Bridges and Structures September 26, 2001

All Employees 521.1

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MM No. 20 (Downdrag Calculations for Piling)

When including downdrag in the calculations for piling length and bearing the following guidelines shall be used.

1. The Soils Section of the Office of Design will indicate if there are any compressible soil layers on the foundation report.

2. Determine the design load of the piles due to the bridge Live Load and Dead Load.

3. Determine downdrag force as follows (Note: Any soil in or above the compressible soil layers must be considered except for the prebore.).
   a. Take chart value for friction resistance from foundations soils information chart and multiply by 2 to eliminate safety factor on values as shown in b.
   b. Down Drag Force = (Thickness of Soil Layer Above the Compressible Layer and below any prebore + Thickness of Compressible Soil Layer) * Chart Values for each soil layer * 2.

4. Determine Pile Length.

   a. Add design load and drag force to determine required pile capacity.
   b. Based on the required pile capacity determine the length of the pile needed below the compressible layer based on chart values for skin friction and end bearing.
   c. Total Pile Length = embedment of pile into footing and cutoff [1 ft. (305 mm)] + the pile length from bottom of footing to the bottom of the compressible layer + the pile length below compressible layer. Round pile length to even 1 ft (300 mm) for concrete piles and 5 ft (1500 mm) for wood or steel piles.

5. When calculating the bearing value for friction piles, include the downdrag forces when checking against the maximum allowable bearing capacity. For example for a HP10x42 steel friction pile, the total bearing capacity including downdrag forces should be 37 tons or less (6000psi * 12.4 in^2) / 2000 lbs/ton.

6. Determine Total Driving Resistance.

   Total Theoretical Driving Resistance = the driving resistance of all layers including any compressible layer for the plan pile length + the end bearing. (Note: Values for driving resistance shall be calculated directly from the values in the Soils charts, which include the factor of safety. Do not include the driving resistance in the prebore length.)

7. Add the following note to the plan.

   "Abutment (or pier) piles are designed to accommodate downdrag force due to soil consolidation under the new earth fill. Piles shall be driven to ___ Tons (kN) based on theoretical driving resistance. This includes ___ Tons (kN) of resistance in and above the compressible layers, ___ Tons (kN) resistance for downdrag forces and ___ Tons (kN) resistance for dead and live load bearing capacity."

Note: The maximum theoretical driving resistance should not be greater than 12 ksi (83 MPa) or 74.4 tons (660 kN) for HP10 x 42. Exceeding the maximum driving resistance may be a problem. For situations where you exceed the 9 ksi (62 MPa) driving resistance, a request for a wave equation analysis of the piles should be made through the Construction Office. The Office of Construction will evaluate the wave equation stresses to determine if there are any overstresses. If overstresses are a problem then check with your section leader for options to eliminate the overstresses. Options available may be to increase the number of piles and reduce the lengths or provide a higher strength pile (50 ksi, 345 MPa).

Example Calculations of Downdrag Forces for an Integral Abutment

This example assumes 150 tons loading due to LL and DL from the bridge and the following soils conditions:

Depth to layer	Material
0-12'	Fill
12-16'	Stiff Silty Clay
16-26'	Soft-Stiff Silty Clay (Compressible Layer)
26-36'	Firm Glacial Clay
>36'	Very Firm Glacial Clay

Note: The downdrag forces are determined from the allowable friction bearing values given in the Office of Design "Foundation Soils Information Chart" without the factor of safety (2) that is used for regular pile length bearing calculations. In order to remove the factor of safety, multiply the chart values by 2.0 when calculating downdrag forces. (Note: The downdrag forces should be calculated from the soil layers in and above the compressible layers.)

1. Calculate downdrag force:

Prebore	0 (8 ft.)	=	0.0 tons
Medium Sand (Fill):	2 (0.6 tons/ft) (4 ft.)	=	4.8 tons
Stiff Silty Clay:	2 (0.3 tons/ft.) (4 ft.)	=	2.4 tons
Soft-Stiff Silty Clay:	2 (0.2 tons/ft.) (10 ft)	=	4.0 tons
Total Downdrag Force:		=	11.2 tons (99.6 kN)

2. Calculate Pile Lengths and Capacity:

Normal Capacity, HP10x42, Friction Pile (6 ksi): = 37 tons (329.2kN)
Reduced Capacity due to Down Drag: 37 tons – 11.2 tons = 25.8 tons (229.6 kN)

This capacity of 37 tons (329.2 kN) is calculated based on friction and end bearing below the compressible layer. The maximum load due to DL and LL from the bridge is limited to 25.8 tons (229.6 kN) because of the deduction for downdrag forces. However, the driving resistance may exceed the 37 tons (329.2 kN) bearing value as shown in the final calculated pile length table (41.8 tons or 371.9 kN).

Number of piles needed = 150/25.8 = 5.8 use 6
Load per pile = 150/6 = 25 tons (222.4 kN)
Calculate Pile Length:

Layer	Length (ft.)	Bearing Calc. (tons)	Σ Brg (tons)	Driving Resistance Calc (tons)	Σ. Driving Resist. (tons)
Embedment in Abut	2.0	NA	NA	NA	NA
Prebore	8.0	NA	NA	NA	NA
Fill	4.0	-2.0 (0.6 t/ft.)(4 ft.) = -4.8	-4.8	(0.6 t/ft)(4ft) = 2.4	2.4
Stiff Silty Clay	4.0	-2.0 (0.3 t/ft)(4 ft) = -2.4	-7.2	(0.3)(4 ft) = 1.2	3.6
Soft-Stiff Silty Clay (Compressible Layer)	10.0	-2.0 (0.2 t/ft)(10ft) = -4.0	-11.2	(0.2 t/ft)(10 ft) = 2.0	5.6
Firm Glacial Clay	10.0	(0.7 t/ft) (10 ft) = 7.0	-4.2	(0.7 t./ft.)(10ft.) = 7.0	12.6
Very Firm Glacial Clay (< 30 ft Exist. Ground)	6.0	(0.7 t/ft)(6 ft) = 4.2	0	(0.7 t/ft)(6 ft) = 4.2	16.8
Very Firm Glacial Clay (> 30 ft Exist. Ground)	18.8	(1.0 t/ft)(18.8 ft) = 18.8	18.8	(1.0 t/ft)(18.8ft) = 18.8	35.6
End Bearing in Very Firm Glacial Clay	NA	(1000 psi)(12.4 in^2) / 2000 lb/t = 6.2	25.0	6.2	41.8

Note: Total length = 62.8 ft. therefore use 65 ft.

3. Provide the following note on the plan with the information filled in as shown:

> "Abutment piles are designed to accommodate downdrag force due to soil consolidation under the new earth fill. Piles shall be driven to 41.8 Tons based on theoretical driving resistance. This includes 5.6 Tons of resistance in and above the compressible layers, 11.2 Tons resistance for downdrag forces and 25.0 Tons resistance for dead and live load bearing capacity."

Summary of example calculations:

1. Pile length is controlled by maximum allowable bearing value of 37 tons (HP10x42, 6 ksi allowable stress).
2. The driving resistance may exceed this value to a maximum of 12 ksi or 74.4 tons for the HP 10 x 42 pile that was used in the example.
3. The reduced DL + LL capacity of the pile is 25.8 tons. This value is used in determining the number of piles needed to carry the bridge loads at the abutment.

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