A DISCUSSION OF DOWNDRAg AND DRAGLOAD:

DOES DRAGLOAD REALLY EXIST AND IF SO, HOW DO WE DEAL WITH IT?

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ASCE Structural Conference
A LITTLE (MORE) ABOUT ME

• B.S. Utah State University - 1998
• M.S. Utah State University - 2000
• Ph.D. Utah State University and UT Austin – 2004
• Licensed Professional Engineer in MN – 2009
• Sabbatical leave with Barr Engineering and Minnesota Department of Transportation during 2012-2013 academic year (“Triple Agent” status)
TRIPLE AGENT???

• What are the major careers in Civil Engineering?
  – Public Sector (DOT, City Engr., County Engr., Etc.)
  – Private Sector (Consulting companies, Etc.)
  – Academia (University faculty, researchers, etc.)
TRIPLE AGENT???

- What have I been up to lately?
  - All of the above!
  - Barr Engineering – Geotechnical Discipline Group
  - MnDOT Consultant – Geotechnical Special Projects
  - And, on occasion, I still make it to campus!
FUNDAMENTAL QUESTION #0:

(YES, Number Zero, not a typo...)

WHAT IS A GEOTECH DOING AT A STRUCTURAL ENGINEERING CONFERENCE?
FUNDAMENTAL QUESTION #1: WHAT IS DOWNDRAUGHT?

Downward load at pile top resisted by upward skin friction in soil layers and end bearing at the pile toe – USUALLY...

But, what if the soil moves downward with respect to the pile???
FUNDAMENTAL QUESTION #2: IF IT EXISTS, HOW MUCH IS THERE?

MnDOT has funded several studies to quantify the magnitude of downdrag experienced at several sites where settlement of the foundation material with respect to the piling was anticipated (i.e., fill placed near piles AFTER pile driving.)

So, how can we measure $R_{s1}$?
FUNDAMENTAL QUESTION #3: WHAT WOULD A “TYPICAL” LOAD DISTRIBUTION LOOK LIKE? (i.e. Static Load Test results, perhaps)
Six projects completed to date (others ongoing):

- Crosstown Commons Expansion, BR 27V74
- Highway 169/CSAH 81 Interchange Reconstruction, BR 27R20
- Forest Lake at Washington County 82 and CSAH 2, BR 82527
- Highway 169/I-494 Interchange, BR 27V97
- Butterfield Bridge Addition, BR 83040
- Steele County Bridge at Owatonna, BR 74551
Sixteen inch CIPC piles instrumented prior to driving (Geokon VW gages)

Instrumentation on one standard pipe pile and two Teflon-coated piles

Gage placement from pile toe to near pile head

Multiple gages and/or cables damaged during driving, leaving an incomplete data set, BUT…
CROSSTOWN COMMONS EXPANSION
CROSSTOWN COMMONS EXPANSION
CROSSTOWN COMMONS EXPANSION
DOES DRAGLOAD EXIST?

Well, honestly, we don’t have a clear idea from THIS project.

Limited data suggests POTENTIALLY more dragload in the Teflon-coated piles relative to the standard piles, but there isn’t adequate data to truly compare the two.

However, a young researcher made some significant strides in the instrumentation arena and subsequent projects were more conclusive!
12.75 inch CIPC piles instrumented with sister bar coil rod after driving (Geokon VW gages)
Instrumentation on one sleeved pipe pile and one unsleeved pile (all other production piles also sleeved)
Gage placement from pile toe to near pile head
HIGHWAY 169/CSAH 81 INTERCHANGE RECONSTRUCTION
QUICK “ASIDE” - OPTIONS AVAILABLE TO REDUCE NEGATIVE SKIN FRICTION?

• Bitumen Coating
• Plastic coating
• Teflon coating
• Pile sleeves
• Other
HIGHWAY 169/CSAH 81 INTERCHANGE RECONSTRUCTION
HIGHWAY 169/CSAH 81 INTERCHANGE RECONSTRUCTION

Instrumented Sleeved Pile

Instrumented Unsleeved Pile
HIGHWAY 169/CSAH 81 INTERCHANGE RECONSTRUCTION
HIGHWAY 169/CSAH 81 INTERCHANGE RECONSTRUCTION
HIGHWAY 169/CSAH 81 INTERCHANGE RECONSTRUCTION (FIRST 50 DAYS)
HIGHWAY 169/CSAH 81 INTERCHANGE RECONSTRUCTION (FIRST YEAR)

- Concrete placed in stickup length & abutment footing, earth loads applied above footing
- Concrete placed for abutment seat, parapet wall; remaining 3 m (10 ft) surcharge material removed from further behind abutment
- Pre-stressed concrete beams placed
- Bridge deck placed

Graph showing Pile Load (kips) vs. Elapsed Time (days) with Vertical Deflection (mm) and estimated structural loads, measured total load, and vertical fill deflection.
HIGHWAY 169/CSAH 81 INTERCHANGE RECONSTRUCTION (FIRST YEAR)

Graph:
- **Pile Load (kips)**
- **Vertical Deflection (mm)**

- **Estimated Structural Loads**
- **Measured Total Load**
- **Vertical Fill Deflection**

Key Points:
- Concrete placed in stick-up length & abutment footing, earth loads applied above footing.
- Concrete placed for abutment seat, parapet wall; remaining 3 m (10 ft) surcharge material removed from further behind abutment.
- Pre-stressed concrete beams placed.
- Bridge deck placed.

*Images of construction site and progress.*
HIGHWAY 169/CSAH 81 INTERCHANGE RECONSTRUCTION

Unsleeved

Sleeved
LOAD PROFILE REGIONS

- Region 1
LOAD PROFILE REGIONS

- Region 2
LOAD PROFILE REGIONS

• Region 3
DOES DRAGLOAD EXIST?

This project got some attention!
Significant load accumulated in BOTH piles before true “structural” loads were applied to the piles. The sleeves seemed to reduce “dragload” in the fill zone, but increases in pile load in the foundation soil were present for both the sleeved and the unsleeved piles.
Sixteen inch CIPC piles instrumented after driving (Geokon VW gages)
Instrumentation on two piles, cap at grade
Gage placement from pile toe to near pile head
FOREST LAKE AT WASHINGTON COUNTY 82 AND CSAH 2

“North Pile” – Test Pile #5

“South Pile” – Test Pile #6
FOREST LAKE AT WASHINGTON COUNTY 82 AND CSAH 2

North (side hill)  South (centerline)
DOES DRAGLOAD EXIST?

Where is the maximum pile load? Convinced?
12.75 inch CIPC piles instrumented after driving (Geokon VW gages)

Instrumentation on two piles

Gage placement from pile toe to near pile head
HIGHWAY 169/I-494 INTERCHANGE

North

South
SAME QUESTION?

Where is the maximum pile load? Neutral Plane?

You have to admit, this is some nice data!
BUTTERFIELD BRIDGE ADDITION

12.75 inch CIPC piles instrumented after driving (Geokon VW gages)

Instrumentation on two piles (one static load test pile, one reaction pile left unloaded!)

Gage placement from pile toe to near pile head
BUTTERFIELD BRIDGE ADDITION

SRP-2
(No top load applied!)

SLT-5
BUTTERFIELD BRIDGE ADDITION

“DELTA”
STEELE COUNTY BRIDGE AT OWATONNA

12x53 H-piles to bedrock, instrumented prior to driving (Geokon VW gages, resistance gages and fiber optic gages)

Instrumentation on one sleeved pile and one unsleeved pile

Gage placement from pile toe to near pile head

Compressible clay overlays bedrock bearing layer

(IF DRAGLOAD EXISTS, THIS IS THE PERFECT SCENARIO!!!)
SPT N values from 5 to 12 in clay foundation material
Several percent strain predicted
STEELE COUNTY BRIDGE AT OWATONNA
STEELE COUNTY BRIDGE AT OWATONNA
STEELE COUNTY BRIDGE AT OWATONNA
STEELE COUNTY BRIDGE AT
OWATONNA
STEELE COUNTY BRIDGE AT OWATONNA
STEELE COUNTY BRIDGE AT OWATONNA (SLEEVED PILE)
STEELE COUNTY BRIDGE AT OWATONNA
CONCLUSIONS

Each project showed measurable dragload, with load distributions in the instrumented piles indicating maximum loads at depths well below the pile head.

At multiple sites, significant pile loads were measured (particularly at MSE wall sites) prior to addition of structural loads (parapet walls, bridge beams, etc.).

For one project (Butterfield) with an “unloaded” pile, the impact of dragload was evident.
CONCLUSIONS

At these sites, the magnitude of the measured dragload was on the same order as the anticipated structural loads, and more than would be incorporated into design if dragload were ignored. No structural or geotechnical performance issues have been documented, overall measured loads on the piles have in some cases exceeded factored design loads.
CONCLUSIONS

Several sites showed a distinct neutral plane, where a reversal of skin friction confirms transition from negative to positive skin friction.
CONCLUSIONS
(FOR THE BUILDING FOLKS)

At least two of the bridge sites discussed showed measureable dragloads with only a couple feet of “working platform” fill material. It doesn’t take much fill (or much relative downward movement of the soil relative to the pile) to develop negative skin friction.

Remember that fill is not the only way the effective stress can increase (dewatering, etc.)
SO, ASSUMING WE BELIEVE THAT DRAGLOAD EXISTS…

Is it a problem?
When/how do we account for it?
When can we safely ignore it?

MnDOT dragload policy recently established
FHWA considering a degree of implementation!
SUMMARY OF MnDOT OBSERVATIONS/APPROACH AS FOLLOWS:

1) Dragload always occurs - but in most cases it is so small as to not be measurable unless you are looking for it.

2) The nominal geotechnical resistance is the same with or without it, making it “mysterious”.
SUMMARY OF MnDOT OBSERVATIONS/APPROACH AS FOLLOWS:

3) Since the dragload later becomes available to restrain top load, the MnDOT Bridge Office has established they do not care if the pile is more heavily loaded at the NP than other portions of the pile; it can exceed what would otherwise be allowable, as the total geotechnical capacity will be unchanged even if the pile is “pre-stressed” or “residually stressed”.
SUMMARY OF MnDOT OBSERVATIONS/APPROACH AS FOLLOWS:

4) Downdrag can most “practically” evidence itself by some minor changes in the deformation profile - but we haven’t been looking for it, so no effects have been attributable to it to date.
SUMMARY OF MnDOT OBSERVATIONS/APPROACH AS FOLLOWS:

5) In most cases, except for piles in the most compliant soup or when installed through compressible soils bearing on the stiffest rock-effects aren’t deleterious owing to relatively large factors of safety applied in general to protect against other performance problems.
SUMMARY OF MnDOT OBSERVATIONS/APPROACH AS FOLLOWS:

6) Dragload doesn’t so much “go away” with added live-load, as an elaborate redistribution of load and deformation occurs to re-establish equilibrium in the soil-pile interaction profile where different components of side friction and end bearing mobilize, based on material stiffness and non-linear behaviors along the pile column.
SUMMARY OF MnDOT OBSERVATIONS/APPROACH AS FOLLOWS:

7) And to “relieve dragload” you actually need to add top load, so you are closer to geotechnical strength limit failure, so don’t bother with that. Money for coatings, sleeves, and other work-arounds (other than perhaps use of spread footings in-lieu of deep foundations) appear of questionable worth.
MANY THANKS TO MY COLLEAGUES AT MnDOT

Derrick Dasenbrock

Dan Mattison

And several others!
QUESTIONS???