LRFD IN PRACTICE – A CASE STUDY FOR FOUNDATION DESIGNERS

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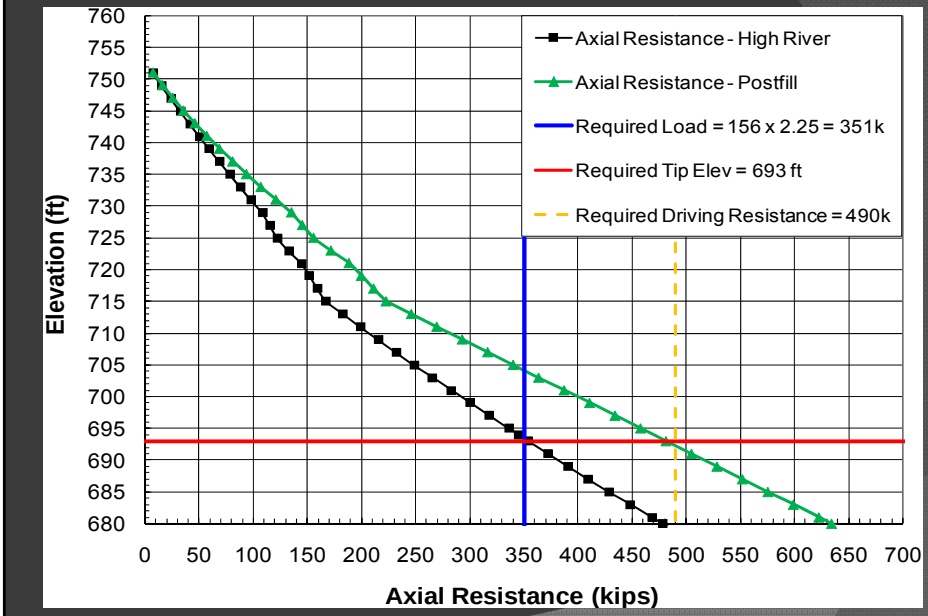
- kcICON project in Kansas City, Missouri
- $150 million design-build project
- Replace I-35 bridge over Missouri River with a new signature structure.

- Main pylon: 10.5-ft diameter drilled shafts, with 20-ft long rock sockets.
- Approach bents: 6.5 to 7.5 ft diameter drilled shafts.
- Abutments (End Bents): Single row of HP 14x73 piles

- Design/Build team allowed to propose either:
  - ASD design (AASHTO 17th, 2002)
  - or LRFD (AASHTO 4th, 2007).
- Team selected ASD.
- The design service loads:
  - 186 kips per pile at the South End Bent
  - 156 kips per pile at the North End Bent.

- Two designs:
  - piles installed after the approach embankment fill was placed and allowed to settle
  - piles installed prior to placement of the fill.
- Selected piles to be driven after the fill was placed.


- The controlling event for pile resistance was the flood case so that load restrictions on the bridge are avoided during floods
- Beta (or effective stress) method for static calculations
- FS = 2.25 (dynamic testing for verification)



- First pile, PDA testing during driving at North End Bent
  - At estimated tip, EOID dynamic capacity was 195 kips << 490 kips target
- Second pile driven 30 feet below estimated tip
  - EOID = 250 kips << 490 kips
- Restrike longer pile six days later
  - CAPWAP analysis = 280 kips
    - 12% increase ; still well below 490 kips.

- Similar dynamic behavior of H-piles observed a few miles upstream of the kcION project.
- Soil conditions similar (recent alluvial deposits)
- Five HP 14x102 test piles
  - dynamic testing during driving and restrikes (w/CAPWAP)
  - Static load tests (ASTM D 1143 Quick Method).
- All five test piles *dynamic* capacities less than *static* load testing with an average underestimate was 31%.

- Dynamic testing was deemed unreliable.
- Static load test was not feasible.
- Sought an analytic solution.
- First alternate: Use FS = 3.0 ASD
  - Change from FS = 2.25 (verification by dynamic testing) to FS = 3.0 (static w/out field testing)
  - FS = 3.0 at extreme flood condition same as FS = 4.0 under normal groundwater conditions
  - Added 15 feet to initial design tip

- Revised ASD analysis completed and new driving criteria submitted.
- FHWA suggested an additional analysis using LRFD.
- Controlling LRFD loads differed from ASD due to different load factors and limit states.
  - North End Bent: ASD = 156 kips; LRFD = 218 kips
  - South End Bent: ASD = 186 kips; LRFD = 241 kips

- Calculations by Nordlund method as suggested by FHWA.
- North End Bent:
  - Piles already installed to elev. 678 feet.
  - Nominal pile resistance > required nominal resistance.
- South End Bent:
  - Calculated pile tip elev. 675 feet for required nominal pile resistance.
  - 18 feet deeper than ASD FS = 2.25
  - 3 feet deeper than the ASD FS = 3

Conclusions

- Piles were originally designed utilizing ASD FS = 2.25 (verification by dynamic testing)
- Dynamic testing was deemed unsuitable for verification
- Pile tip elevations were re-evaluated using AASHTO 2007 LRFD code.

Conclusions

- North End Bent piles as-installed for FS = 3.0 revised ASD design were acceptable
- South End Bent design pile tip elevations were:
  - 18 feet lower than original ASD design (FS = 2.25)
  - 3 feet longer than the revised ASD design (FS = 3).

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