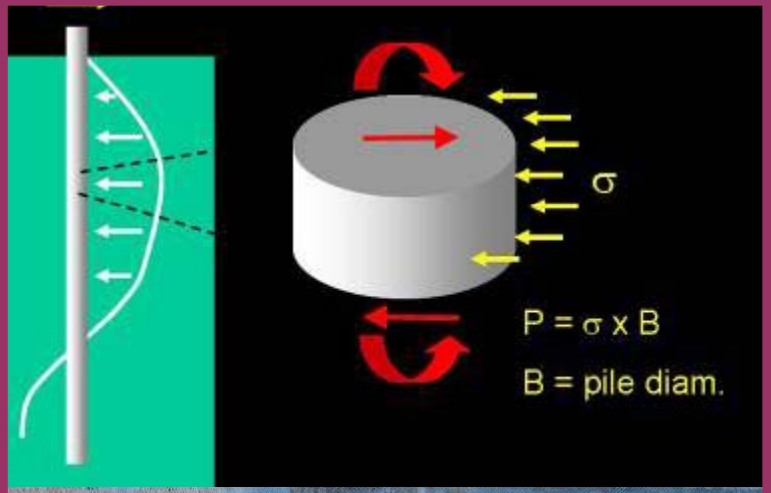

EFFICIENT DESIGN OF VERTICAL MICROPILE SYSTEMS TO LATERAL LOADING

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Andy Baxter, P.G.

ISM International Society for Micropiles

Schnabel Engineering

Outline

- When are micropiles subject to lateral load?
- How do we analyze them?
  - Shear Friction Concept
  - “Bending Friction”
- Example
- The case of Crystal Bridges

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Where are micropiles subject to lateral load?

- Building foundations (earthquake, wind)
- Basement wall foundations
- Retaining wall foundations
- Excavation support
- Tower and stack foundations
- Machine foundations
- Slope stabilization

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Bridge and tower foundations

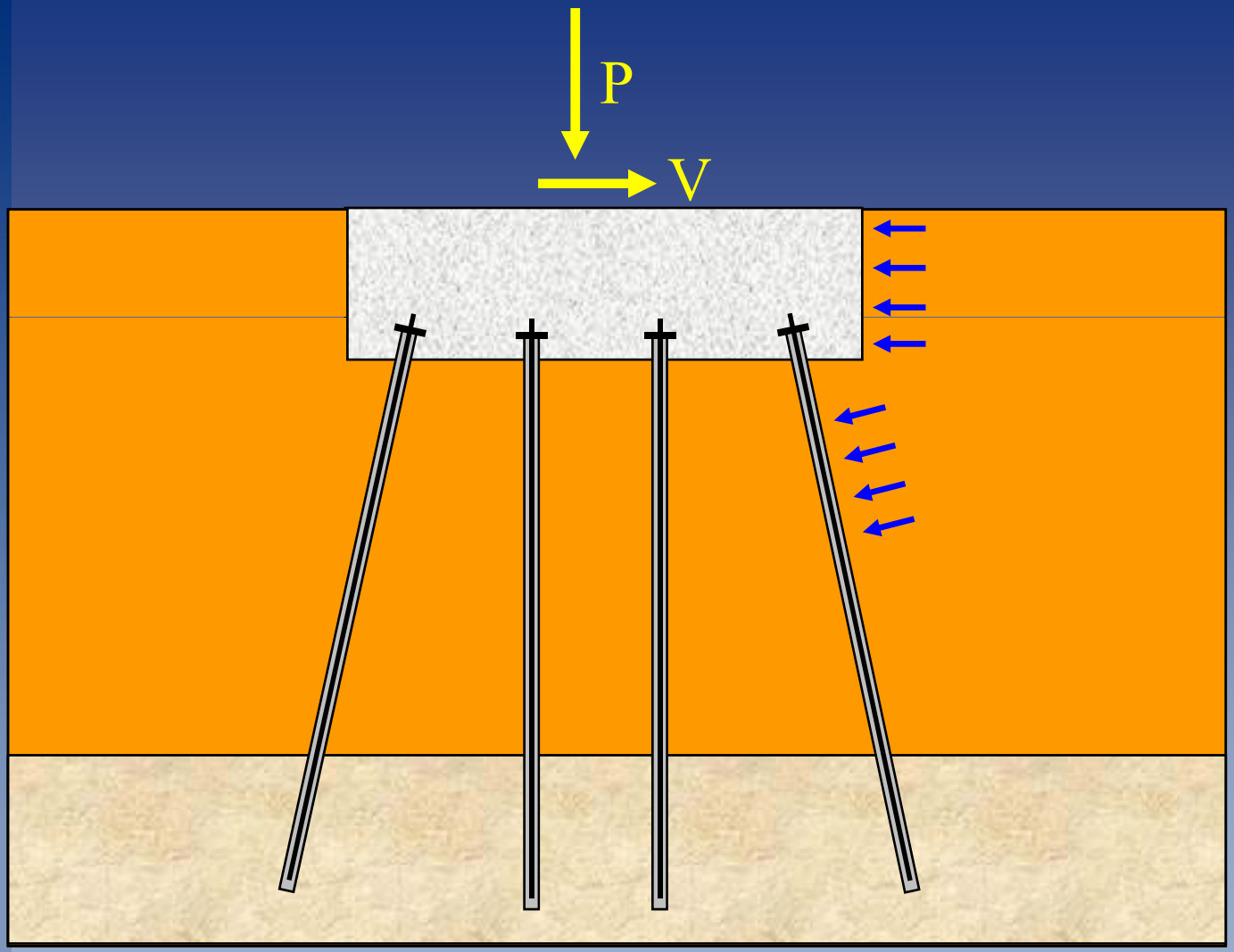
Courtesy: Fundaciones Franki, C.A.

Bridge and tower foundations

Courtesy: Precomprimidos- Venezuela

Bridge and tower foundations

Building foundations



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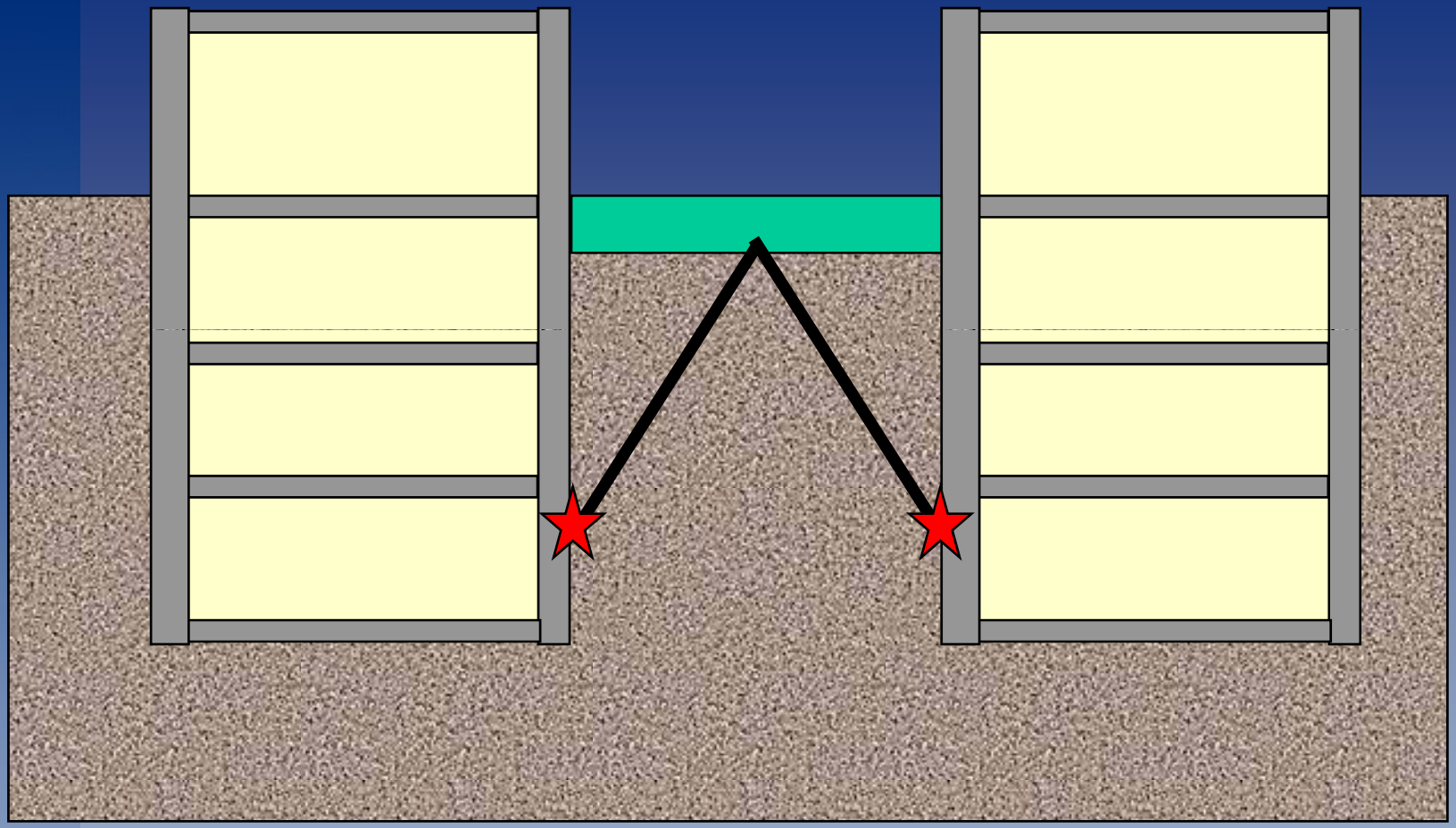
Why just not use battered micropiles?



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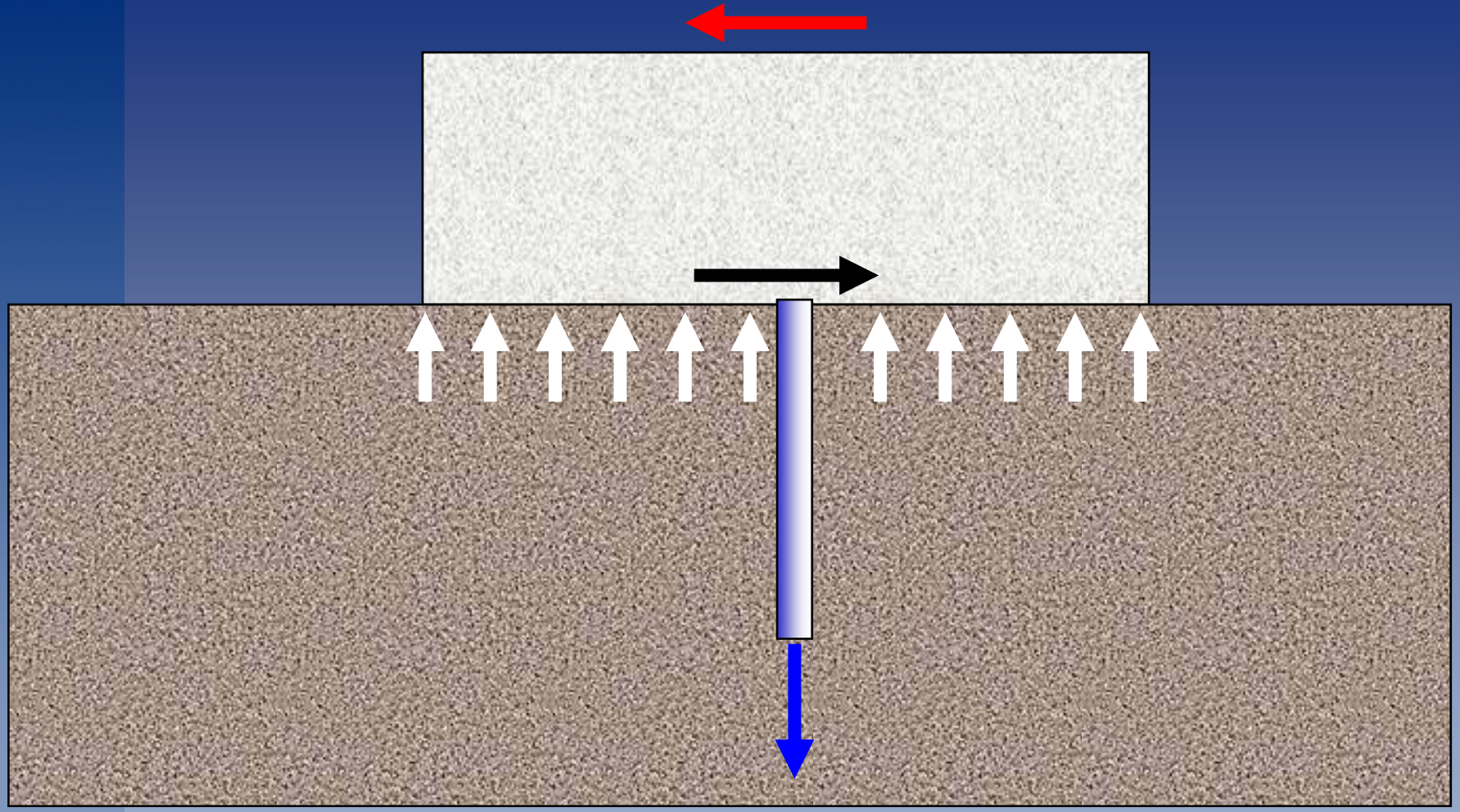
Analysis of vertical micropiles subject to lateral loads

- A micropile is not good for lateral loading when working alone
- In soils, 10-20 kip is typical maximum
- Use pile cap-micropile system instead

Shear Friction



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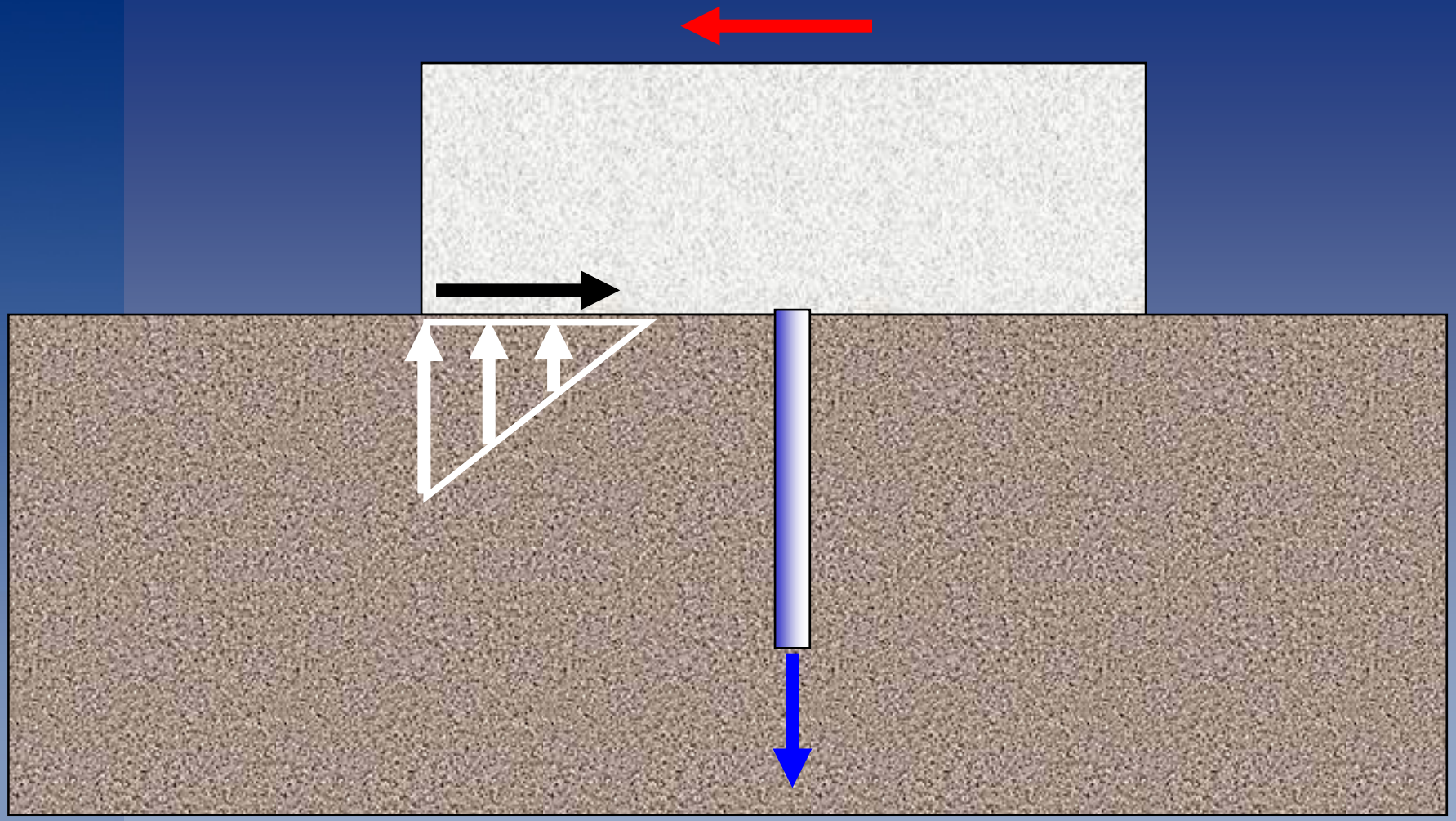
Shear Friction

- Does not consider lateral resistance of pile itself
  - Lateral resistance offered by soil acting on pile
  - Shear or bending resistance of pile
- Does not consider moment equilibrium
- Only translational movement

“Bending Friction”



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“Bending Friction”

- Does not consider lateral resistance of pile itself
  - Lateral resistance offered by soil acting on pile
  - Shear or bending resistance of pile
- Considers moment equilibrium
- Only rotational movement
- The larger the lateral load, the larger the resistance
- Closed form solution assuming linear elastic materials

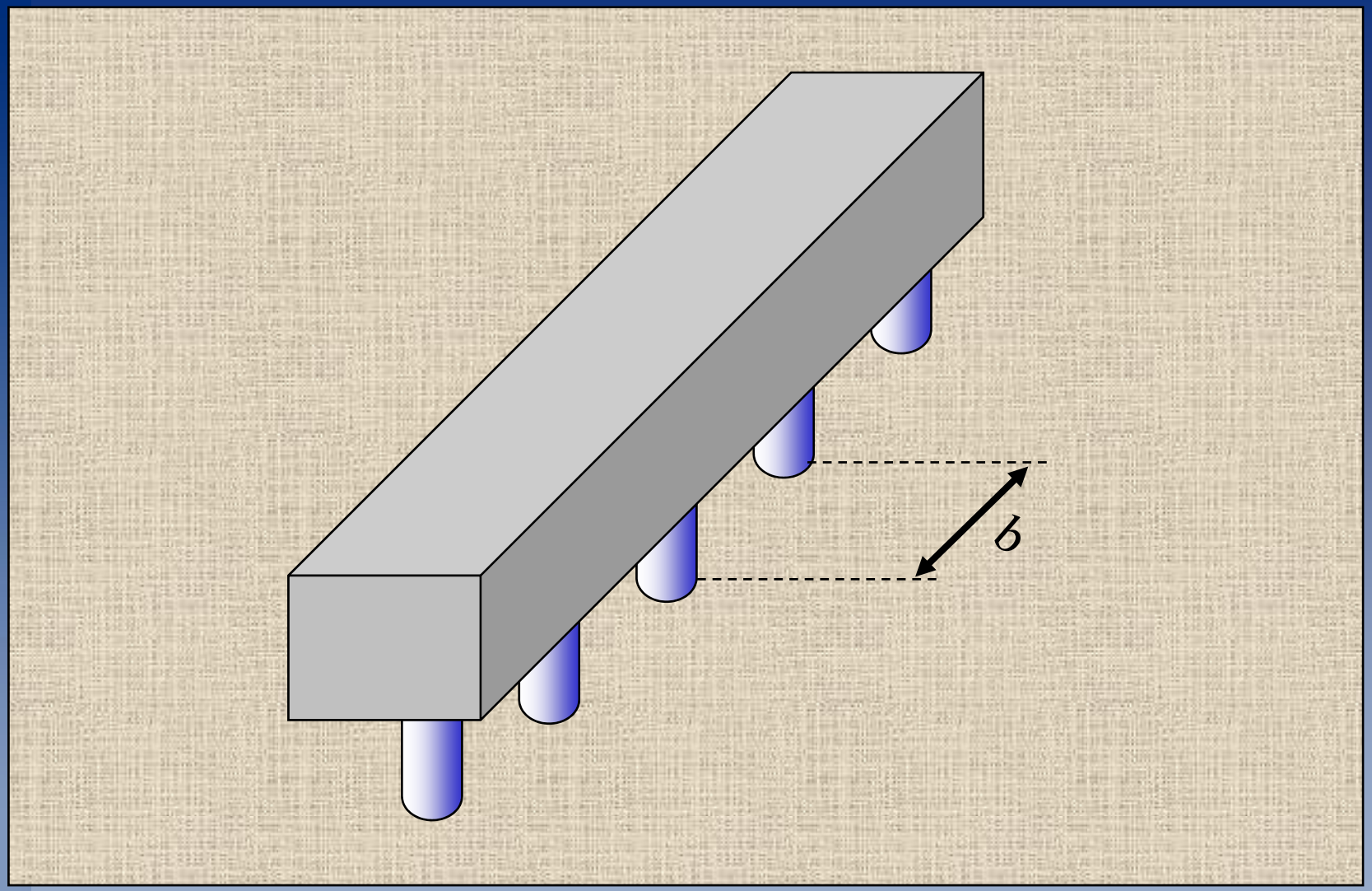
“Bending Friction”

- Failure occurs as:
  - Bearing capacity failure of soil/rock
  - Geotechnical or structural failure of pile in uplift
  - Structural failure of pile cap in shear or bending
- In rock, capacity can be very large
- In soils, capacity can be larger than expected
- Efficient design is finding suitable pile cap dimensions

“Bending Friction”

- Shear friction, shear and bending resistance of micropile also develop
- We have not combined all formulations
- This is not necessarily new. Tiedowns used sometimes in the heel of L-shaped retaining walls

Formulation



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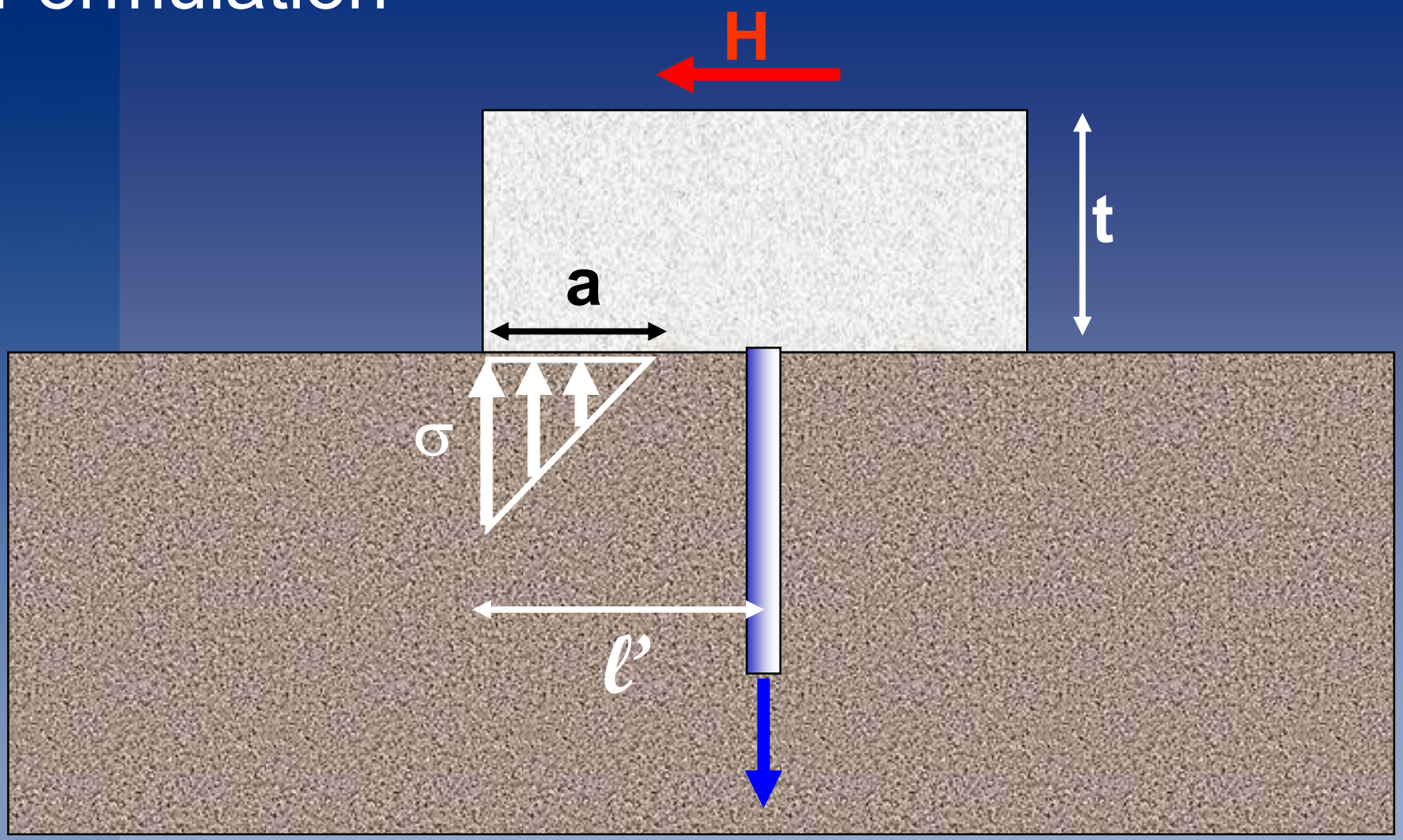
Formulation



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Formulation

$$a = \frac{-E_p + \sqrt{E_p^2 + 2 \cdot E_s \cdot E_p \cdot b \cdot l'}}{E_s \cdot b}$$

$$\Delta_s = \frac{H \cdot t}{\frac{1}{2} E_s \cdot b \cdot l' \cdot a - \frac{1}{6} E_s \cdot b \cdot a^2}$$

$$\Delta_p = \frac{(l' - a)}{a} \Delta_s$$

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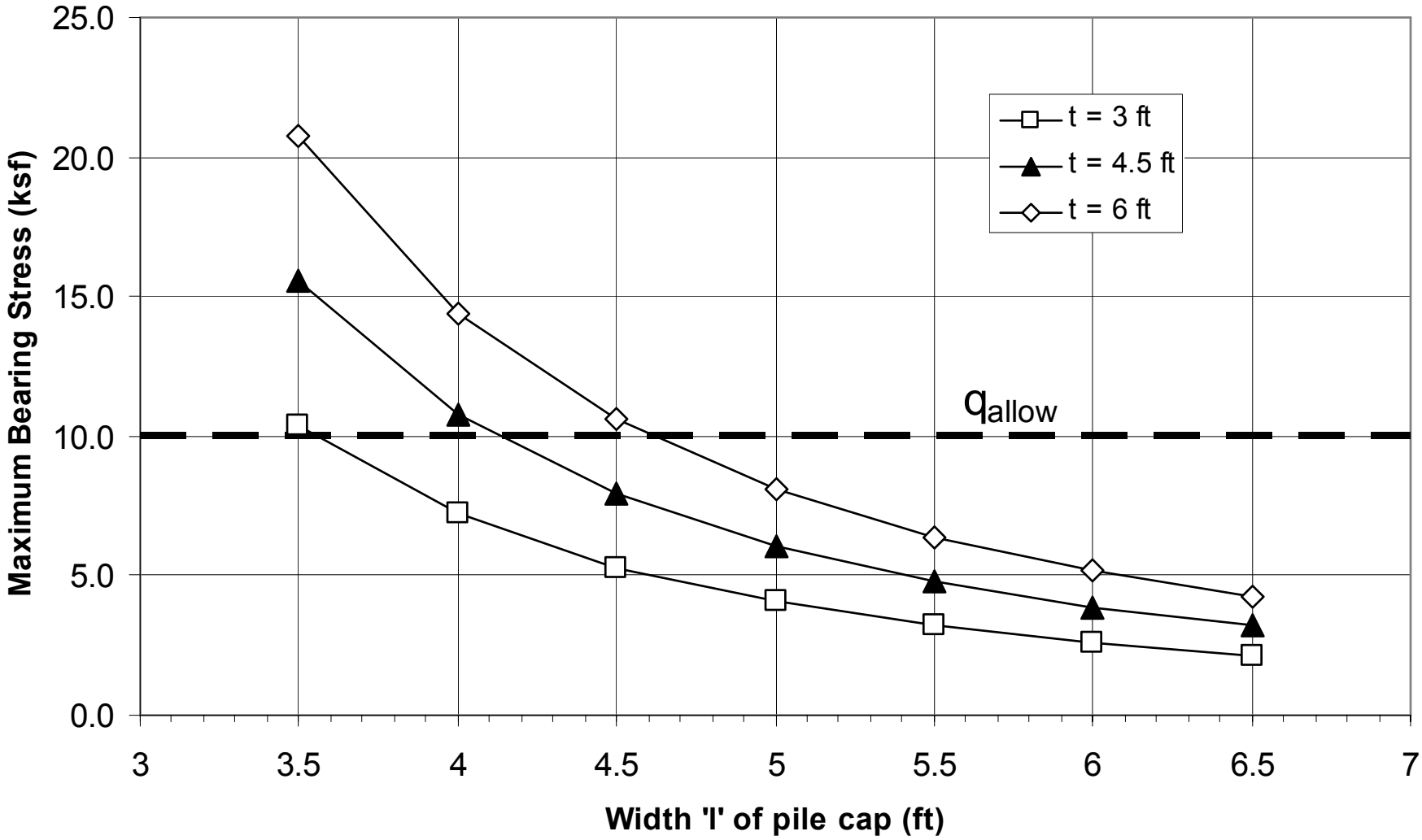
Example

- b = 5 ft
- Allowable bearing pressure = 5 ksf
- Pile cap-soil interface friction angle = 32 degrees
- Young's modulus of soil = 1,000 ksf
- Micropile : 1 # 14 bar, Fy = 75 ksi. Apparent elastic length = 10 ft. Tallow = 108 kip
- Lateral load 30 kip per micropile

Example



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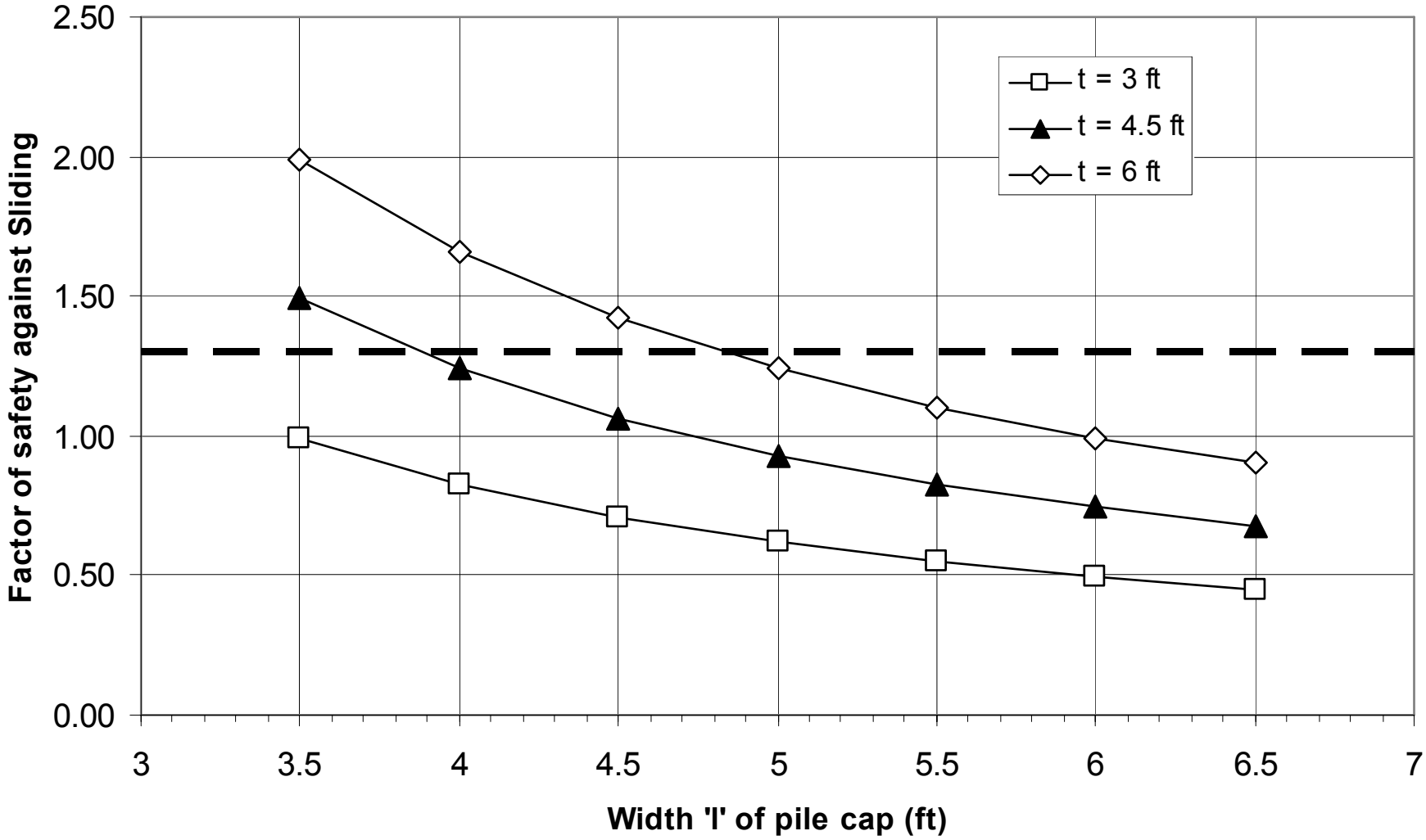
Example



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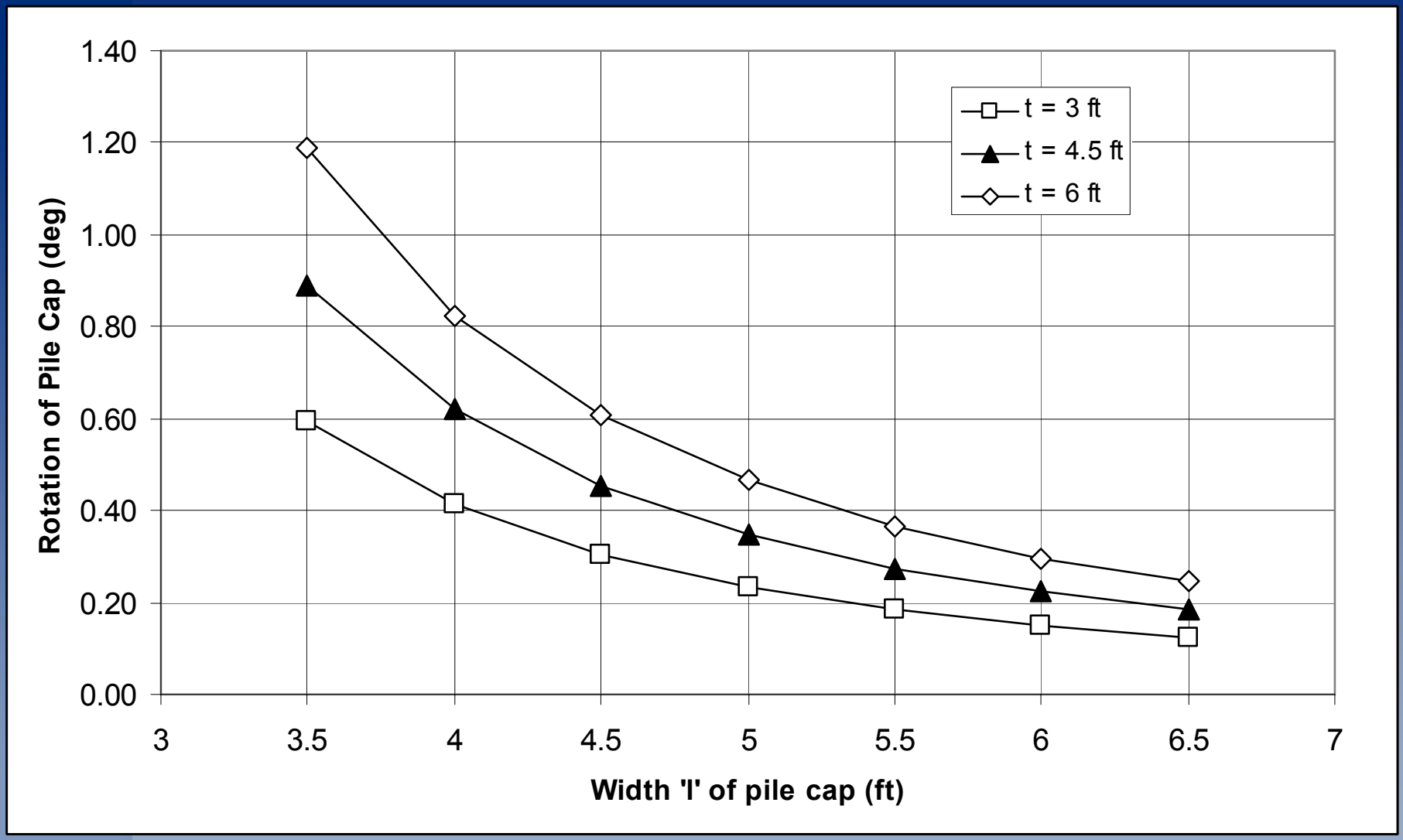
Example



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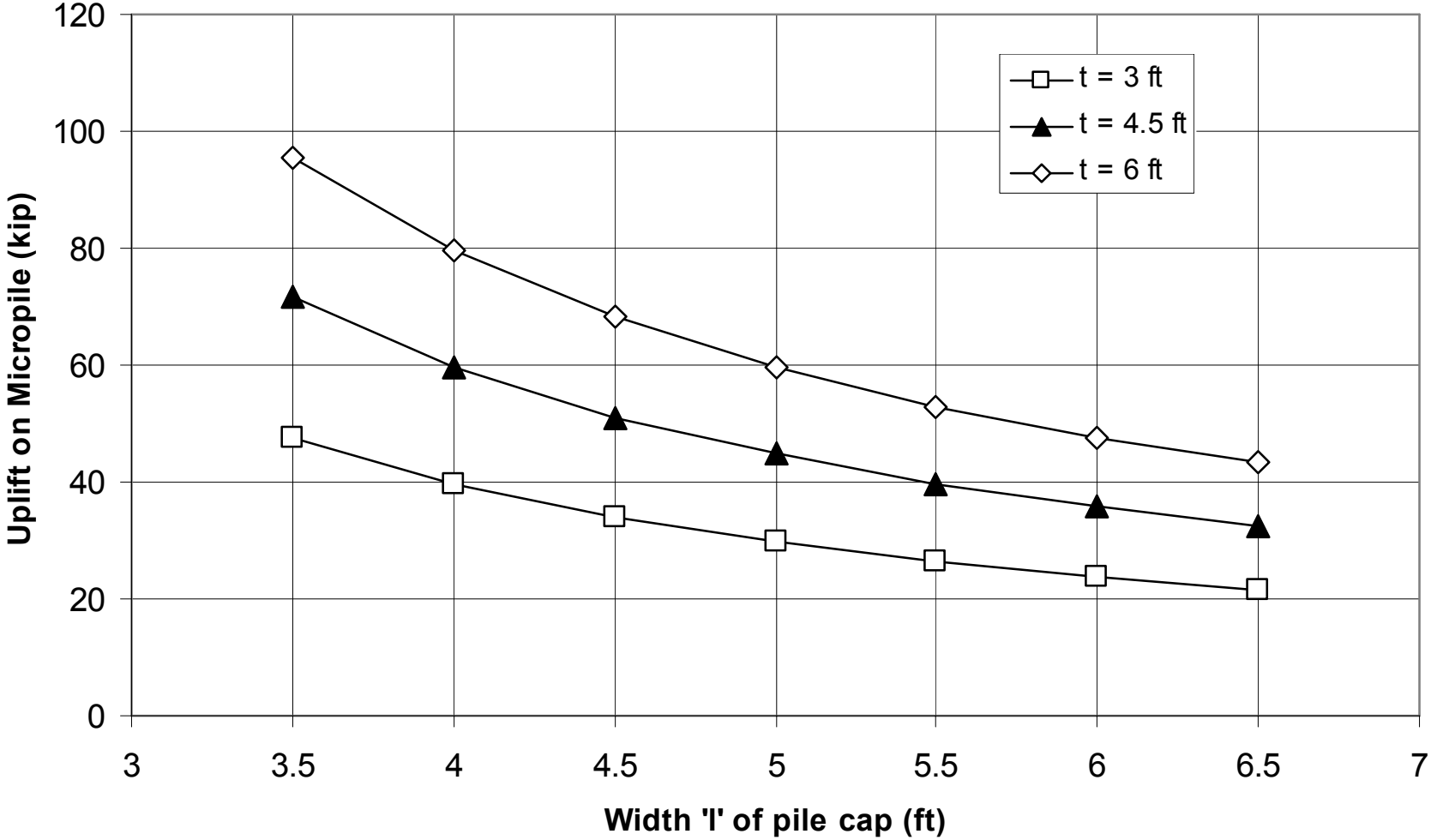
Example



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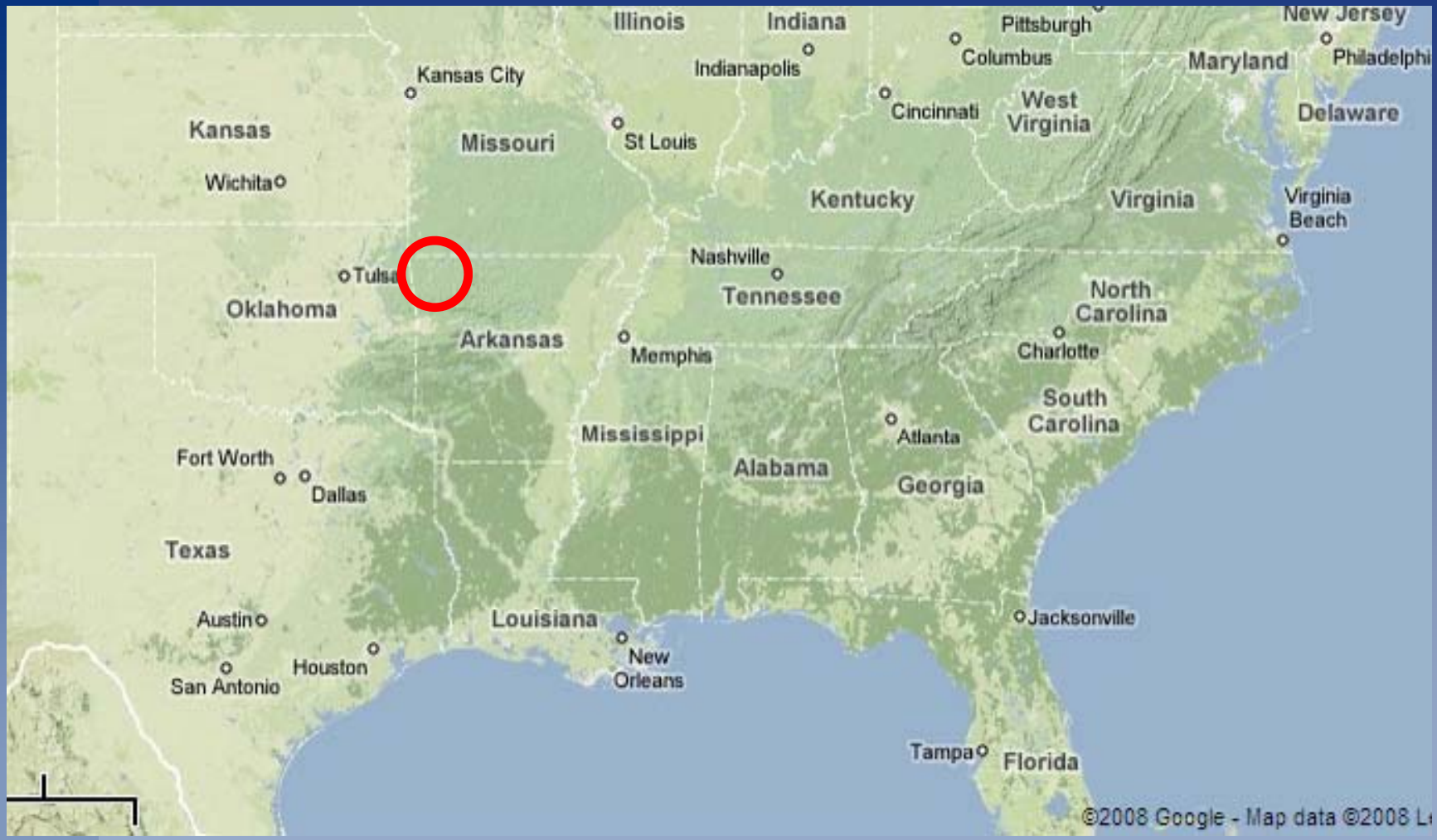
Crystal Bridges Museum of American Art

Site Location



Crystal Bridges

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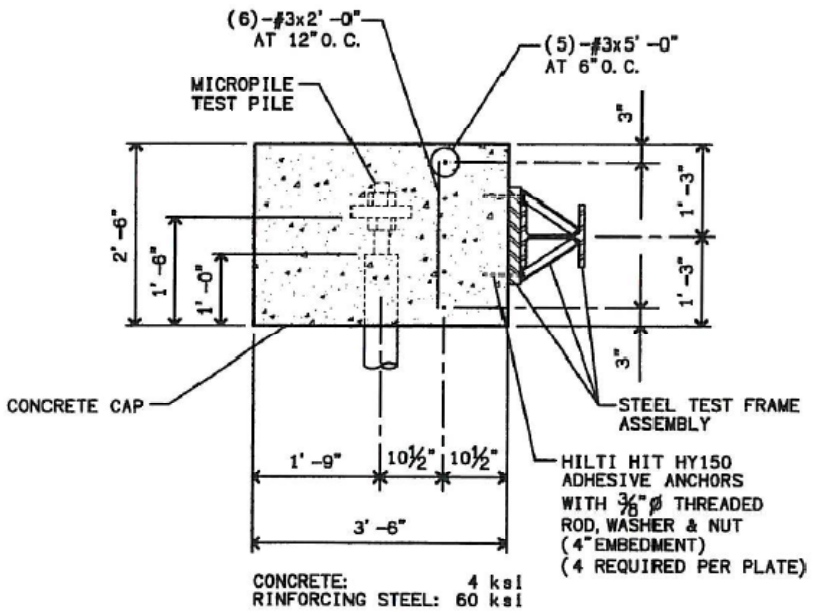
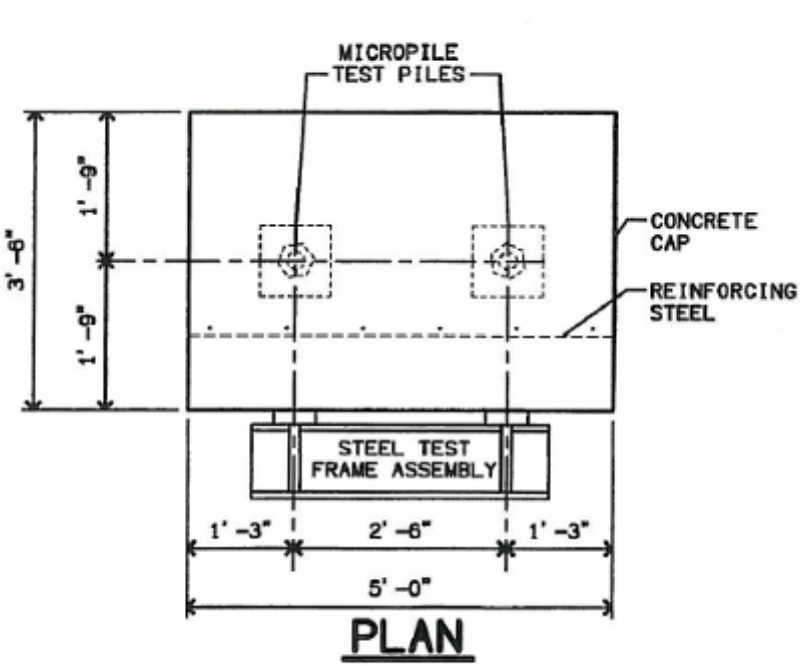
Crystal Bridges

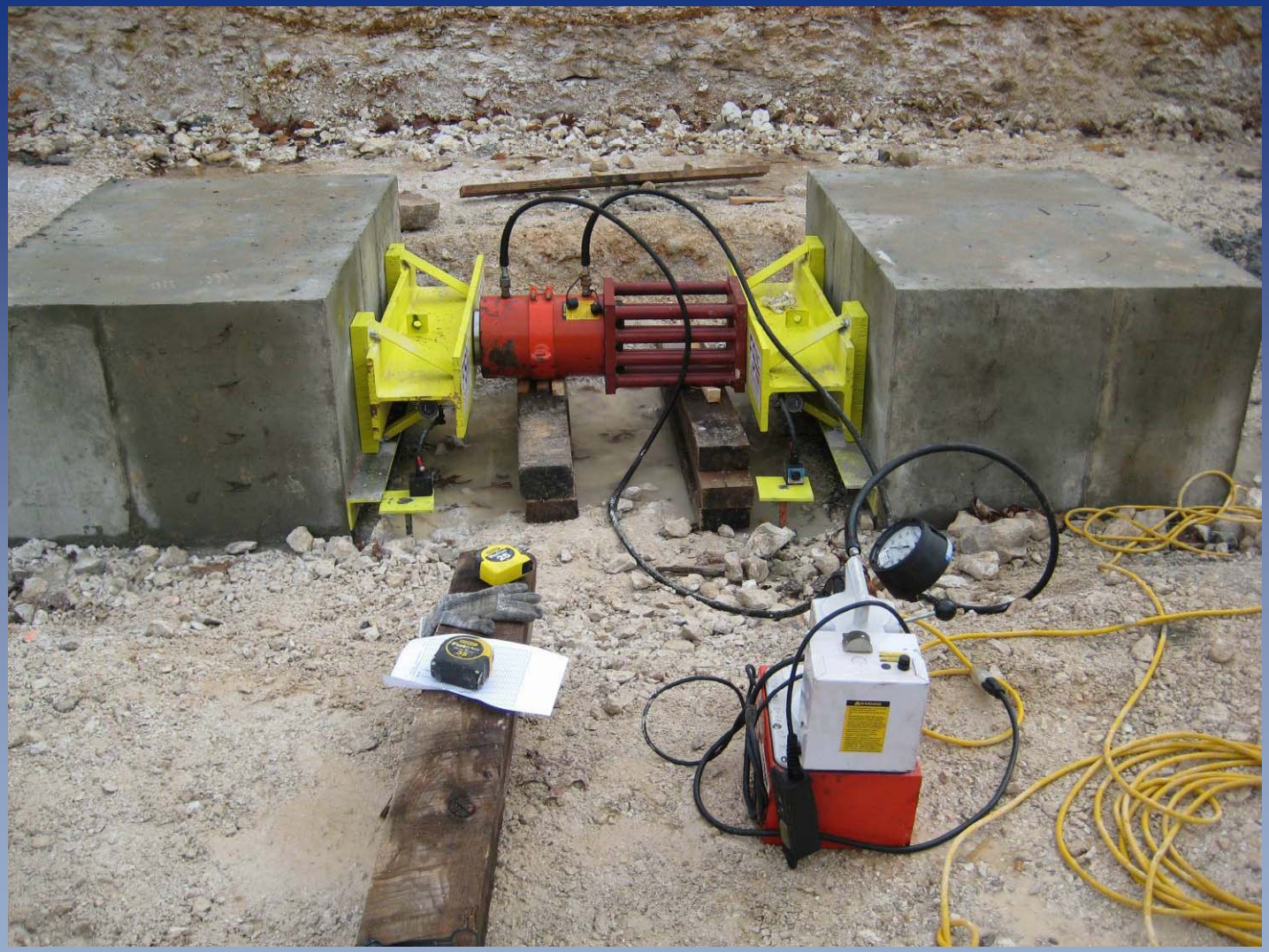
Micropile Installation

Micropiles under wall

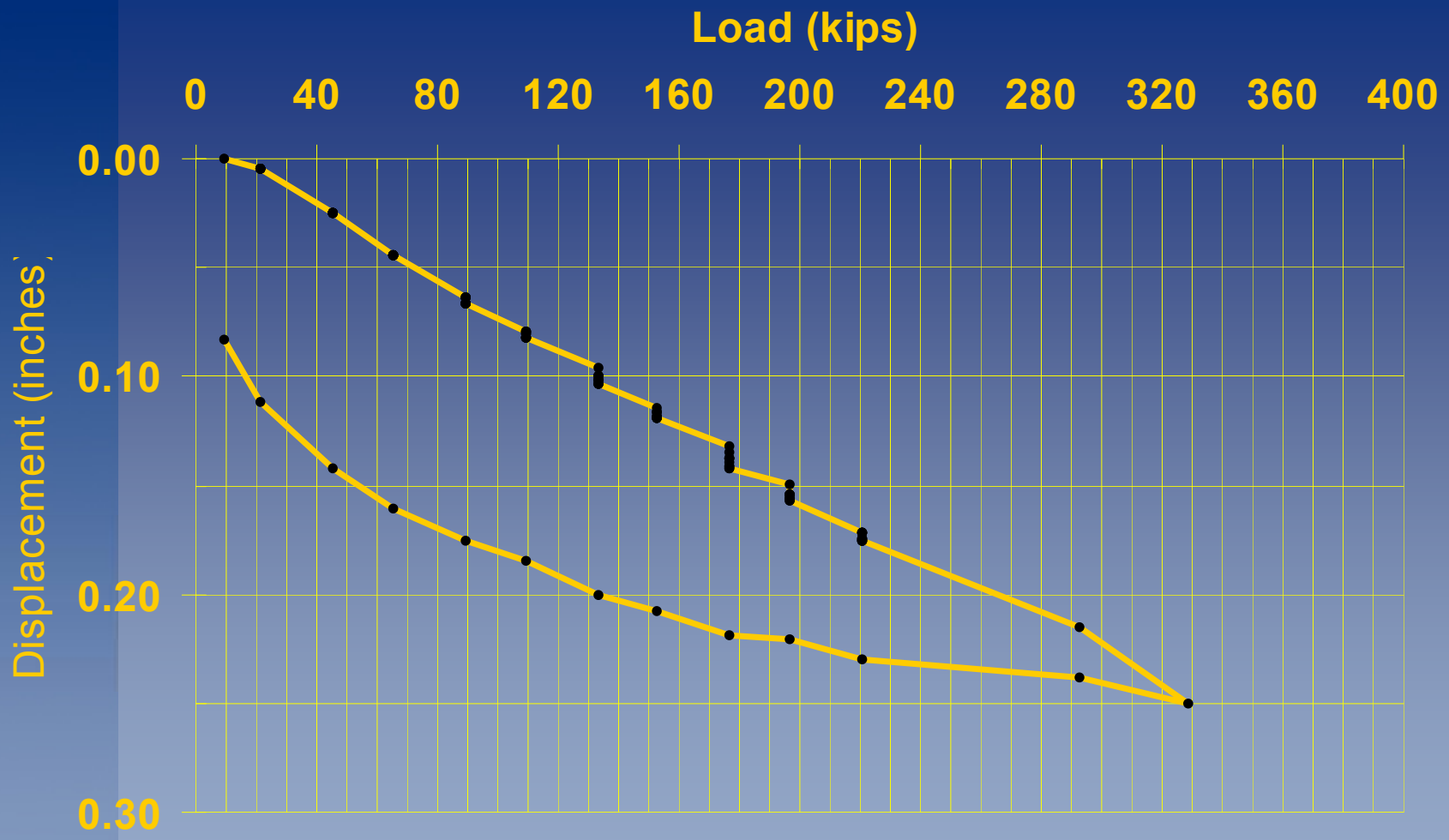

(6)-#3x2'-0" AT 12" O.C.
(5)-#3x5'-0" AT 6" O.C.
MICROPILE TEST PILE
3"
1'-3"
1'-3"
3"
2'-6"
1'-6"
1'-0"
CONCRETE CAP
STEEL TEST FRAME ASSEMBLY
1'-9"
10½"
10½"
3'-6"
HILTI HIT HY150 ADHESIVE ANCHORS WITH ⅞"Ø THREADED ROD, WASHER & NUT (4" EMBEDMENT) (4 REQUIRED PER PLATE)
CONCRETE: 4 ksi
RINFORCING STEEL: 60 ksi
DETAIL SECTION


MICROPILE TEST PILES
3'-6"
1'-9"
1'-9"
CONCRETE CAP
REINFORCING STEEL
STEEL TEST FRAME ASSEMBLY
1'-3"
2'-6"
1'-3"
5'-0"
PLAN

Lateral Load Test



Lateral Load Test



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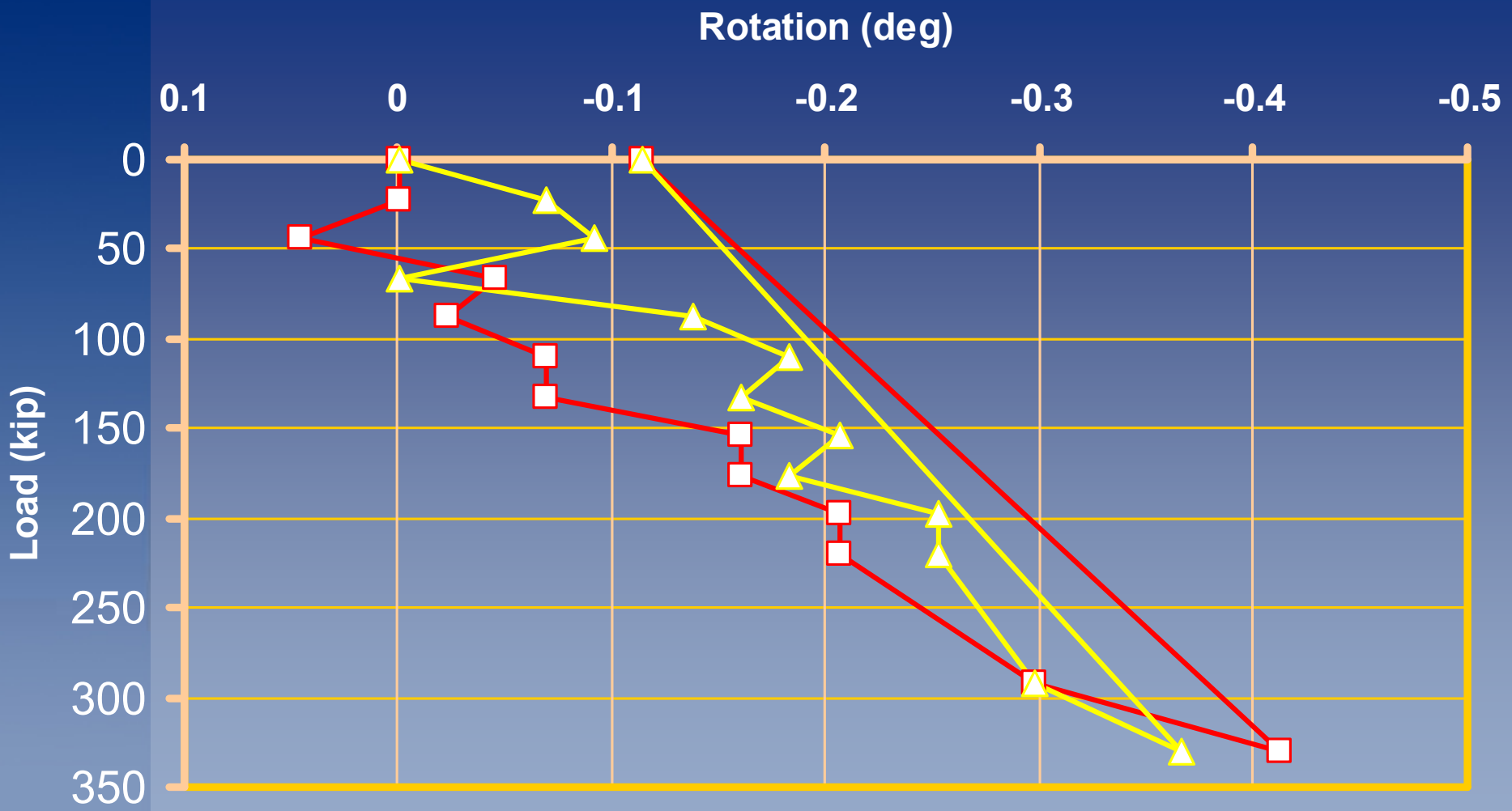
Lateral Load Test



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Evidence of lateral deflection

Strain Gauges

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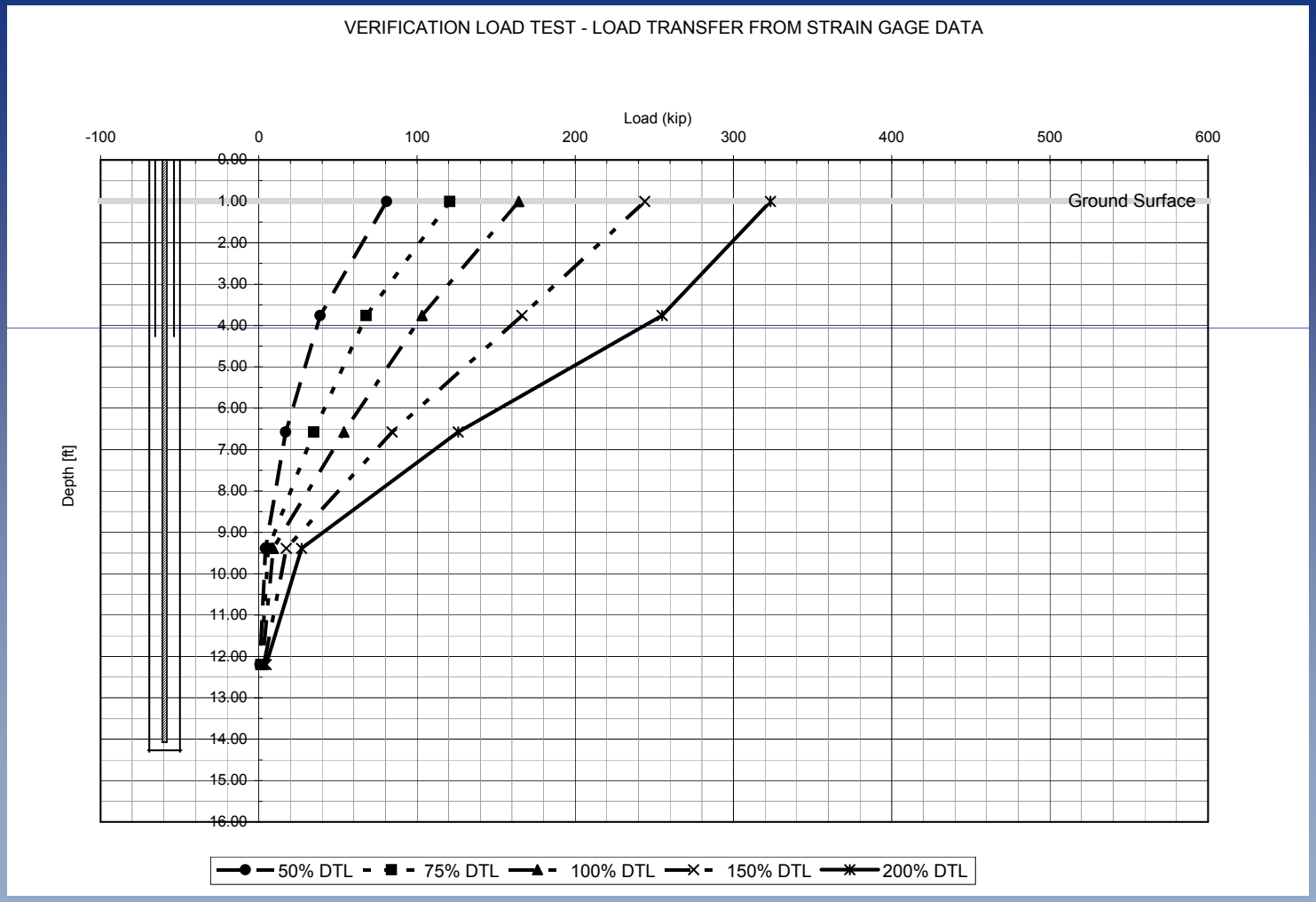
Lateral Load Test



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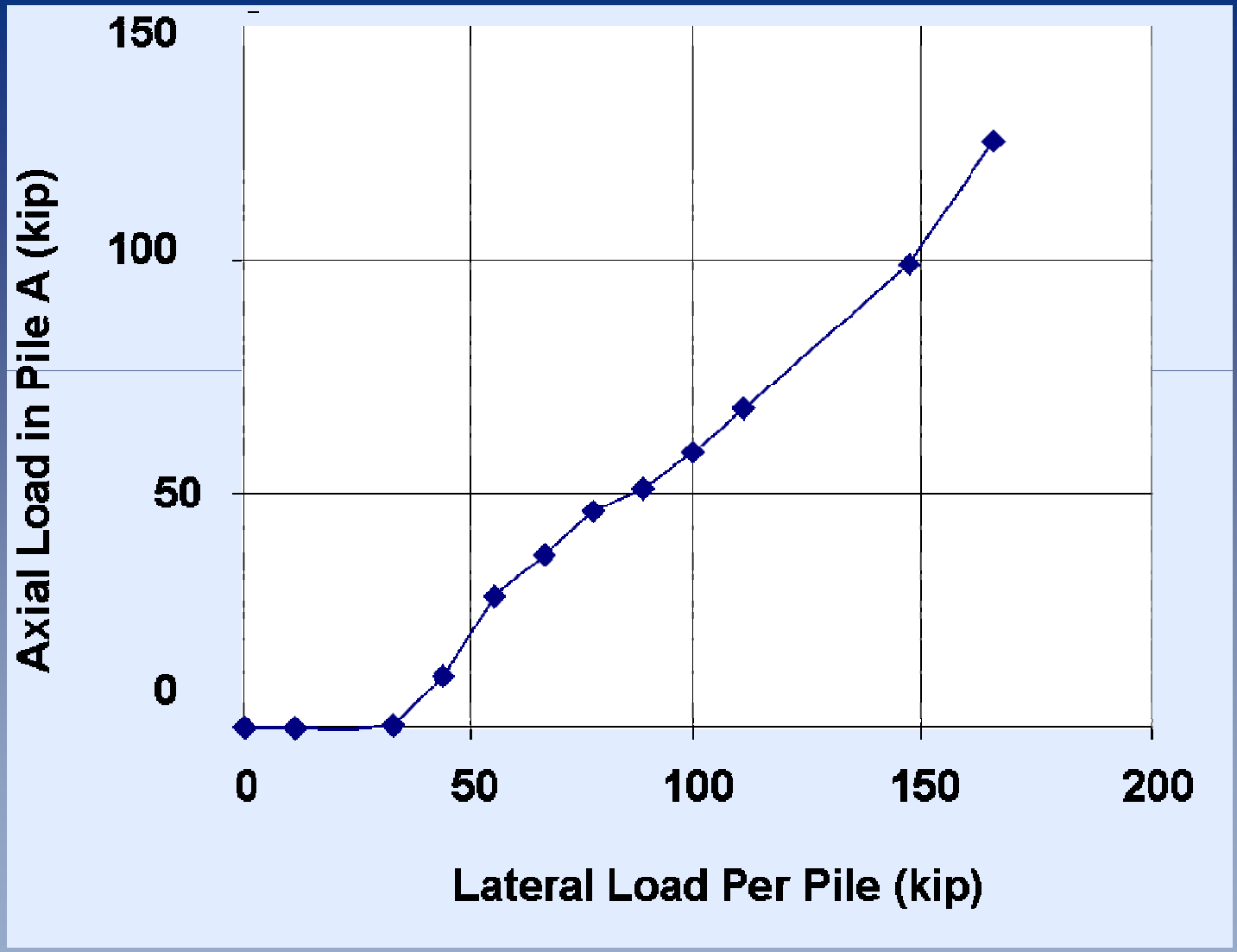
Lateral Load Test



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Conclusions

- Vertical micropile systems can resist significant lateral loads
- Twelve micropiles in rock loaded to 160+ kip without signs of failure
- In soils, possible to obtain large lateral capacities through efficient design of laterally loaded systems
- Testing of micropile systems in soils needed (research effort)
- Naturally, battered micropiles seem more efficient for lateral resistance, but not always practical

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