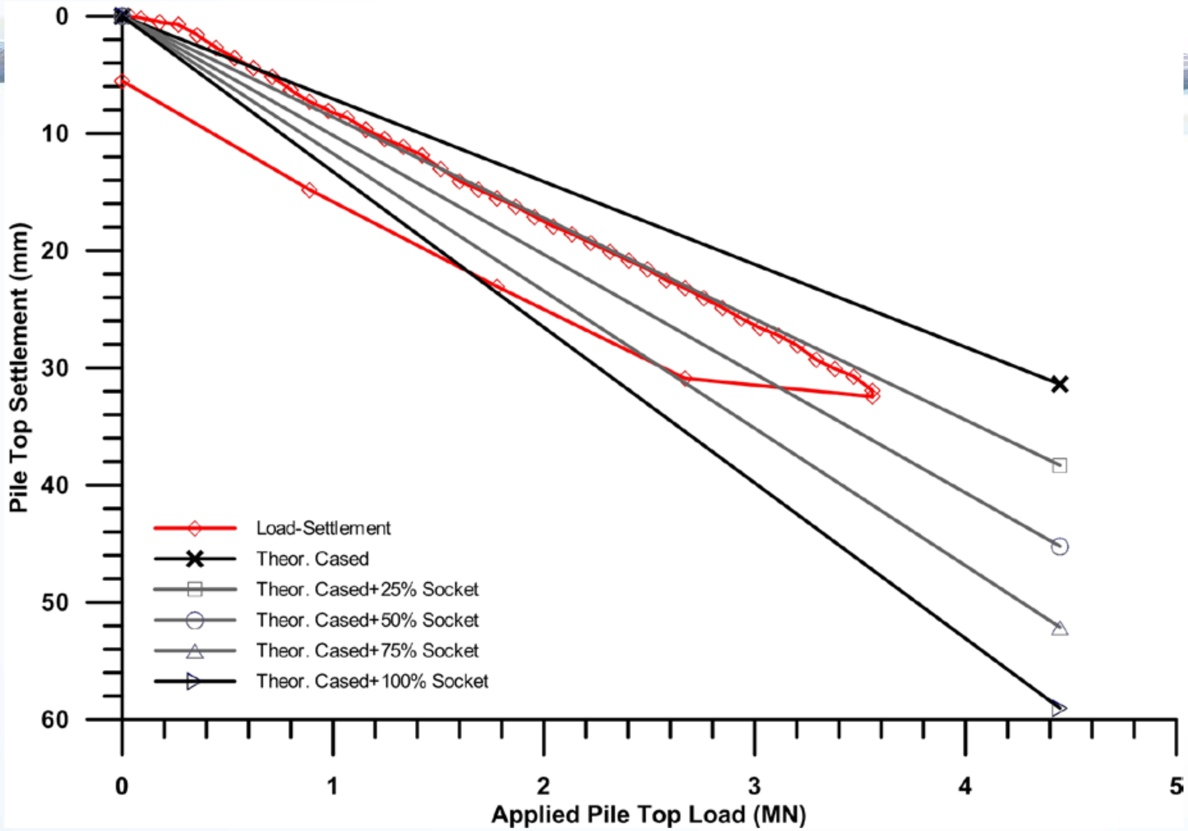
Design of Micropile Support

- 68 micropiles distributed beneath ring foundation
  - Note flexibility for relocating around utilities
- Heavily reinforced ring beam foundation, 1.22 m thick
  - 823 and 626 kN/m line loads
  - 8,450 mm^2 ring and 1,884 mm^2 transverse



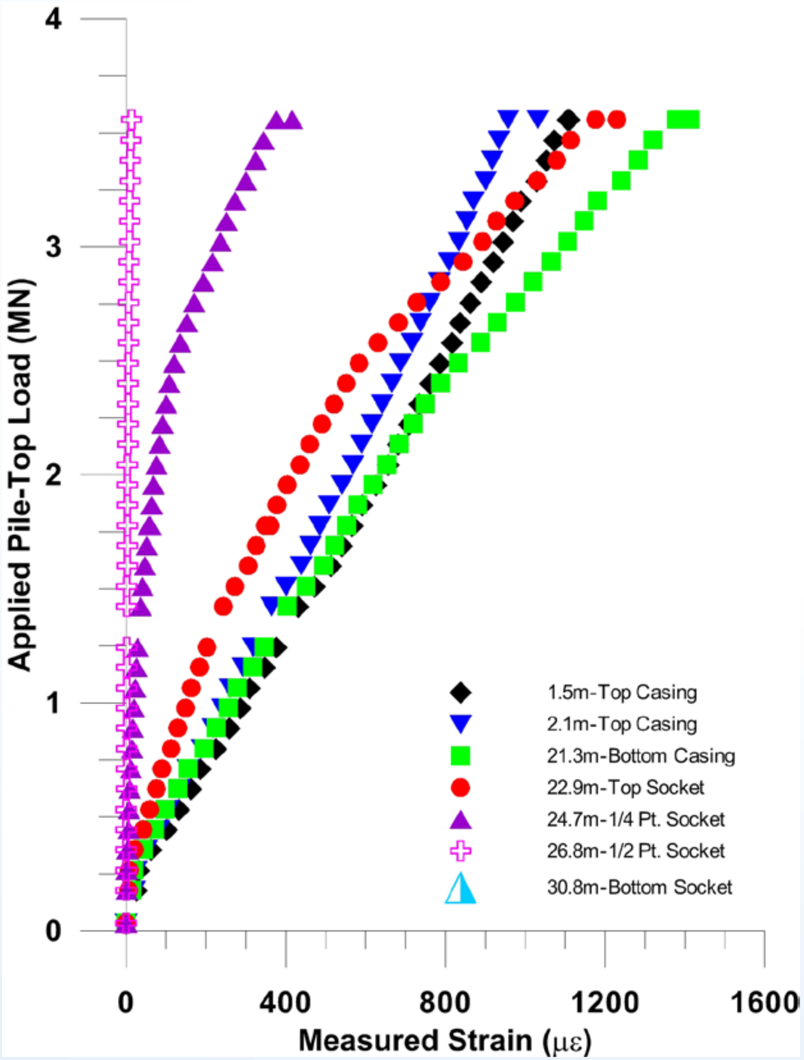


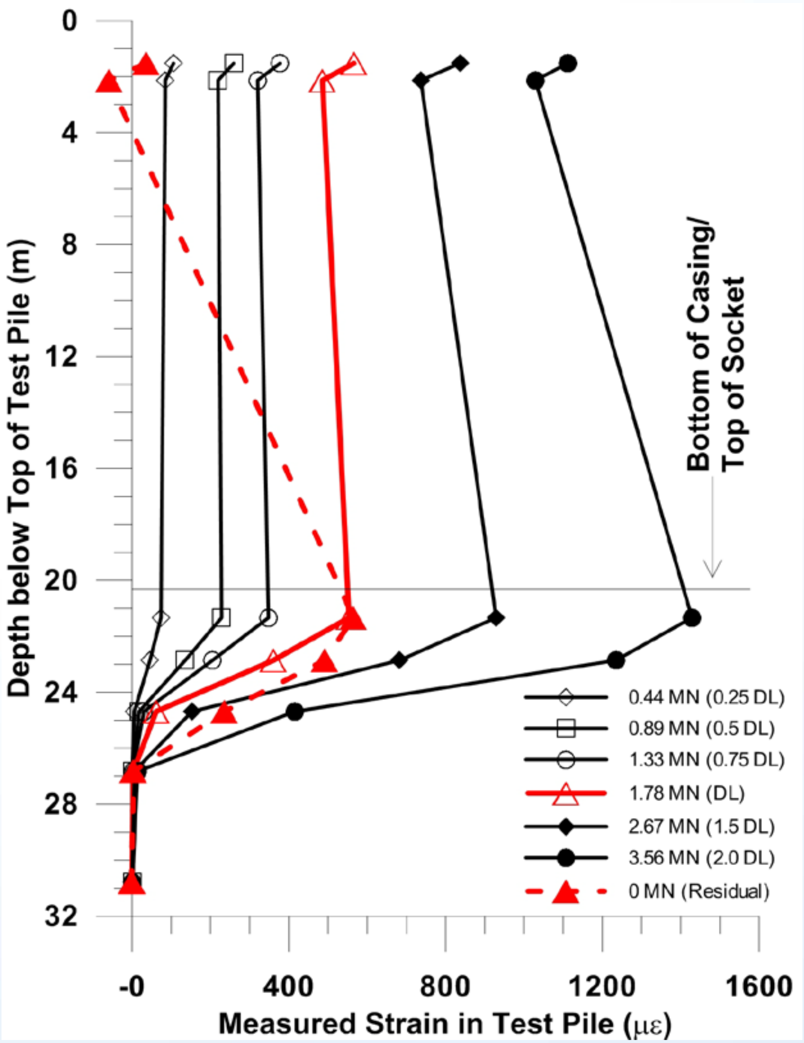
Load Testing



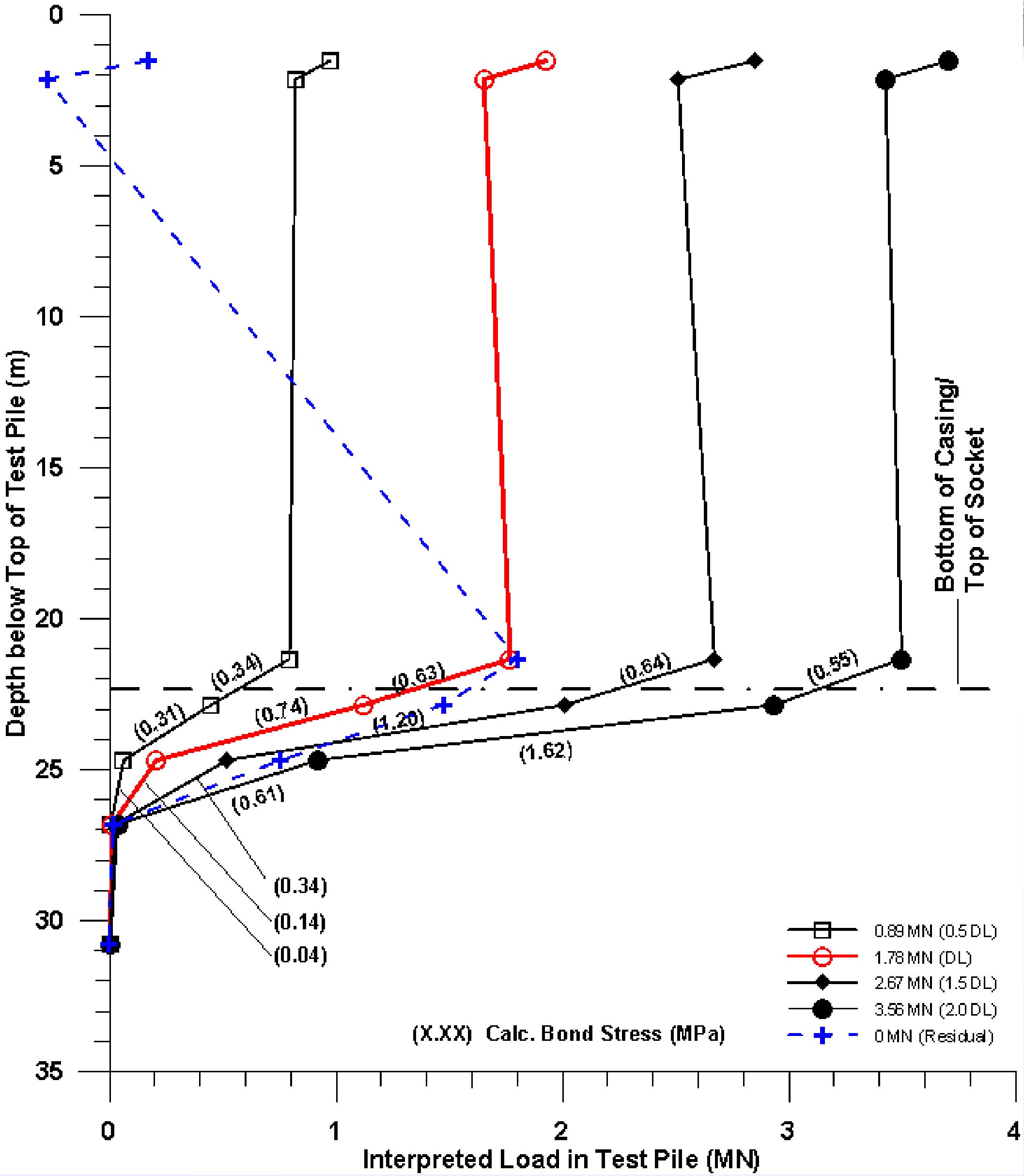
- Compression load test on sacrificial micropile
- Installed test pile using hard formation roller bit rather than down the hole hammer
- Installed 6 levels of vibrating wire strain gauges
- ASTM D1143-07 Quick Test to 2 × working load, 3.56 MN

Load Testing





Load Testing

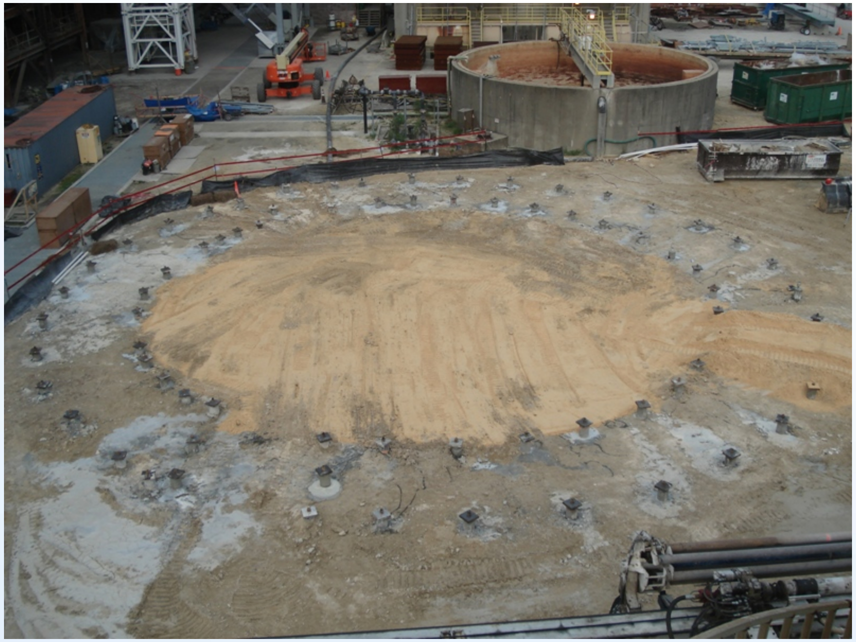


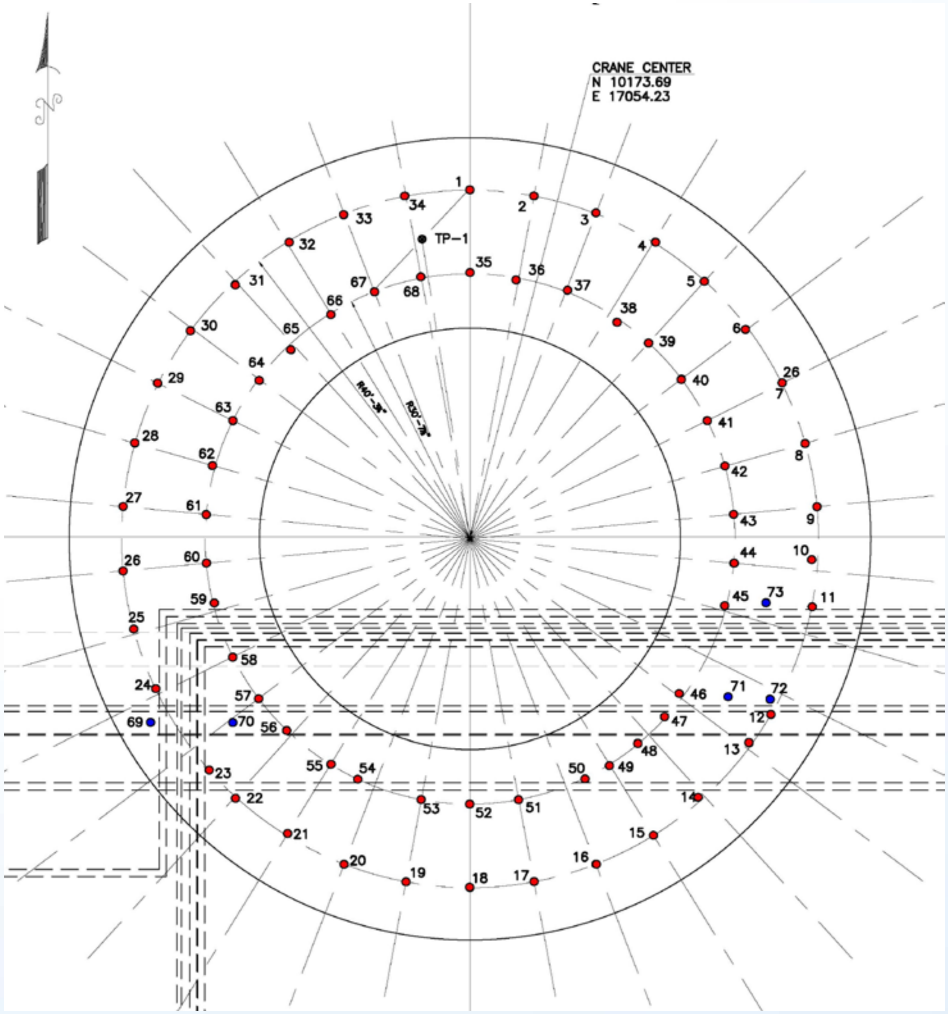
- Developed load distribution using Tangent Modulus method
- α_{mob} in the socket was 1.62 MPa, 2.5 × the α_{ult} assumed in design
- Significant residual loads in socket, 0.54 MPa, upon unloading
- Potential to optimize socket length…

Production Pile Installation & Challenges – Utilities and Access

Production Pile Installation & Challenges – Utilities and Access

- 72 piles eventually installed due to utilities
- Local overstressing expected due to as-built pile configuration
  - Some additional reinforcement
  - 22% overstress in SE quadrant





Cap Construction

System Performance

- Total micropile and cap construction took 44 calendar days
- Mammoet 1800 metric tonne ring crane was assembled during December 2009 and January 2010
- Active crane use began in February 2010 and continued until late May 2010
- No performance metrics out of crane operation bounds by on-board measurement

Conclusions

- Value engineering acceptance!
- Micropiles had significant benefit over drilled shafts for support of this crane in difficult conditions
  - Adaptation to complex buried utility system
  - Develop high working loads in a small cross section within weak limestone rock
  - Reduce concrete cap thickness
  - Reduce schedule
- Rock socket length reduction of up to 3 m feasible from load test results, but reserve capacity desired due to potential for overstressing, which ultimately came true

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QUESTIONS?