INTRODUCTION TO GEOPIER® SYSTEM

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April 14, 2010

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OUTLINE

1. History of Foundation Support
2. Geopier System Construction
3. Engineering Basics
4. Different soil types
5. Limitations
6. Industrial Applications
7. Case study

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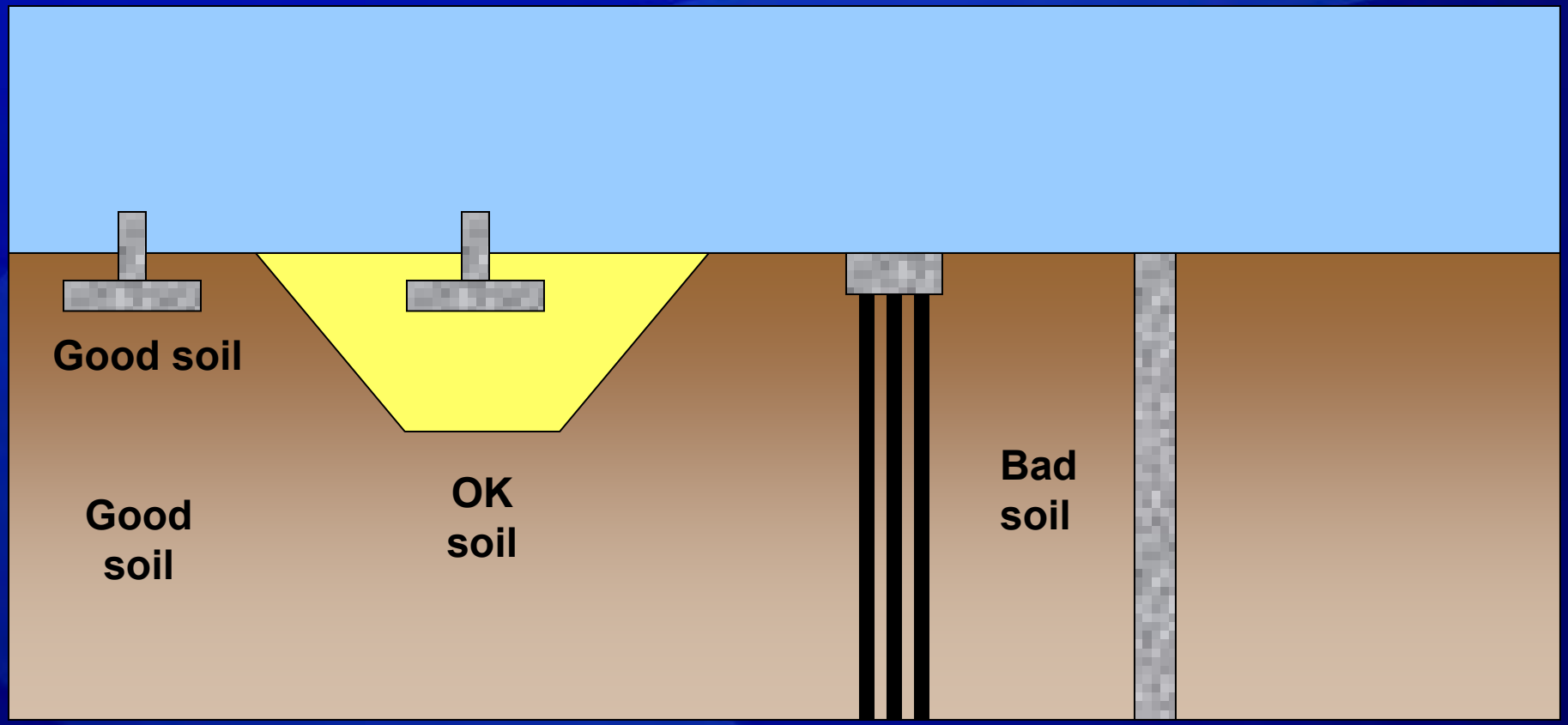
History of foundation systems

Two choices:



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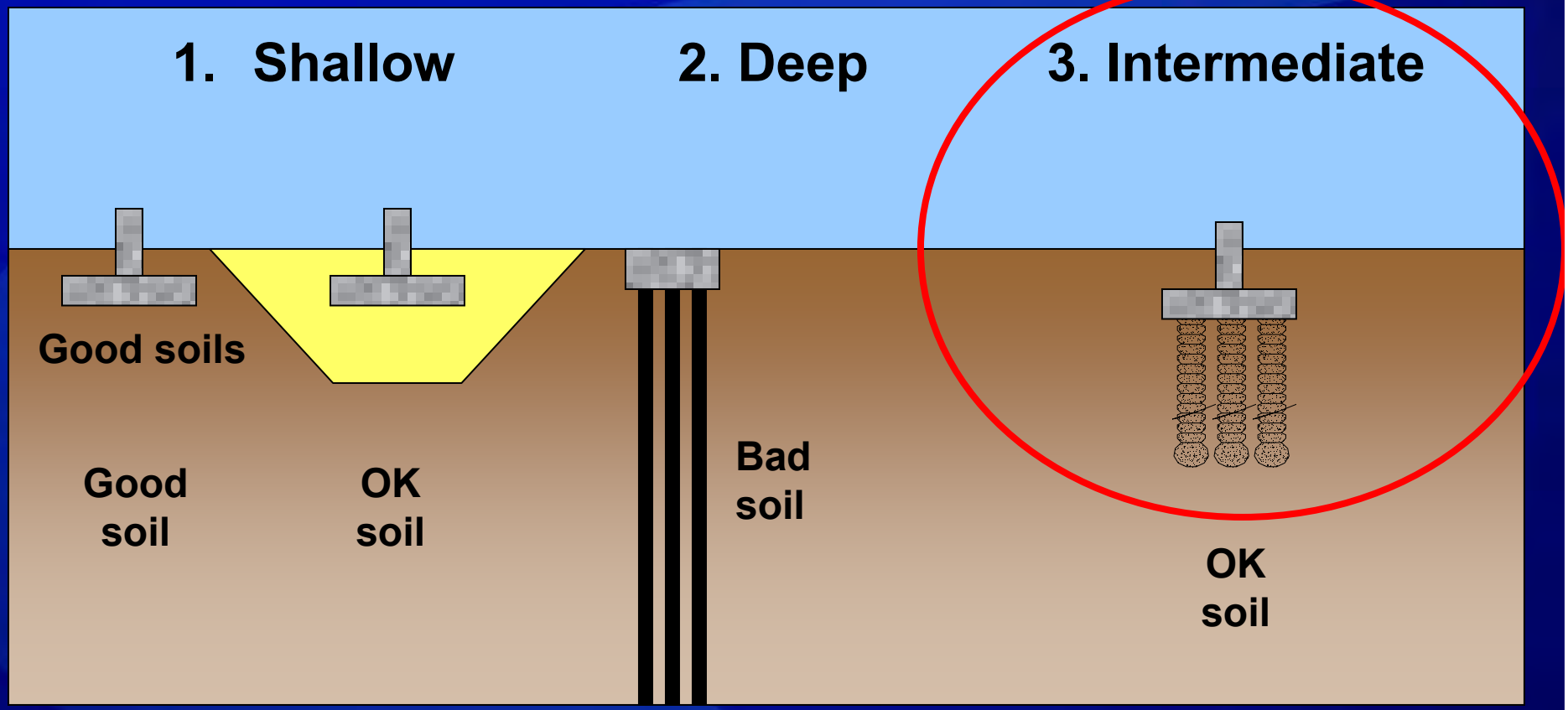
History of foundation systems

In early 1990's a third choice emerged: Intermediate Foundation® systems



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History of foundation systems

The Geopier® Systems are made up of Rammed Aggregate Pier® elements.

With time, the Geopier System gained popularity with cost and schedule benefits.

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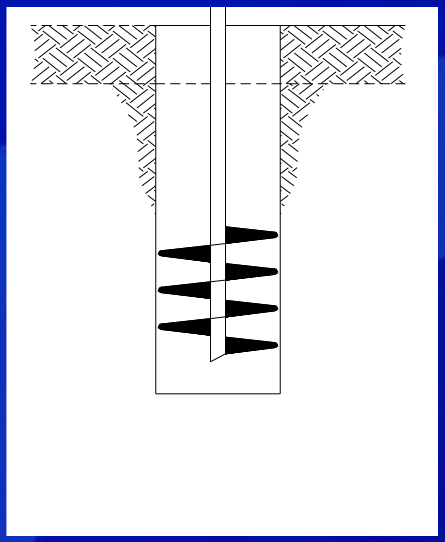
Rammed Aggregate Pier Construction



1. Created by forming a cavity

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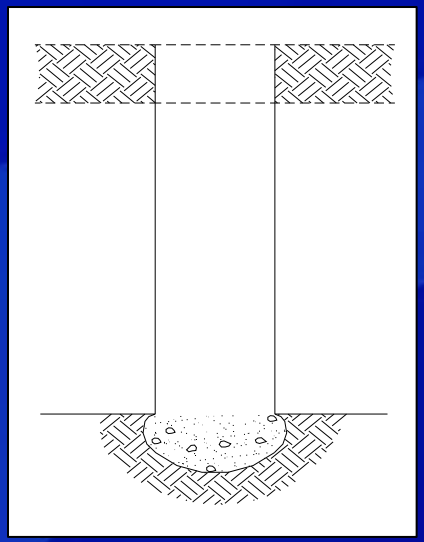
Rammed Aggregate Pier Construction



2. Adding thin lifts of Aggregate, and

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Rammed Aggregate Pier Construction

3. Vertically RAMMING the thin lifts of aggregate

Rammed Aggregate Pier Construction

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Rammed Aggregate Pier Construction

Temporary casing used to stabilize caving soils

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Displacement Construction

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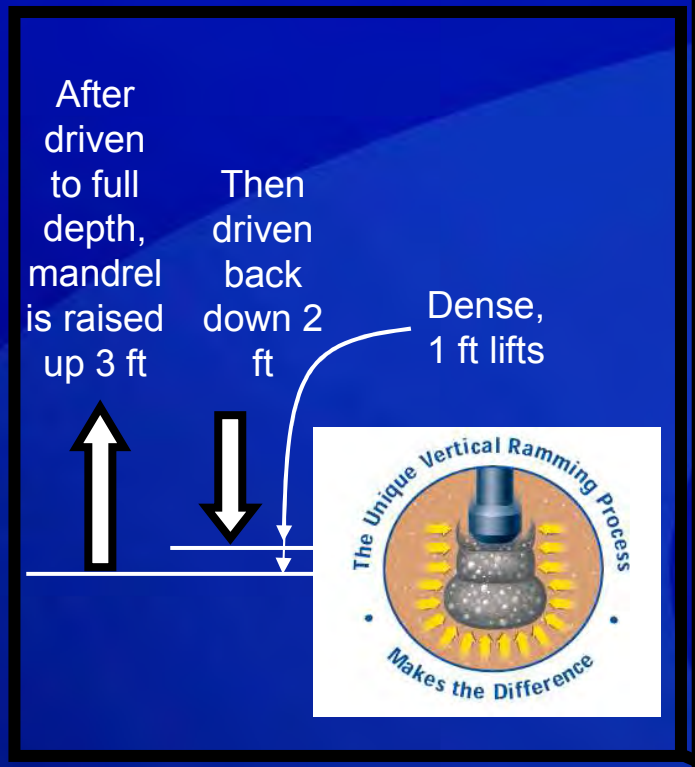
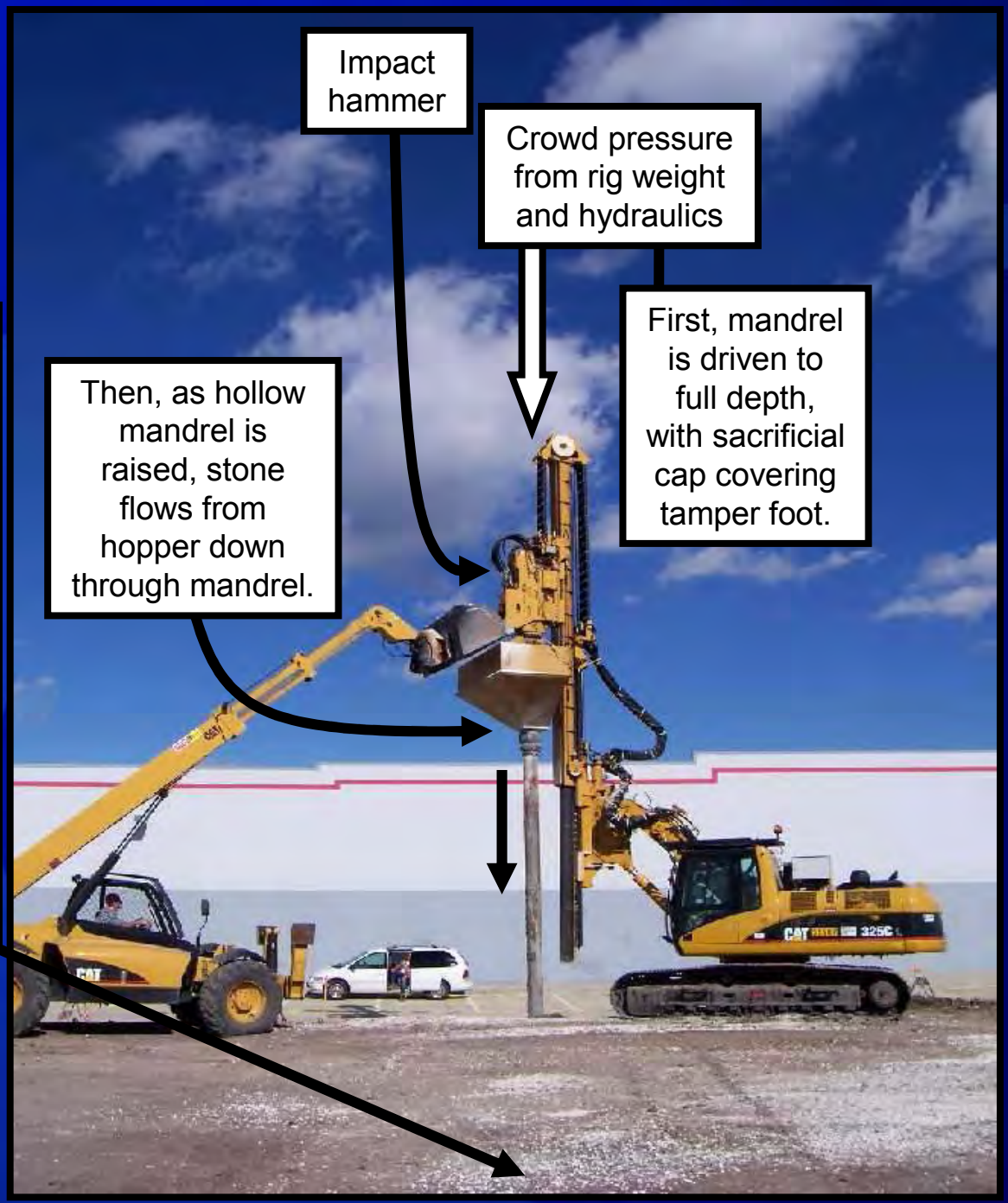
Displacement Construction





Footing Construction

- Excavate for footings
- Compact footing bed
- Place steel
- Pour concrete

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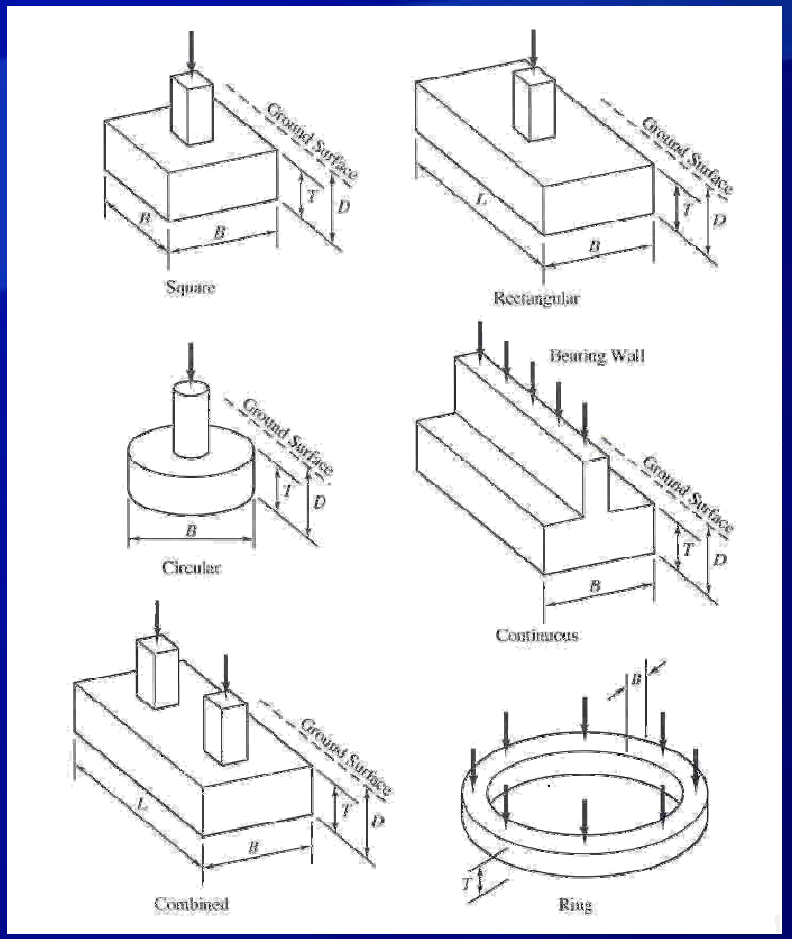
Types of Foundations Supported

- Isolated Spread footings
- Continuous footings
- Retaining Walls
- Lightly loaded slabs
- Heavily loaded slabs
- Uplift Anchors



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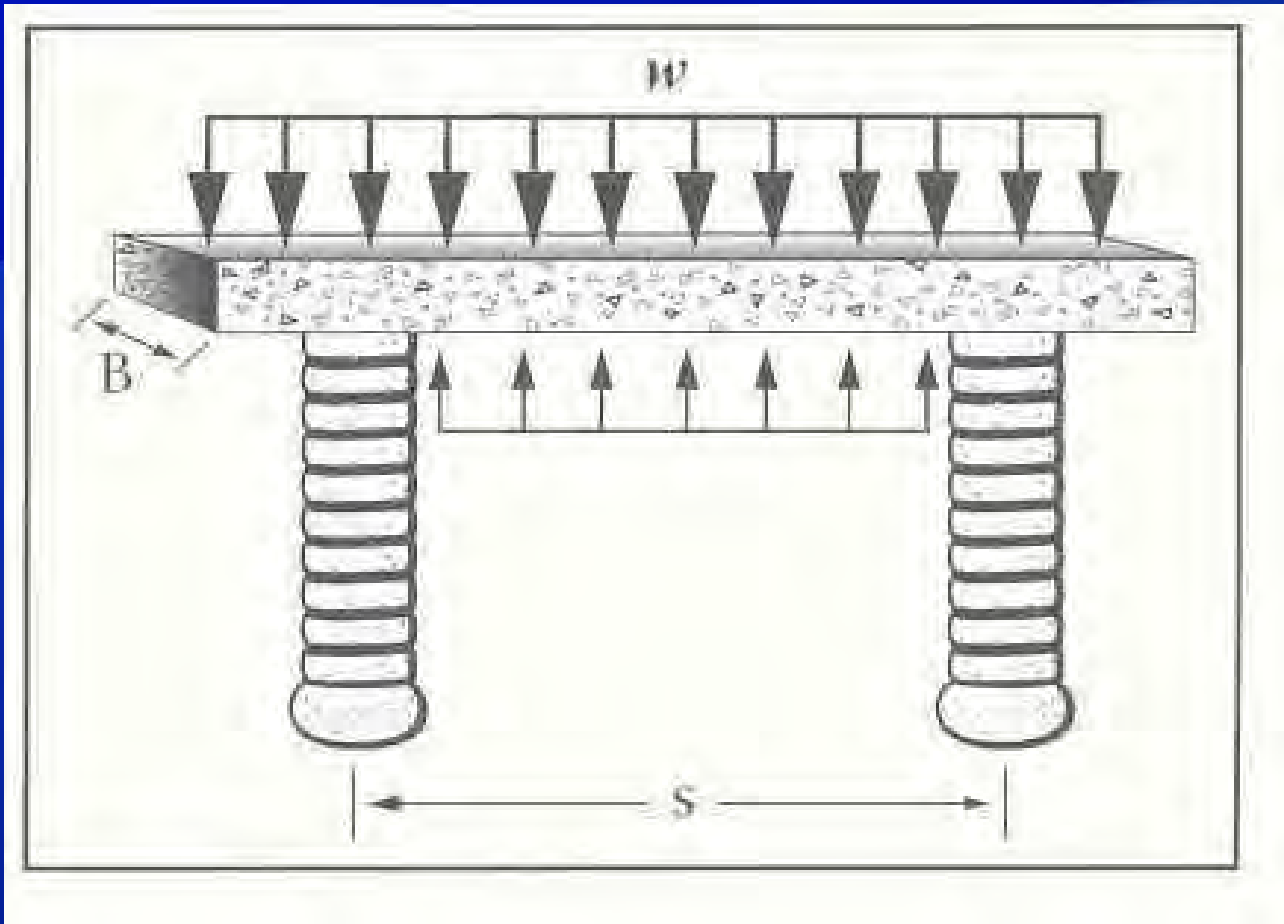
Flexible Continuous Footings



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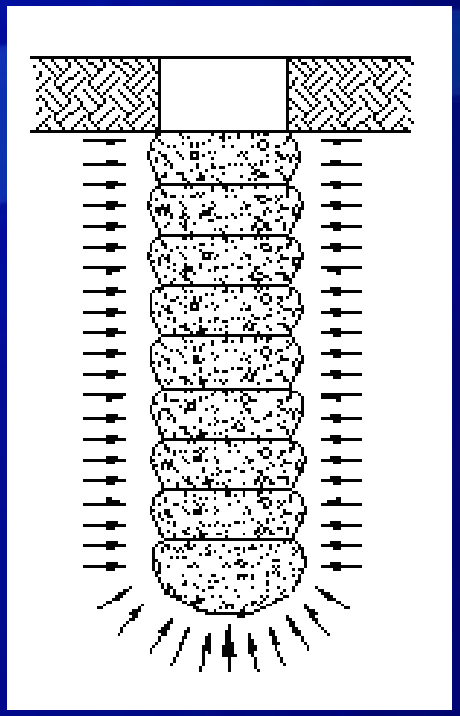
Geopier System Features

The keys to success are:

1. **Vertical RAMMING (to achieve very low void ratio) and**
2. **Increase in lateral effective stress from the beveled tamper foot**



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Geopier System Features

- High allowable bearing capacity
- Control settlement
- Uplift resistance
- Lateral load resistance

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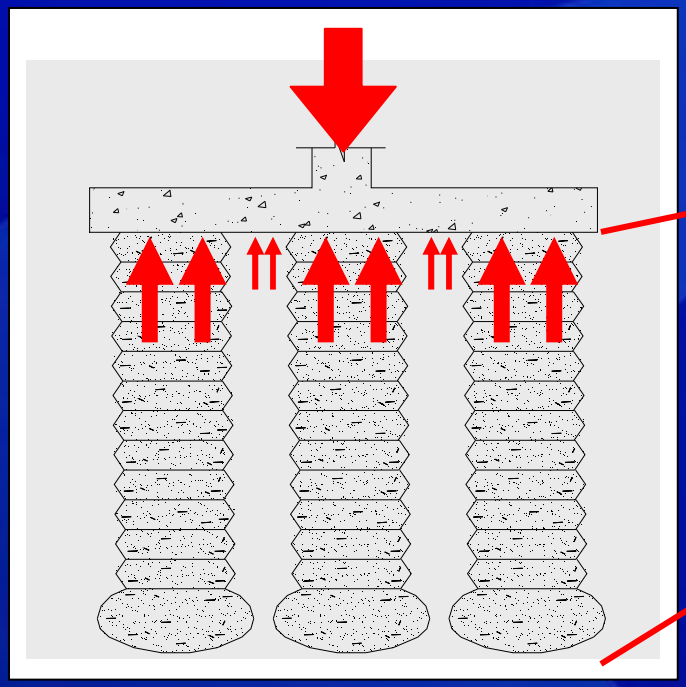
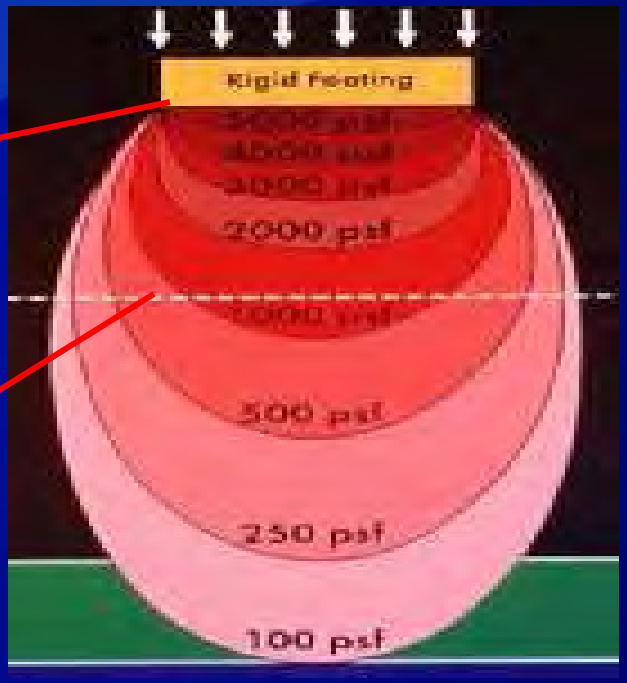
Engineering basics

How do RAP systems work?





Push down on footing, the stiff element (pier) takes more of the load

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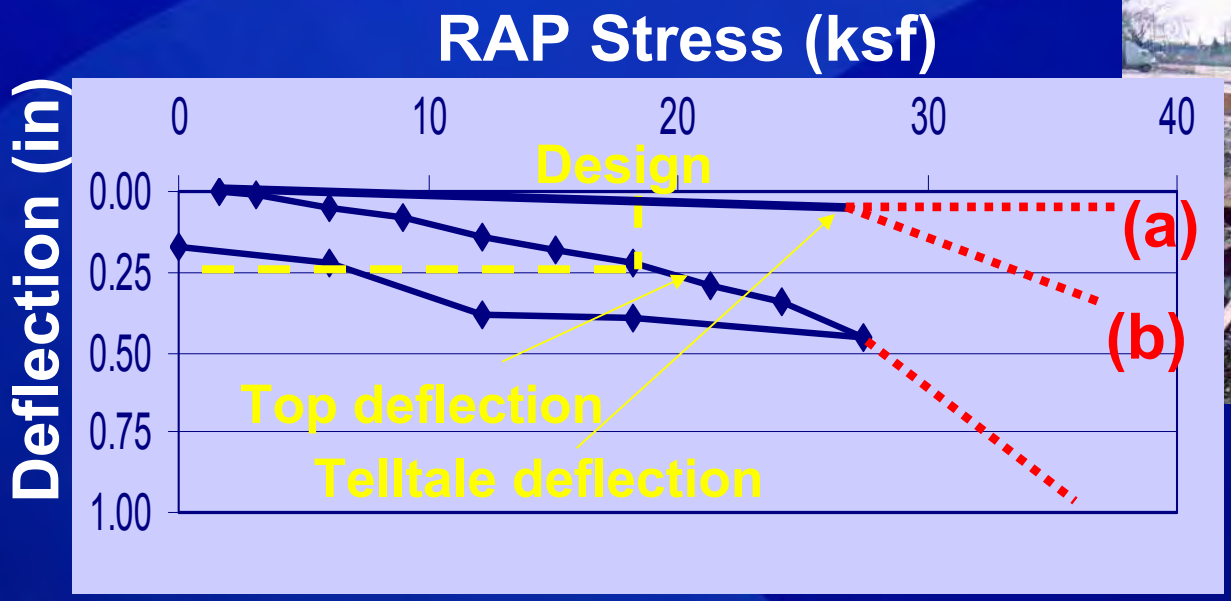
Engineering basics

How do RAP systems work?

The strength and stiffness of the pier determined using a Modulus Test which gives you a spring constant



- Deflection = 0.25-inch
- k_g = stress / deflection = 500 pci

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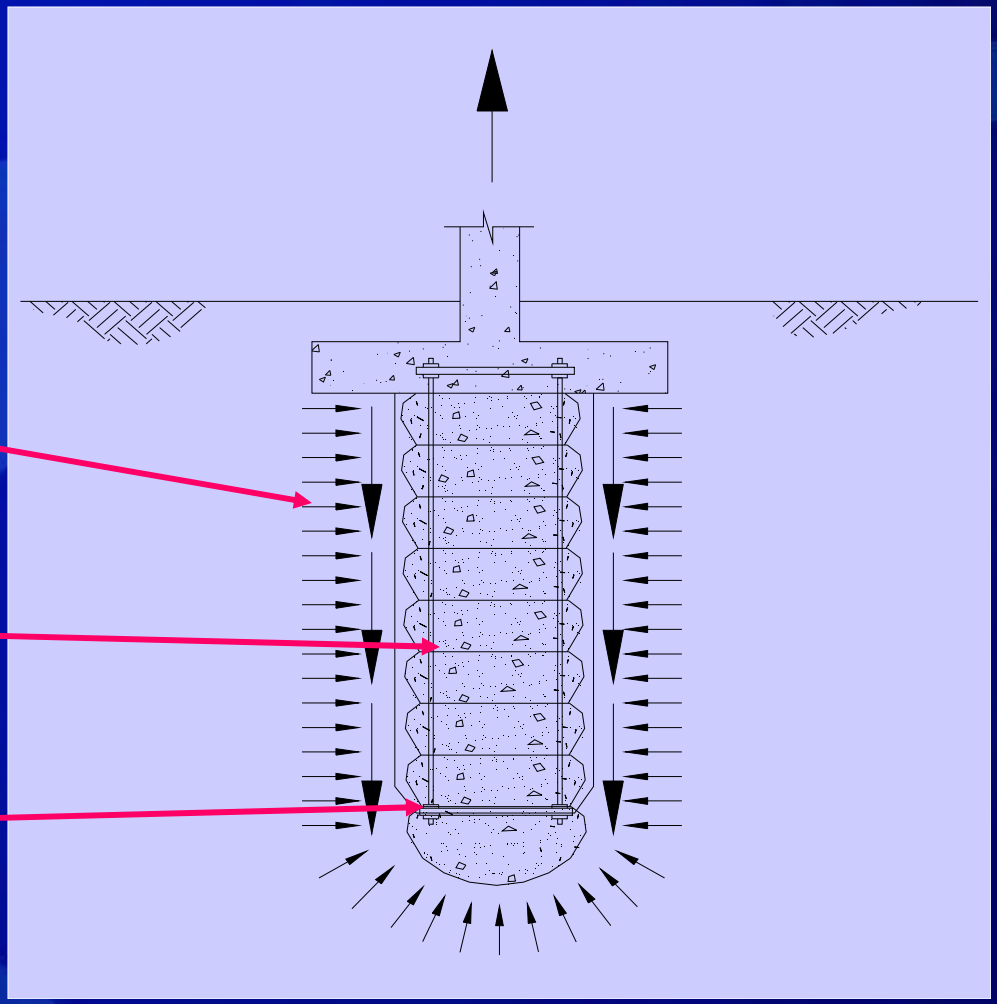
Uplift Resistance

Uplift anchors required to resist tensile loads

Cylindrical shearing surface

Threaded rods

Steel Plate



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Uplift Resistance

Load Test Uplift Element
at UC Davis

Production Uplift Elements

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Lateral Resistance

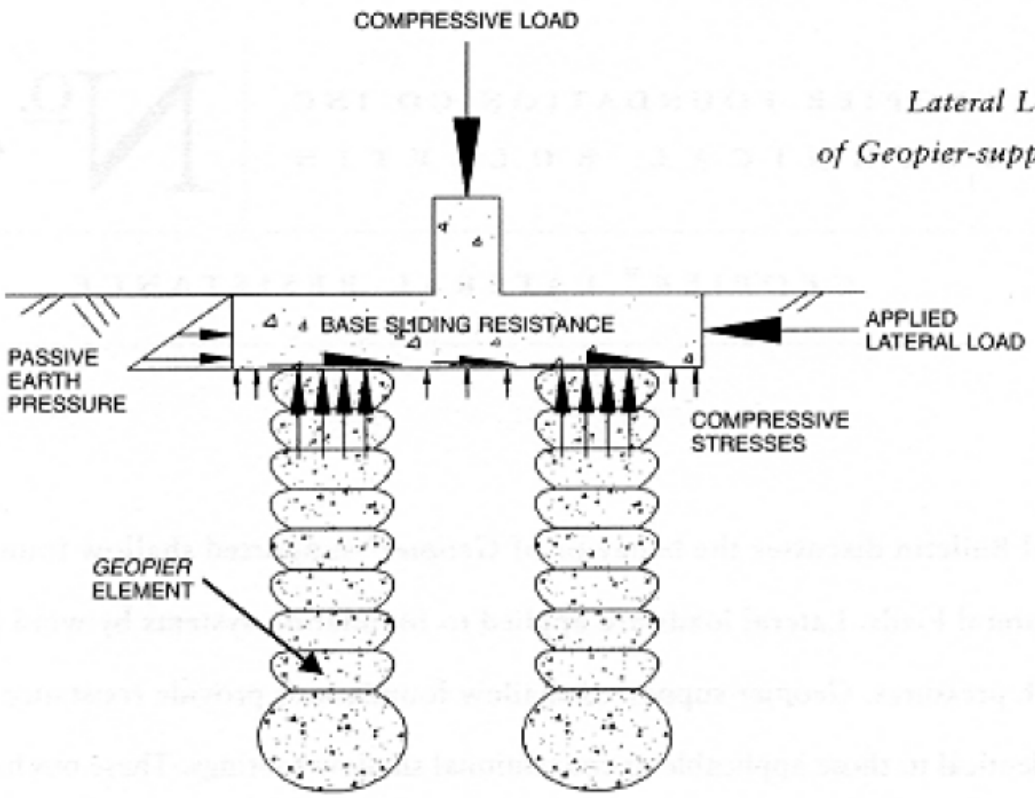

Figure 1.
Lateral Load Resistance
of Geopier-supported Footing.

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RAP and Soil Types

- Sand, silty/clayey sand, gravel (SP, SW, SM, SC, GW, GP)
- Clays and silts (CL, ML)
- Peats and organics (PT, OL)
- Undocumented fill

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GEOPIER LIMITATIONS

- Extreme loads on extremely soft soils
- Sinkholes
- Expansive / swelling clay
- Obstructions during drilling

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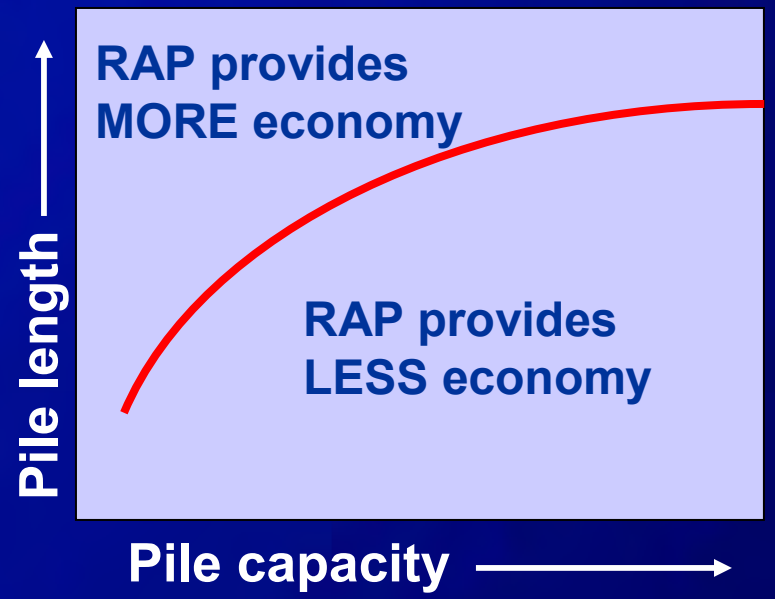
When To Consider RAP Systems

Economics:

Often provide a 20% to 40% cost savings in comparison with Deep Foundations when:

- **High capacity > 75 tons and length > 30 feet**
- **Moderate capacity > 40 to 60 tons and length > 20 feet**
- **Low capacity < 40 tons and any length**



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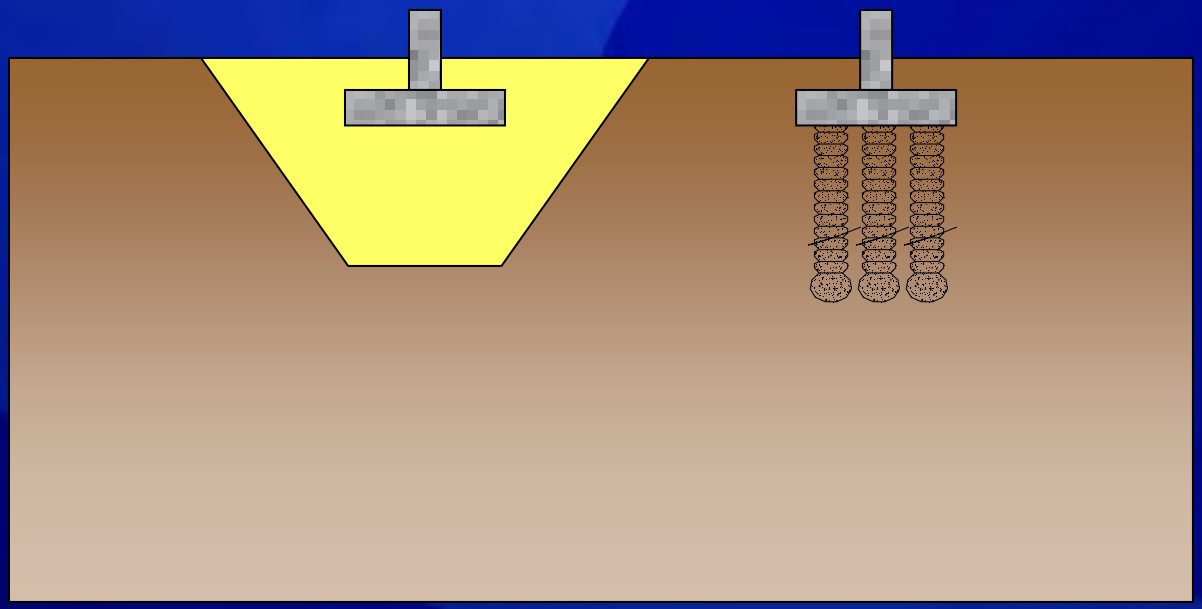
When To Consider RAP Systems

Economics:

Often provide a 20% to 40% cost savings in comparison with over-excavation and replacement when:

- **The depth of overexcavation exceeds 5 - 8 feet.**



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Geopier System Applications

Building Foundation Support

Industrial & Tank Support

Floor Slab Support

Transportation

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CASE STUDY

VICTORYLAND PARKING DECK
SHORTER, ALABAMA

- Five story parking deck
- 63,000 sf footprint
- 77 columns with loads ranging from 200 to 1220 kips
- Foundation options for RAPs and auger cast piles

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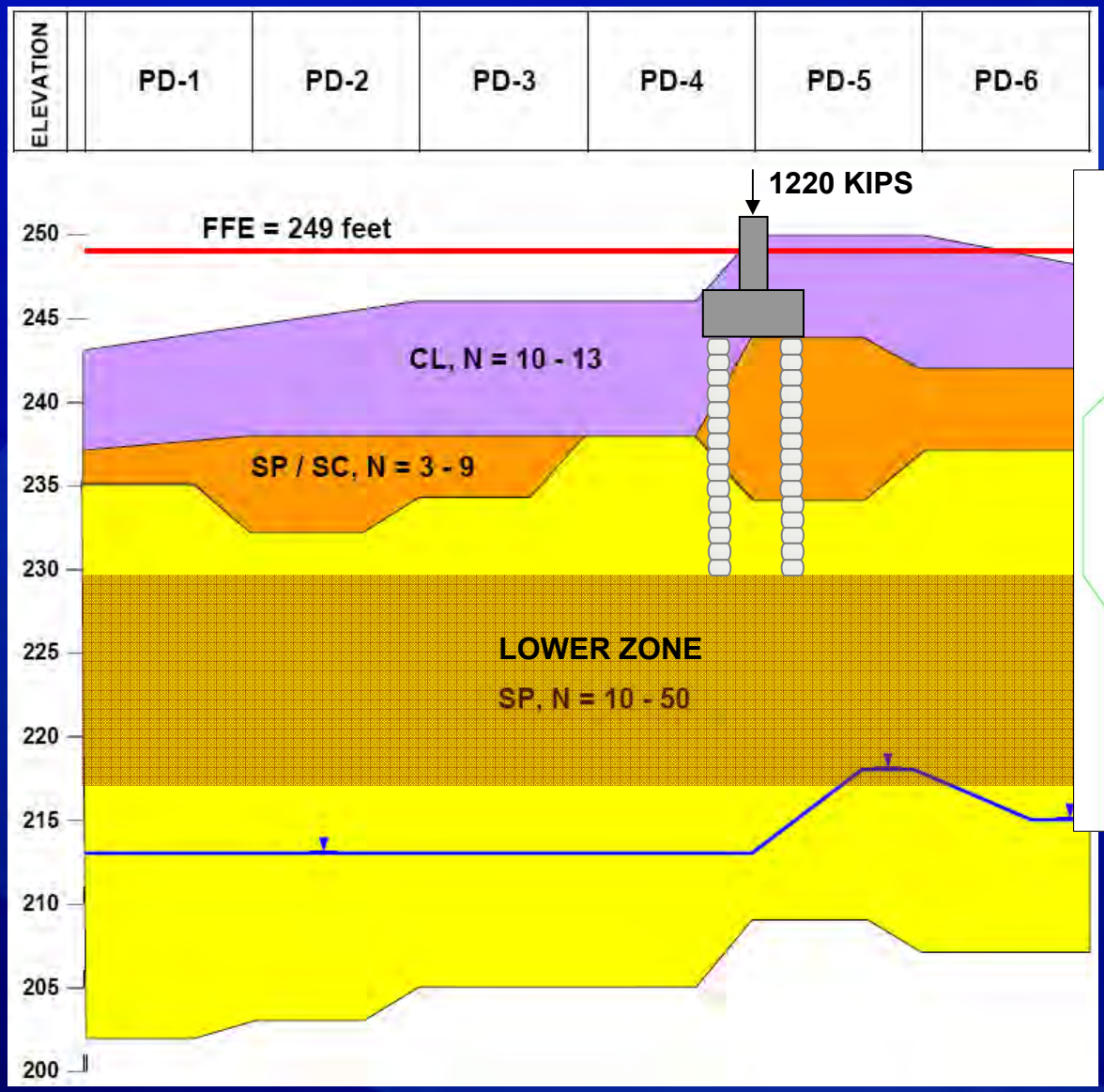
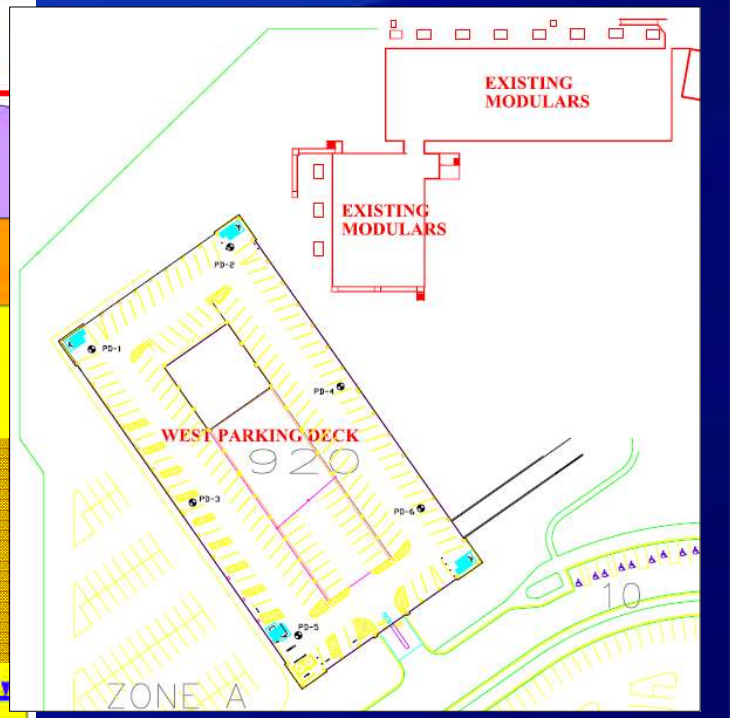
SUBSURFACE PROFILE





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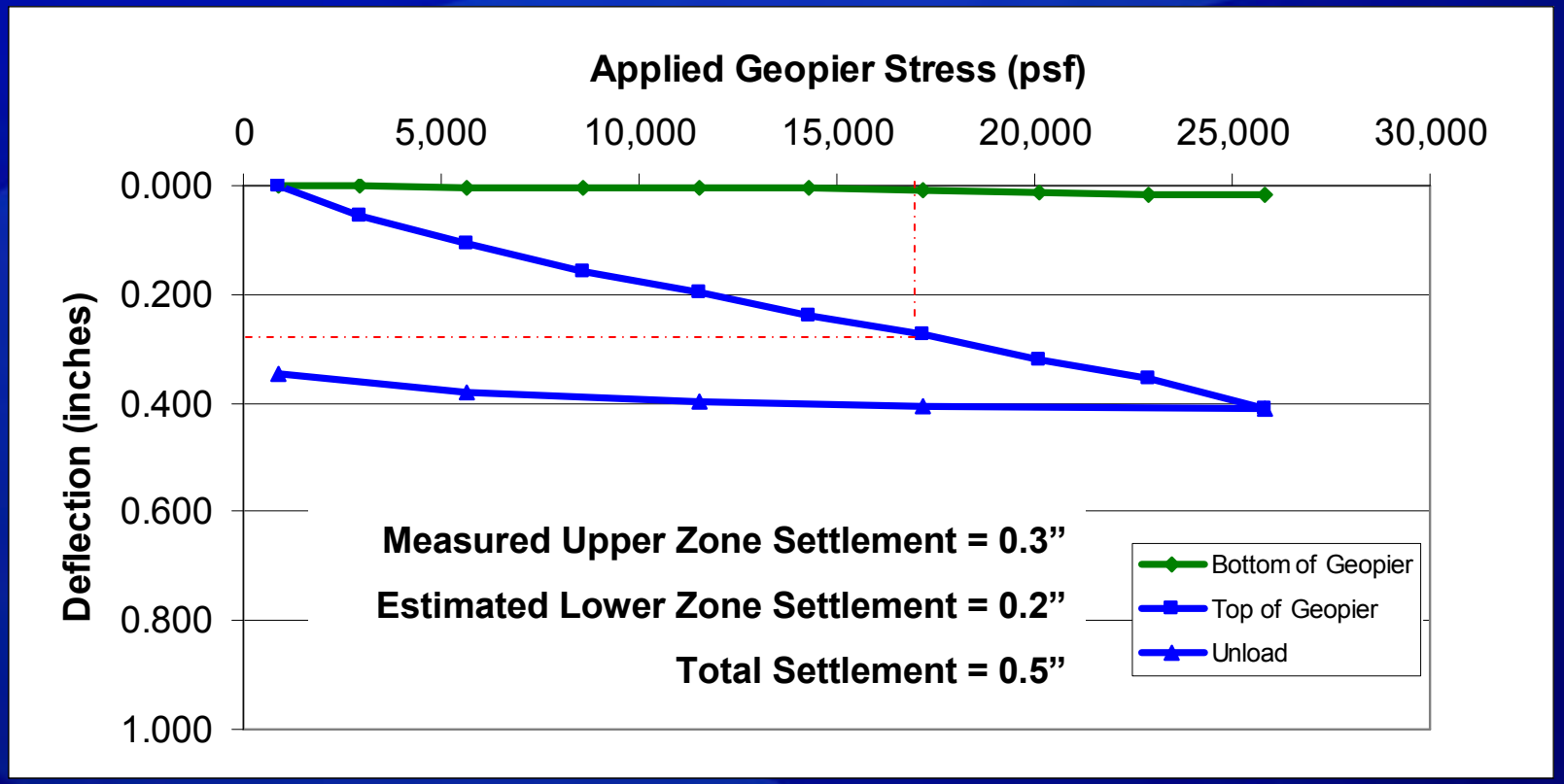
VICTORYLAND PARKING DECK

Modulus test results



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VICTORYLAND PARKING DECK

530 RAP elements installed in 11 days!

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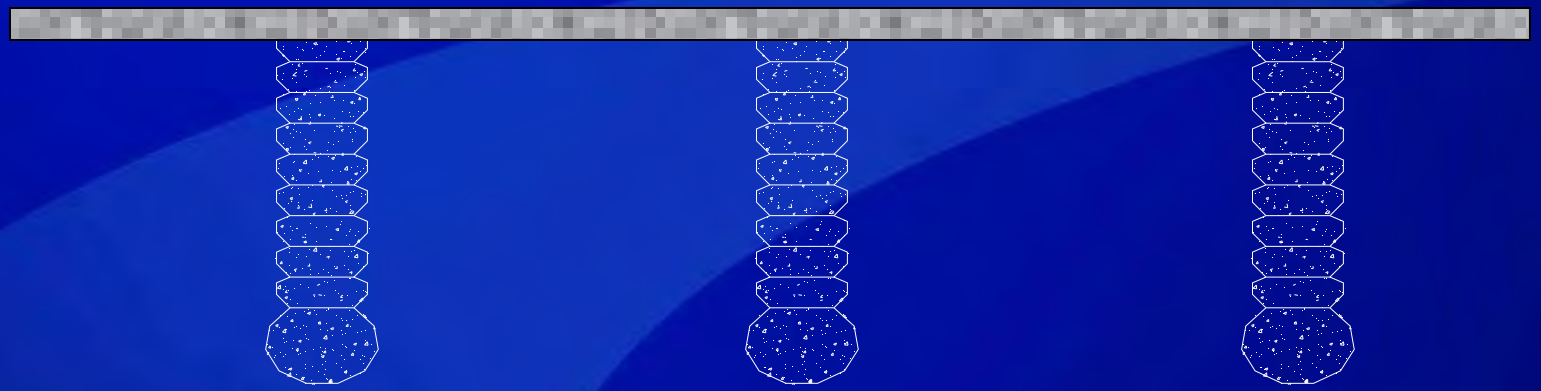
FLOOR SLAB SUPPORT



Elements reinforce soft and compressible soils for support of relatively thin floor slabs.

Replace structural floor slabs on piles.

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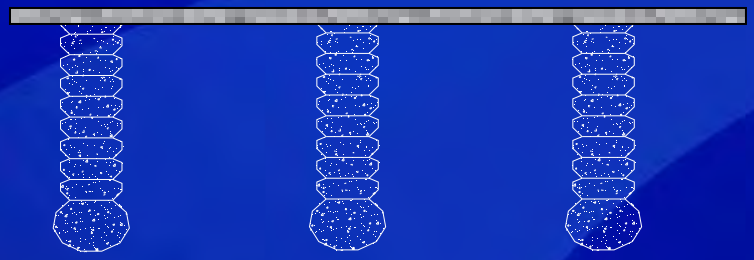
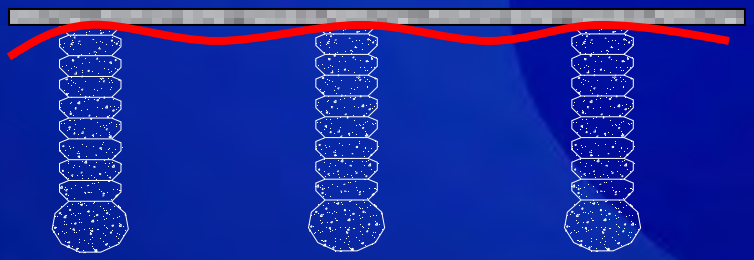
FLOOR SLAB SUPPORT

Design Considerations



Geotechnical
(settlement, etc)



Structural
(slab design, etc)

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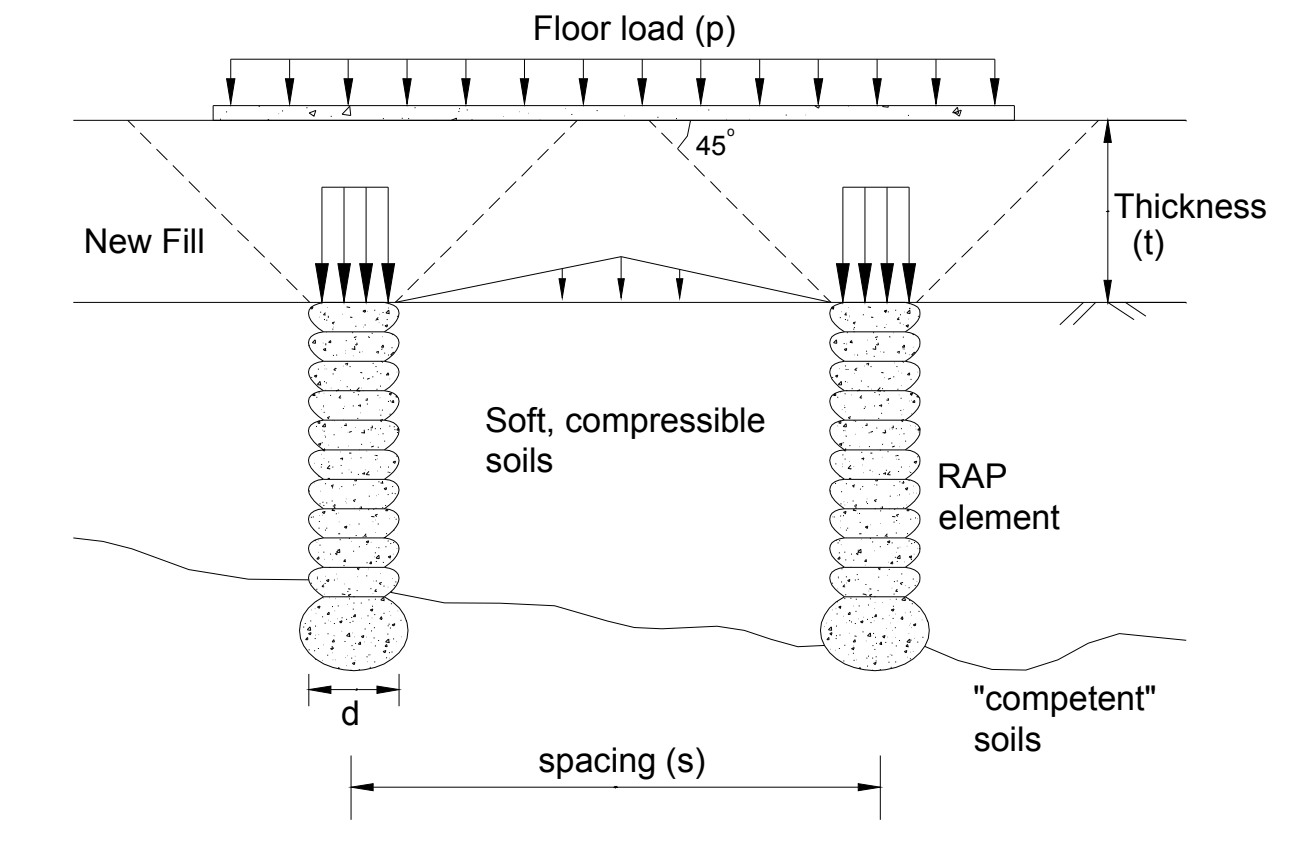
FLOOR SLABS - GEOTECHNICAL

Fill and floor slab support



Arching transfers pressures to pier

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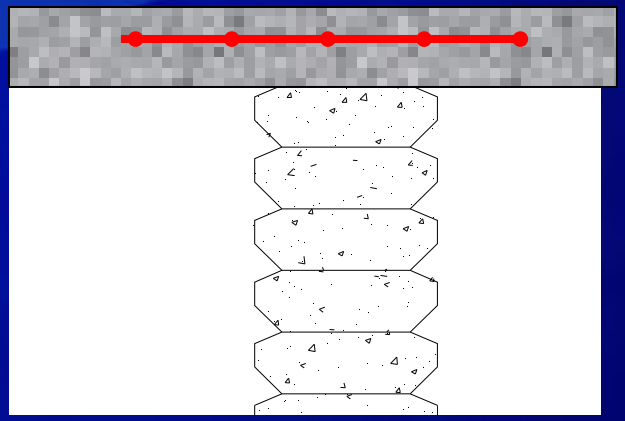
FLOOR SLABS – STRUCTURAL

Steel Reinforcement

May be required to resist tensile stresses within top of slab overlying Geopier elements.



Need to:

- Work closely with structural engineer
- Perform finite element analysis (project SE or GFC SE)

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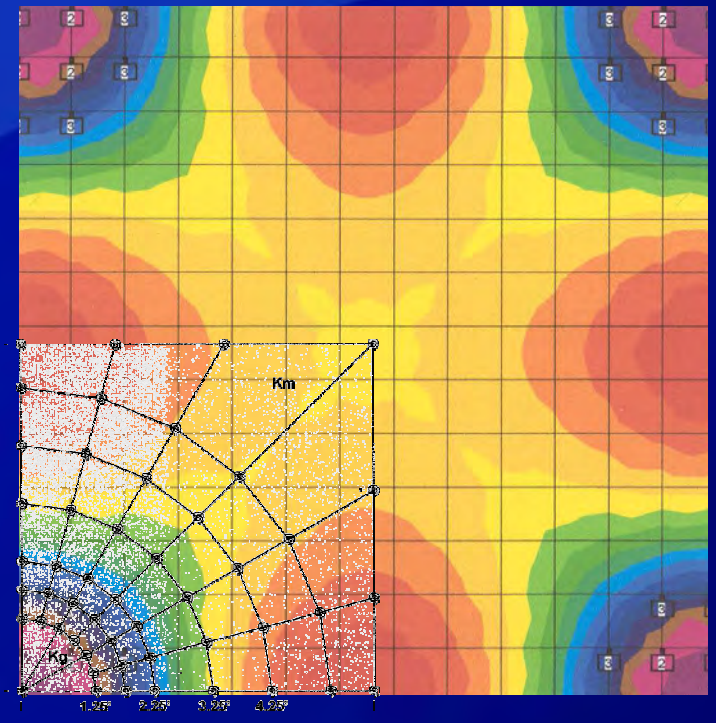
FLOOR SLABS – STRUCTURAL

Finite Element Analysis (FEA)

Results of analysis identify areas of higher bending stresses

Indicate whether added reinforcement or thicker slab is needed



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FLOOR SLAB SUPPORT

Boeing Building 101, St. Louis, MO

Delta Marine, Seattle, WA

Costco Retail Store, Tacoma, WA

Polaris Plant, Vermillion, SD

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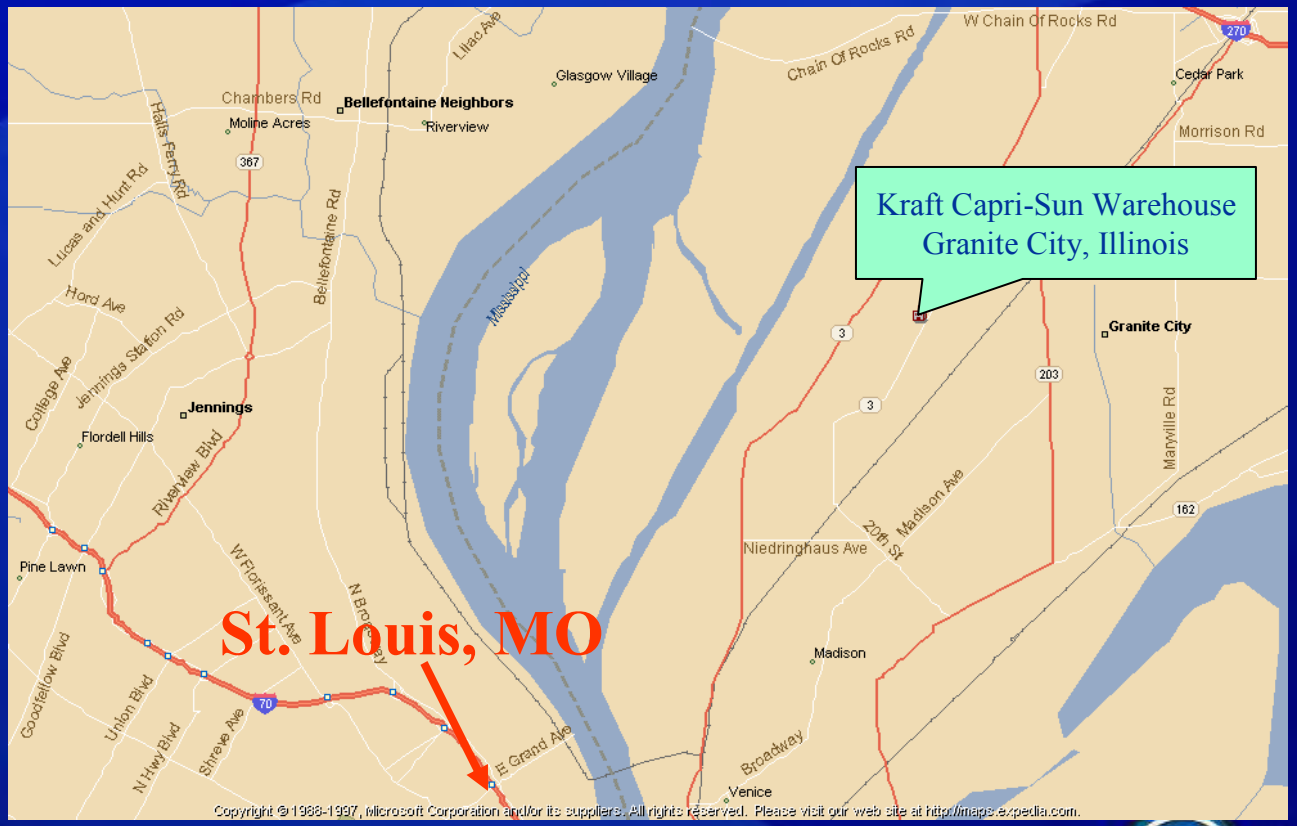
FLOOR SLABS - EXAMPLE

KRAFT CAPRI-SUN WAREHOUSE
GRANITE CITY, ILLINOIS



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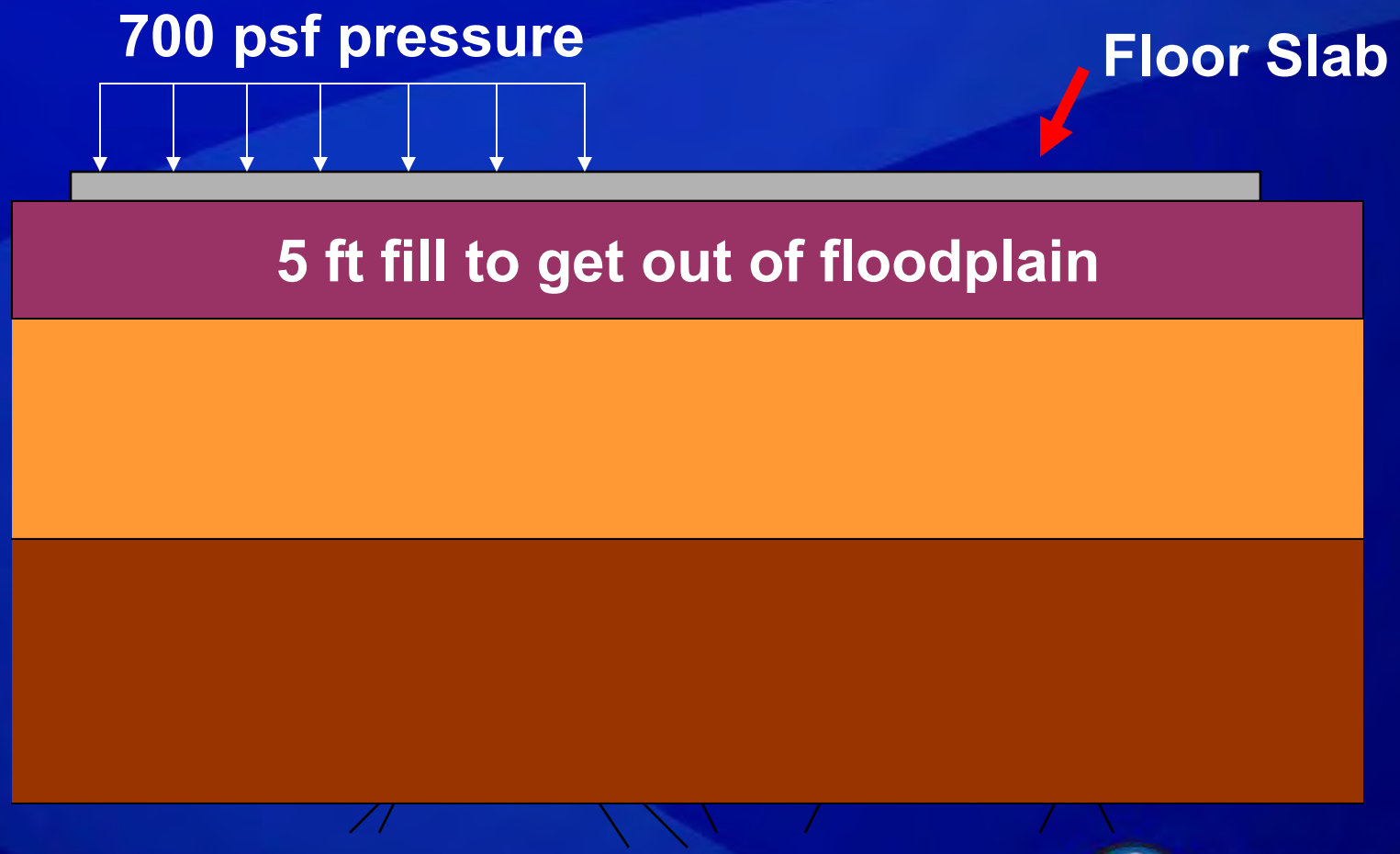
FLOOR SLABS - EXAMPLE



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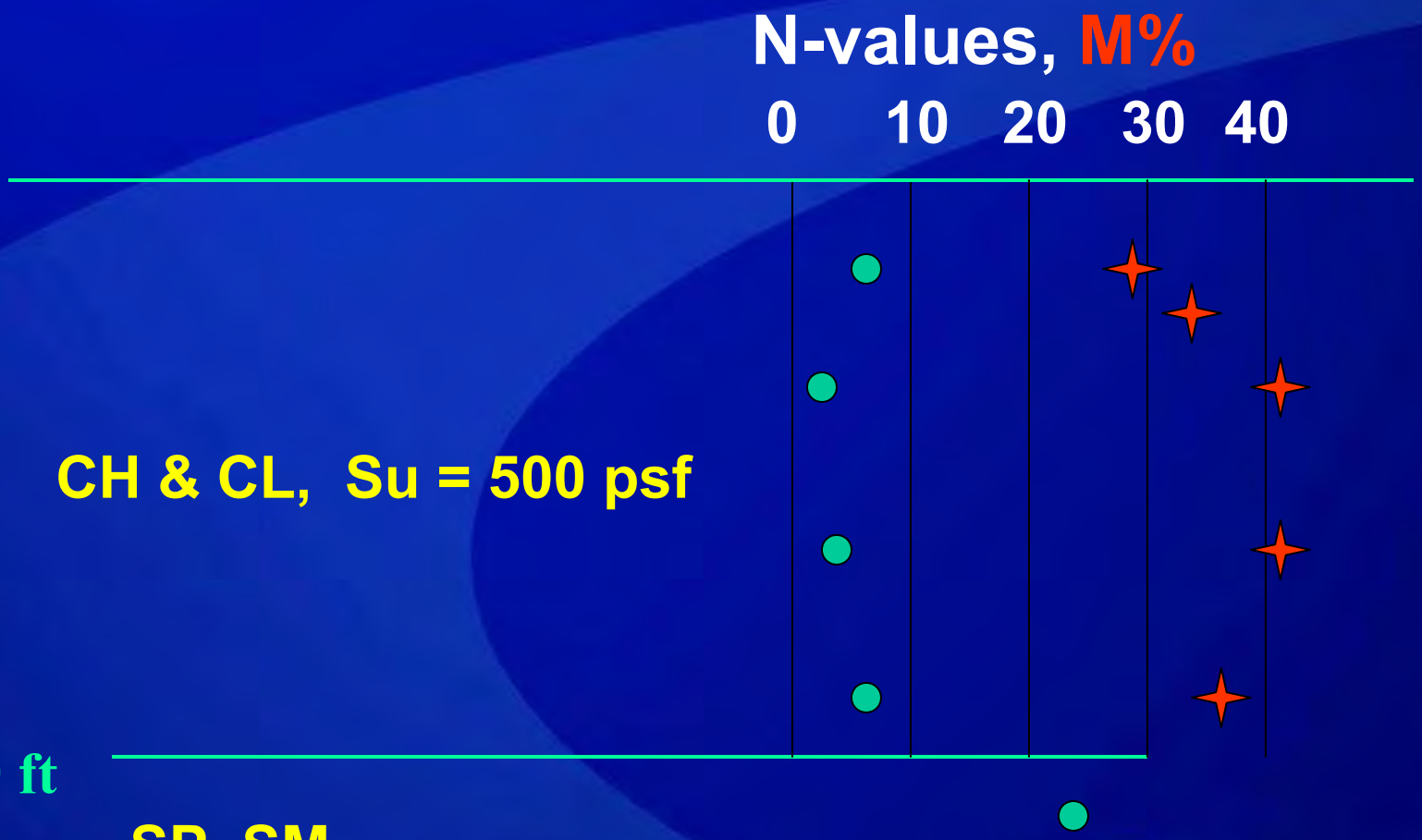
FLOOR SLABS - EXAMPLE

Subsurface conditions



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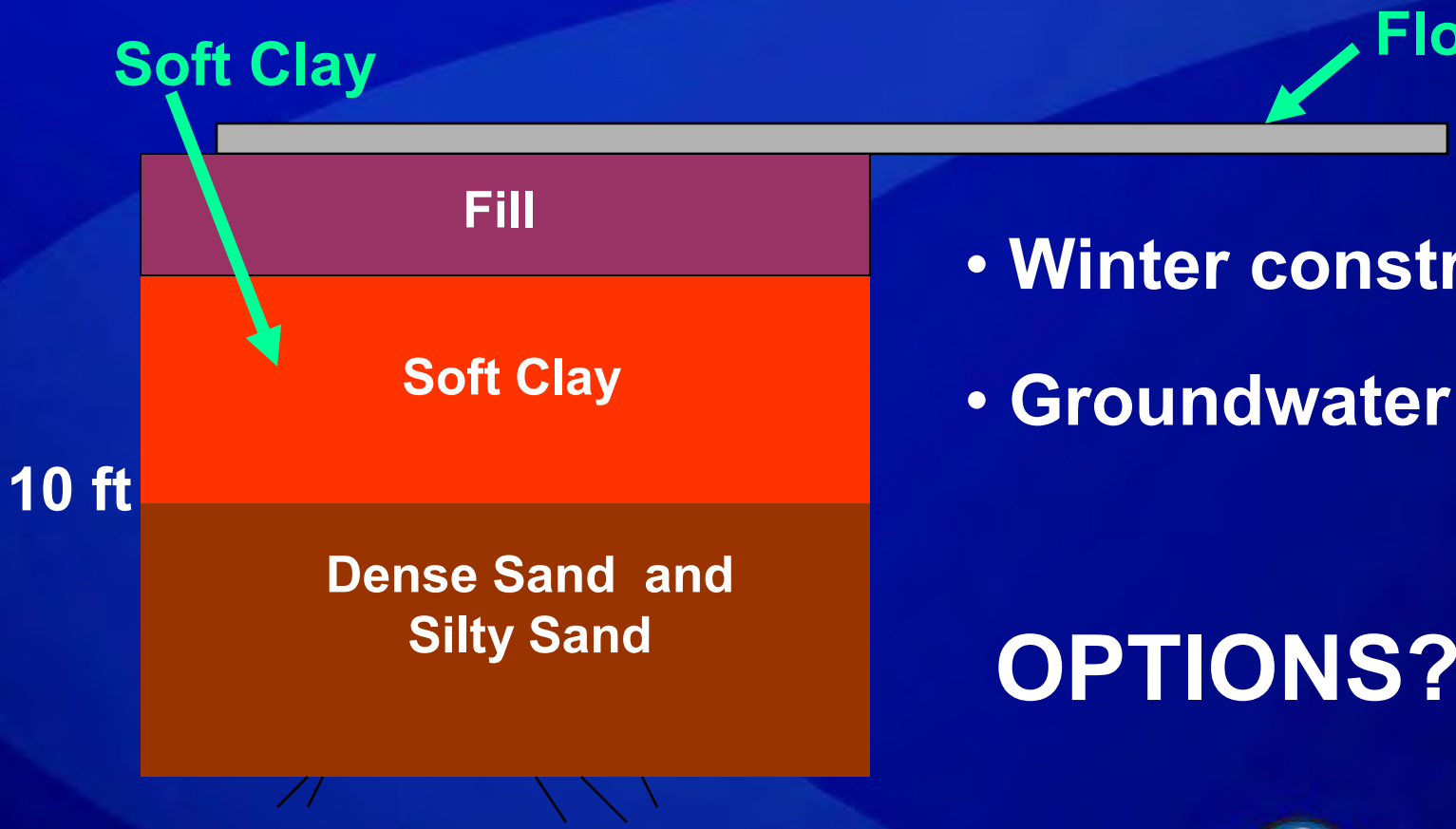
FLOOR SLABS - EXAMPLE

Planned construction



- Winter construction
- Groundwater

OPTIONS?

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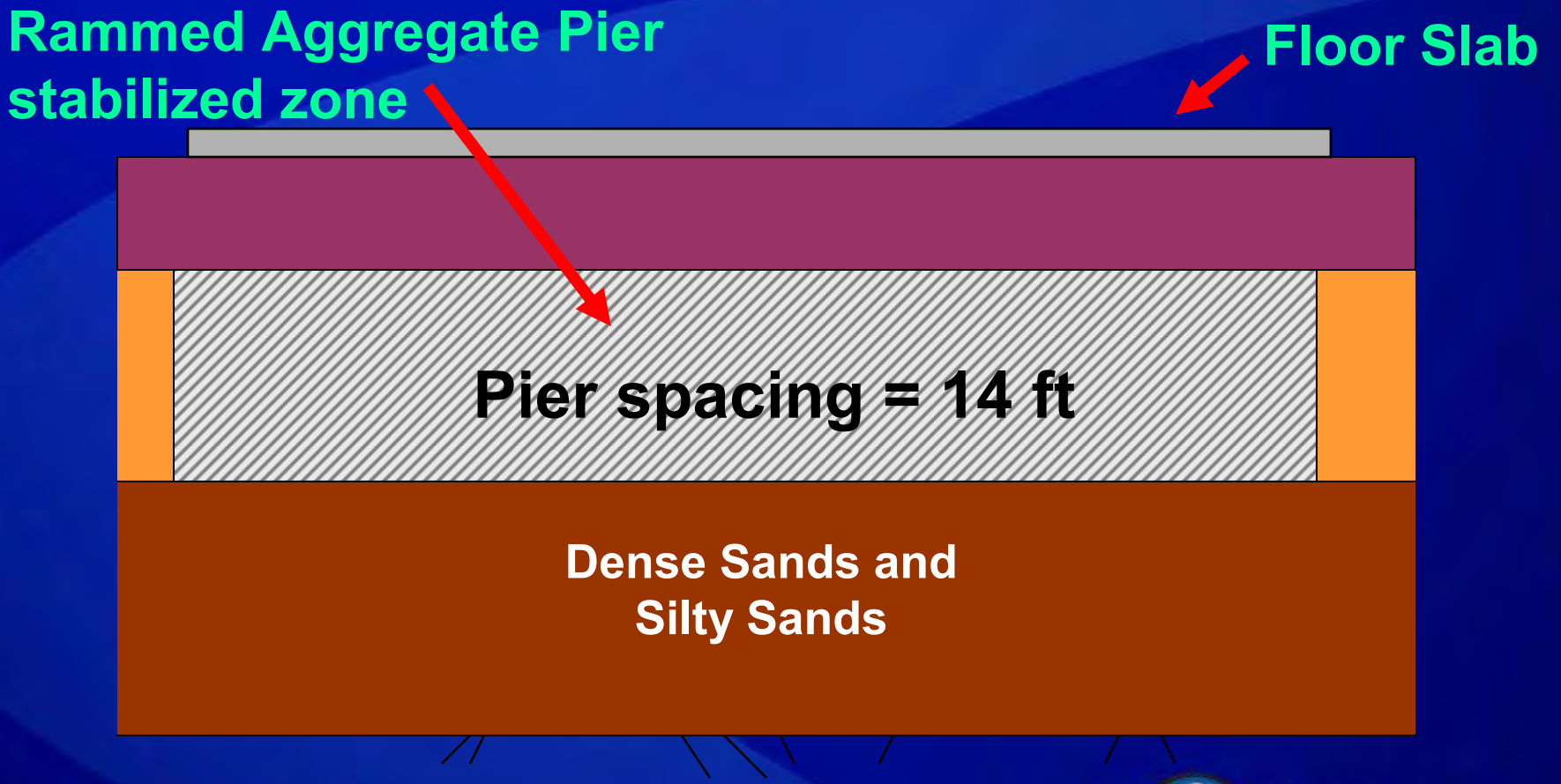
FLOOR SLABS - EXAMPLE

Value engineering proposal



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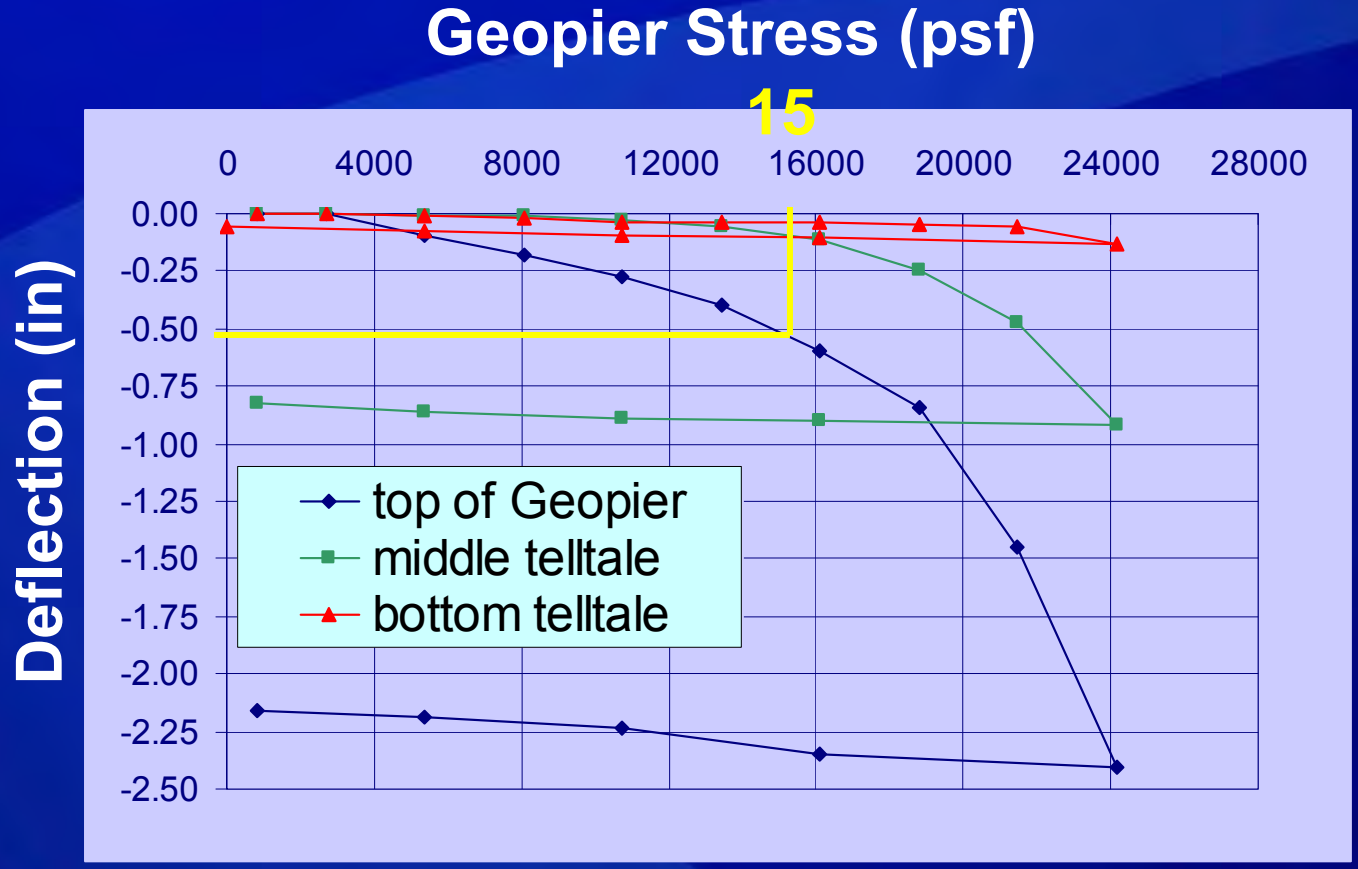
FLOOR SLABS - EXAMPLE

Modulus test



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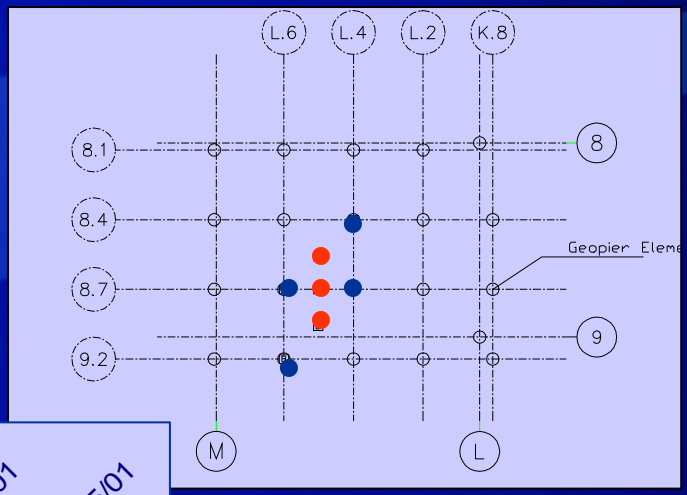
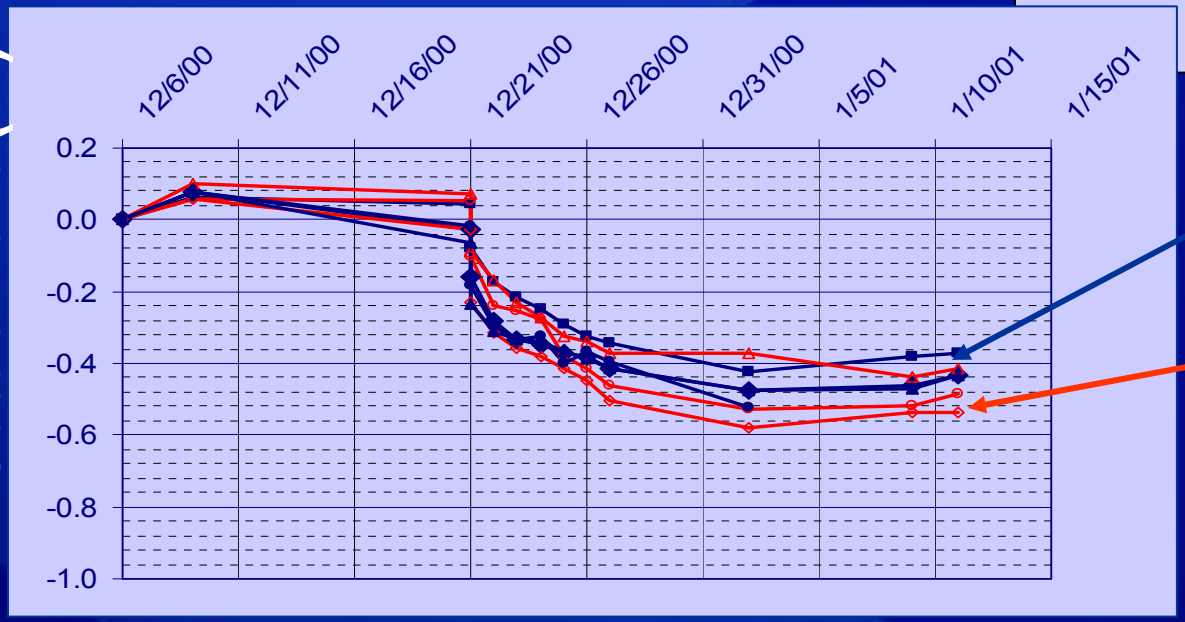
FLOOR SLABS - EXAMPLE

Differential settlement



Settlement Monitoring



Pier = 0.5 in (0.6)

Soil = 0.6 in (0.6)

Differential = 0.1 in (0 in)

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FLOOR SLAB SUPPORT

- 360,000 sq. ft. manufacturing facility addition
- Floor slab pressures = 700 psf
- 2,100 *Geopier* elements installed in one month

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POWER GENERATION
Mirant Power Plants, MD

Morgantown Plant

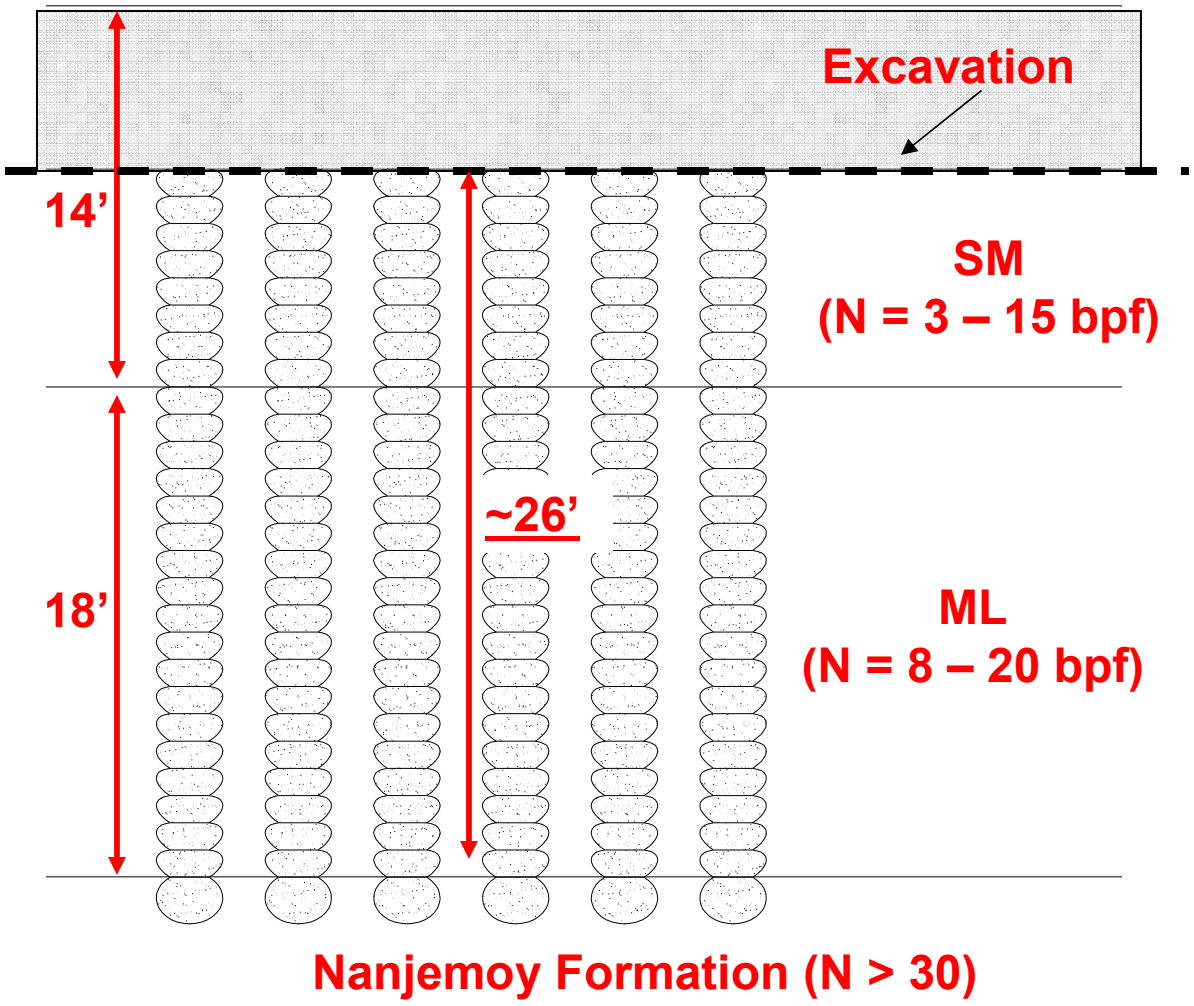
Absorber stacks and building

Mat foundation:
91-ft x 357-ft

Design pressures:
3 ksf at building
6 ksf at stacks

Impact RAPs:
4 to 6 ft o-c

Est. settlements:
~ 2.5 inches



Chalk Point Plant

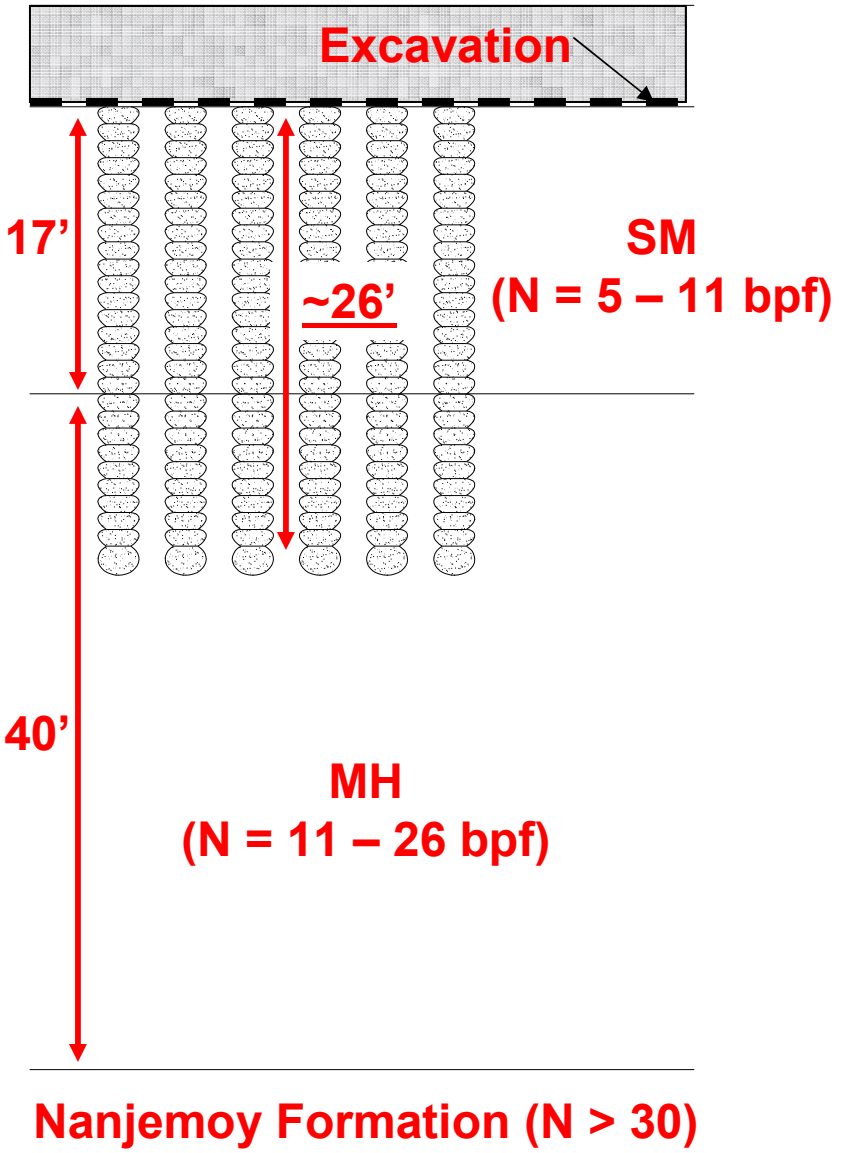
Absorber stacks and building

Mat foundation:
87-ft x 219-ft

Design pressures:
3 ksf at building
6 ksf at stacks

Impact RAPs:
4 to 6 ft o-c

Est. settlement:
~ 3.8 inches



TANK SUPPORT

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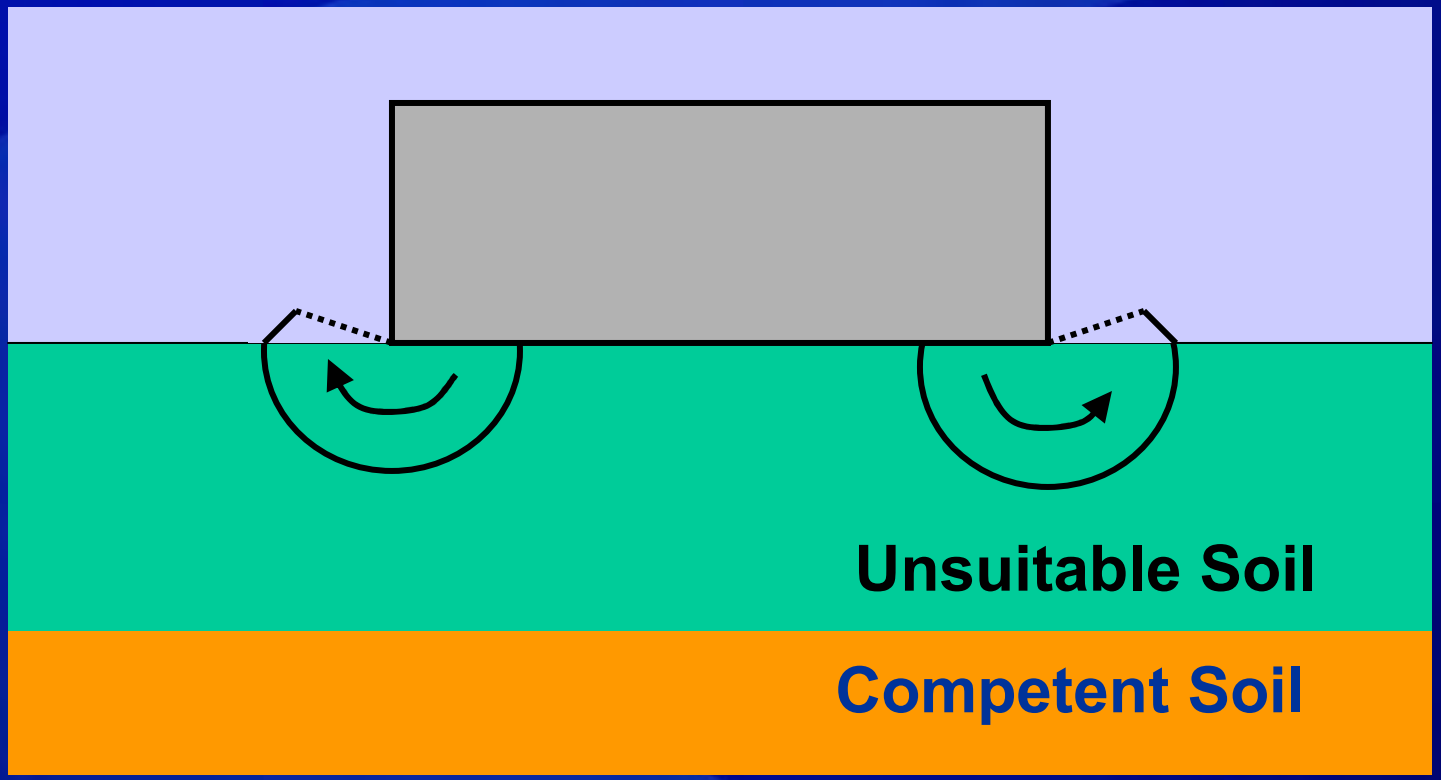
DESIGN ISSUES

Bearing Capacity



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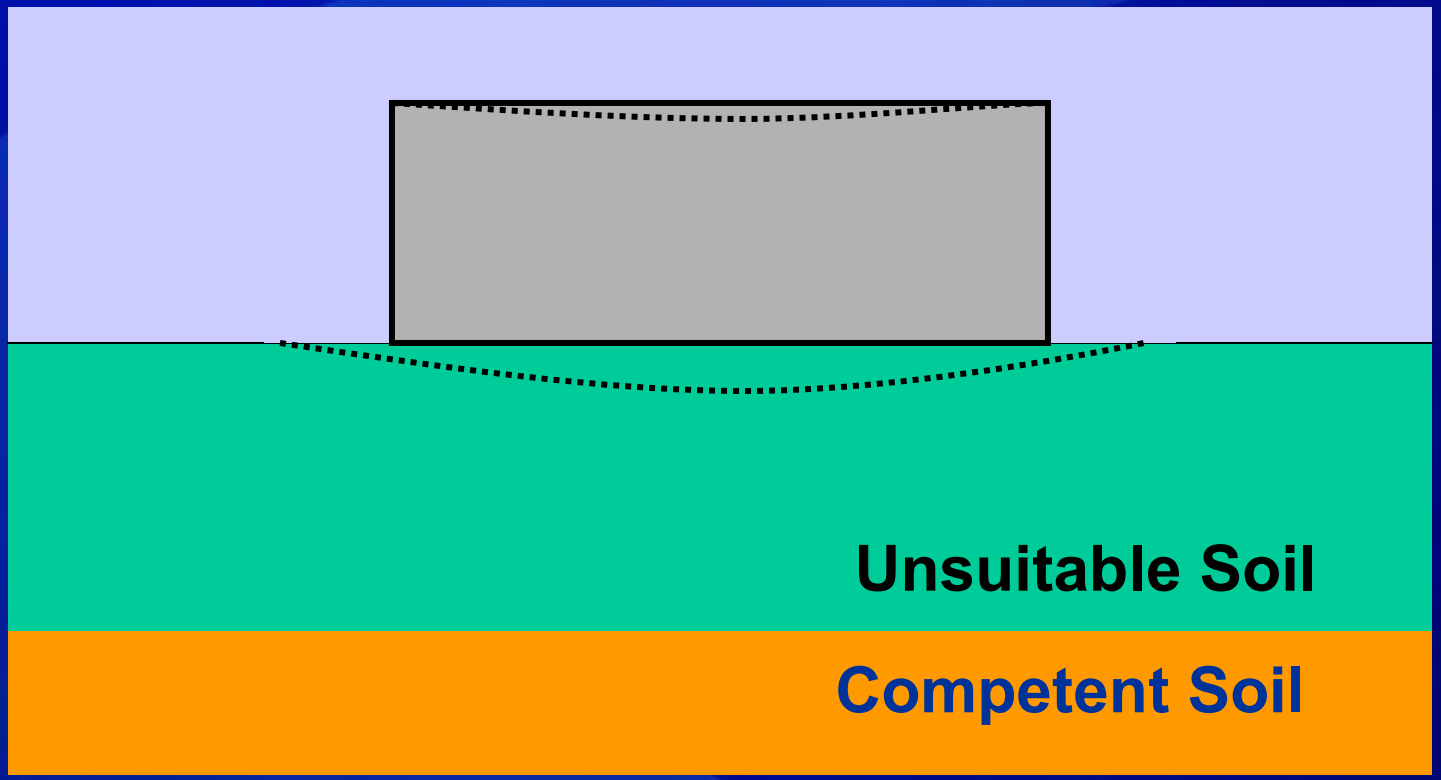
DESIGN ISSUES

Settlement



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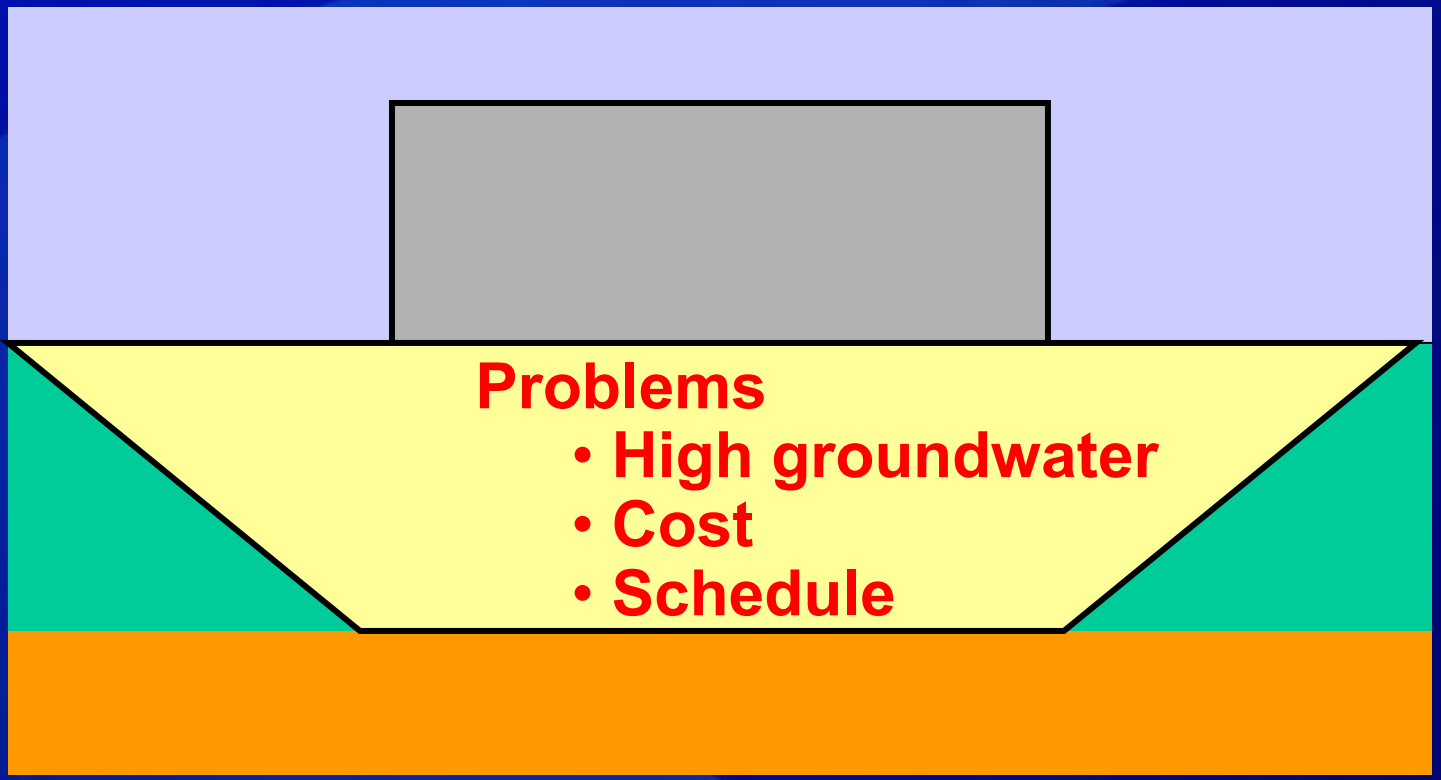
DESIGN OPTIONS

Overexcavation and Replacement



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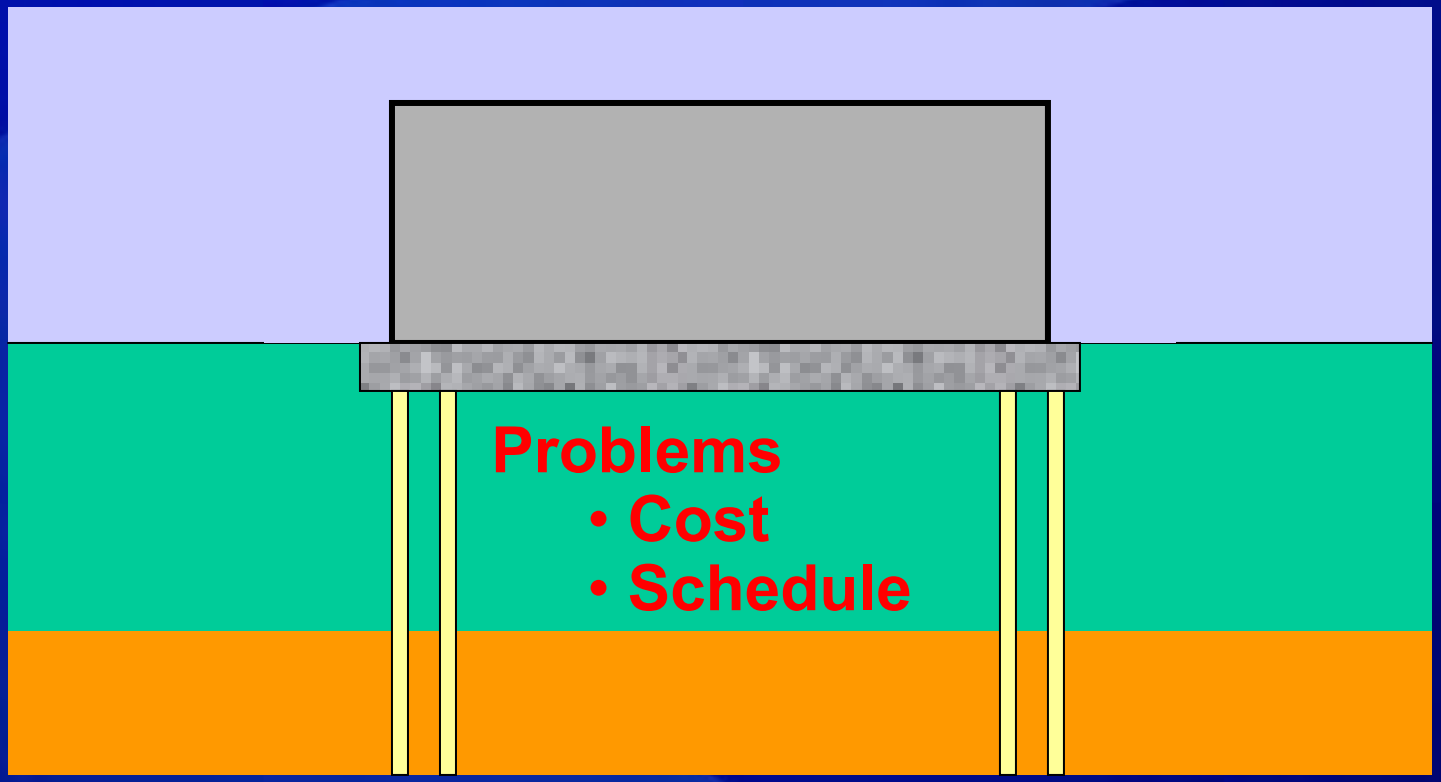
DESIGN OPTIONS

Pile-supported concrete pad



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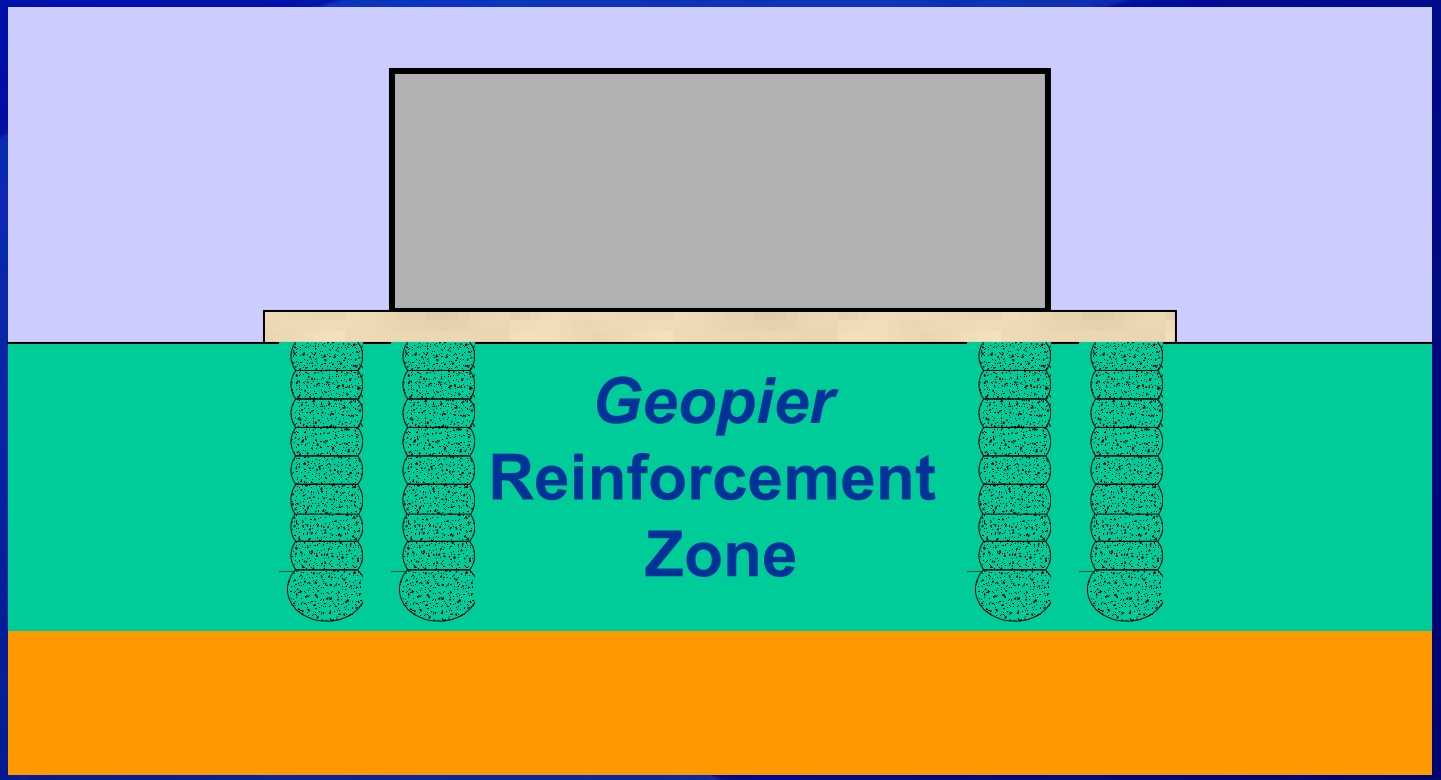
DESIGN OPTIONS

Granular pad over *Geopier* reinforced zone



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SAMPLE INDUSTRIAL PROJECTS

- Houston Fuel Oil Terminal Tank Support
- Kinder Morgan Tank 150-27 Repair
- Valero Refinery Tank TK-443
- Lyondell-Citgo Tank Repair
- Kinder Morgan Tank 150-44
- Valero Refinery Tank TK-231
- Industrial Zeolite Plant
- ExxonMobil Tank 2176 Repair
- ConocoPhillips Refinery

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CASE HISTORY:
VALERO REFINERY TANK TK-231
HOUSTON, TX

VALERO ENERGY CORPORATION

- New tank construction
- 125-foot diameter
- 48-ft tall
- Design pressure = 3 ksf

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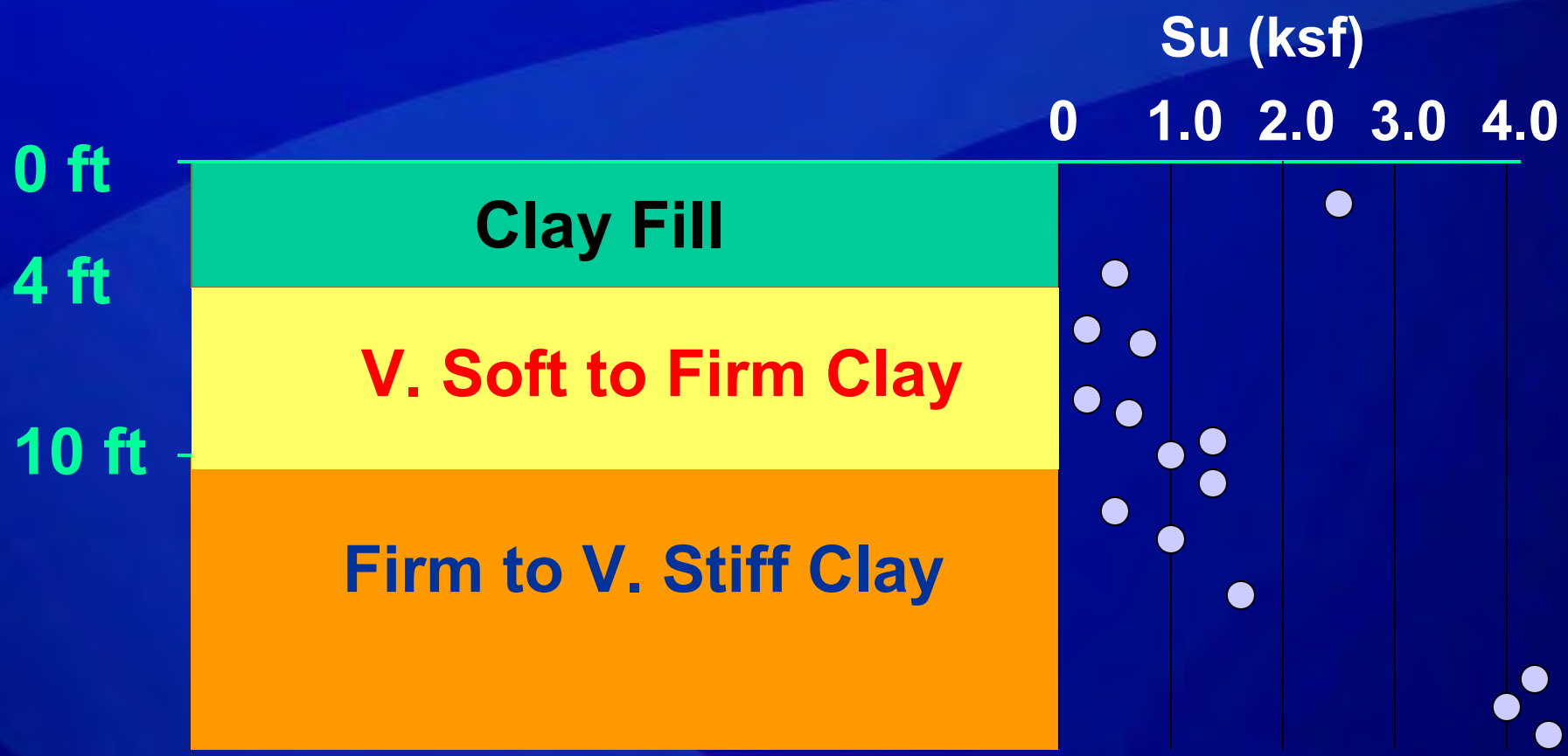
SUBSURFACE CONDITIONS



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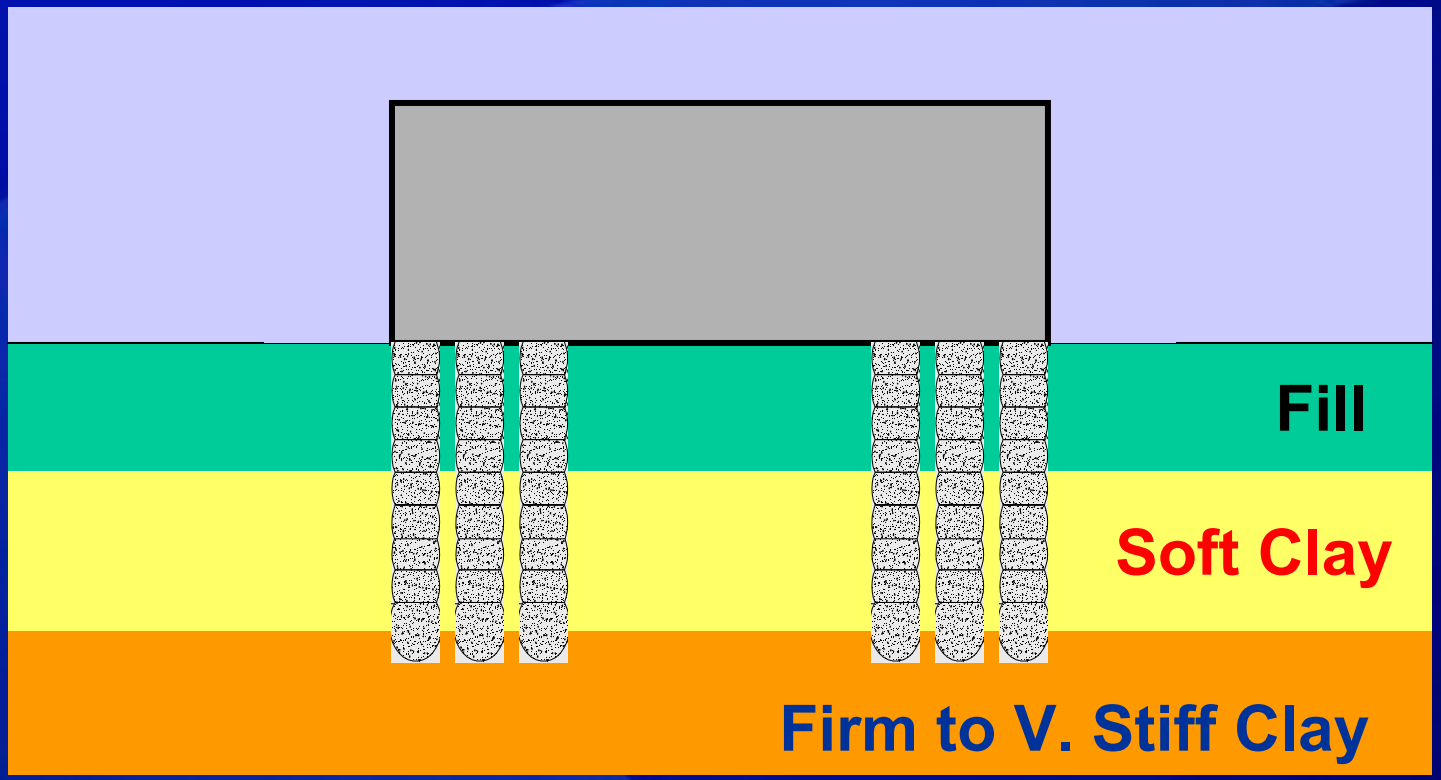
GEOPIER SOLUTION

Perimeter Differential Settlement Control



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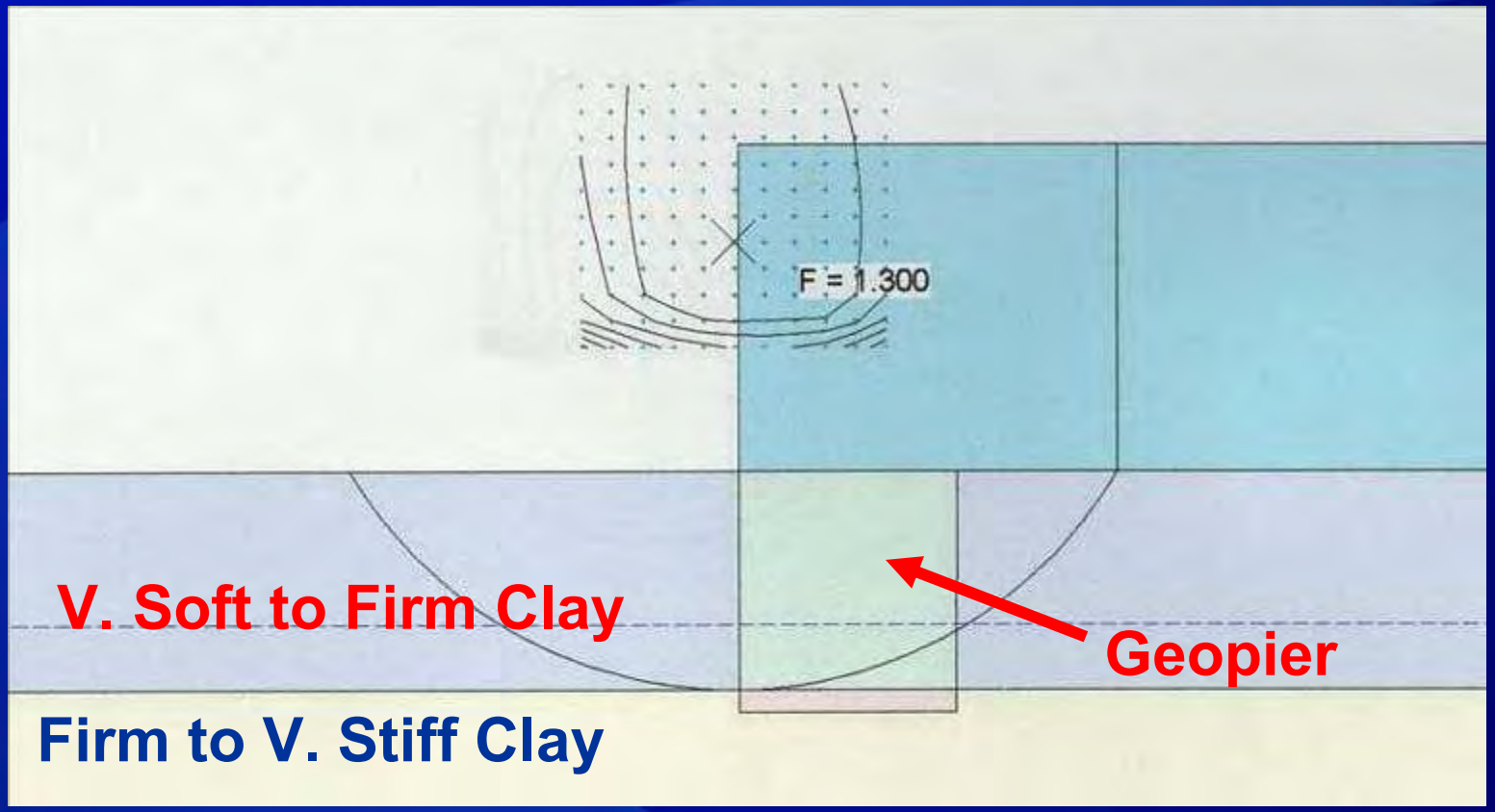
GEOPIER SOLUTION

Bearing Capacity – Edge Instability



FS for Geopier-reinforced soil = 1.30

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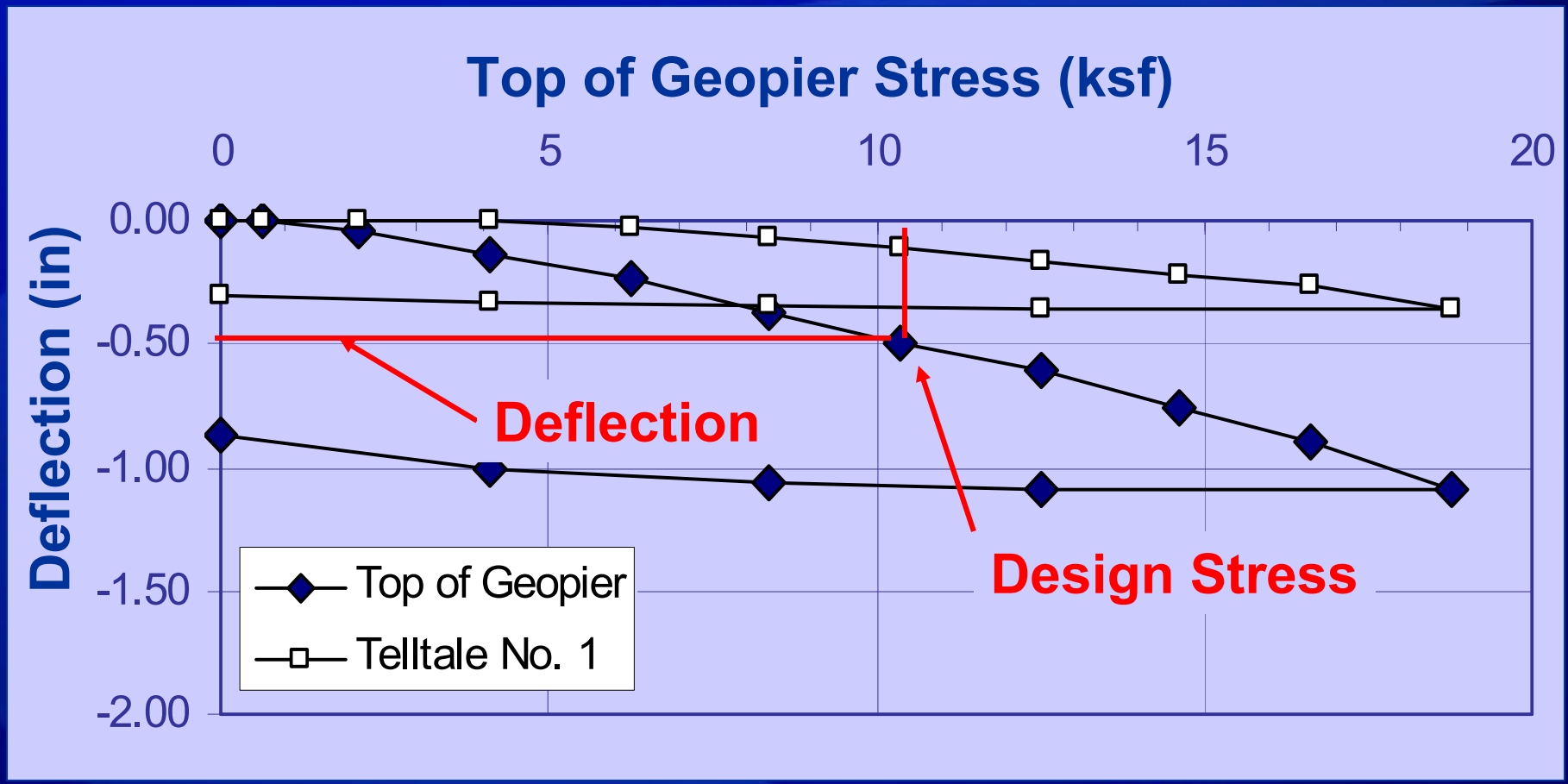
GEOPIER SOLUTION

Modulus Load Test Results



Settlement = 0.5 in at design stress

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GEOPIER SOLUTION

- Installed 243 piers in 8 days (30 piers / day)
- Increased edge stability (FS = 1.3)
- Limited perimeter differential settlements

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Selected National Clients

- Duke Energy
- Ameren (UE)
- Motiva
- Lockheed
- ExxonMobil
- Valero
- Nucor Steel
- General Motors
- BNSF
- Kinder Morgan
- Boeing
- U.S. Food Services
- Certainteed
- Kraft
- John Deere
- Case New Holland
- Pfizer
- Wal-Mart
- Michelin
- Maybelline
- Pacific Bell
- Sara Lee
- Anheuser Busch
- General Mills

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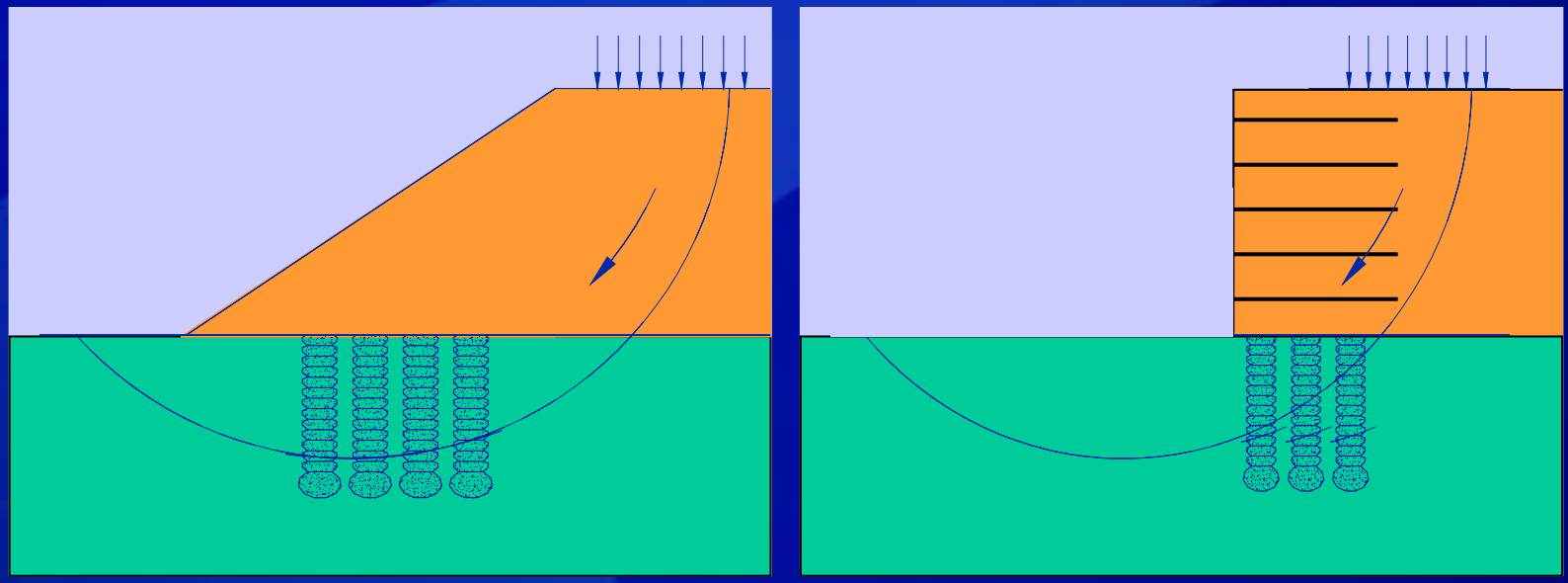
TRANSPORTATION APPLICATIONS



Shear reinforcement in *Geopier* zone

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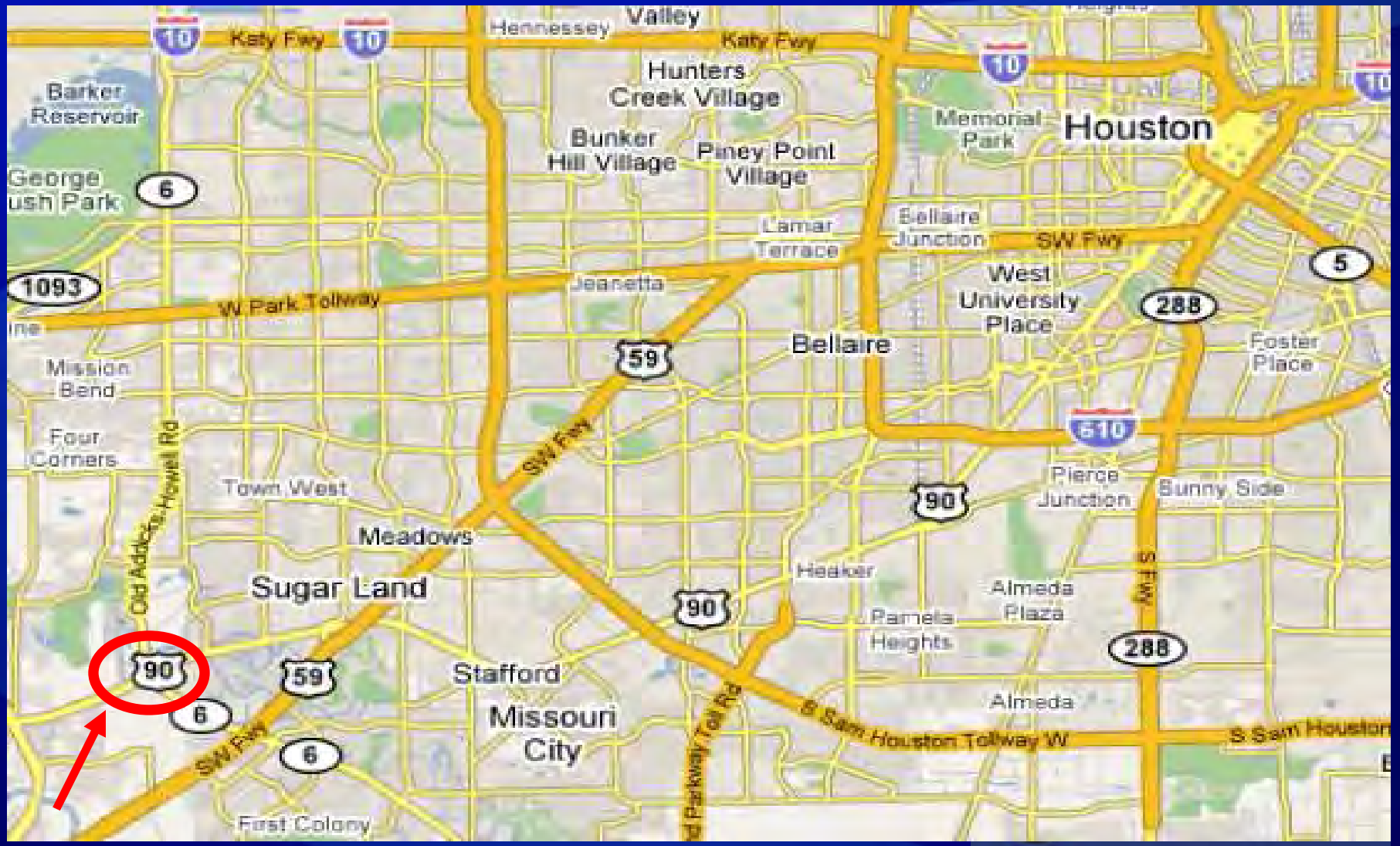
US-90 & SH-6 Intersection Upgrades, Sugarland, Texas

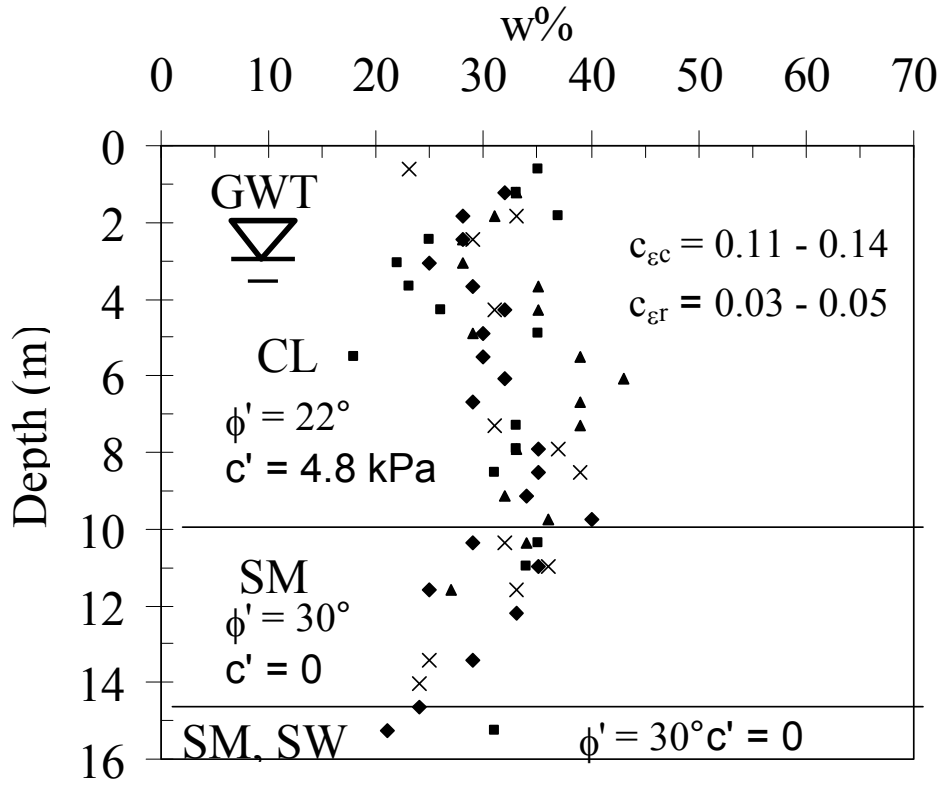
Site Plan

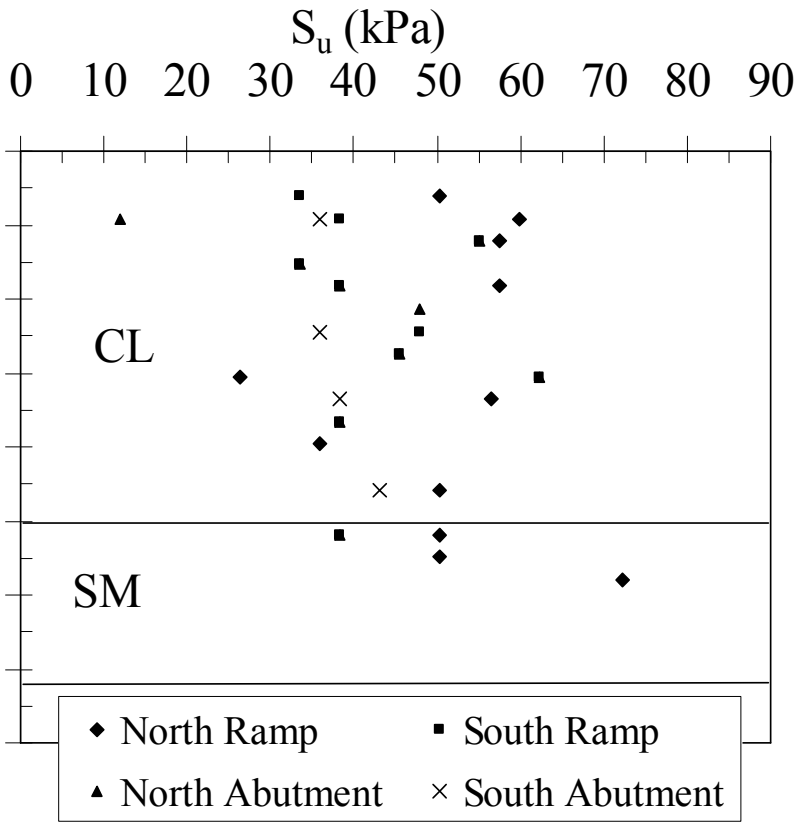


SCOPE OF WORK

MSE Wall Location	Length (m)/[ft]	Max. Height (m)/ [ft]
North Abutment	79 / 260	7.3 / 24
South Abutment	69 / 227	8.2 / 27
North Ramp	107.6 / 353	7.3 / 24
South Ramp	107 / 353	6.7 / 22

Typical Soil Conditions





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Geopier Installation

- Total Number of Piers = 1411
- Two Crews
- 20 to 25 RAPs
- Cost ~ $1,000,000
- Bid Through DOT letting
- FHWA funded the geotechnical instrumentation

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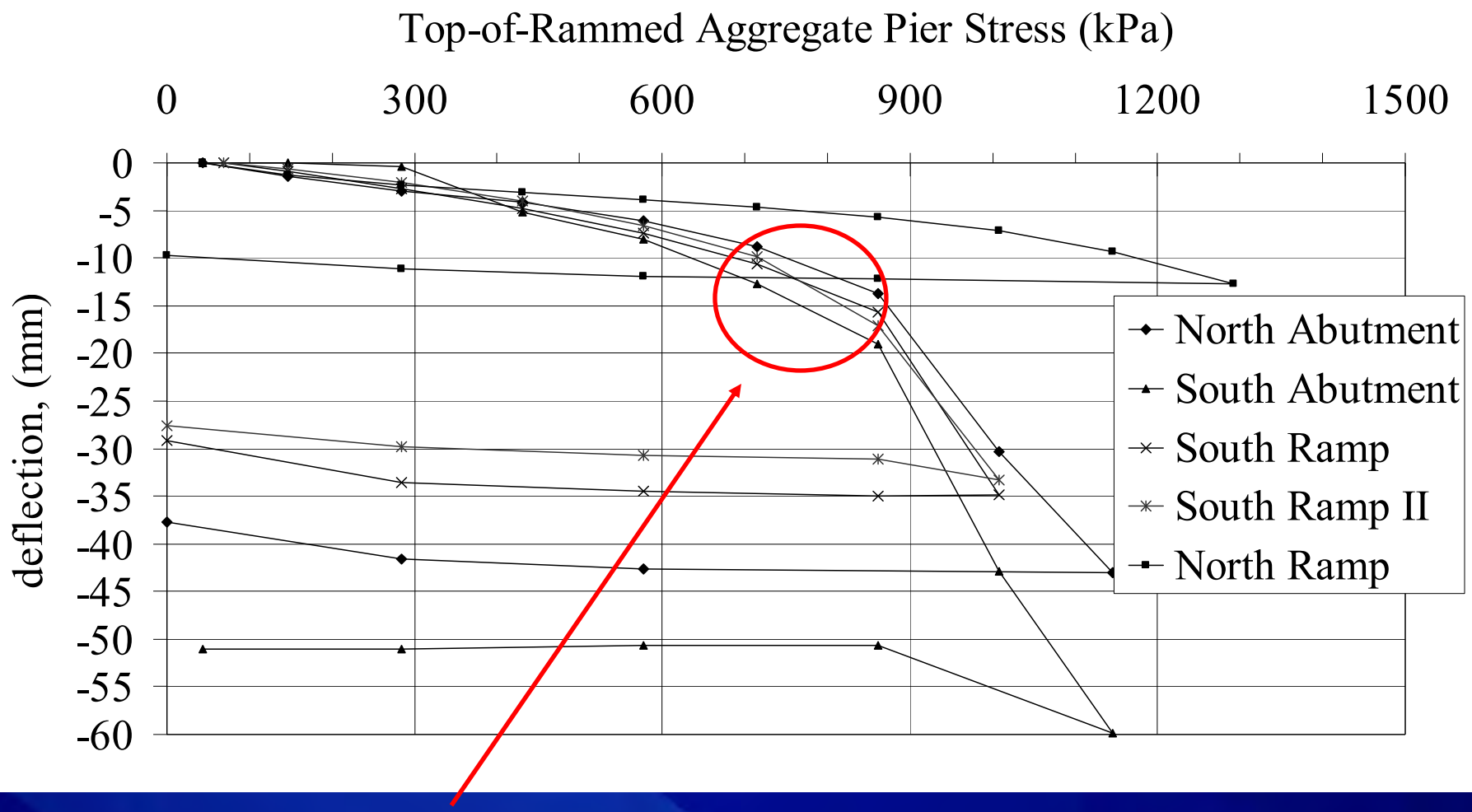
Modulus Test Results



Design Stress < 18000 psf
< ¾-in top vertical deflection

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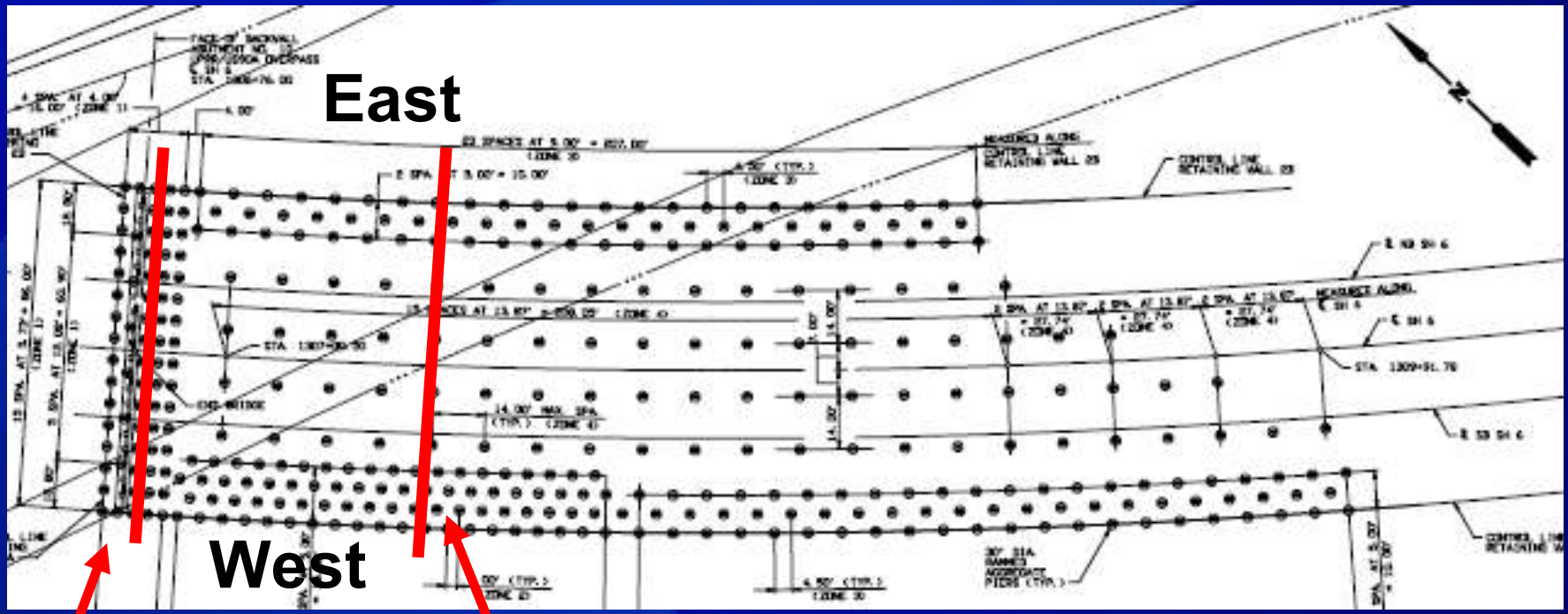
Geotechnical Instrumentation Layout

Near the Bridge Abutments at general locations of higher bearing pressure



Monitoring Station 1

Monitoring Station 2

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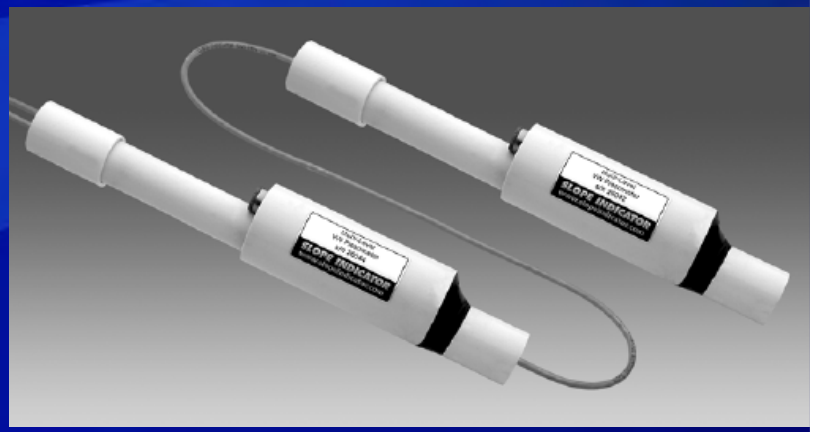
Geotechnical Instrumentation

Horizontal and Vertical Inclinometers



Vibrating Wire Piezometers

Sondex Settlement System

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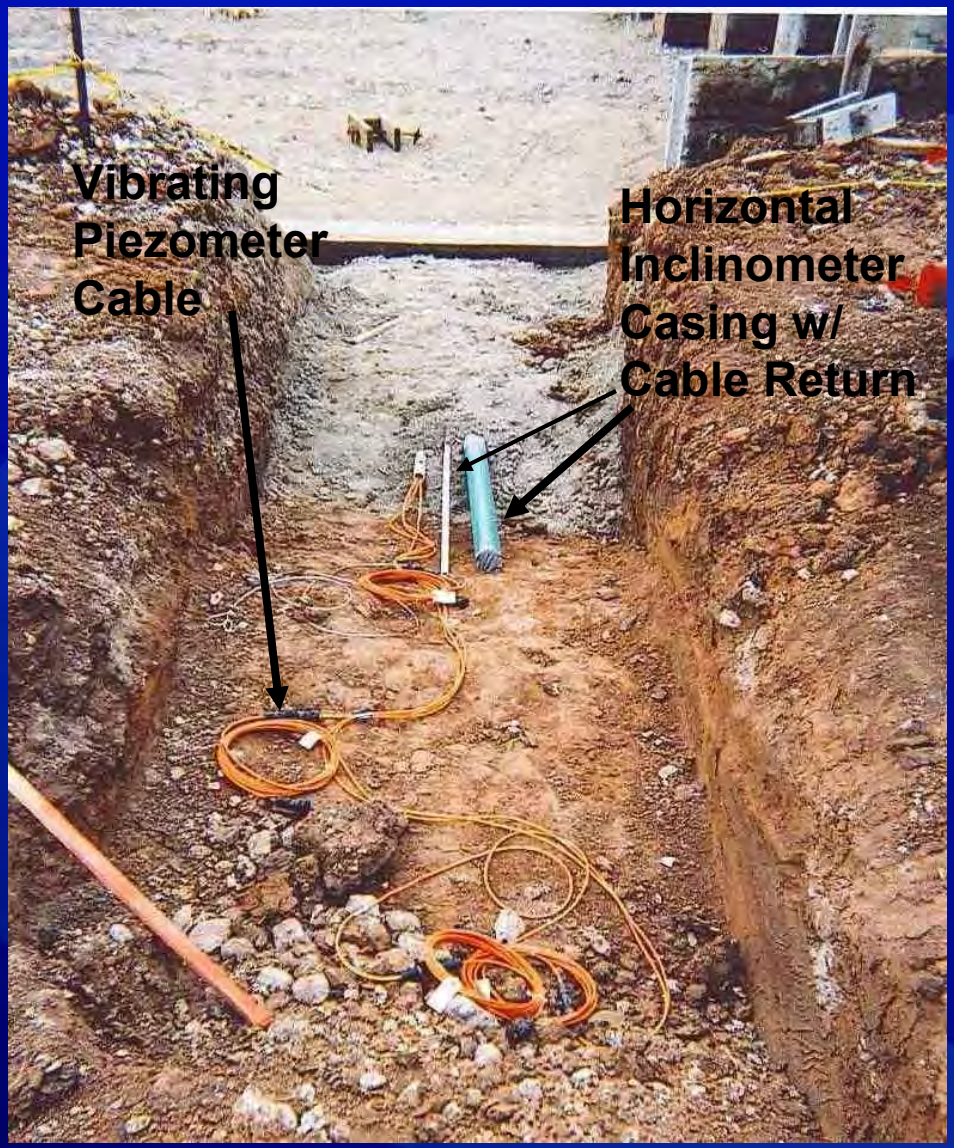
Instrumentation Installation



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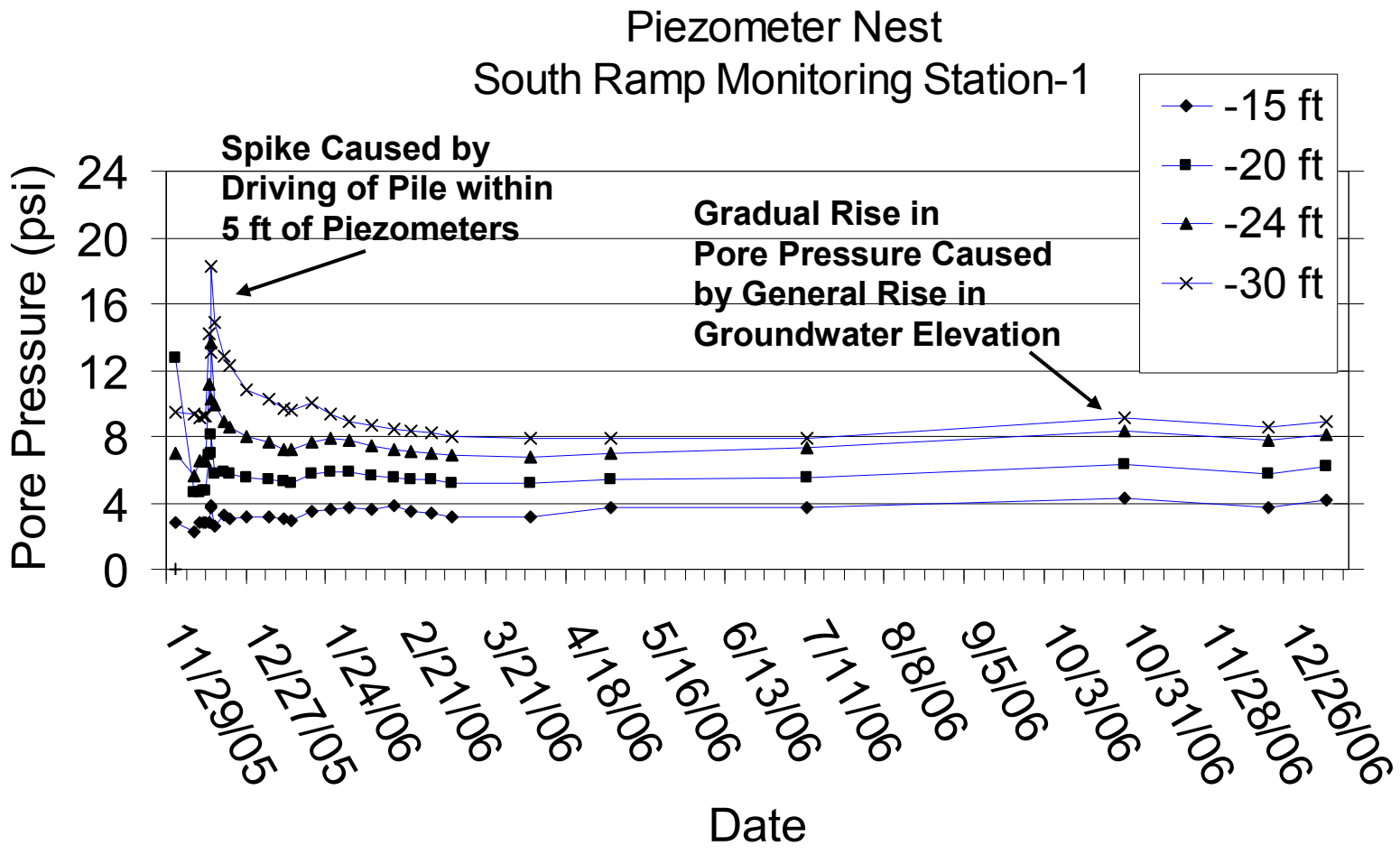
Instrumentation Monitoring Results



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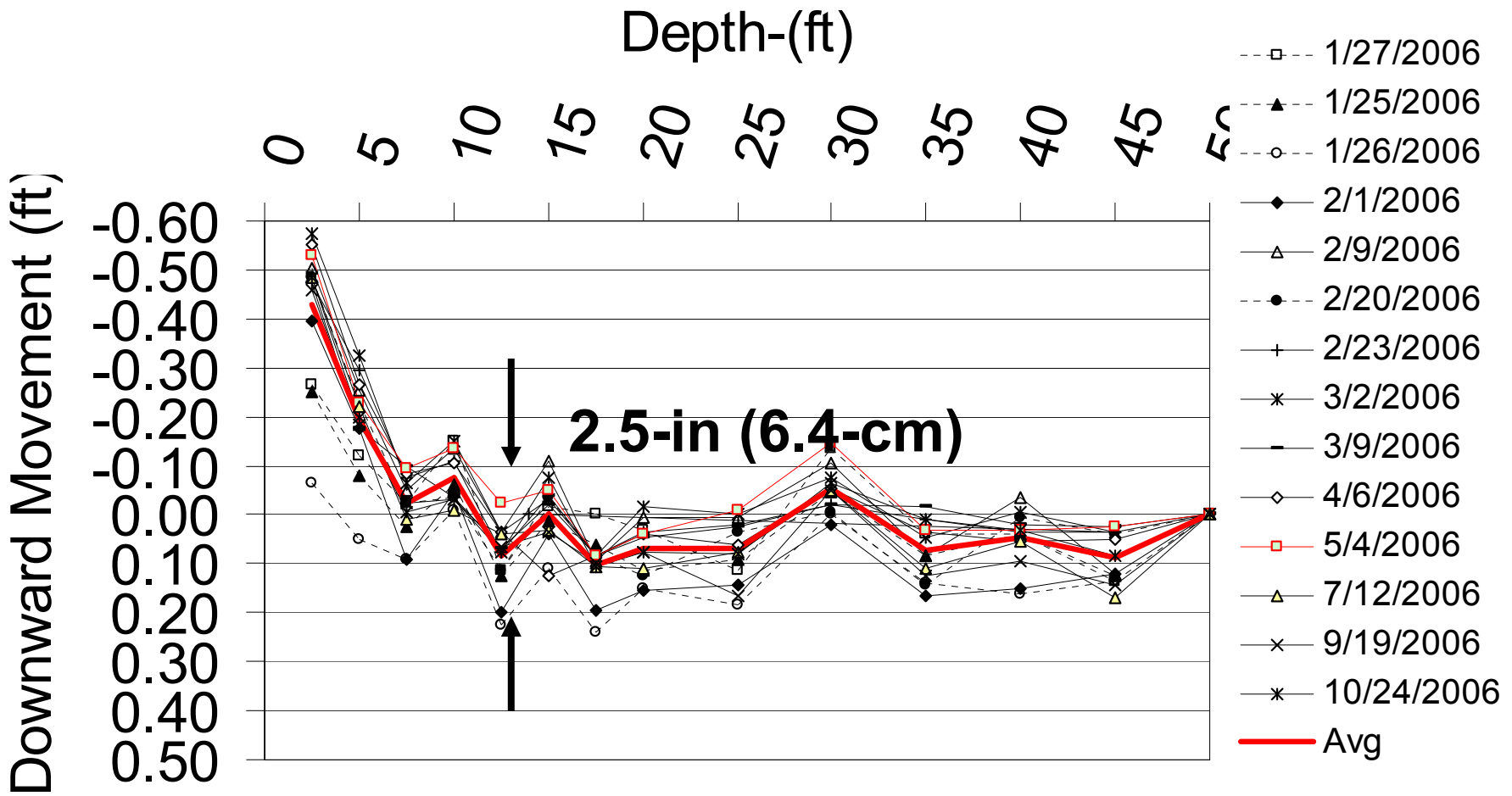
Instrumentation Monitoring Results

Sondex Settlement System- South Ramp-West



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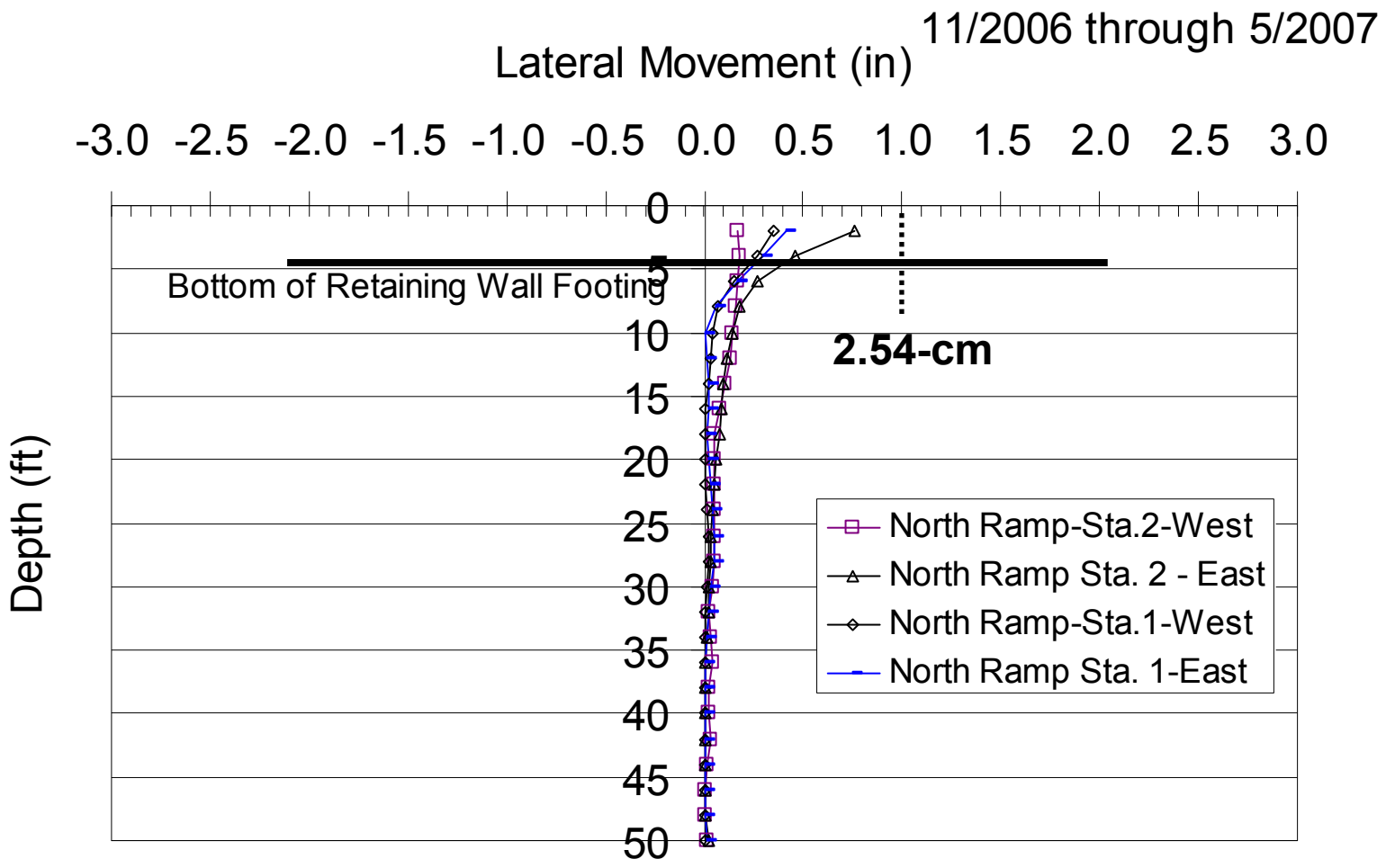
Instrumentation Monitoring Results

Vertical Inclinometers at North Ramp



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NORTH ABUTMENT

SOUTH ABUTMENT

NORTH RAMP

SOUTH RAMP

Conclusions

-Vertical Settlement 2.5 to 3-inches

-Horizontal Displacement < 1.5-inches

-Rapid Pore Water Pressure Dissipation Afforded by Radial Drainage into RAPs

-Vertical Displacement < 2-inches Post-Construction

- Complied with FHWA requirements

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Questions?

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