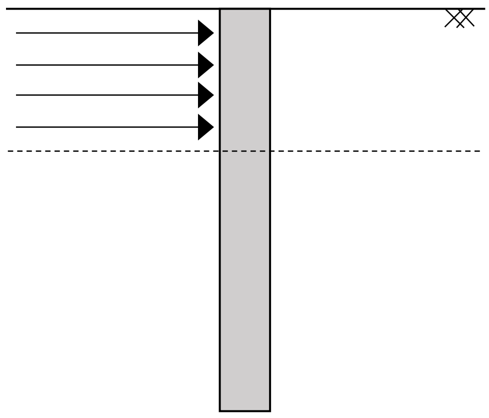
RSPile

Axial and Lateral Pile Analysis



Verification 6 Laterally Loaded Steel Pipe in Layered Soil Loaded by Moving Soil

Keywords: Laterally Loaded Pile, Steel Pipe, Soft Clay (Matlock), Sand (Reese), Dry Stiff Clay (Reese), LPile, Sliding Depth, Soil Movement

6 Steel Pipe in Layered Soil Subjected to Sliding Soil

6.1 Problem Description

This problem examines a pile in layered soil, loaded by laterally moving soil. These analyses simulate a typical pile support in soil with soil moving at a few different sliding depths. The problem will analyze deflections, bending moments and shear forces in the pile.

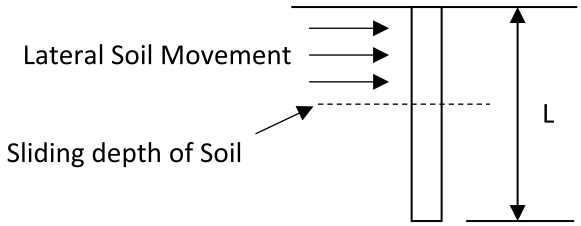


Figure 6-1: Pile embedded in soil loaded by laterally moving soil

The soil layers and their properties are defined in the following tables:

Table 6-1: Layer 1 – Soft Clay / Depth: 0m-2m

Parameter	Value
Effective Unit Weight of Soil	8 kN/m^3
Undrained Shear Strength	25 kPa
Strain Factor ε_{50}	0.02

Table 6-2: Layer 2 – Sand / Depth: 2m-4m

Parameter	Value
Effective Unit Weight of Soil	8 kN/m^3
Friction Angle	30°
Factor ks	5400 kN/m^3

Table 6-3: Layer 3 – Dry Stiff Clay / Depth: 4m-15m

Parameter	Value
Effective Unit Weight of Soil	10 kN/m^3
Undrained Shear Strength	100 kPa
Strain Factor ε_{50}	0.005

The pile is a solid elastic cylinder and the properties are shown in Table 6-4:

Table 6-4: Pile Properties

Parameter	Value
Elastic Modulus	200 GPa
Diameter	0.61 m
Wall Thickness	0.02 m
Embedment Length	15 m

6.2 Numerical Solution

Using the following differential equation from beam theory (shown in Equation 1), the numerical finite difference method is used to achieve results.

$$E_p I_p \frac{d^4y}{dx^4} + P_x \frac{d^2y}{dx^2} + E_{py}(y - y_{soil}) - W = 0 \qquad \text{Equation 1}$$

Where	y	=	Lateral deflection of the pile
	y_{soil}	=	Soil movement loading the pile
	$E_p I_p$	=	Bending stiffness of pile
	P_x	=	Axial load on pile head
	E_{py}	=	Soil reaction modulus based on p-y curves
	W	=	Distributed load down some length of the pile

The textbook referenced here cites the finite difference method as well.

6.3 Results

Figure 6-2 through Figure 6-4 show the results obtained in comparing RSPile to the results from LPile. The analysis was run at four different sliding depths (1m, 3m, 5m, 10m) at a soil movement of 30mm with the pile discretized into 100 nodes.

500 nodes is generally more accurate, but these analyses shown are so close that it would not provide any further proof that they produce the same result. Figure 6-5 shows the p-y curves generated at 1m, 3m, and 5m below the ground surface. Using the Method of Georgiadis, equivalent depths of soil had to be found for each layer below the top. Figure 6-5 also shows how using 500 nodes instead of 100 nodes gives closer results between LPile and RSPile.

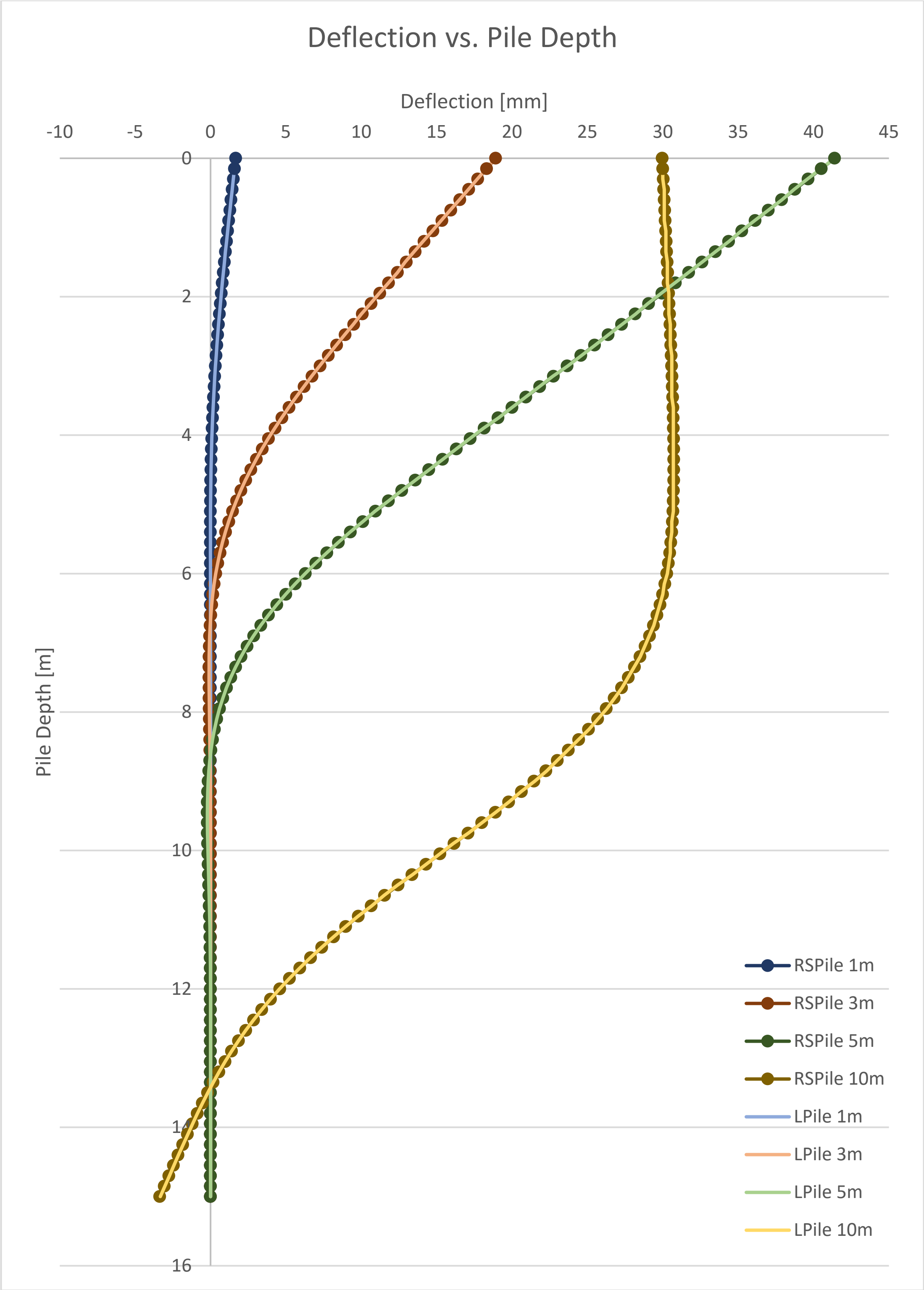


Figure 6-2: Pile Deflection at Sliding Depths

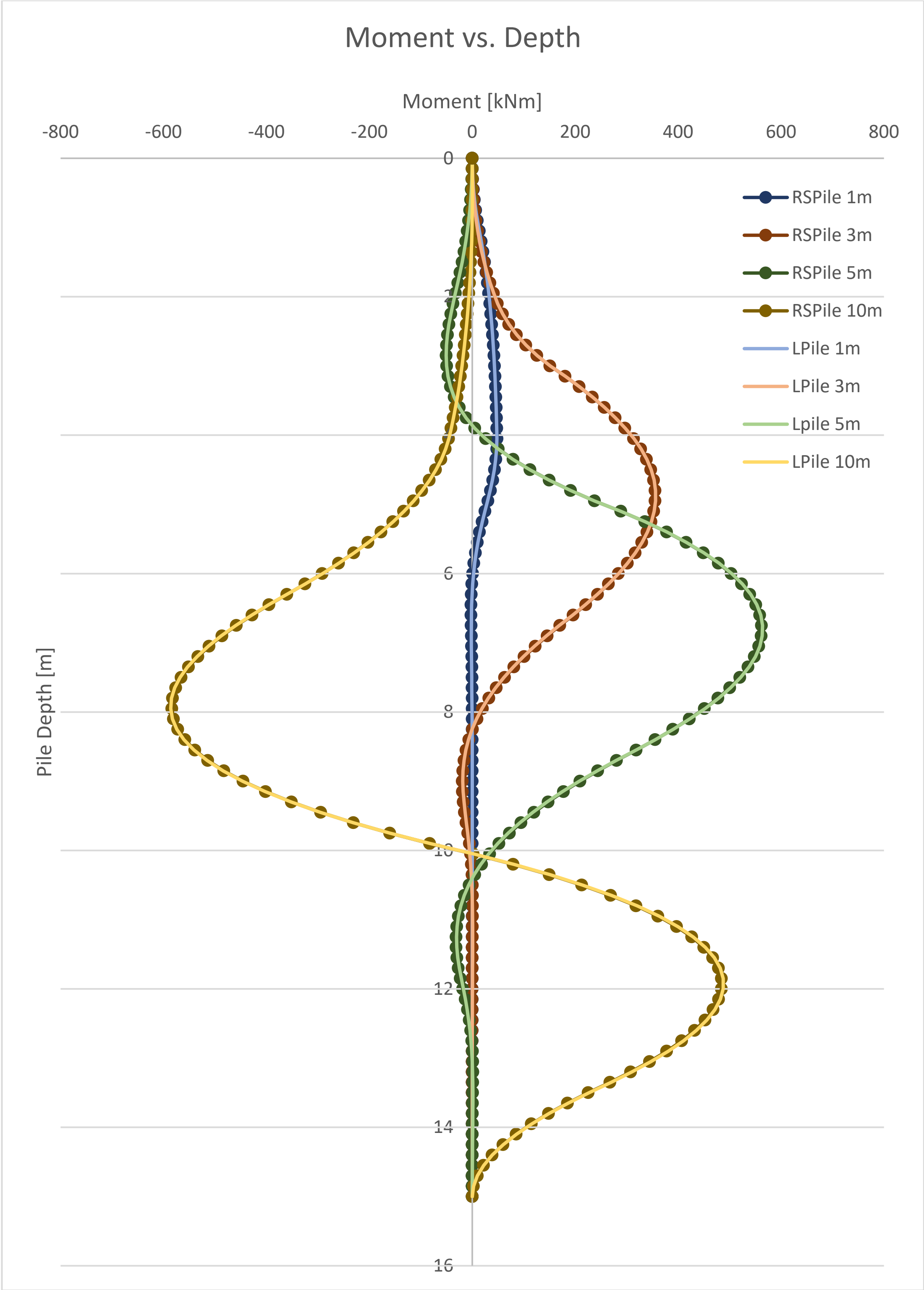


Figure 6-3: Pile Moment at sliding depths

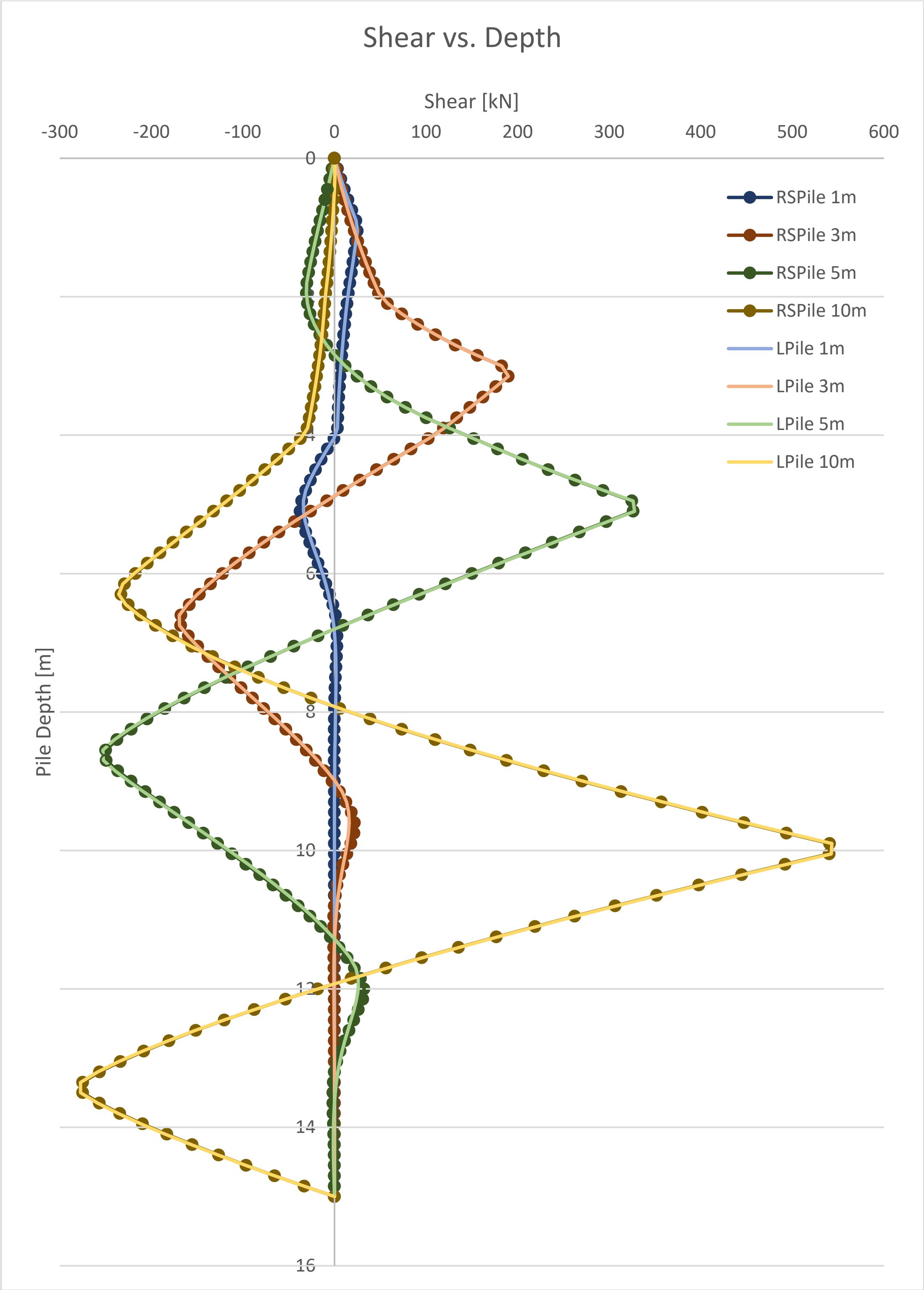


Figure 6-4: Pile Shear at sliding depths

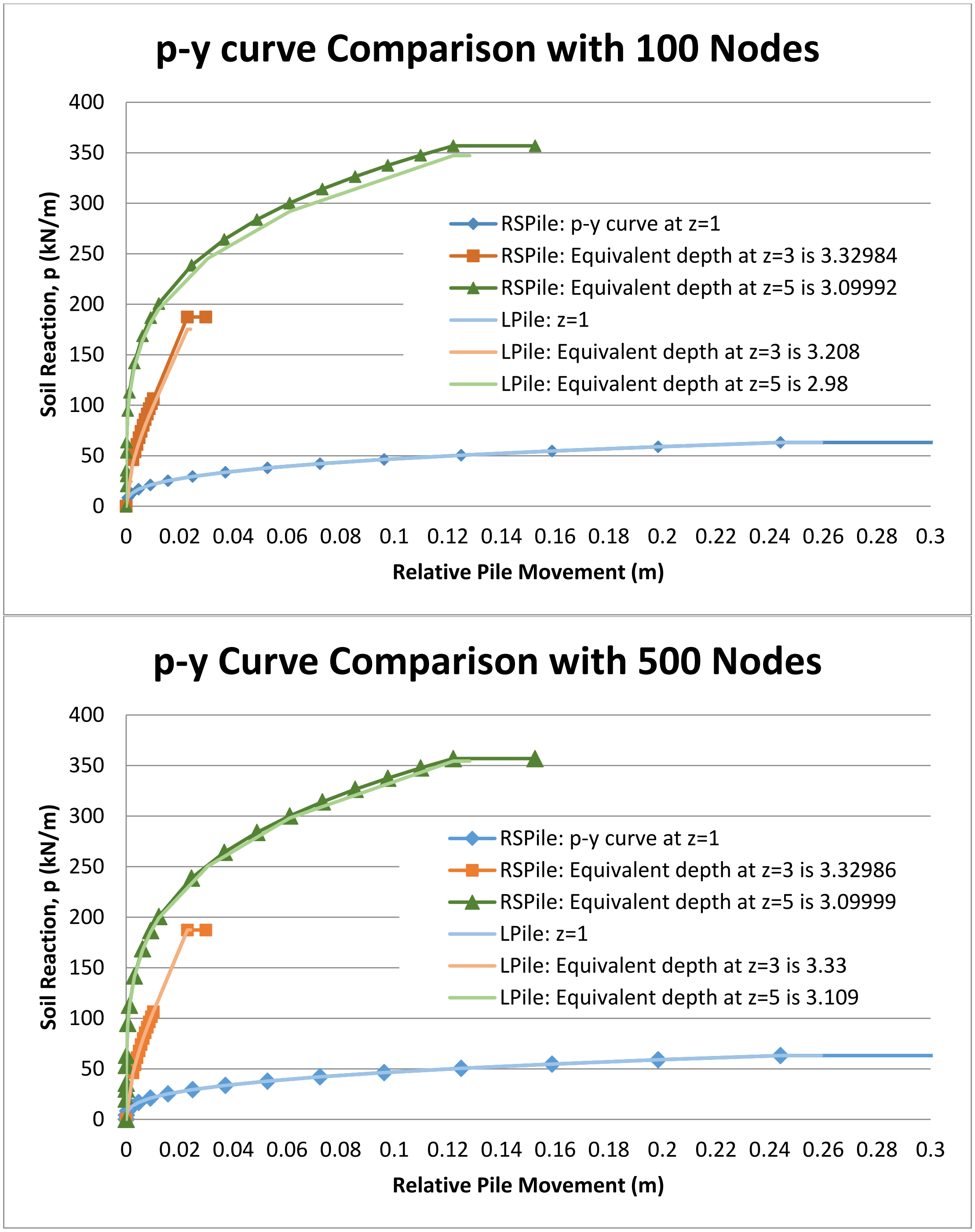


Figure 6-5: p-y Curves at a depth in each layer

6.4 References

1. Reese, L.C. & W.M. Van Impe. (2011). "Single Piles and Pile Groups Under Lateral Loading 2nd Edition." pp. 95.

2. Ensoft, Inc. *LPile*. Computer software. Vers. 2013-7.007. Ensoft, Inc., 24 Oct. 2013.

6.5 Data Files

The input data files below can be found in the installation folder.
Verification 006 (Layered with Soil Movement).rspile