Foundations Updates

Brandon Day | Bridge Engineer Final Design

May 17, 2017

DEPARTMENT OF TRANSPORTATION

Outline

- Topics covered:
  - Downdrag
  - MnDOT Pile Formula (MPF)

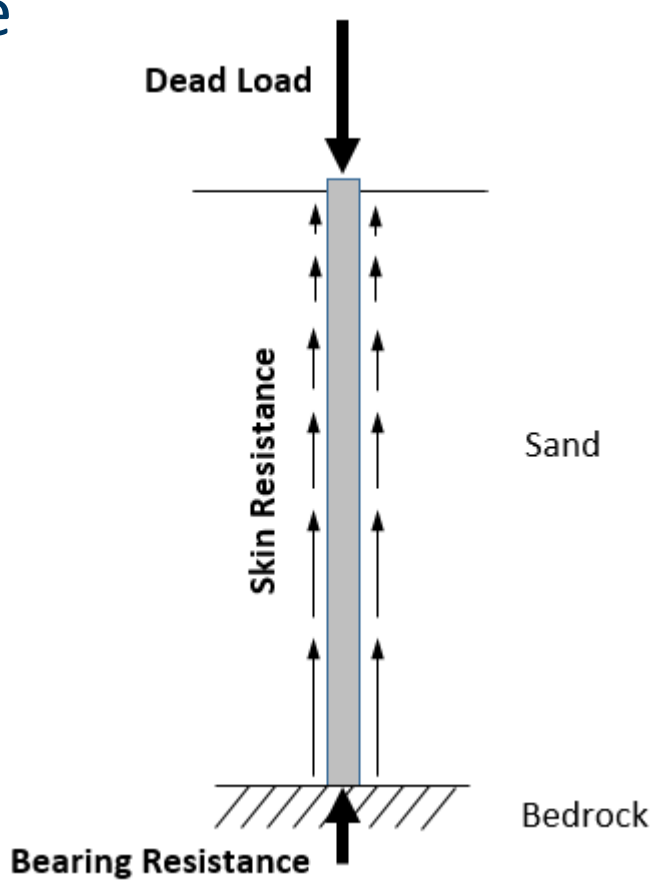
Downdrag

- Downdrag
  - As soil layers compress/settle, movement of the soil relative to the pile may induce a downward force.
  - Downdrag (settlement) vs Dragload (force)

- MnDOT Geotechnical Manual – Appendix F
  - http://www.dot.state.mn.us/materials/manuals/geotechnical/appendixfdowndrag.pdf

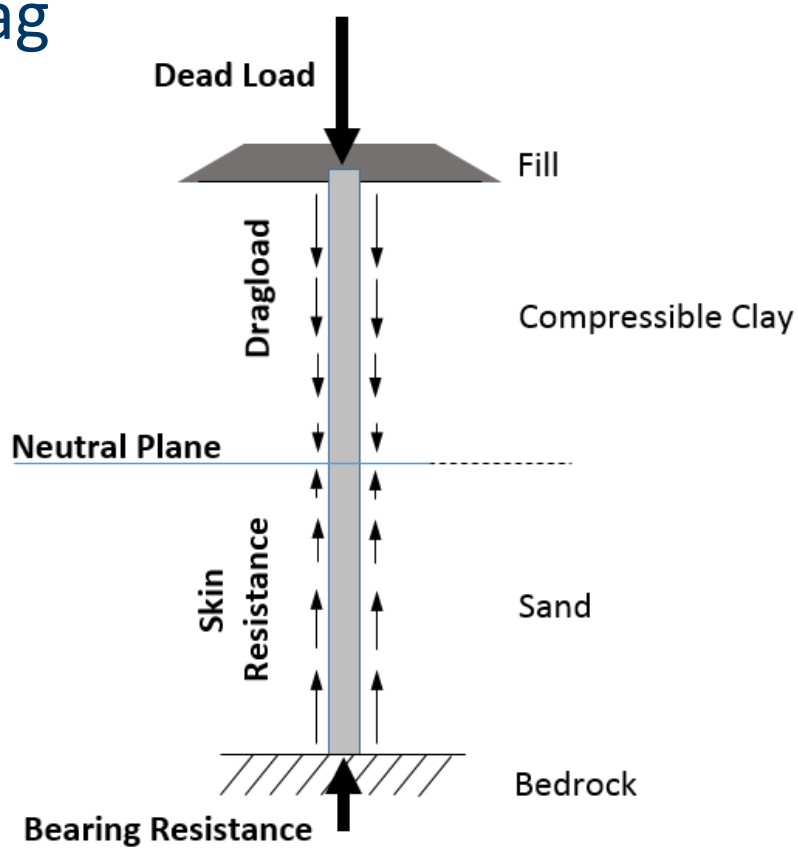
Downdrag

Well behaved pile



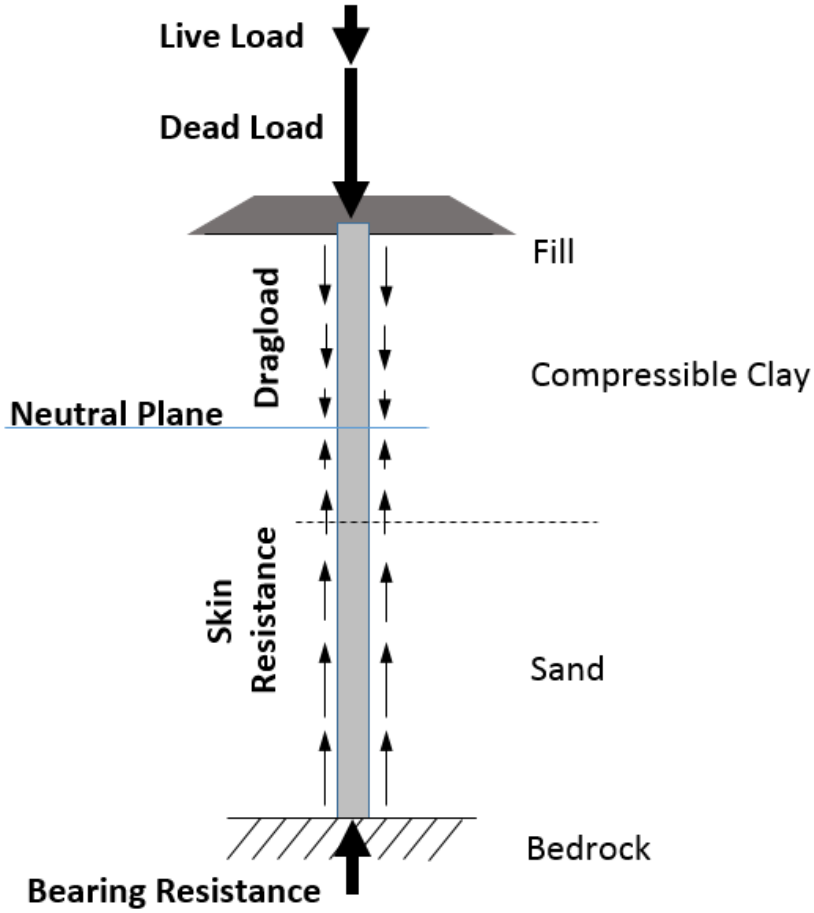
Downdrag

Pile with Downdrag



Downdrag

Downdrag with Live Load



Downdrag

- Factors affecting Downdrag:
  - Amount of fill
  - Location of compressible layers
  - Thickness of compressible layers
  - Soil stiffness
  - Top load
  - Pile tip bearing resistance
  - Water table

Downdrag

- Methods of calculating Dragload
  - AASHTO 10.7.3.8.6 discusses methods for calculating DD
    - α-, β-, λ-methods – These effectively multiply depth by a coefficient
    - Load & Resistance Factors given in AASHTO Table 3.4.1-2
  - MnDOT uses the Neutral Plane Method
    - Load & Resistance Factors are defined by MnDOT as

$$\gamma = 1.10 \quad \& \quad \phi = 0.70$$

    - FS = 1.10/0.70 = 1.57 > 1.50

Downdrag

- From Geotech Manual – Appendix F

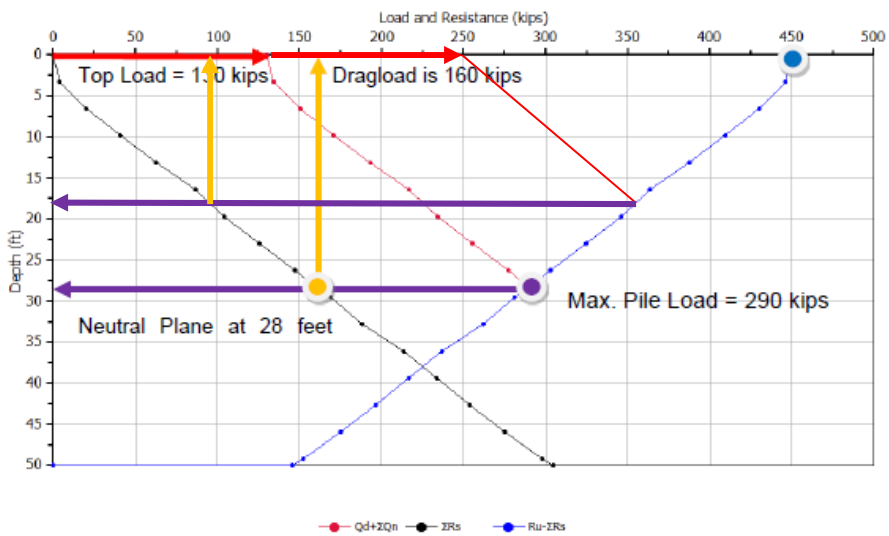
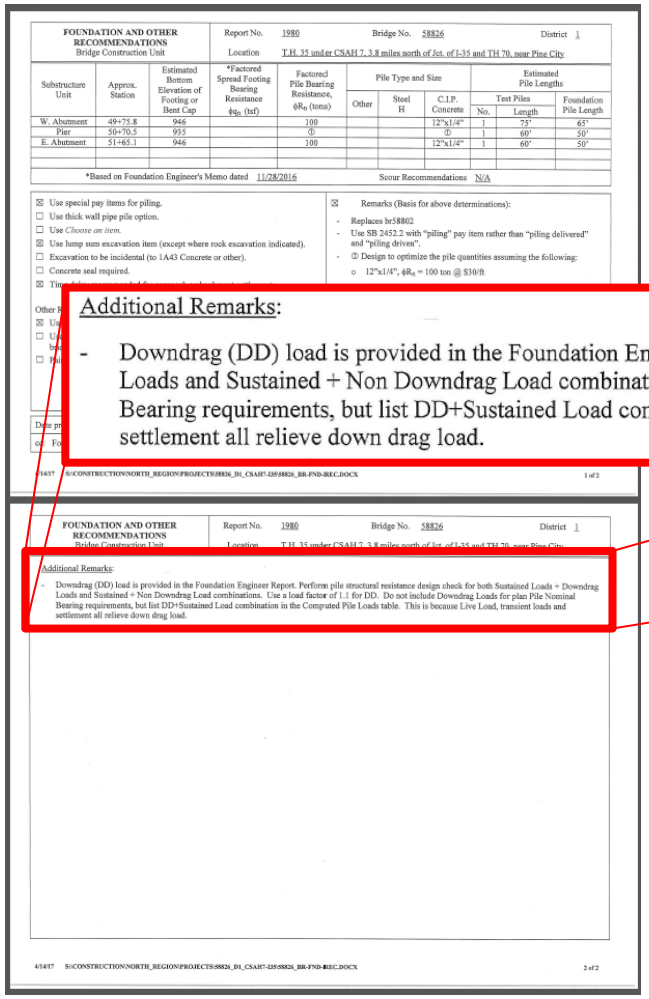


Figure F-7-1: A typical chart developed for neutral plane analysis. The black line is the pile side resistance as a function of depth. The red line represents an offset equal to the permanent structural "top load' (in this case 130 kips). The blue line is the sum of maximum available toe resistance and maximum cumulative side resistance at the Strength Limit State (geotechnical failure); a fixed pile length must be selected to develop the blue line (in this case, 50 ft.) and evaluate the case.

Downdrag

- Design Process
  - Foundation Recommendation will inform you if DD is to be designed for.
  - Foundation Engineering Report will provide DD magnitudes.
  - Design piles using appropriate load cases and factors.
    - 1.10*DD replaces 1.75*LL
  - Enter the appropriate loads in the Standard Plan Note Tables.

Downdrag



FOUNDATION AND OTHER RECOMMENDATIONS
Bridge Construction Unit

Report No. 1980 Bridge No. 58826 District 1
Location T.H. 35 under CSAH 7, 3.8 miles north of Jct. of I-35 and TH 70, near Pine City

Substructure Unit	Approx. Station	Estimated Bottom Elevation of Footing or Bent Cap	*Factored Spread Footing Bearing Resistance ϕq_n (tsf)	Factored Pile Bearing Resistance, ϕR_n (tons)	Pile Type and Size: Other	Pile Type and Size: Steel H	Pile Type and Size: C.I.P. Concrete	Estimated Pile Lengths: Test Piles No.	Estimated Pile Lengths: Test Piles Length	Estimated Pile Lengths: Foundation Pile Length
W. Abutment	49+75.8	946		100			12"x1/4"	1	75'	65'
Pier	50+70.5	935		①			①	1	60'	50'
E. Abutment	51+65.1	946		100			12"x1/4"	1	60'	50'

*Based on Foundation Engineer's Memo dated 11/28/2016 Scour Recommendations N/A

☒ Use special pay items for piling.
☐ Use thick wall pipe pile option.
☐ Use *Choose an item.*
☒ Use lump sum excavation item (except where rock excavation indicated).
☐ Excavation to be incidental (to 1A43 Concrete or other).
☐ Concrete seal required.

☒ Remarks (Basis for above determinations):
- Replaces hr58802
- Use SB 2452.2 with "piling" pay item rather than "piling delivered" and "piling driven".
- ① Design to optimize the pile quantities assuming the following:
  - 12"x1/4", ϕR_n = 100 ton @ $30/ft

Additional Remarks:

- Downdrag (DD) load is provided in the Foundation Engineer Report. Perform pile structural resistance design check for both Sustained Loads + Downdrag Loads and Sustained + Non Downdrag Load combinations. Use a load factor of 1.1 for DD. Do not include Downdrag Loads for plan Pile Nominal Bearing requirements, but list DD+Sustained Load combination in the Computed Pile Loads table. This is because Live Load, transient loads and settlement all relieve down drag load.

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FOUNDATION AND OTHER RECOMMENDATIONS
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Foundation Recommendation

Downdrag

Foundation Engineering Report

12-inch CIP Pipe-Boring T4, West Abutment

Assumed Bottom-of-Pile-Cap Elevation = 957.2							
Pile Length	Dead Load	Live Load	Drag Force	Neutral Plane	Maximum	Nominal Geotechnical	Estimated Pile Settlement
(feet)	(tons)	(tons)	(tons)	Depth / Elev.	Force In Pile	Pile Capacity	(inches)
25	50	10	33.7	19.2 / 938	66.8 tons	92.6 tons	.9
37	60	10	36	20.2 / 937	78 tons	106.8 tons	.96
50	100	10	29.6	25.6 / 931.6	129.6 tons	167.5 tons	.99
69	155	10	46.4	38.3 / 918.9	201.4 tons	253.7 tons	.99

If your pile length doesn't match one on the table you can interpolate, cautiously.

If your dead load is significantly different from the table or if you're concerned about the above interpolation, call the Bridge Office or the Geotech Office.

Downdrag

Additional Load Case

$$1.25DL + 1.10DD \leq 0.70R_n$$

Downdrag

Standard Plan Notes

d. ADDITIONAL LOAD TABLE FOR PILES WHERE DOWNDRAG OCCURS

_____ ABUTMENT COMPUTED PILE LOAD – TONS/PILE	
FACTORED DEAD LOAD + EARTH PRESSURE	
FACTORED DOWNDRAG	
*** FACTORED DEAD LOAD + EARTH PRESSURE + DOWNDRAG	

*** BASED ON _____ LOAD COMBINATION, NOT INCLUDING TRANSIENT LOADS. ONLY USED FOR COMPARISON WITH FACTORED STRUCTURAL RESISTANCE. NOT TO BE USED FOR DRIVING.

PIER _____ COMPUTED PILE LOAD – TONS/PILE	
FACTORED DEAD LOAD	
FACTORED OVERTURNING	
FACTORED DOWNDRAG	
*** FACTORED DEAD LOAD + OVERTURNING + DOWNDRAG	

*** BASED ON _____ LOAD COMBINATION, NOT INCLUDING TRANSIENT LOADS. ONLY USED FOR COMPARISON WITH FACTORED STRUCTURAL RESISTANCE. NOT TO BE USED FOR DRIVING.

Downdrag

Live Load

South ABUTMENT COMPUTED PILE LOAD – TONS/PILE	
FACTORED DEAD LOAD + EARTH PRESSURE	100.0
FACTORED LIVE LOAD	20.0
* FACTORED DESIGN LOAD	120.0

* BASED ON STR I LOAD COMBINATION.

South ABUTMENT REQUIRED NOMINAL PILE BEARING RESISTANCE FOR H-PILES R_n – TONS/PILE		
FIELD CONTROL METHOD	ϕ_{dyn}	** R_n
MNDOT PILE FORMULA 2012 (MPF12) $R_n = 20\sqrt{\frac{W \times H}{1000}} \times \log\left(\frac{10}{S}\right)$	0.60	200.0
PDA	0.65	184.6

** R_n = (FACTORED DESIGN LOAD) / ϕ_{dyn}

$\leftarrow \frac{120}{0.60}$

$\leftarrow \frac{120}{0.65}$

Dragload

South ABUTMENT COMPUTED PILE LOAD – TONS/PILE	
FACTORED DEAD LOAD + EARTH PRESSURE	100.0
FACTORED DOWNDRAG	40.0
*** FACTORED DEAD LOAD + EARTH PRESSURE + DOWNDRAG	140.0

*** BASED ON STR I LOAD COMBINATION, NOT INCLUDING TRANSIENT LOADS. ONLY USED FOR COMPARISON WITH FACTORED STRUCTURAL RESISTANCE. NOT TO BE USED FOR DRIVING.

MnDOT Pile Formula

MnDOT Pile Formula (MPF12)

H-Piles

_____ ABUTMENT REQUIRED NOMINAL PILE BEARING RESISTANCE FOR H-PILES R_n – Tons/Pile		
FIELD CONTROL METHOD	φ_{dyn}	* R_n
MnDOT Pile Formula 2012 (MPF12) $R_n=20\sqrt{\frac{W\times H}{1000}\times\log(\frac{10}{S})}$	0.60	
PDA	0.65	

* R_n = (Factored Design Load) / φ_{dyn}

PIER _____ REQUIRED NOMINAL PILE BEARING RESISTANCE FOR H-PILES R_n – Tons/Pile		
FIELD CONTROL METHOD	φ_{dyn}	* R_n
MnDOT Pile Formula 2012 (MPF12) $R_n=20\sqrt{\frac{W\times H}{1000}\times\log(\frac{10}{S})}$	0.60	
PDA	0.65	

* R_n = (Factored Design Load) / φ_{dyn}

CIP Piles

_____ ABUTMENT REQUIRED NOMINAL PILE BEARING RESISTANCE FOR CIP PILES R_n – Tons/Pile		
FIELD CONTROL METHOD	φ_{dyn}	* R_n
MnDOT Pile Formula 2012 (MPF12) $R_n=20\sqrt{\frac{W\times H}{1000}\times\log(\frac{10}{S})}$	0.50	
PDA	0.65	

* R_n = (Factored Design Load) / φ_{dyn}

PIER _____ REQUIRED NOMINAL PILE BEARING RESISTANCE FOR CIP PILES R_n – Tons/Pile		
FIELD CONTROL METHOD	φ_{dyn}	* R_n
MnDOT Pile Formula 2012 (MPF12) $R_n=20\sqrt{\frac{W\times H}{1000}\times\log(\frac{10}{S})}$	0.50	
PDA	0.65	

* R_n = (Factored Design Load) / φ_{dyn}

http://www.dot.state.mn.us/bridge/pdf/lrfdmanual/lrfdbridgedesignmanual.pdf

Memo #2012-02

MnDOT Pile Formula

- 2005 MnDOT Std. Spec. for Construction Section 2452.3E2:

$$R_n = \frac{3.5E}{S + 0.2} \; x \; \frac{W + 0.1M}{W + M}$$

- 2016 MnDOT Std. Spec. for Construction Section 2452.3E3:

$$R_n = 20\sqrt{\frac{W \; x \; H}{1000}} \log\left(\frac{10}{S}\right)$$

MnDOT Pile Formula

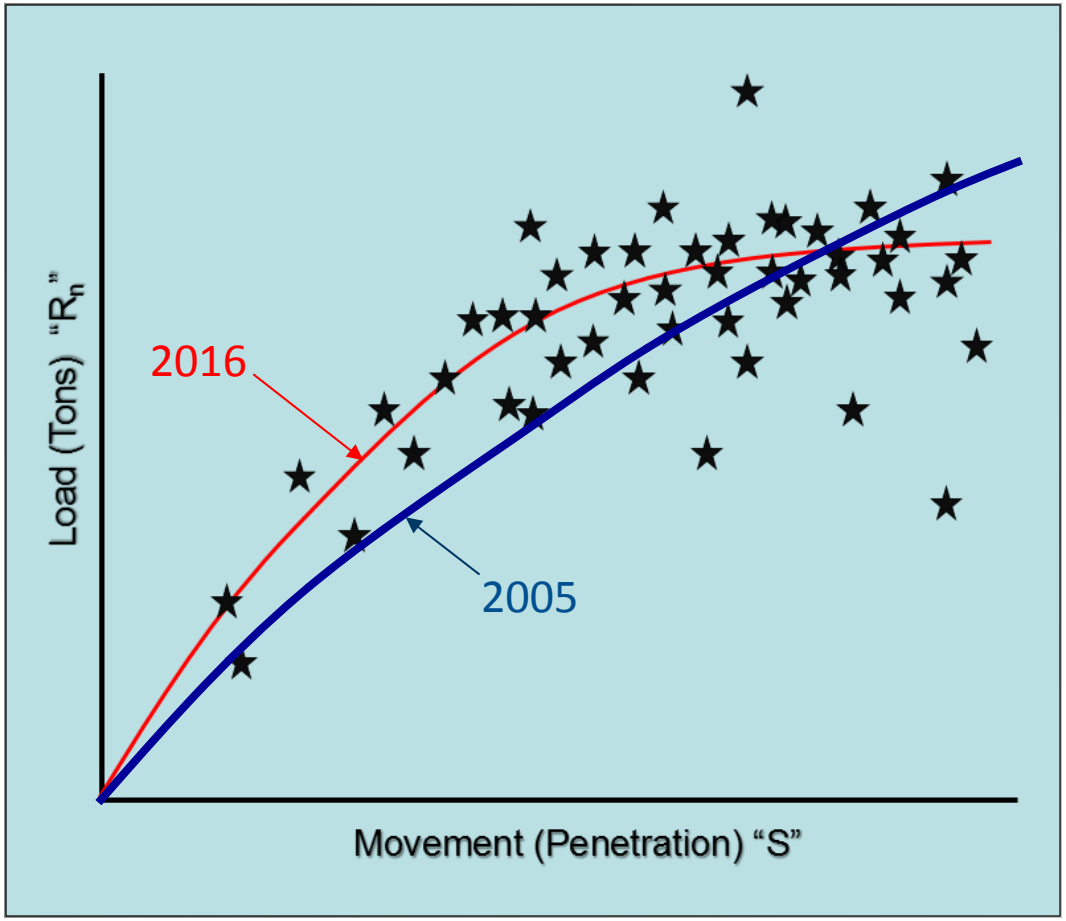
- MPF development and calibration
  - Arose from the need to switch to LRFD
  - MnDOT uses different piling than other parts of the country
  - Desire to calibrate to our soils

MnDOT Pile Formula

- MnDOT research project tested piles to determine improved resistance formula
  - Many different formulas were considered

Eq #	Equation	Description	Reference
4.1	$R_u = \frac{12(W_r * h)}{S + 0.1}$	Drop Hammer	Engineering News-Record (1892)
4.2	$R_u = 27.11\sqrt{E_n * e_h}(1 - \log s)$		Gates (1957)
4.3	$R_u = 1.75\sqrt{E_n} * \log(10 * N) - 100$	Modified Gates Equation	FHWA (1982)
4.4	$R_u = 6.6 * F_{eff} * E * Ln(10N)$		Washington State DOT (Allen, 2005)
4.5	$R_u = \frac{10.5E}{S + 0.2} x \frac{W + 0.1M}{W + M}$	Uniform Format for all piles	Minnesota DOT (2006)
4.6	$R_u = 35\sqrt{E_h} \times \log(10N)$	See Chapter 6 for details	First Stage Proposed New Mn/DOT Equation

MnDOT Pile Formula



MnDOT Pile Formula

$$R_n = 20\sqrt{\frac{W\ x\ H}{1000}}\log\left(\frac{10}{S}\right)$$

MnDOT Pile Formula

- Note the different Resistance Factors
  - H-Piles: 0.60
  - CIP-Piles: 0.50
- Formula is calibrated to 12” piles
  - Slightly conservative for 16” piles when R_n > 170 tons
  - Projects with multiple R_n values may require different size hammers

Thank you again!

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