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IOWA DEPARTMENT OF TRANSPORTATION

To Office Bridges and Structures Date May 21, 2004

Attention All Employees Ref No. 521.1

From Gary Novey

Office Bridges and Structures

Subject Methods Memo No. 87(Revised Downdrag Calculations)

Questions have been brought up recently about the office's policy on downdrag design. In some projects done recently, there were large downdrag forces found in the calculations making it difficult to do the pile design. After discussion, it was determined that the factor of safety for downdrag should be modified from 2 to 1.

Therefore, the downdrag will be entered in the notes as half the value currently used (the same value as the driving resistance in and above the compressible layer). The driving graph prepared by the Office of Design has a factor of safety of 2, therefore piles have an ultimate resistance of 2times the plan total driving resistance. The factored downdrag force (2 * Chart Values) is resisted by the ultimate resistance of the material below the compressible layer (2 * chart values). Any variability in the downdrag load will be resisted by similar variability in the material below the compressible layer to pick up the load. Essentially a factor of safety of one is considered adequate for this application

The downdrag force should now be calculated as follows: (Note: Any soil in or above the compressible soil layers must be considered except for the prebore.)

1. Take the chart value for friction resistance from foundations soils information chart without any modification.
2. 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.

Revised Example Calculations of Downdrag Forces for an Integral Abutment (See Methods Memo No. 20, 9-26-01 for original example)

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" with the factor of safety (2) that is used for regular pile length bearing calculations. (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):	(0.6 tons/ft) (4 ft.)	=	2.4 tons
Stiff Silty Clay:	(0.3 tons/ft.) (4 ft.)	=	1.2 tons
Soft-Stiff Silty Clay:	(0.2 tons/ft.) (10 ft)	=	2.0 tons
Total Downdrag Force:		=	5.6 tons (49.8 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 – 5.6 tons = 31.4 tons (279.3 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 31.4 tons (279.3 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 (41.2 tons or 366.5 kN).

Number of piles needed = 150/31.4 = 4.8 use 5
Load per pile = 150/5 = 30 tons (266.9 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	-(0.6 t/ft.)(4 ft.) =-2.4	-2.4	(0.6 t/ft)(4ft) = 2.4	2.4
Stiff Silty Clay	4.0	-(0.3 t/ft)(4 ft) = -1.2	-3.6	(0.3)(4 ft) = 1.2	3.6
Soft-Stiff Silty Clay (Compressible Layer)	10.0	-(0.2 t/ft)(10ft) = -2.0	-5.6	(0.2 t/ft)(10 ft) = 2.0	5.6
Firm Glacial Clay	10.0	(0.7 t/ft) (10 ft) = 7.0	1.4	(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	5.6	(0.7 t/ft)(6 ft) = 4.2	16.8

Very Firm Glacial Clay (> 30 ft Exist. Ground)	18.2	(1.0 t/ft)(18.2 ft) = 18.2	23.8	(1.0 t/ft)(18.2ft) = 18.2	35.0
End Bearing in Very Firm Glacial Clay	NA	(1000 psi)(12.4 in^2) / 2000 lb/t = 6.2	30.0	6.2	41.2

Note: Total length = 62.2 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 41.2 tons based on theoretical driving resistance. This includes 5.6 tons of resistance in and above the compressible layers, 5.6 tons resistance for downdrag forces and 30.0 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 31.4 tons. This value is used in determining the number of piles needed to carry the bridge loads at the abutment.
4. Theoretical pile length is based on actual number of piles divided into the total dead load and live load (150 tons / 5 piles equals 30 tons).
5. Plan pile length is rounded to the next 5-foot interval for steel piles (65 ft.).

GAN/DGB/bj