FINITE ELEMENT ANALYSIS OF

THE AXIAL CAPACITY OF MICROPILES

By

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B A C K G R O U N D

BACKGROUND

Micropiles: small-diameter (typically less than 30 cm), drilled and grouted replacement piles that are typically reinforced .

Types of Micropiles (FHWA Classification):

a) Philosophy of behaviour

- Case 1: micropiles ar directly loaded.
- Case 2: Support and stabilization by interlocking.

b) Method of grouting

- Type A: grouting under gravity head.
- Type B: grouting pressure between 0.3 and 1.0 MPa.
- Type C: grouting pressure 1.0 MPa.
- Type D: grouting pressure between 2.0 and 8.0 MPa.

O B J E C T I V E S

OBJECTIVES

Case study, Type B micropile (Han and Ye, 2006)

Model calibration PLAXIS 2D

Quantifying adhesion properties

Uncertainties in soil testing and numerical modeling

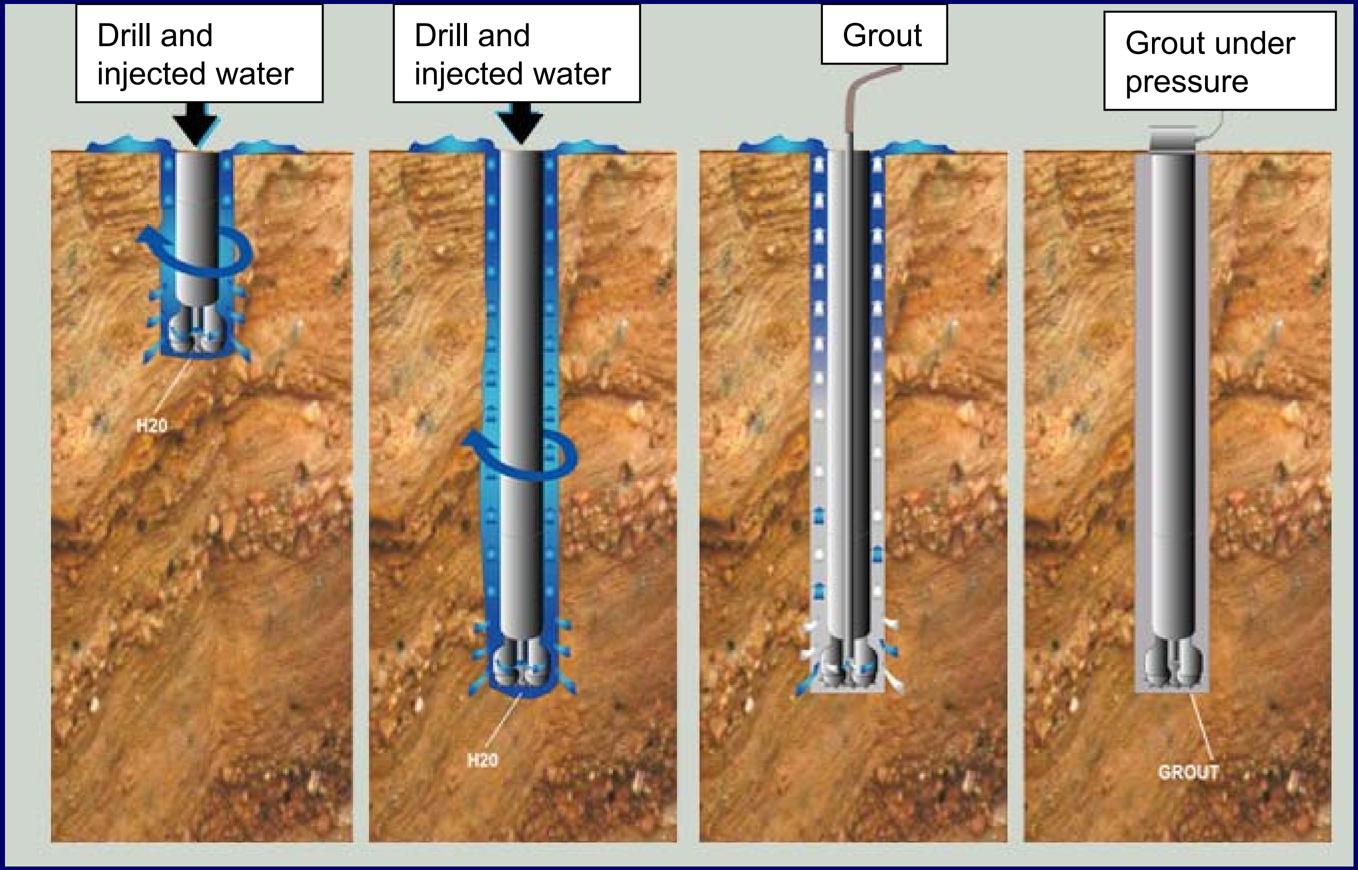
Micropile enlarged portion length

Effect of micropile diameter

Overview

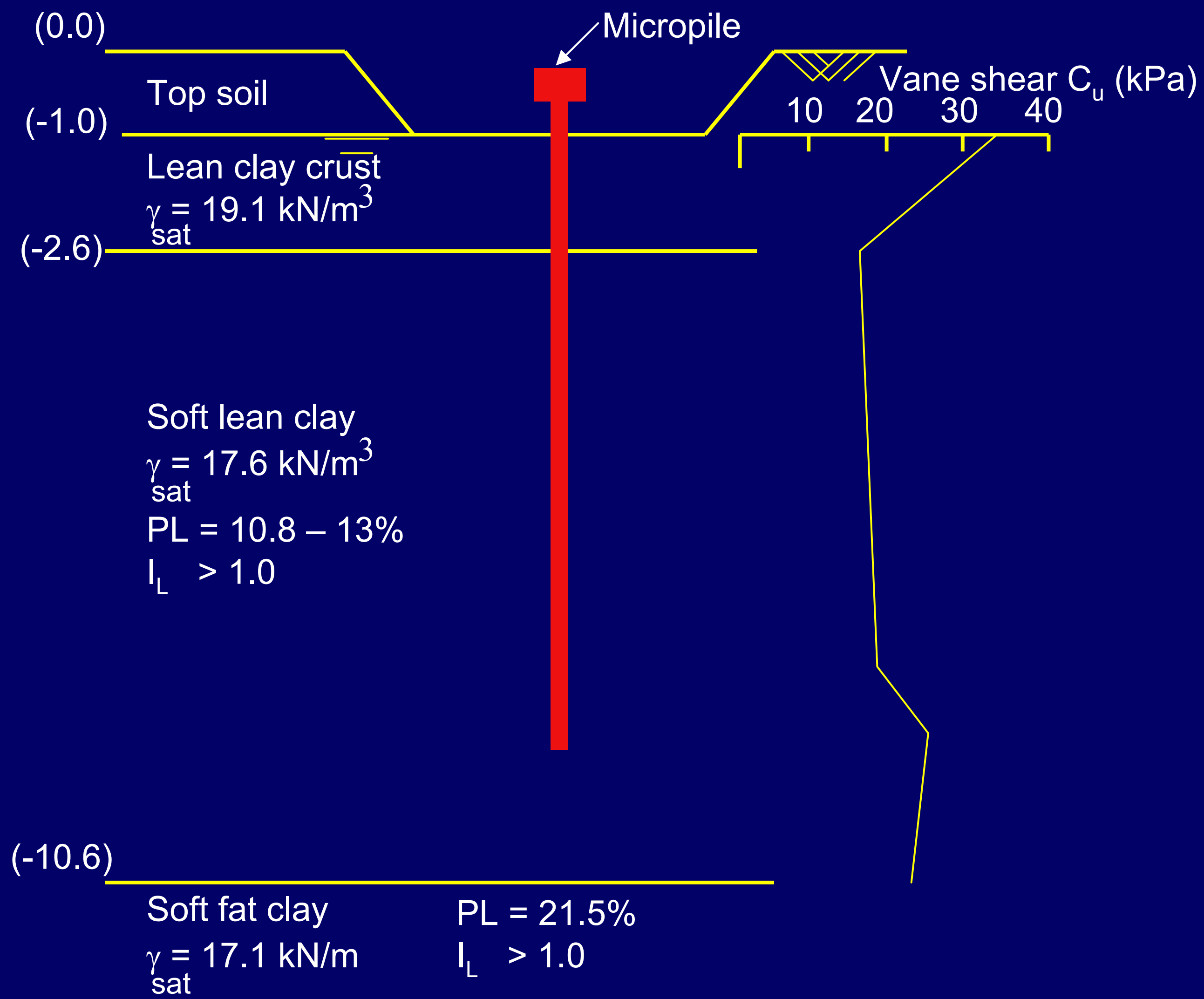
Micropile:

Type B, Diameter = 0.15m, Length = 8.0m, Grouting pressure = 0.2 – 0.5MPa.



Overview

Site soils:



Geometrical Modeling

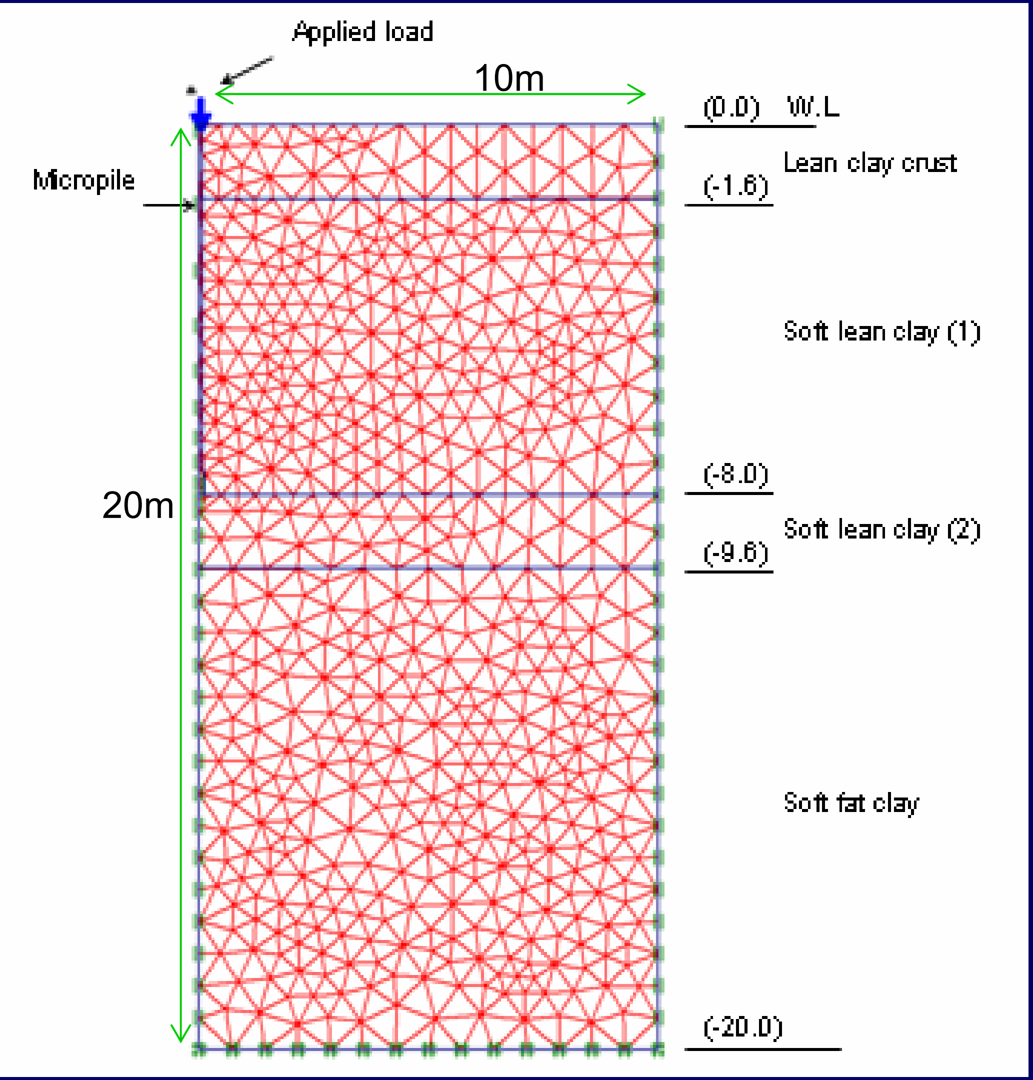
- Axisymmetrical model.
- 15-noded triangular element.
- Randolph and Wroth (1978):

  - Horizontal boundary placed at 2.5 L.

  - Vertical boundary placed at

    r = 2.5L(1-ν)

- Quick maintained load test.

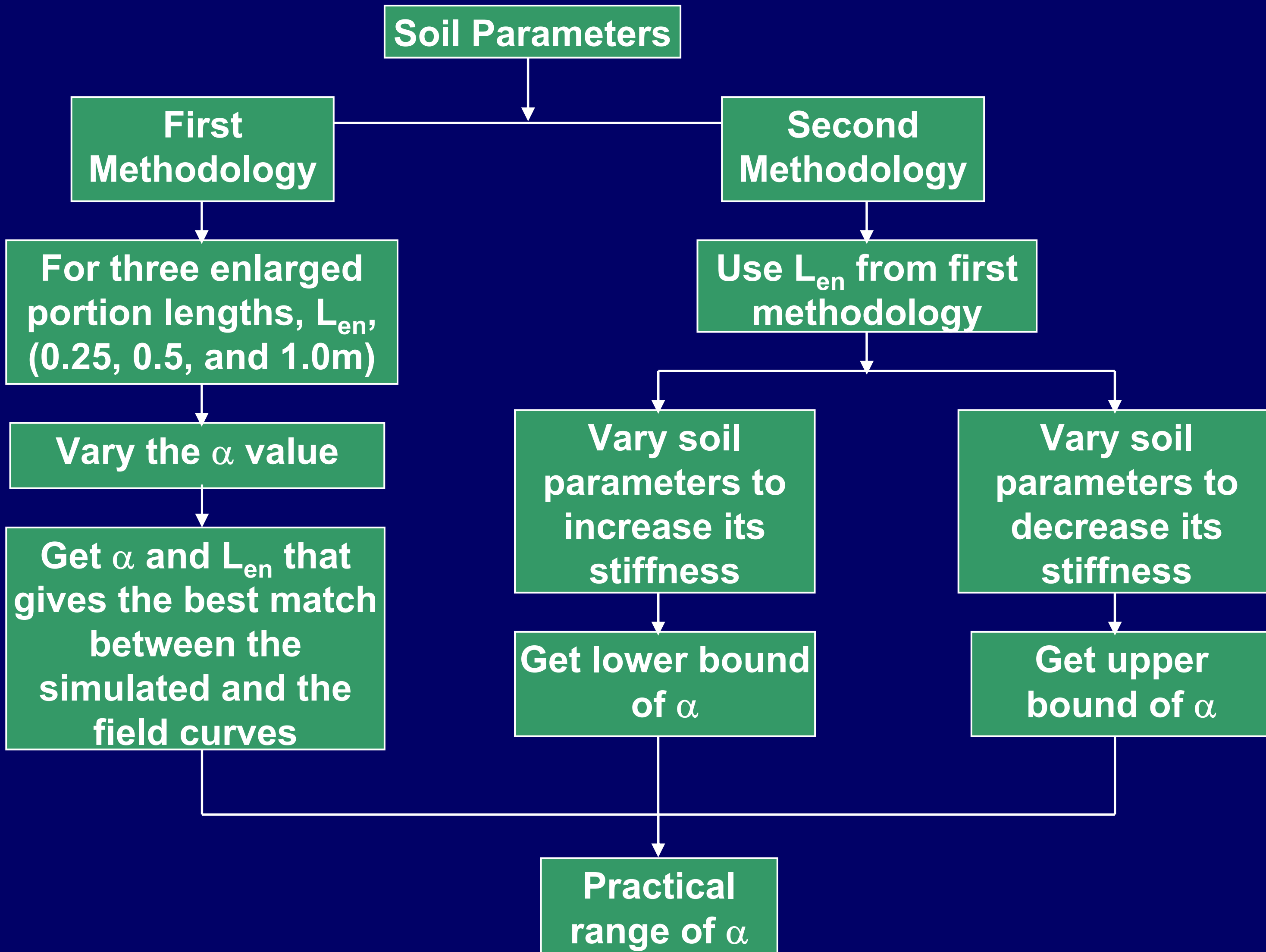


Material Modeling

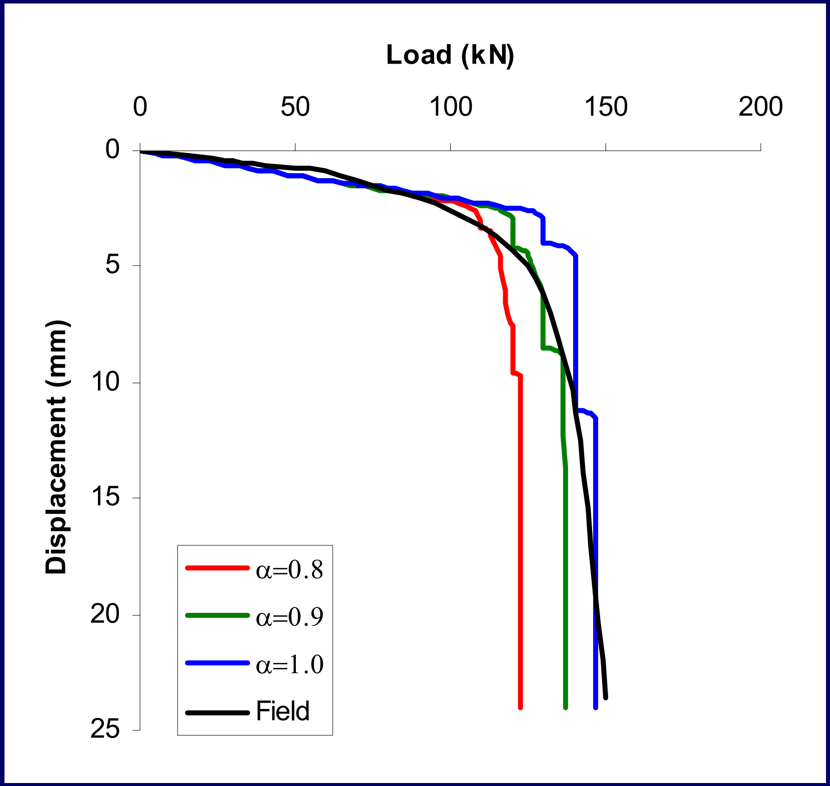
	Lean clay crust	Soft lean clay (1)	Soft lean clay (2)	Soft fat clay	Micropile
Model	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Linear-Elastic
Behaviour	Undrained	Undrained	Undrained	Undrained	Non-porous
C (kPa)	41.3-29	29	35	23.5	-
ϕ °	0	0	0	0	-
E\` (MPa)	13.30	13.30	27	9.40	31400
ψ °	0	0	0	0	-
ν\`	0.35	0.35	0.35	0.35	0.15
K_v (m/sec)	2.55×10^{-9}	1.85×10^{-9}	1.85×10^{-9}	1.85×10^{-9}	-
K_h (m/sec)	6.48×10^{-9}	2.93×10^{-9}	2.93×10^{-9}	2.93×10^{-9}	-
R_{int}	Variable	Variable	variable	variable	-

Lateral earth pressure, $K_o = (1 - \sin\phi`)\, OCR^{\sin\phi`}$

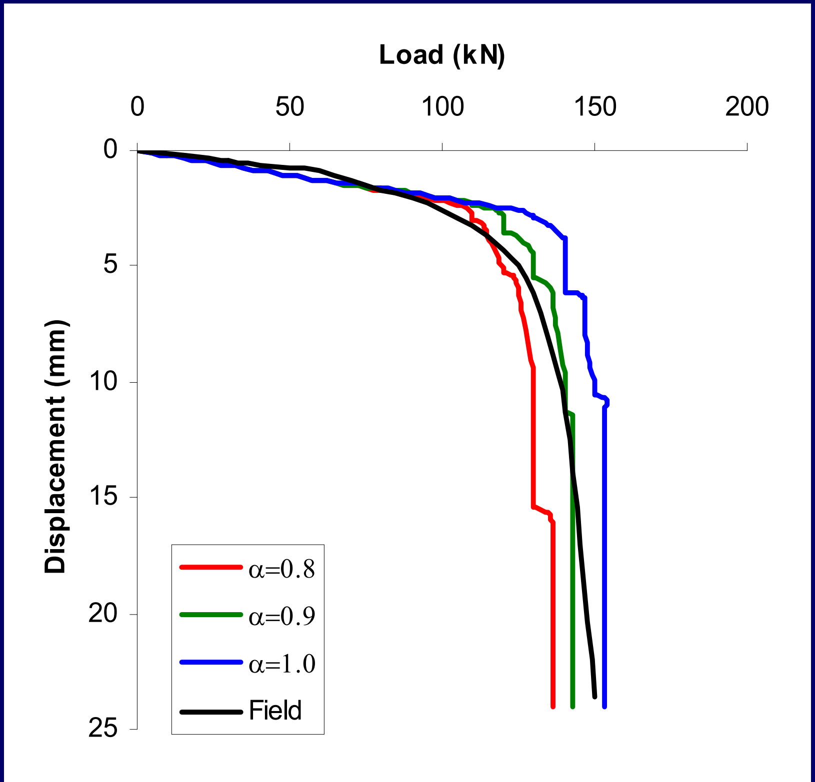
$C_a = R_{int} . C_u \longrightarrow C_a = \alpha . C_u$


Soil Parameters
First Methodology
Second Methodology
For three enlarged portion lengths, L_{en}, (0.25, 0.5, and 1.0m)
Vary the α value
Get α and L_{en} that gives the best match between the simulated and the field curves
Use L_{en} from first methodology
Vary soil parameters to increase its stiffness
Vary soil parameters to decrease its stiffness
Get lower bound of α
Get upper bound of α
Practical range of α

First Methodology

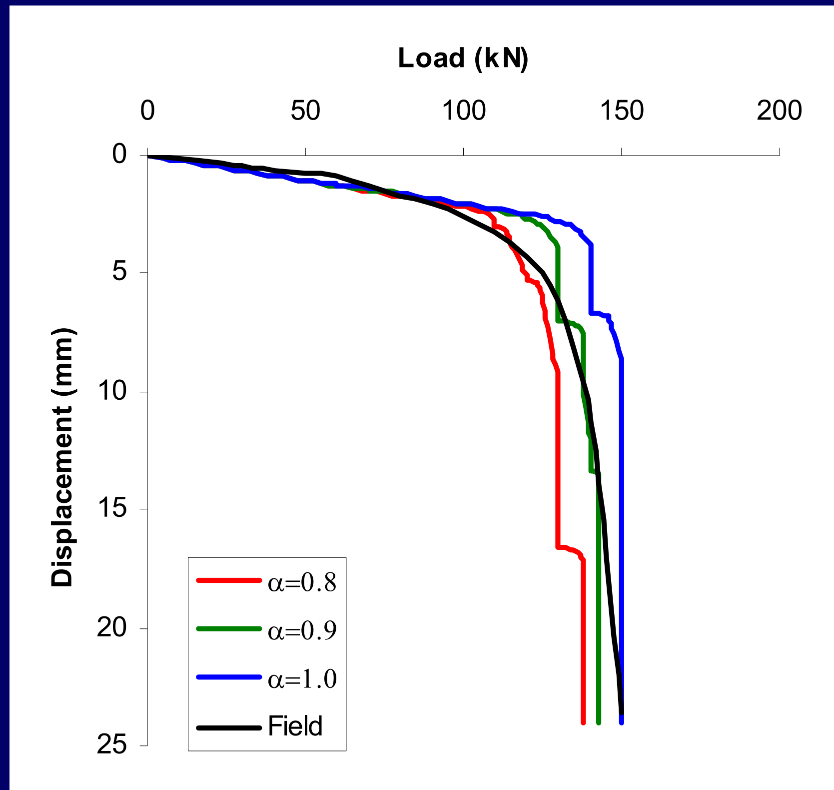


a) Case of enlarged portion length = 0.25m



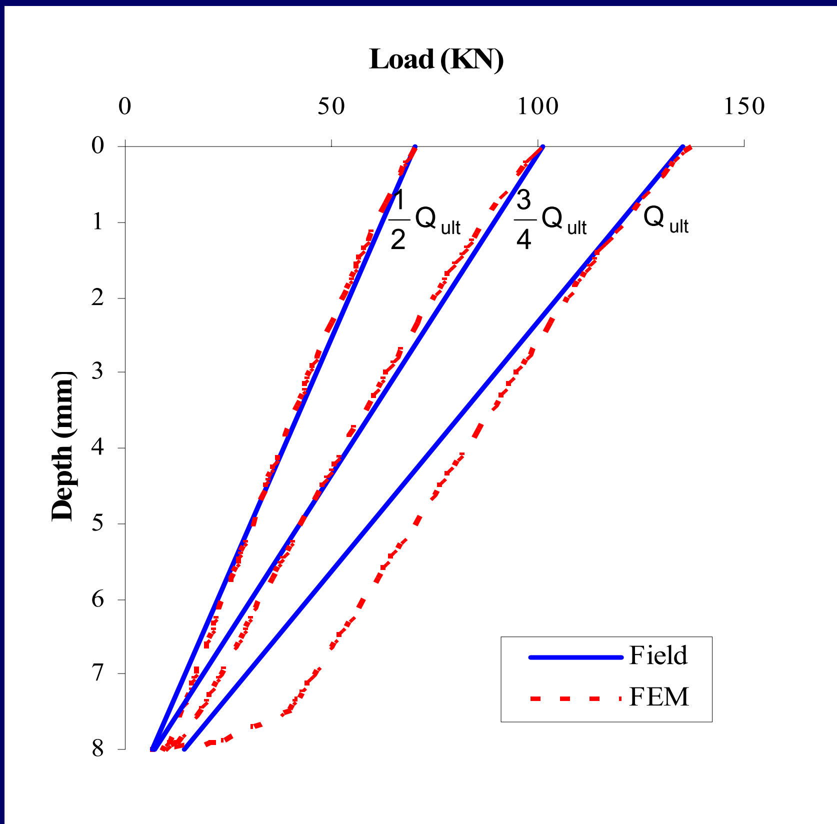
b) Case of enlarged portion length = 0.5m

First Methodology

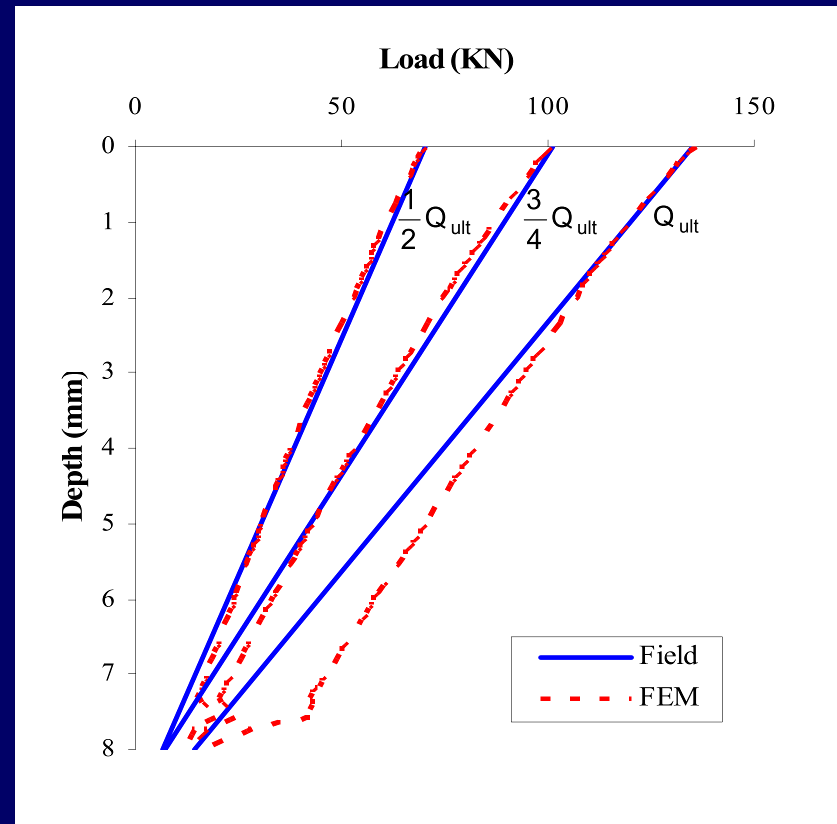


c) Case of enlarged portion length = 1.0m

First Methodology



a) Case of enlarged portion length = 0.25m

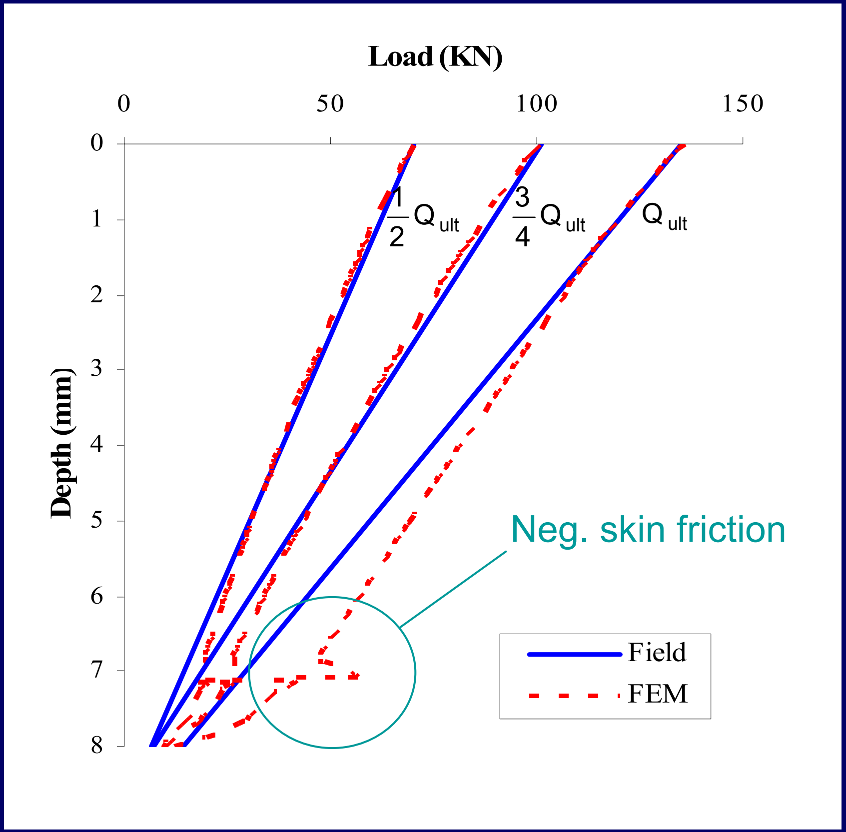


b) Case of enlarged portion length = 0.5m

First Methodology

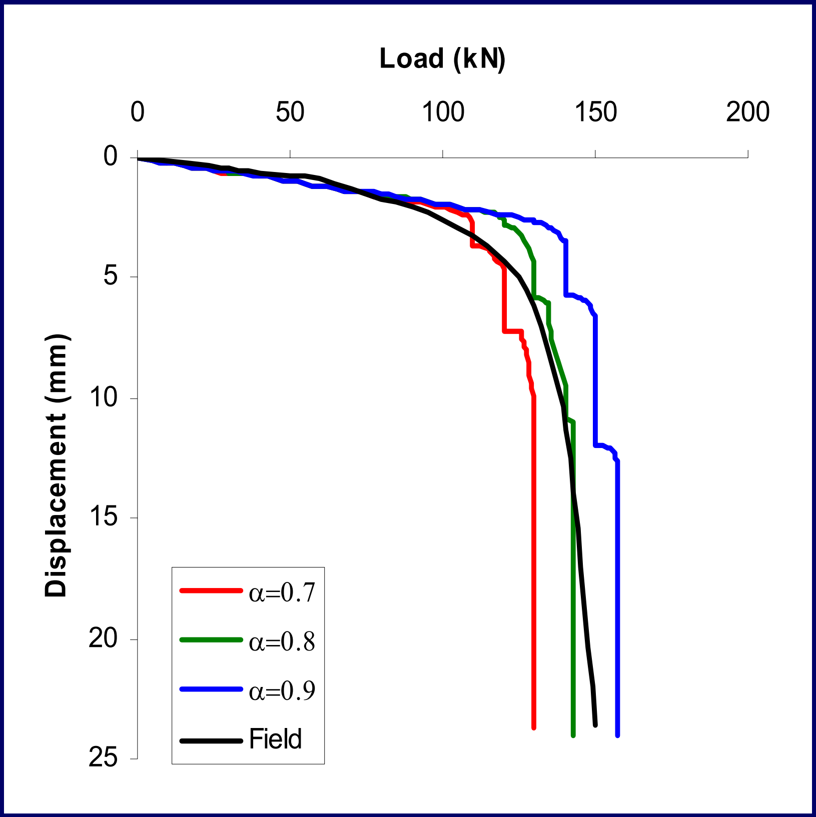
Type	Ult. Load (kN)	Toe resist. (kN)	Shaft resist. (kN)	% toe resist.	% shaft resist.
Numerical	135	11	124	8.0	92
Field	135	11.7	123.2	8.7	91.3

- Enlarged portion length (Len)= 1.0m
- Adhesion coefficient α = 0.9
- Failure of surrounding soil (see related slides)

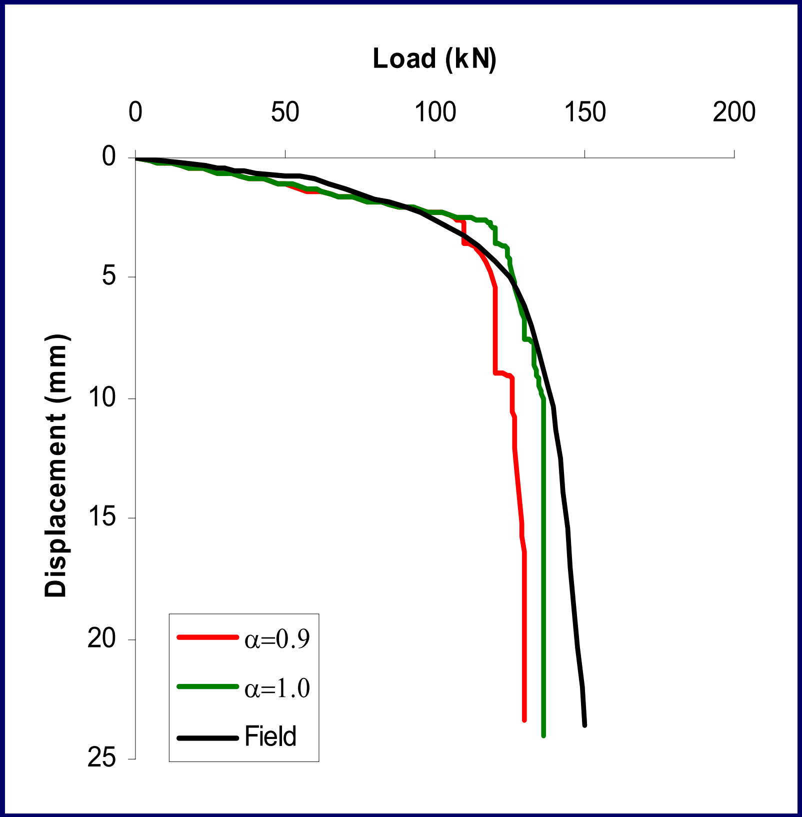


d) Case of enlarged portion length = 1.0m

Second Methodology



a) Lower bound (α)



b) Upper bound (α)

- α varies between 0.8 and 1.0 with best estimate of 0.9
- Bruce (1994): a varies between 0.6 and 0.8

EFFECT OF SHAFT DIAMETER

Diameter (m)	Ult. Load (kN)	Toe resist. (kN)	Shaft resist. (kN)	% increase in ult. load	Unit shaft resist. (kPa)
0.15	135	11	124	-	30.8
0.17	150	7.3	142.7	11	32
0.19	163	8.8	154.5	21	31.5
0.228	181	12.6	168.4	34	29.5

- Ultimate load increases by a factor of 2
- Unit shaft resistance is approximately constant (Frassetto, 2004)
- Abrupt increase in axial load in pile near toe diminishes as shaft diameter approaches enlarged portion diameter

CONCLUSIONS

- Adhesion factor α ranges between 0.8 and 1.0, with the best estimate of 0.9.
- Estimated α values are highly dependent on factors such as site soils, method of construction, etc.
- The enlarged base can mobilize some negative skin friction.
- The failure of surrounding soft clay initiated at the toe and expanded upward and laterally along the shaft.
- Ultimate capacity increased approximately linearly with the increase of shaft diameter.
- Unit shaft resistance remained approximately the same with the increase of shaft diameter.

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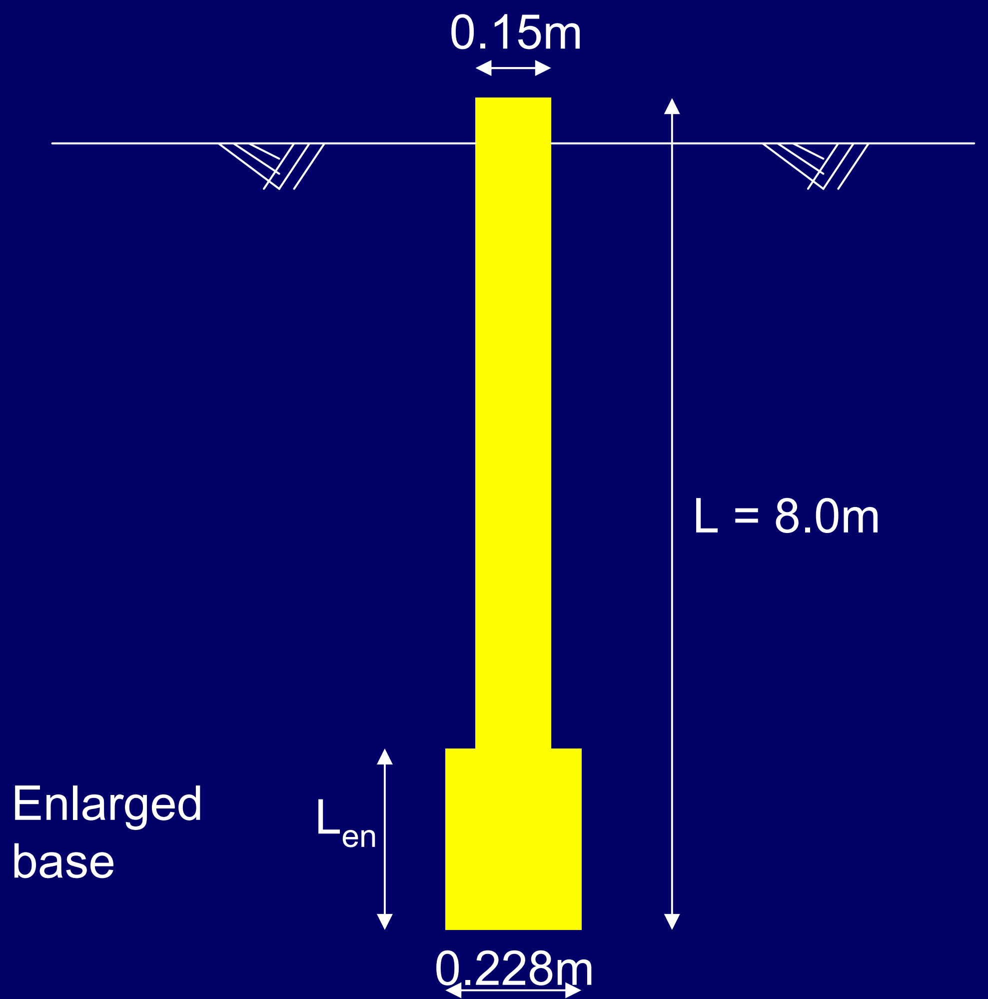
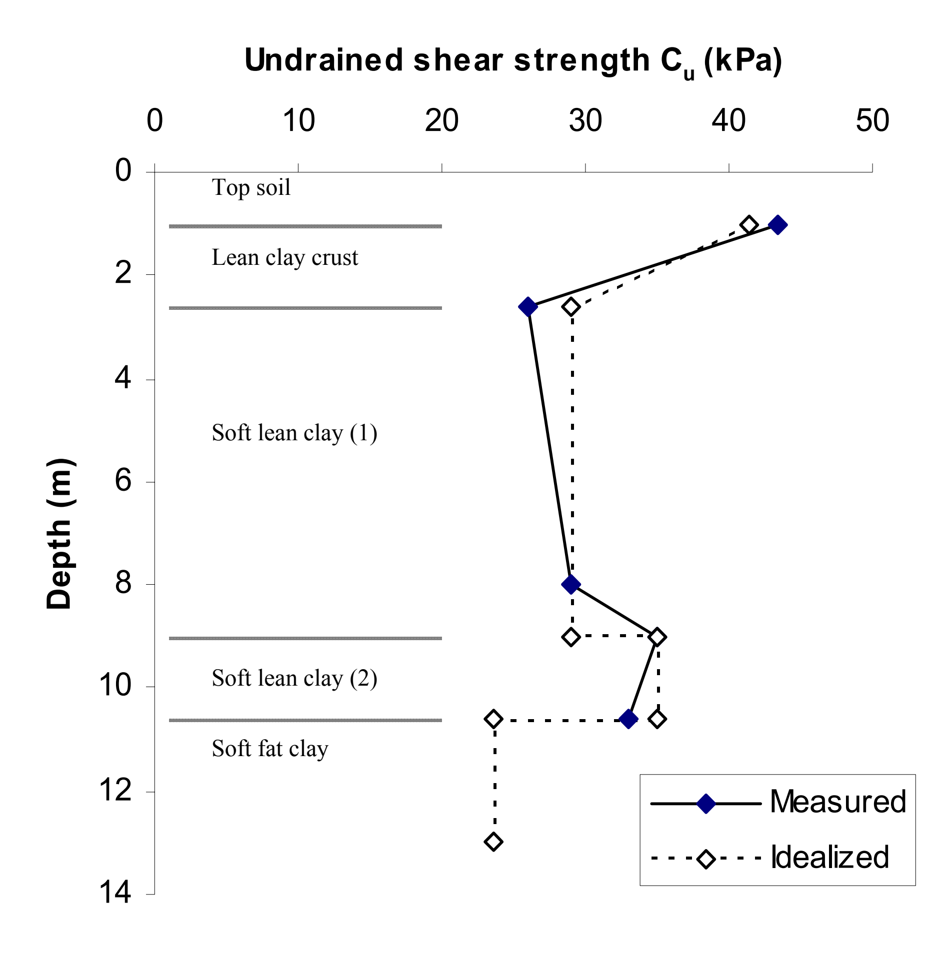
Overview



CASE STUDY (HAN and Ye, 2006)

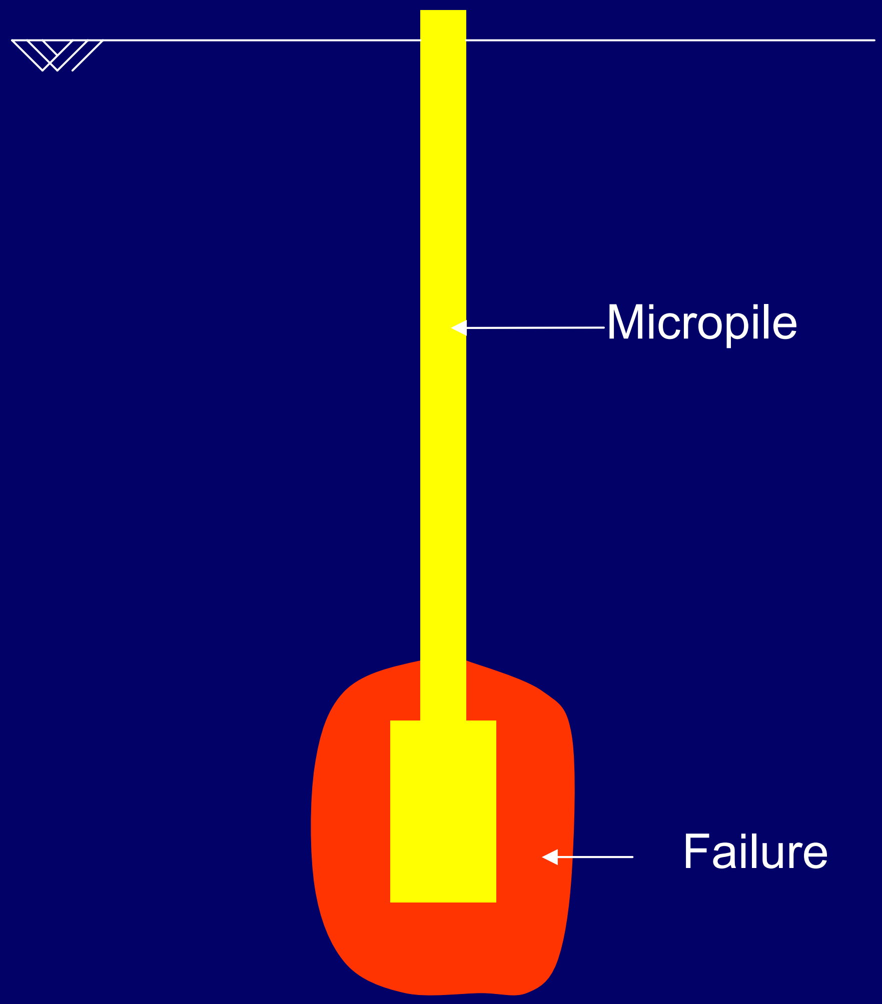
Overview



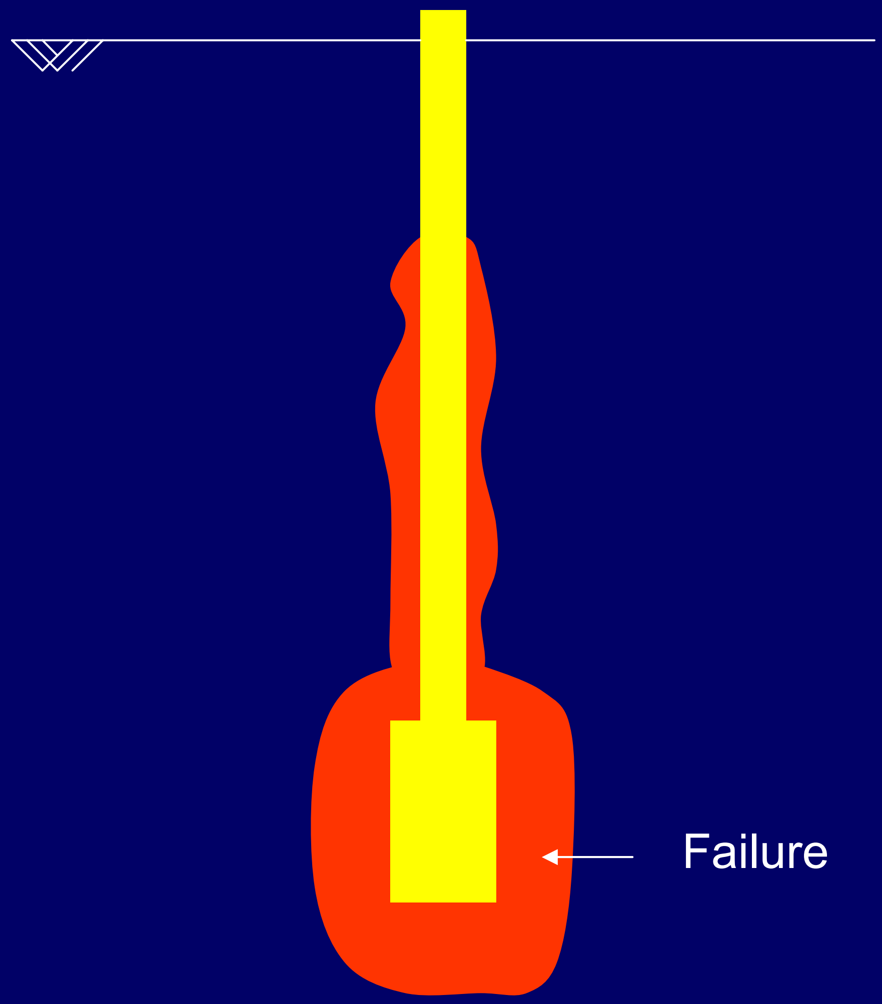
Soft fat clay

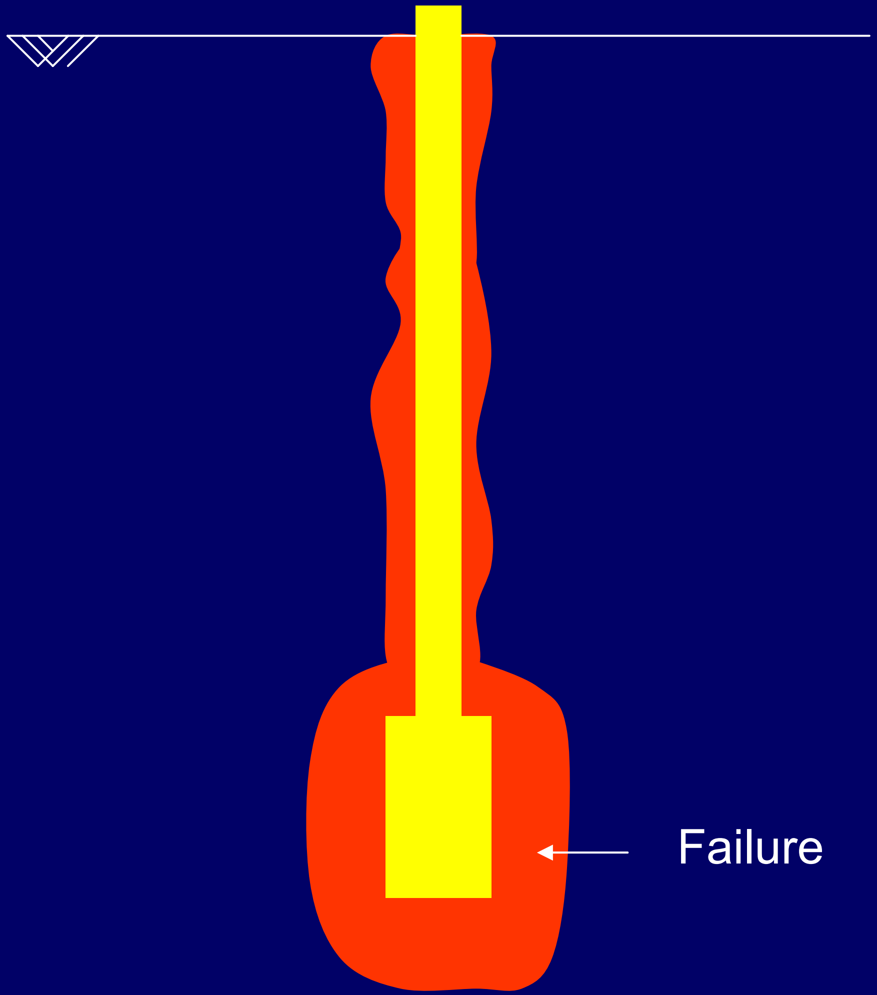
$C_u = 11.w_c^{-1.13}$

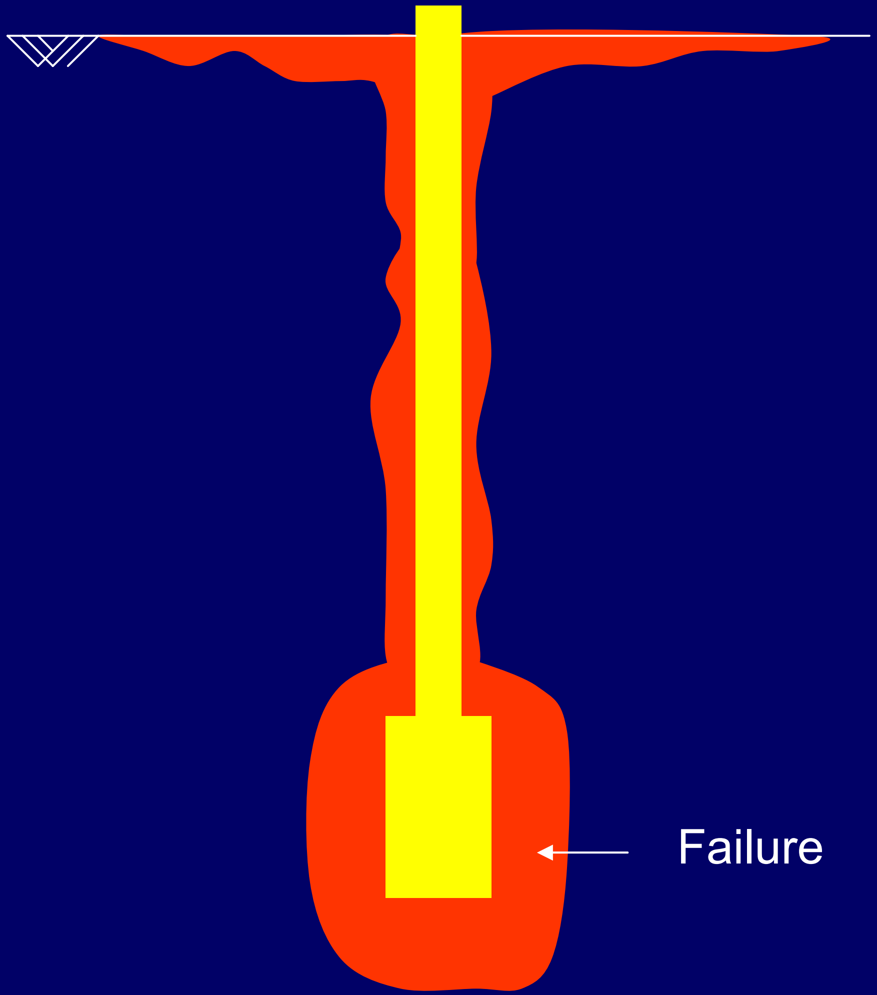
Gao (1994)


Micropile
Failure

IENTERFACE PROPERTIES




Failure


Failure