6 Axially Loaded Piles in Cohesionless Soil

6.1 Problem Description

This problem examines two load transfer mechanisms in axially loaded piles: skin friction along the shaft, and end-bearing. The pile is first subjected to axial loads until failure resisted only by skin friction along the shaft. End-bearing effects are then included and the simulation is repeated. The ultimate bearing capacity for both conditions are calculated and compared.

6.2 Analytical Solution

The following equations were taken from the FLAC3D - Structural Elements Manual (Itasca Consulting Group Inc., 2002). Cernica (1995) calculates the ultimate bearing capacity of a single pile in cohesionless soil from shaft resistance due to skin friction as:

$$Q_s = \sum_i L_i (a_s)_i (s_s)_i$$

where	L_i	=	pile length at i increment
	$(a_s)_i$	=	area of pile surface per length in contact with soil at increment i
	$(S_s)_i$	=	unit shaft resistance at increment i

The equation can be simplified assuming uniform soil material and constant pile cross section, a_s and s_s become constant:

$$Q_s = L a_s s_s$$

In free draining cohensionless soil, unit shaft resistance, s_s, is given by:

$$s_s = K_s \sigma_{avg} \tan \phi_s$$

where	K_s	=	average coefficient of earth pressure on the pile shaft
	σ_{avg}	=	average effective overburden pressure along pile shaft
	ϕ_s	=	angle of skin friction

The end-bearing capacity, Q_p, of a single pile in cohesionless soil is given by (Cernica, 1995):

$$Q_p = A_p \gamma L N_q$$

where	A_p	=	cross sectional area of pile tip
	γ	=	unit weight of soil
	N_q	=	$\left(\frac{1+\sin\phi}{1-\sin\phi}\right)^2$, bearing capacity factor where ϕ is the soil friction angle

The total pile bearing capacity is simply the sum of skin resistance and end-bearing:

$$Q = Q_s + Q_p = La_s K_s \sigma_{avg} \tan \phi_s + A_p \gamma L \left(\frac{1+\sin\phi}{1-\sin\phi}\right)^2$$

6.3 Model Information

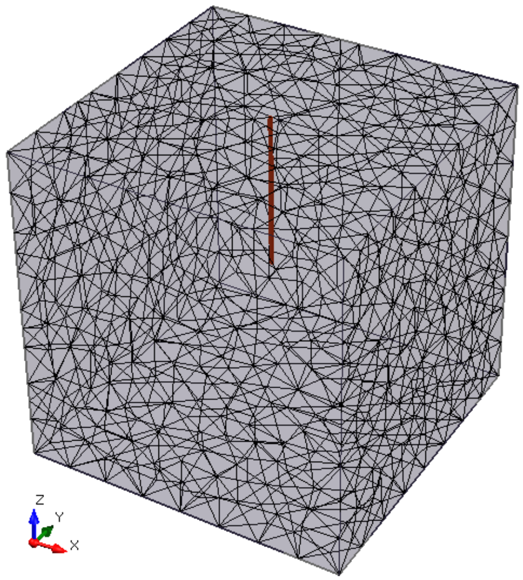

Figure 6-1: Plain strand cable rockbolt as modeled in *RS3*

Table 6-1 Soil Properties

Parameter	Value
Young's modulus (*E*)	2812.5 MPa
Unit weight	0.02 MN/m^3
Poisson's ratio	0.40625
Friction angle	10°
Cohesion strength	0 MPa
Average coefficient of earth pressure, (K_s)	1

Table 6-2 Pile Properties

Parameter	Value
Young's modulus (E)	80000 MPa
Poisson's ratio	0.3
Length	7 m
Diameter	1 m
Shear stiffness	2812.5 MPa/m
Normal stiffness	28125 MPa/m
Base normal stiffness	28125 MPa
Base force resistance	0.222 MN
Skin friction angle	10º
Skin cohesion	0 MPa

The model shown in Figure 6-1 is made up of an elastic host material containing a 7 m pile to which various axial forces (10 kN to 500 kN) were applied.

6.4 Results

The graphs below show the load displacement response for axial load tests. Figure 6-2 shows the load-displacement response of piles considering only skin resistance. Figure 6-3 shows the load-displacement response after considering end-bearing effects. The graphs illustrate a clear plateau at the expected ultimate bearing capacity.

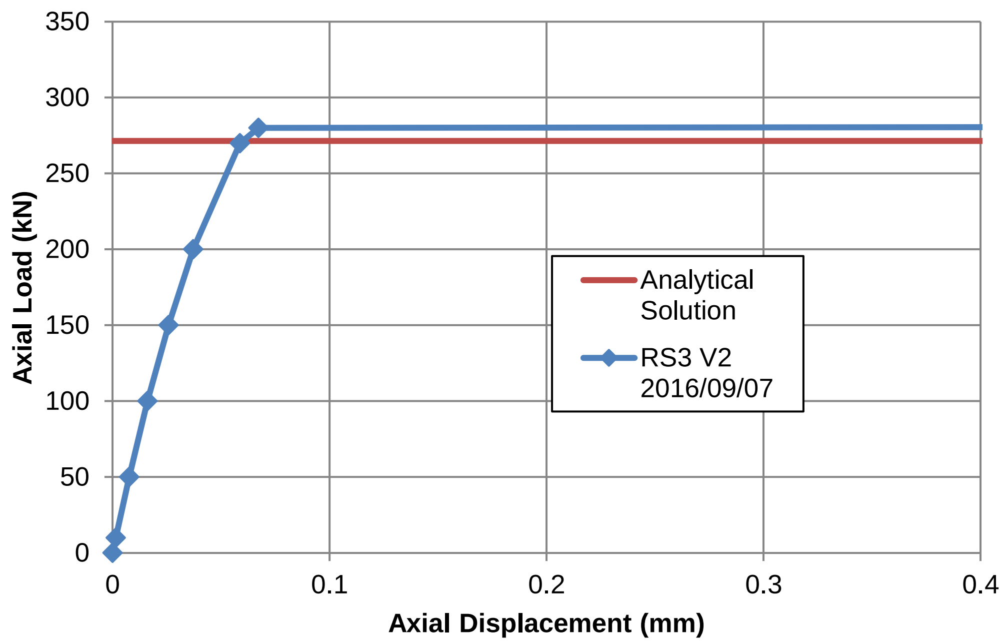

Figure 6-2: Load-displacement response of piles considering only skin resistance

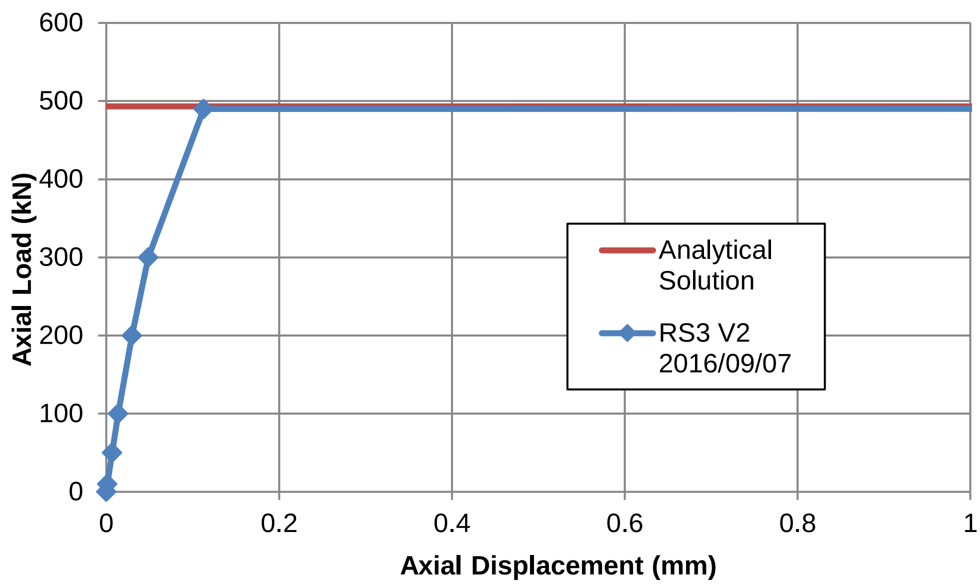

Figure 6-3: Load-displacement response of piles considering skin resistance and end-bearing effects

Table 6-3: Comparison of ultimate bearing capacity results

Effects considered	***RS3*** **Results**	**Analytical Solution**
Skin resistance only	280 kN	271 kN
Skin resistance and end-bearing	494 kN	493 kN

The graphs and the table above show that ***RS3*** results are in close agreement with the analytical solution.

6.5 References

1. Cernica, J. N. (1995). *Geotechnical Engineering: Foundation Design*, New York: John Wiley & Sons,Inc.
2. Itasca Consulting Group Inc., 2004. *FLAC3D v 2.1 User's Guide - Structural Elements*, Minneapolis, Minnesota, USA.

6.6 Data Files

The input data files
V006 no end bearing.rs3model and **V006 end bearing.rs3model** can be found in the ***RS3*** installation folder.