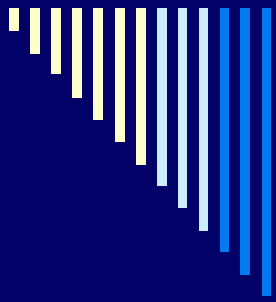


Class I and Class II Micro-Piles with Hollow- Bar Reinforcement

**Load Tests and Performance
Measurements**



Introduction

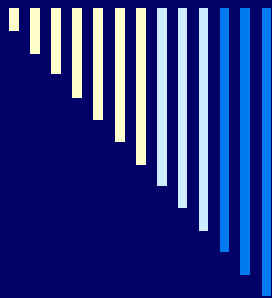
Hollow-Bar Characteristics

(based solely upon our observations
and the
comments of other competent designers
of our acquaintance)

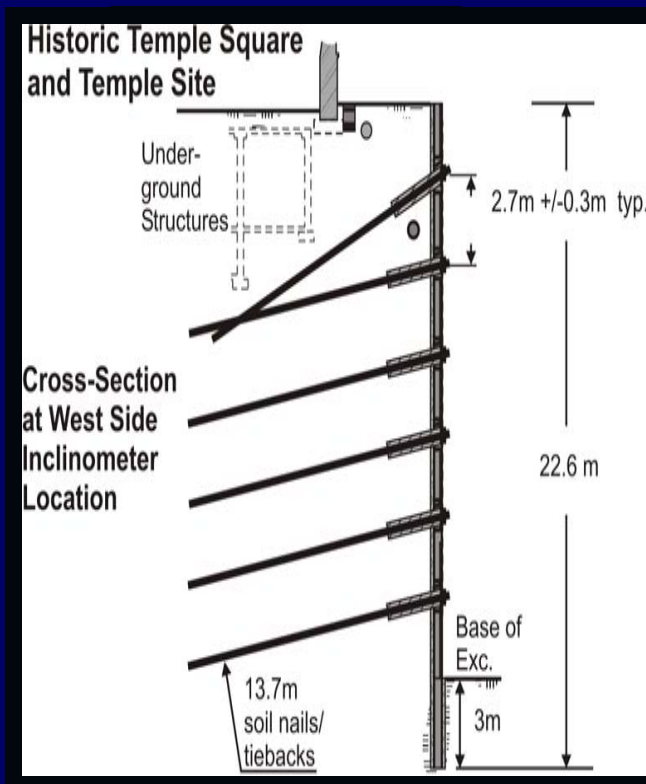
Hollow-bars Provide Our Contractor Clients Construction Characteristics They Desire:



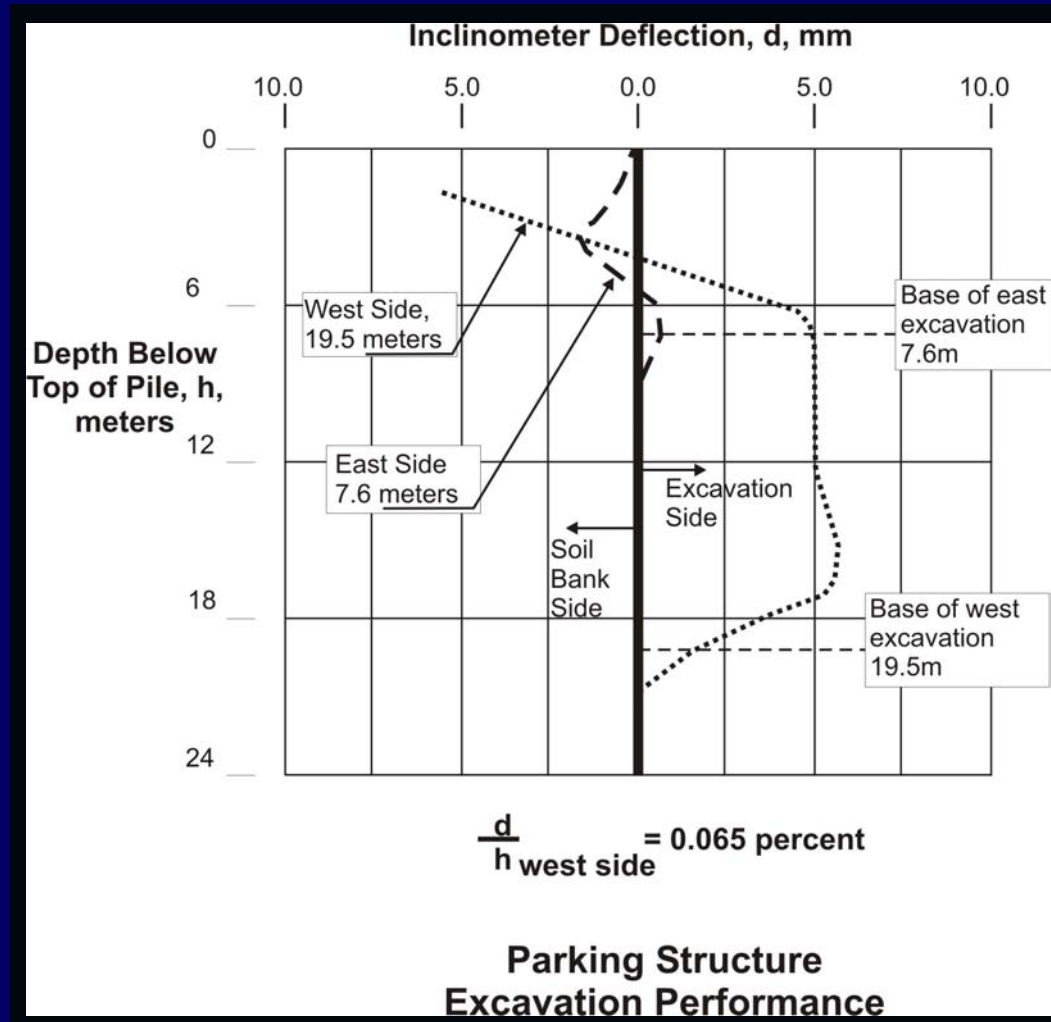
- ❑ Simple installation in caving and squeezing soils
- ❑ High skin friction
- ❑ Easy installation with common drilling equipment

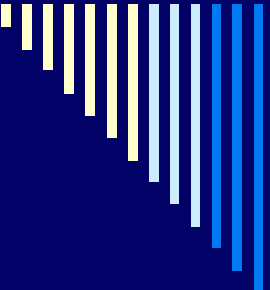


Twenty-Two Meter Soil Nail Excavation With Structural Face

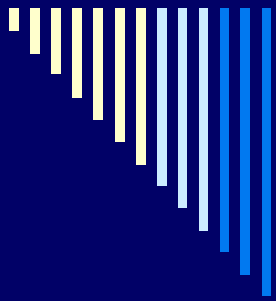


Typical Performance Results





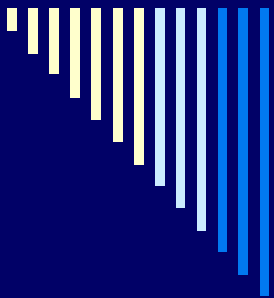
**Drill Hole Support
And Ground
Improvement
(with Grout having
Specific Gravity = 1.8)**



Drill Hole Support
And Ground
Improvement



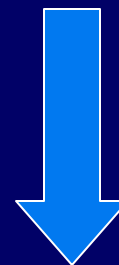
**Drill Hole Side Walls
Do Not Yield
(soil particles
do not “disengage”
or relax)**



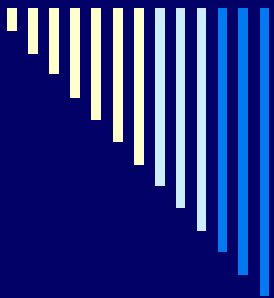
Drill Hole Support
And Ground
Improvement



Drill Hole Side Walls
Do Not Yield



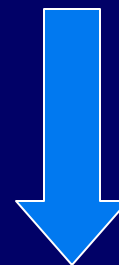
**Soil Arching
Continues
Without
Interruption**



Drill Hole Support
And Ground
Improvement



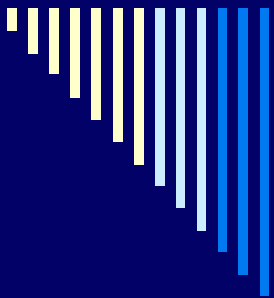
Drill Hole Side Walls
Do Not Yield



Soil Arching



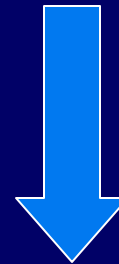
**Low Yield Structures
That Behave as
A Contiguous Mass
Of Earth**



Drill Hole Support
And Ground
Improvement



Drill Hole Side Walls
Do Not Yield

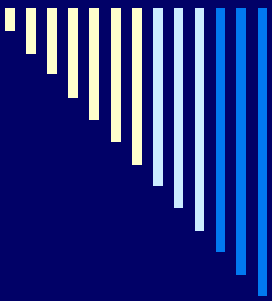


Low Yield Structures
That Behave as
A Contiguous Mass
Of Earth



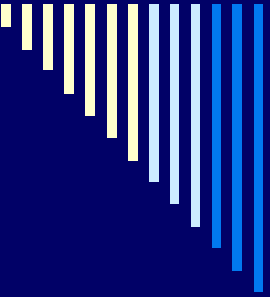
Soil Arching

**Consistent Behavior observed in all of over a
hundred structures we have designed**



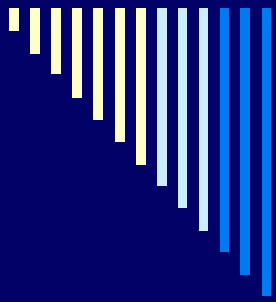
Hollow-Bar Micro-Piles

- Exploit These Characteristics
 - Present Additional Possibilities
-



Additional Characteristics Attractive to Contractors re Hollow-Bar Micro-piles

- Several low to medium capacity piles can be economically placed to support foundations
 - Small and *inexpensive* equipment can be used for limited access projects.
-



The key

for us

Is

“Small Equipment”

Class I Load Tests

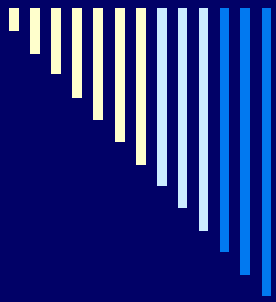
**Utah State
Capitol
Building
Seismic
Renovation
And Restoration
Project**





Utah State Capitol Project

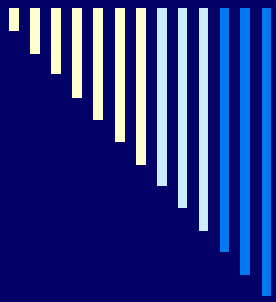
- Install a complete base isolation system to support the 100 year old building during a M 7.4 seismic event.
-



Project Requirements

(all areas but center rotunda)

- **Remove existing basement slab down to foundation soil.**



Project Requirements

(all areas but center rotunda)

- Remove existing basement slab down to foundation soil.
- **Construct an independent load transfer system.**



Project Requirements

(all areas but center rotunda)

- Remove existing basement slab down to foundation soil.
 - Construct an independent load transfer system.
 - **Temporary suspend the building on this load transfer system, in a phased manner.**
-



Project Requirements

(all areas but center rotunda)

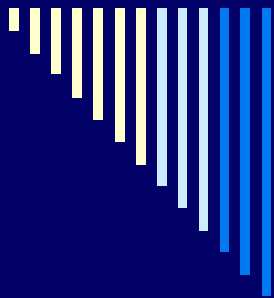
- ❑ Remove existing basement slab down to foundation soil.
 - ❑ Construct an independent load transfer system.
 - ❑ Temporary suspend the building on this load transfer system, in a phased manner.
 - ❑ **While temporarily suspended, remove the base of every column in the building and fit it with a base isolator.**
-



Project Requirements

(all areas but center rotunda)

- ❑ Remove existing basement slab down to foundation soil.
 - ❑ Construct an independent load transfer system.
 - ❑ Temporary suspend the building on this load transfer system, in a phased manner.
 - ❑ While temporarily suspended, remove the base of every column in the building and fit it with a base isolator.
 - ❑ **Construct and complete a structural mat to carry all of the base isolators throughout the building.**
-

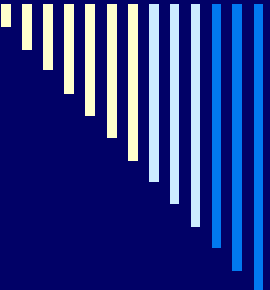


Basement Columns Set At 4.3 Meter Centers Throughout (except Rotunda).



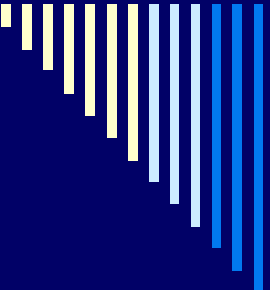
Load Transfer Foundation Performance Requirement

No movements any greater than 8 mm
after loading is commenced



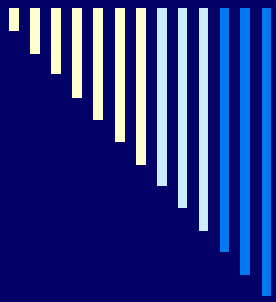
Hollow-bar micro-piles chosen to provide inexpensive, multiple supports throughout. Over 3,000 micro-piles were required for entire project.





Cost Savings over all other
methods/bidders - \$1,000,000 +



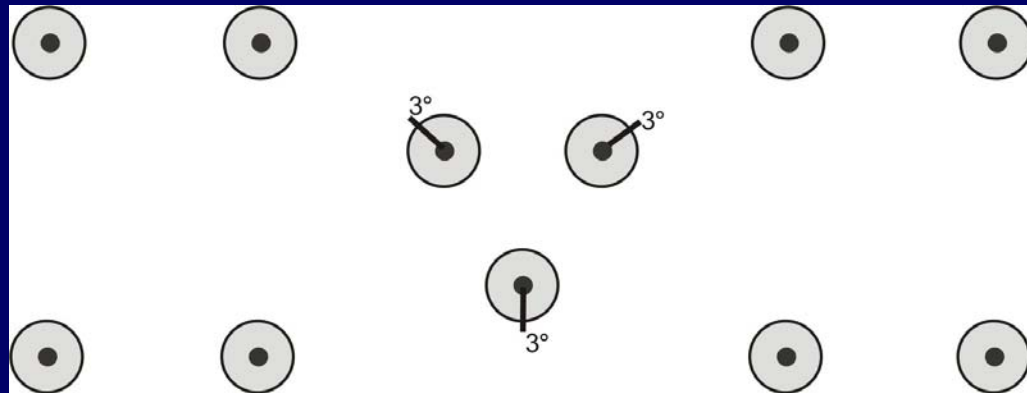


- Load Tests - Load Transfer Foundations

- Pre-bid micro-piles tested individually to establish validity of system and provide basis for bid.
 - Production piles tested in group to verify capacity.
-



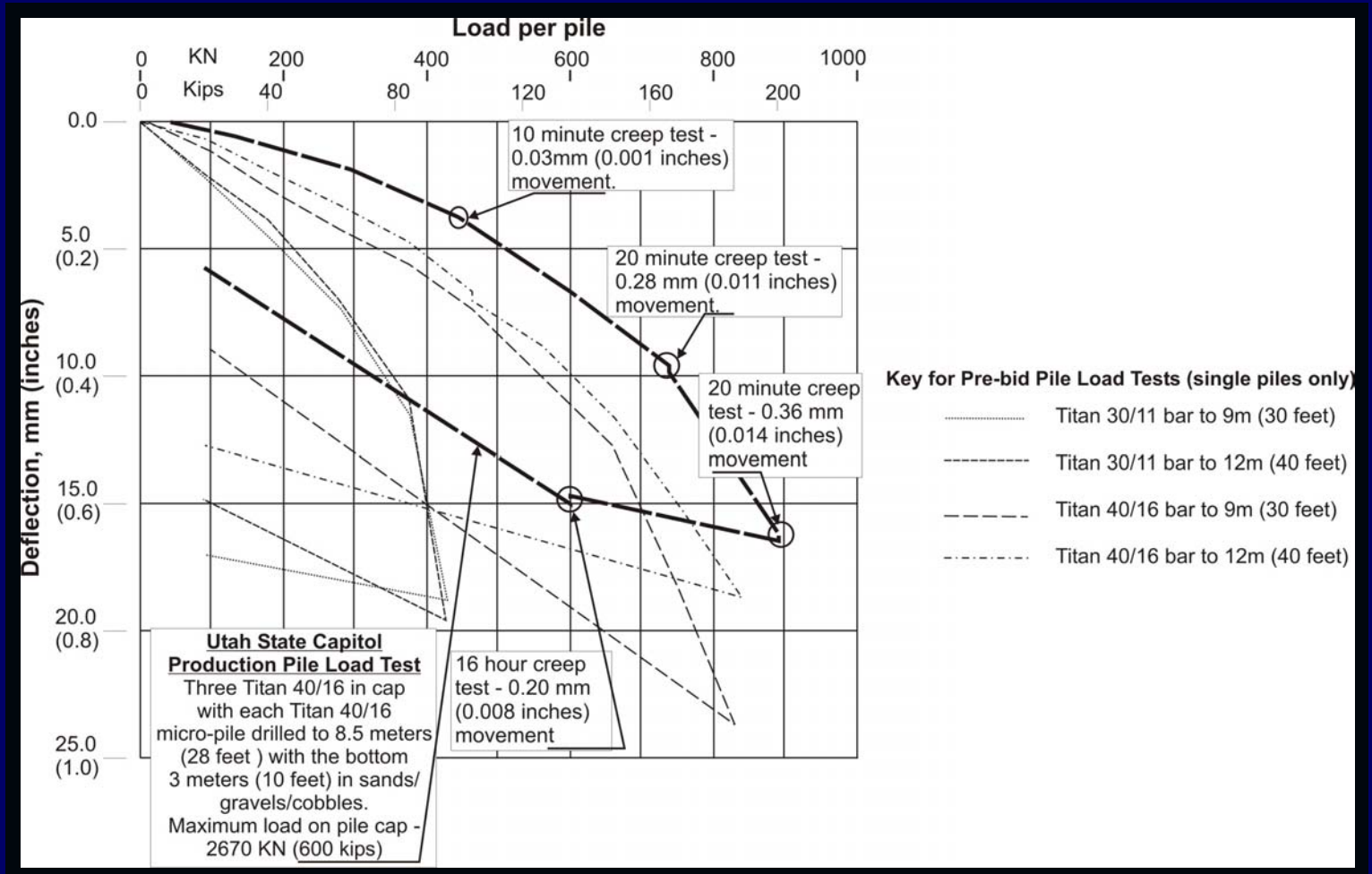
Micro-Pile Test Layout

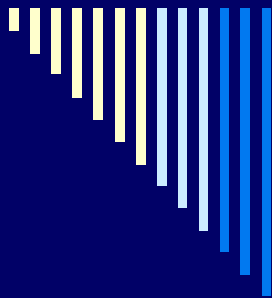


Pile Group Load Frame



Capitol Load Test Results





Four Additional Projects Recently Tested

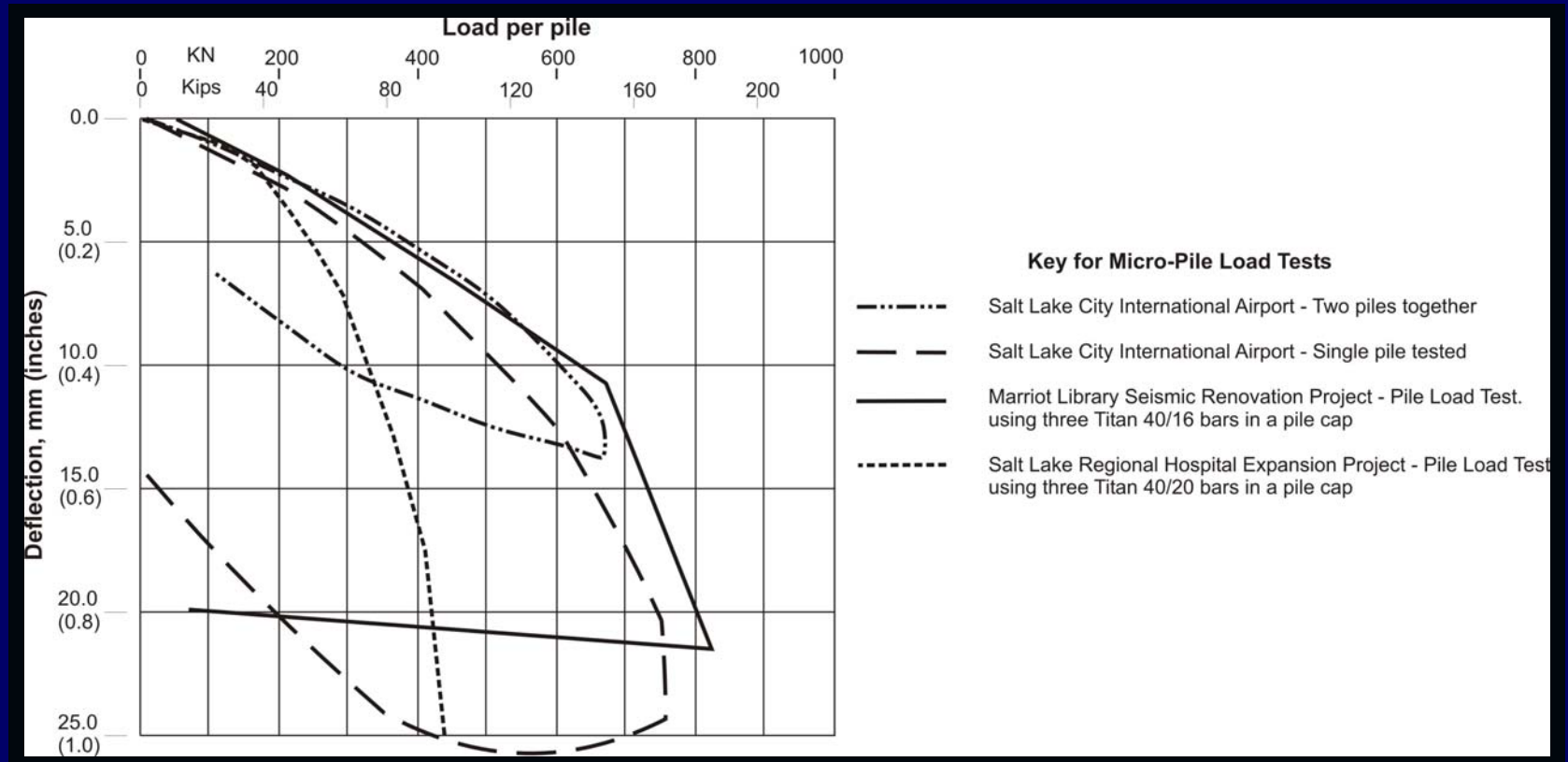
- Salt Lake City International Airport
 - Marriot Library – Seismic Retrofit
 - Salt Lake Regional Hospital Expansion
 - LDS Tabernacle Renovation and Seismic Upgrade
-

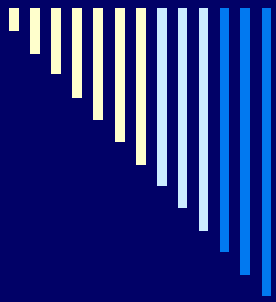


Soil Conditions (first three)

- Marriot Library – Medium Stiff Clay with no groundwater
 - Salt Lake City Airport – Soft, silty clay with thin layers of silty fine sand; groundwater at approximately 2 m
 - Hospital - Disturbed (fill) soft silty clay; groundwater at 2m-3m
-

Other Projects Test Results





Test Implications





Test Implications

- Single piles likely buckled for failure
-



Test Implications

- Single piles likely buckled for failure
 - Group tests show ground improvement
-



Test Implications

- Single piles likely buckled for failure
 - Group tests show ground improvement
 - Individual piles in group show much greater unit capacities
-



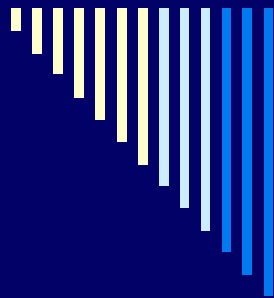
Test Implications

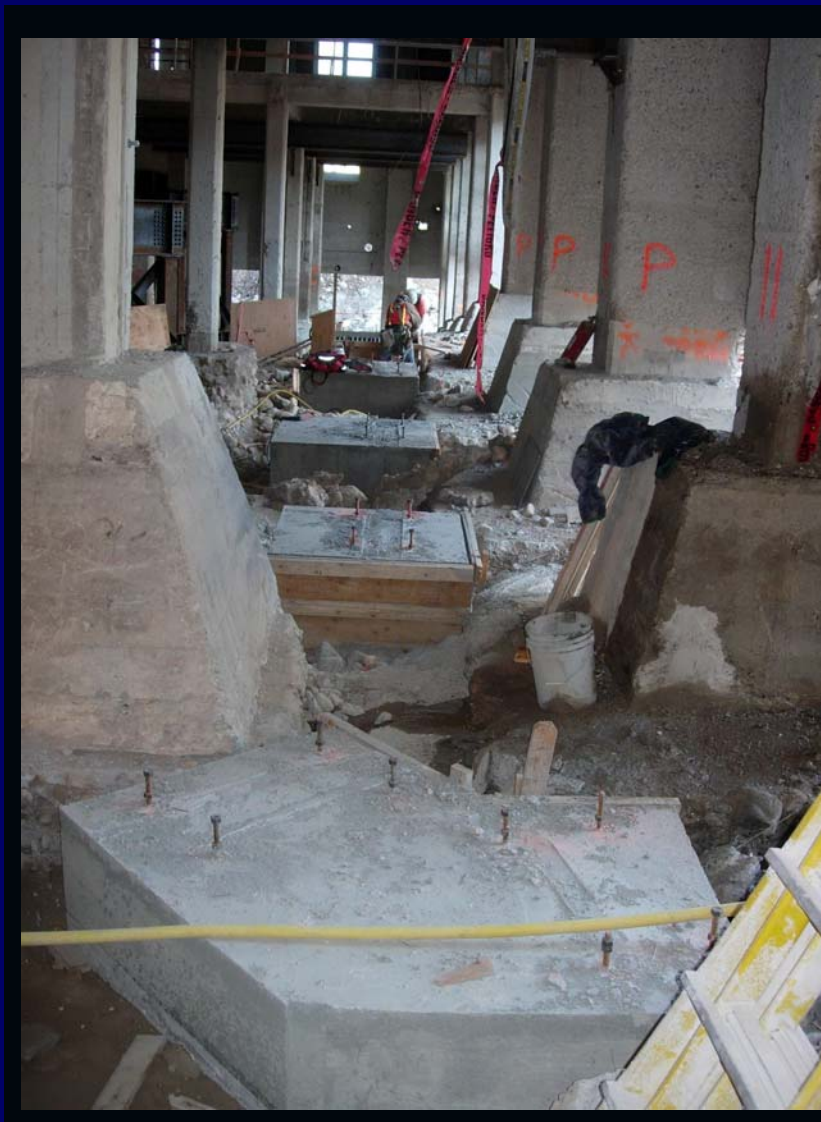
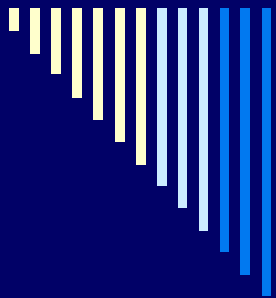
- Single piles likely buckled for failure
 - Group tests show ground improvement
 - Individual piles in group show much greater unit capacities
 - Group possibly a stiffer system
-

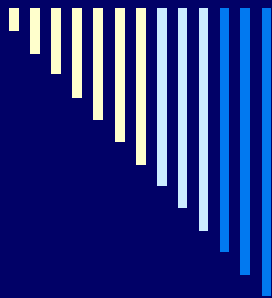


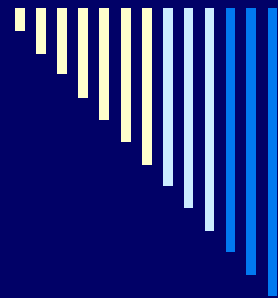
95 percent of Load Transfer complete – no more than 4 mm of settlement measured

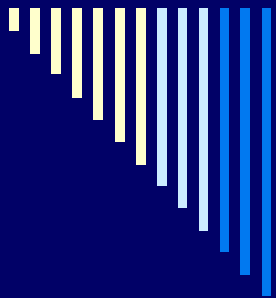


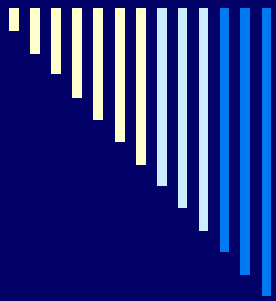












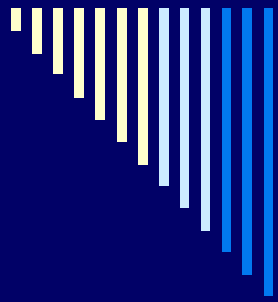
Class II Micro-Piles Rotunda Support

- Permanent Support
- Two New Mats (3m by 10.5m) – Support Each Buttress Pier
- Maximum Load – 960 kPa
- 9mm Maximum Deflection



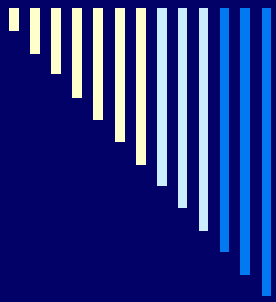
Design Constraint

- 3 meter Layer of Medium Stiff Silty Clay at 5 meters below grade
 - Maximum past pressure – 240 kPa
 - Estimated deflection of original design
----- 50 to 70 mm -----
-



Direct support using larger piles – such as the Titan 73/53 pile – was not possible.

Access required for a drill rig large enough to install these piles could not be provided



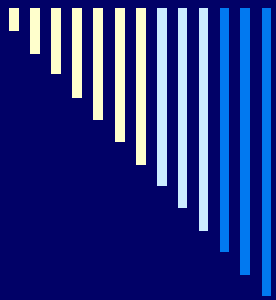
Indirect Support Chosen





Indirect Support Chosen

- **No direct coupling to foundation (terminate 50 to 75 mm below mat)**
-



Indirect Support Chosen

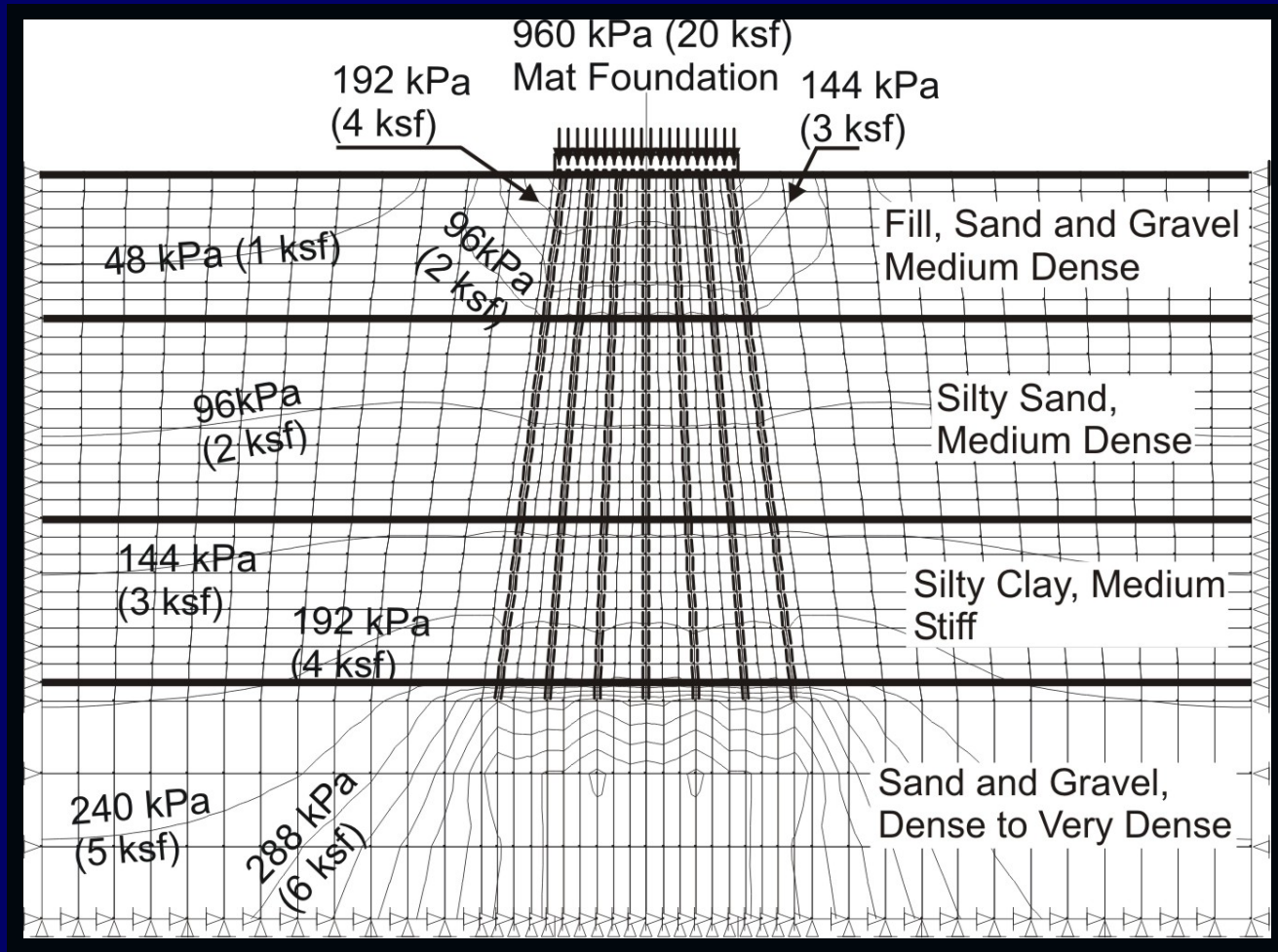
- No direct coupling to foundation (terminate 50 to 75 mm below mat)
- **Stiffen soil with network of Titan 40 mm bars to use BOTH soil and micro-pile capacity**

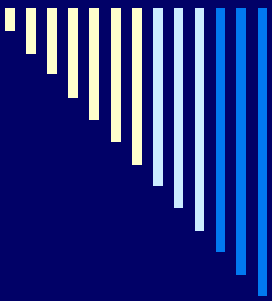


Indirect Support Chosen

- No direct coupling to foundation (terminate 50 to 75 mm below mat)
 - Stiffen soil with network of Titan 40 mm bars to use BOTH soil and micro-pile capacity
 - **Limit Pressure within zone of clay soil to 240 kPa**
-

FEM Design for Stresses only





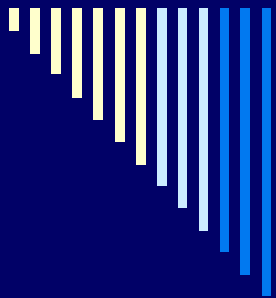
Rotunda Mats Drilled and Instrumented with Pressure Cells



Two Pressure Cells at each of Two Mat Locations:

One cell at 0.5 meters and one at 1.7 meters to allow contouring of pressures beneath the loaded mat





THE RESULTS

Not Available YET!!!

Six months of delays for this part of the project

Loading the first instrumented mat next week

Results to be included
in Final Paper Submittal for this Conference



Some Conclusions

- **Hollow-Bar Micro-Piles can be installed with little or no yield of surrounding soil**
-



Some Conclusions

- Hollow-Bar Micro-Piles can be installed with little or no yield of surrounding soil
 - **Reasonably high compressive capacity**
-



Some Conclusions

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-



Some Conclusions

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 - **Group capacity enhanced by arching and soil improvement**
-



Some Conclusions

- Hollow-Bar Micro-Piles can be installed with little or no yield of surrounding soil
 - Reasonably high compressive capacity
 - Excellent skin friction characteristics
 - Group capacity enhanced by arching and soil improvement
 - **Low deflections possible at little or no increase in cost**
-



Other Applications: Composite Walls



Other Applications: Composite Walls

- Micro-piles stiffen face as the vertical element
-



Other Applications: Composite Walls

- Micro-piles stiffen face as the vertical element
 - Stiffness can be varied according to project requirements by different pile diameters, spacing and number of rows
-



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 - Create a simple curtain wall to depths of 20 meters or more
-



Other Applications: Composite Walls

- Micro-piles stiffen face as the vertical element
 - Stiffness can be varied according to project requirements by different pile diameters, spacing and number of rows
 - Stabilization of loose materials for easy excavation
 - Create a simple curtain wall to depths of 20 meters or more
 - Provide direct support for columns and walls on top
-



LDS Tabernacle Project

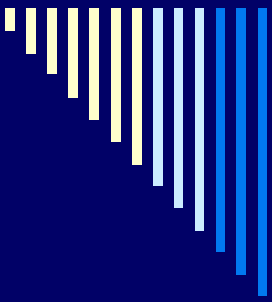
- Seismic Renovation
 - Basement Construction
-

Basement Extension – 8 meters

Support of existing wall eliminated the need for off-loading.

Eliminated a temporary support system and a complete new wall from construction.





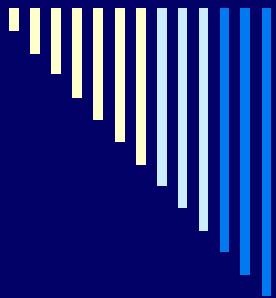






Acknowledgments

- Becho Inc. (SLC)
 - Build Inc. (SLC)
 - Ralph Wadsworth Construction (SLC)
 - Nicholson Construction (SLC Office)
 - Jacobsen Construction (SLC)
 - Okland Construction (SLC)
 - Ischebeck Company of Ennepetal,
Germany
-



Thank You
