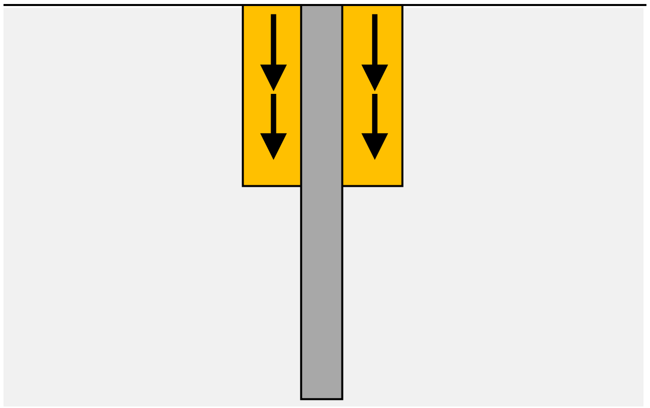
RSPile

Axial and Lateral Pile Analysis



Verification 3 Axially Loaded Steel Pipe in Uniform Soil Subjected to Downdrag

Keywords: Axially Loaded Pile, Steel Tube Pile, Analytical Solution, Downdrag, Applied Axial Displacement

3 Axially Loaded Steel Pipe in Uniform Soil Subjected to Downdrag

3.1 Problem Description

This problem examines an axially loaded steel tube pile in uniform soil subjected to downdrag. Downdrag is the settlement of soil surrounding a pile that develops negative skin friction along the shaft. Essentially, the pile is pulled downwards by the soil friction thus acting as a load along the pile shaft. To isolate the effects of downdrag, no axial load is applied to the pile. This analysis simulates a slope stability problem where the settlement region is the axial component of the displacement caused by a failure surface. The problem will analyze the load distributions in the pile when subjected to increased soil settlement until the pile has reached maximum axial capacity. The results will be compared to a numerical solution by Loehr and brown (2008) [1] and to *TZPile* [2], a commercial software for analyzing axially loaded piles.

A 30 m steel pipe is embedded into a uniform material with an assumed unit skin friction of 150 kPa and end bearing resistance of 21645.1 kPa. Since the cross-sectional area is 0.2 m^2, the end bearing resistance is 17,000 kN assuming plugged condition. The pile is subjected to a uniform soil settlement profile over the first 10 m of soil as shown in Figure 3-1. The settlement (δ_{soil}) cases examined include 0.001 m, 0.0025 m and 0.1 m. The pile properties are presented in Table 3-1 and the soil properties are presented in Table 3-2.

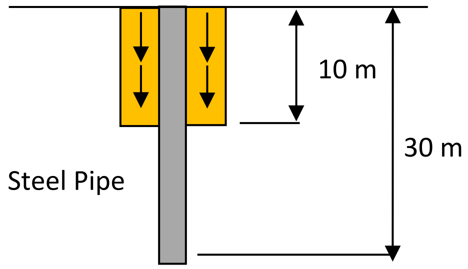


Figure 3-1: 30 m embedded steel pipe in uniform soil subjected to downdrag

Table 3-1: Pile Properties

Parameter	Value
Young's modulus (*E*)	200 GPa
Cross-sectional Area (*A*)	0.2 m^2
Outer Diameter	1 m
Embedment Length	30 m

Table 3-2: Soil Properties

Parameter	Value
Ultimate Unit Skin friction (top and bottom of layer)	150 kPa
Ultimate End Bearing Resistance	21645.1 kPa

The load transfer curve for skin friction is presented in Figure 3-2 and Table 3-3.

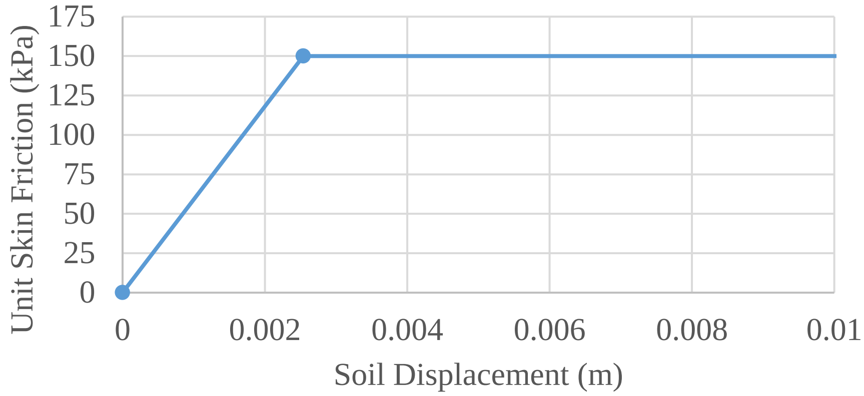


Figure 3-2: Load transfer (t-z) curve for skin resistance

Table 3-3: Load-transfer (t-z) curve for skin resistance

Soil displacement (m)	Unit Shear Transfer (kPa)
0	0
0.00254	150
∞	150

The end bearing resistance is presented in Figure 3-3 and Table 3-4.

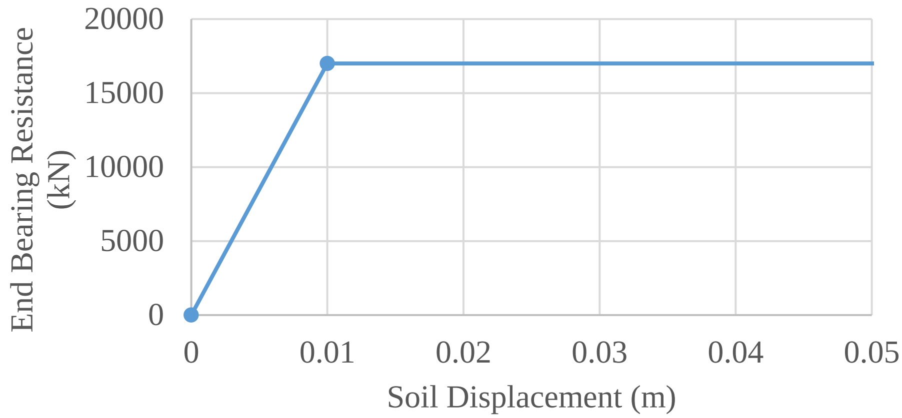


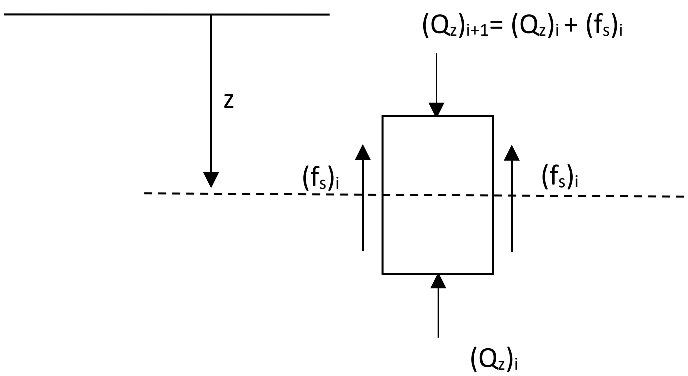
Figure 3-3: Load transfer (Q-z) curve for end bearing resistance

Table 3-4: Load-transfer (Q-z) curve for end bearing resistance assuming plugged condition

Soil displacement (m)	End Bearing Resistance (kN)
0	0
0.01	17,000
∞	17,000

3.2 Numerical Solution

Using a calculation spreadsheet based on the methodology described by Loehr and Brown (2008) [1], a pile can be discretized into segments as follows:



The force equilibrium equation at each calculation node i is as follows.

$$(Q_z)_{i+1} = (Q_z)_i + (f_s)_i$$

where z	=	depth to midpoint of pile segment
$(Q_z)_{i+1}$	=	top axial force of pile segment at calculation node $i+1$
$(Q_z)_i$	=	bottom axial force of pile segment at calculation node i
$(f_s)_i$	=	Soil skin friction at depth z for calculation node i

The spreadsheet uses an iterative process to solve for internal forces in the pile beginning with an assumed toe settlement and calculating the end bearing resistance from the load transfer curve due to the assumed settlement. Soil skin friction can be obtained iteratively by assuming a soil displacement at the midpoint of the pile segment, obtaining the corresponding load from the load transfer curve and verifying the assumed soil displacement from force equilibrium taking into account axial compression or tension of the pile due to the assumed displacement. Computation progresses from the toe to head by satisfying force equilibrium at each calculation node using the equation above.

3.3 Results

Figure 3-4 shows the load distribution throughout the pile subjected to increasing soil settlement of 0.001 m, 0.0025 m and 0.1 m. The results from *RSPile* compare well with the spreadsheet by Loehr and Brown (2008) [1] and with *TZPile* [2].

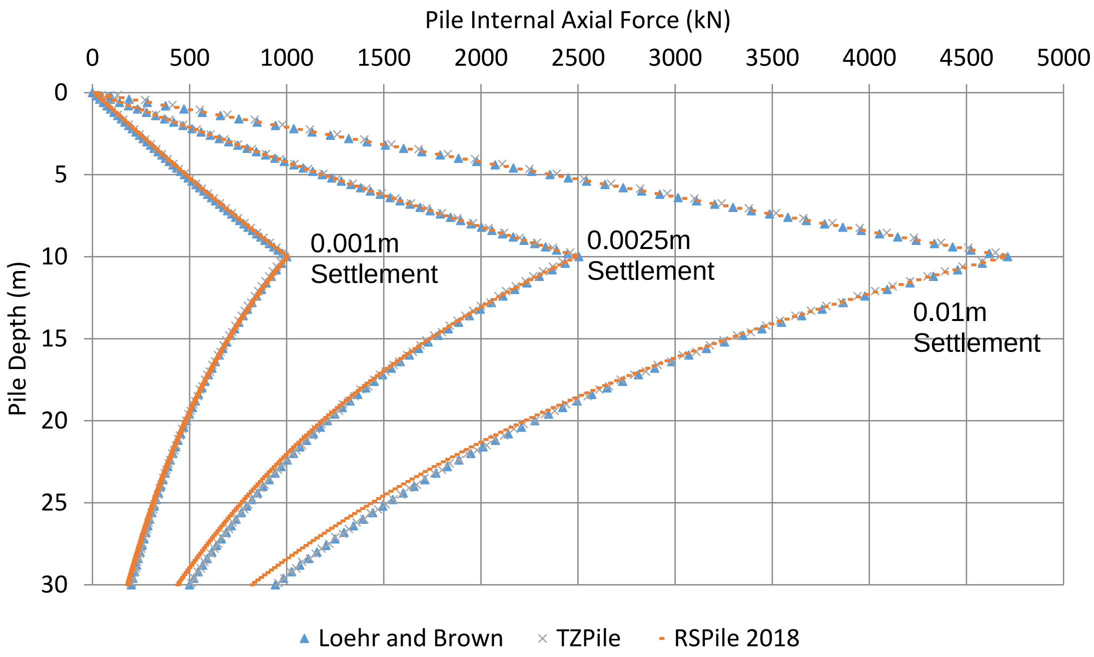


Figure 3-4: Pile load distribution for various settlement cases

3.4 References

1. Loehr, E.J. and Brown, D.A. (2008). "A Method for Predicting Mobilization Resistance for Micropiles Used in Slope Stabilization Applications", A Report Prepared for the Joint ADSC/DFI Micropile Committee.

2. Ensoft, Inc. *TZPil*e. Computer software. Vers. 2014.3.2. Ensoft, Inc., 21 Jan. 2015.

3.5 Data Files

The input data file **Verification 003 (Axially Loaded Steel Pipe in Uniform Soil Subjected to Downdrag).rspile** can be found in the installation folder.

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