Support of an Excavation Face with Micropiles

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SPACE….. the final frontier….

Space and time are merging together to become THE continuum for geo-structures designers.

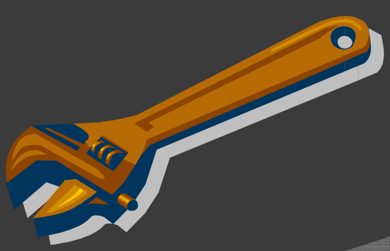
Today our work is driven by intense competition for

Less COST

Less SPACE

Less TIME

More and more we are pushed to take soil…which is a blunt instrument…



…. and use
it as a
scalpel.

One formula for space and time efficient excavation…

A (generally) efficient wall design – Soil Nailing

+

Easily tailored, vertical improvement elements - Micropiles

= A Composite Wall Design

Composite Structure:

A structure in which all of the elements function together, including **steel**, **concrete** *and* **soil**.

Designed to solve specific problems.

Typical Problems:

- Limited Access (build within centimeters or even beneath existing walls)
- Load Support (directly on shoring walls)
- Accessibility for Heavy Construction Equipment
- Headroom Limitations
- Face Stability
- Groundwater Control
- etc……ad nauseam …. ad infinitum

…used where we do not have the ability to build traditional soldier pile, secant pile, steel sheet pile or slurry wall systems.

...for the purposes of this discussion, micropiles refer to center reinforced micropiles, not cased.

Composite Walls

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- Stabilize of loose materials for easy excavation
- Create a simple curtain wall
- Provide direct support for columns and walls on top

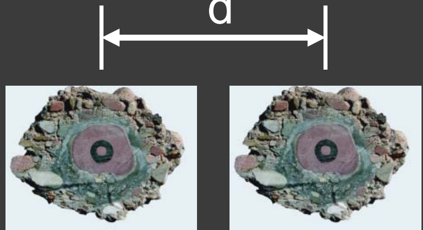
A simple example:

Problem: Stabilize talus face to create a vertical soil nail wall

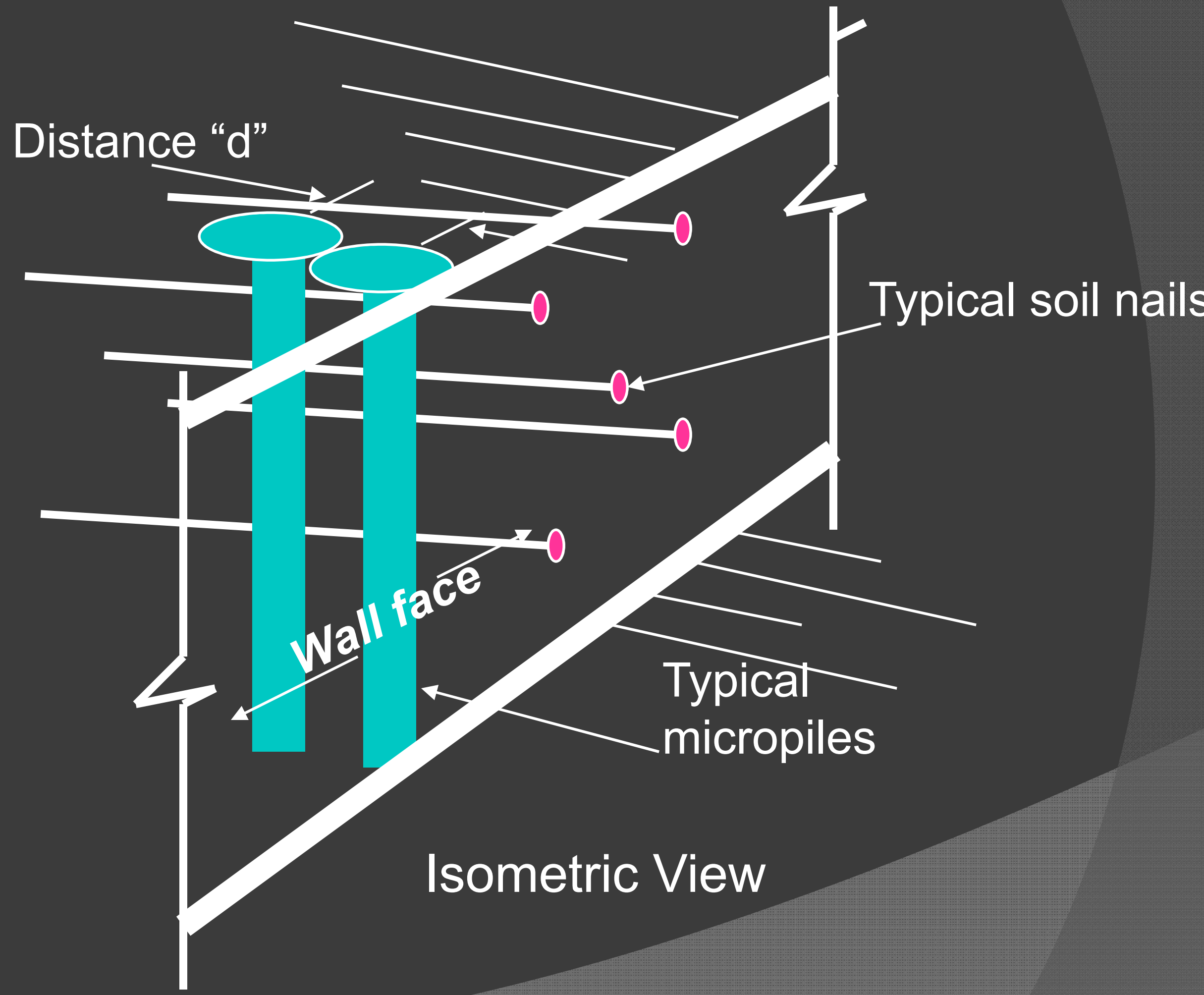
- Micropiles added to create grout columns and control face stability.
- No drilled piers or driven piles to achieve vertical face.

A simple way to look at a stiffness design using multiple rows of micropiles…..

Distance "d"

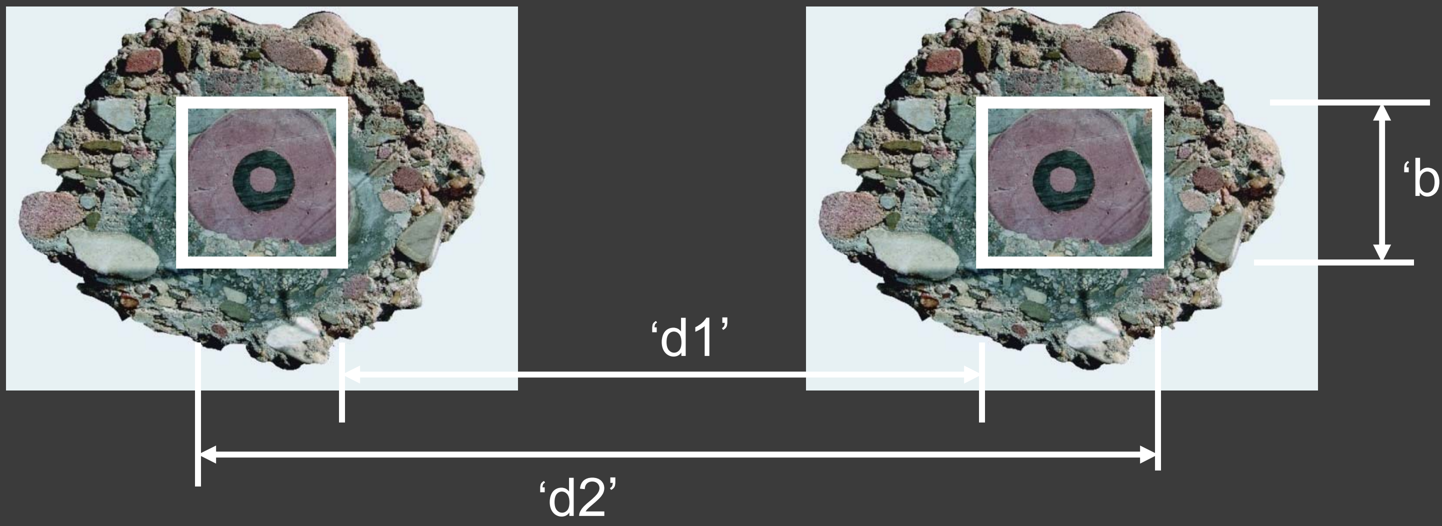


Plan View of Micropiles



This offset distance "d" between piles implies …….

Stiffness Estimate



$$S_x = \frac{b\,(d2^3 - d1^3)}{6\,(d2)}$$

… A simplified and conservative estimate,
to **approximate** the solution

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- Micropiles reinforce soil just as rebar reinforces concrete.
- Stiffness roughly estimated by section modulus, Sx, created by two elements a distance ‘d’ apart….caused by arching between elements.
- Stiffness increased by placing pairs closer or adding rows to solve specific problems.
- **Soil nail spacing designed to reduce stiffness requirements at the face.**

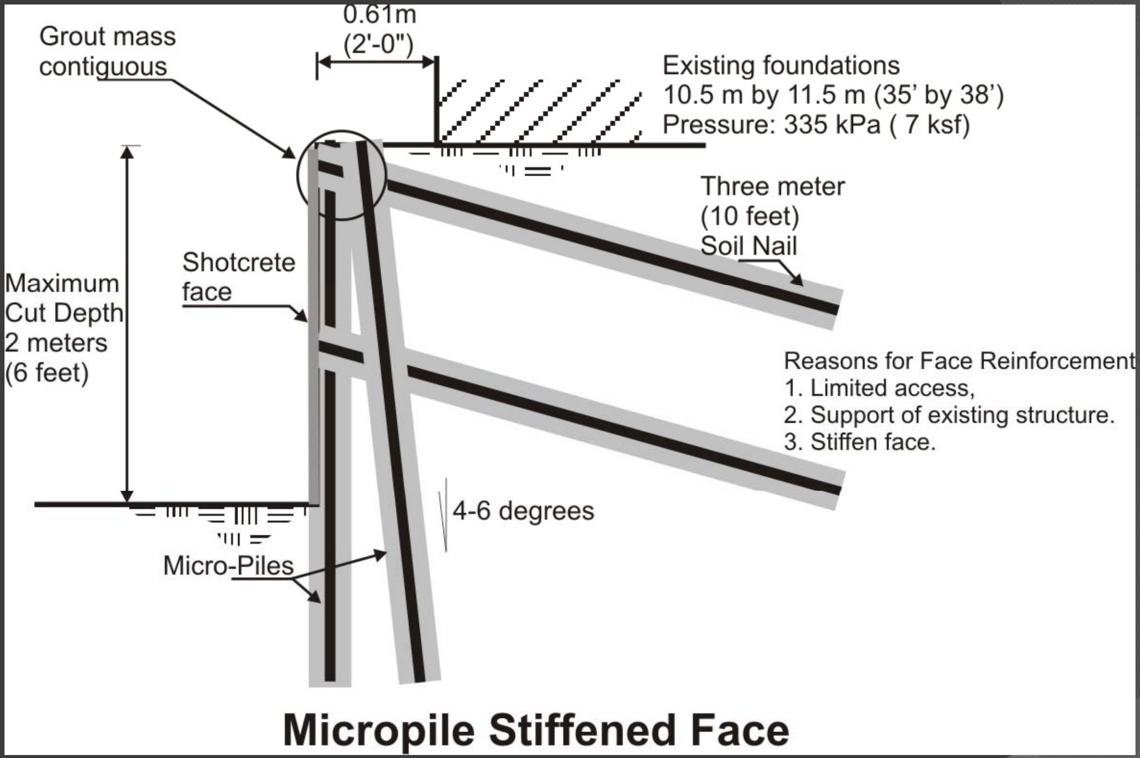
However:

- This a not precise calculation (arching factors, development length, material variations, construction imprecision, etc. etc. etc.)
- Other proven methods (Goldnail, SnailWin, SlopeW, etc.) needed to compare and complete the sizing of elements.

Case Histories

No 1

- Old foundations carried 335 kPa
- Distance between micropiles in "A" frame varied to provide req'd Sx with depth
- Sx minimized by tieback spacing (shorter cuts used one tieback and walls with no foundation used just "A" frame).



No 1

- Individual "A" frame grout bulb being measured
- Single anchor and grout bulb removed for evaluation

No 1

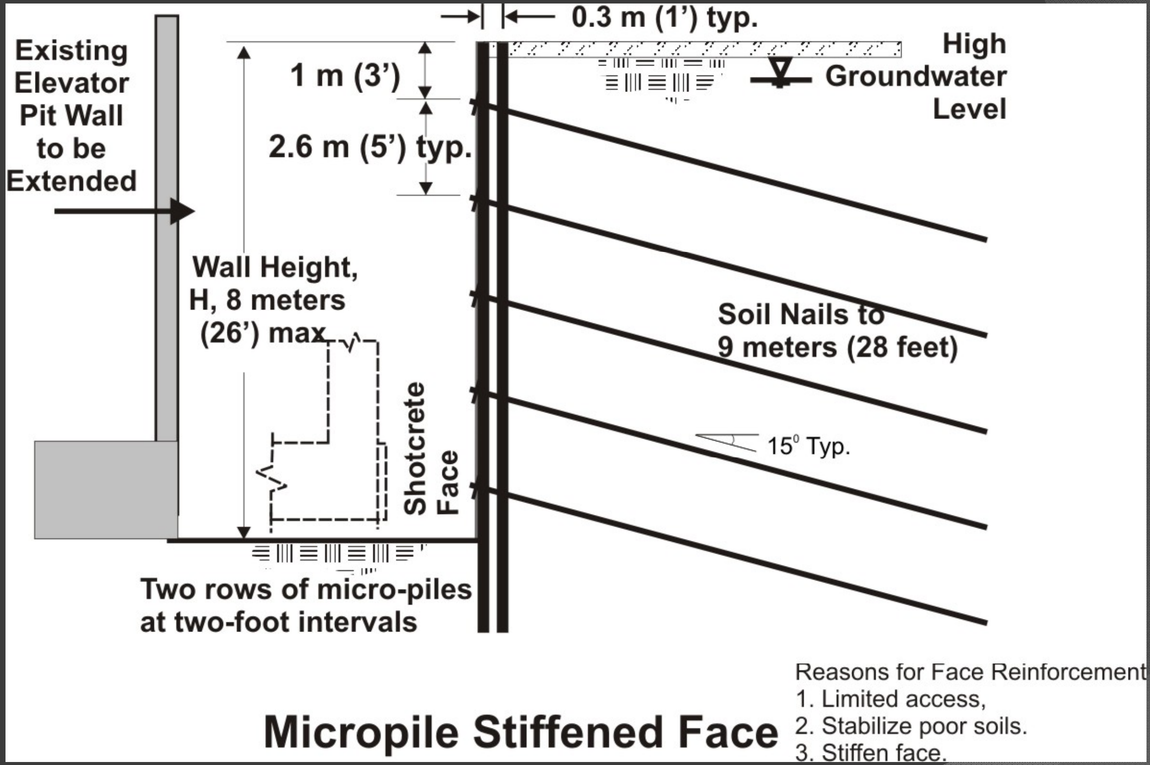
- Row of “A” frames along the side of the existing footing

- Excavation completed

No 2

Problems:

- Access - widen existing elevator pit in basement.
- Control existing groundwater levels



No 3

Problem:

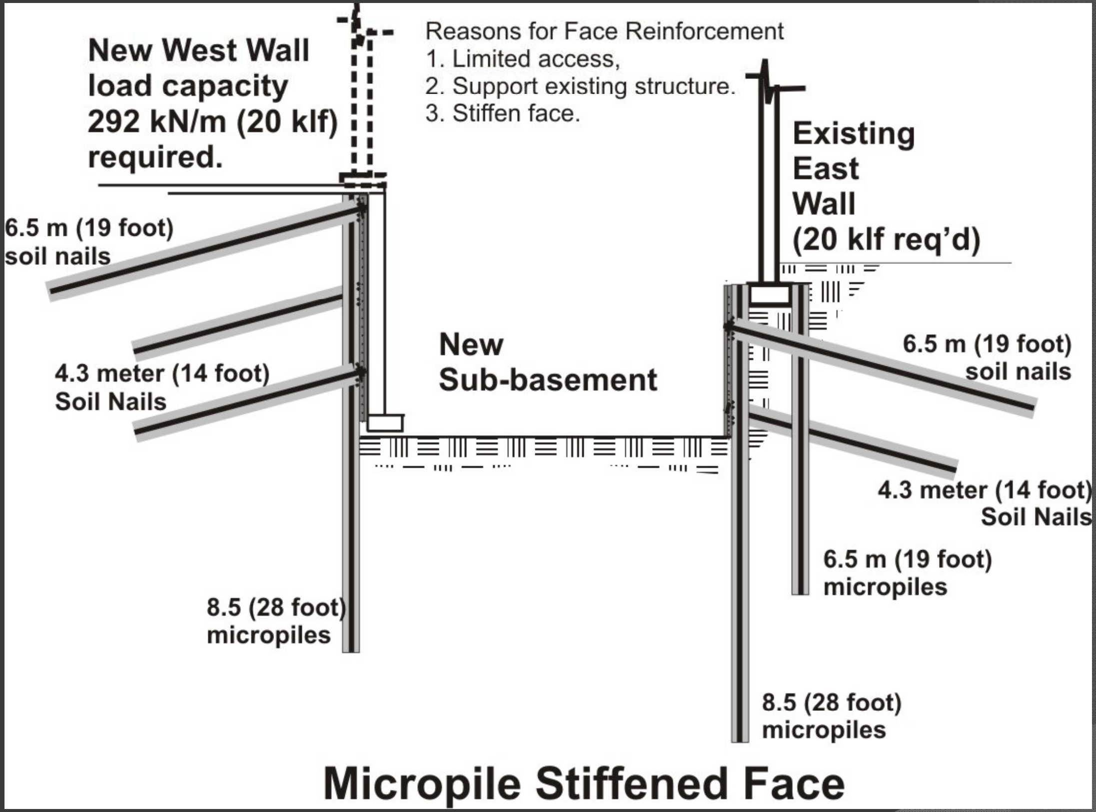
- New Basement Construction to a depth of 3 to 5 meters below original grade.
- Carry existing and future walls.
- Access – Required to do all work WITHOUT affecting existing historical structure.

No 3

- Support existing east wall to eliminate temporary support for superstructure, and construction of new wall.

No 3

- Load bearing/ wall stiffness provided by soil nails and micropiles.
- Face Stiffness varied as req'd



- North end of east wall shown with micro-piles supporting wall (both sides) and soil nails beneath.

No 3

- New basement from main floor, looking south at excavation. Micropile/soil nail supported wall in foreground. Micropile supported column in center.

No 3

- Looking south through new basement walls, column and exterior walls (location of maximum cut).
- NO adverse effects on existing building.

GDSI has designed several composite walls since 2004. Each one progressively has introduced:

Increased Complexity

Greater Size

Higher Load-Carrying Requirements

No 4

MDCI and GDSI recently completed a Design-Build of our most ambitious wall to date:

13 meter cut (42 feet)

Supports a six-story settlement-sensitive structure

Excavated through layered silt and sand

Groundwater present throughout lower half

Against the uphill side of the groundwater flow

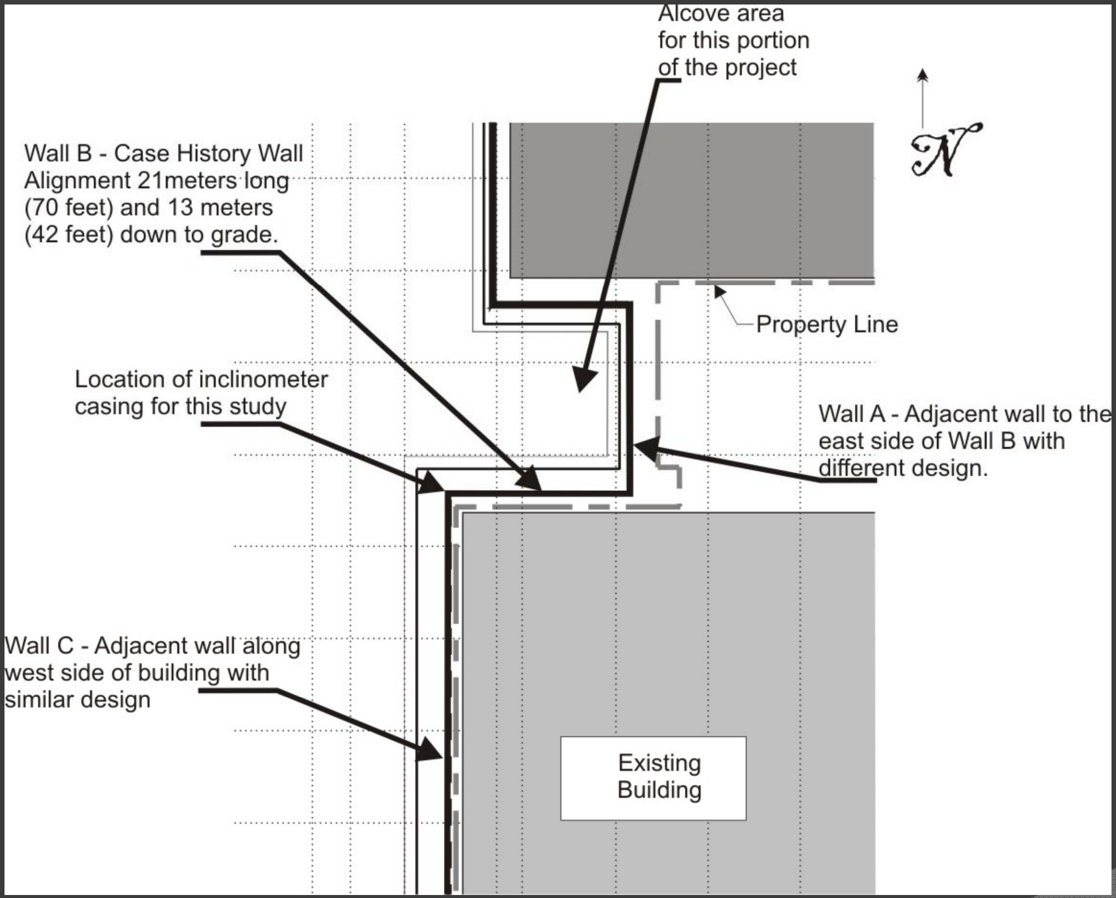
Only 60 cm (2 feet) allowed for shoring wall construction

Face of Shoring to be finished face for single form construction

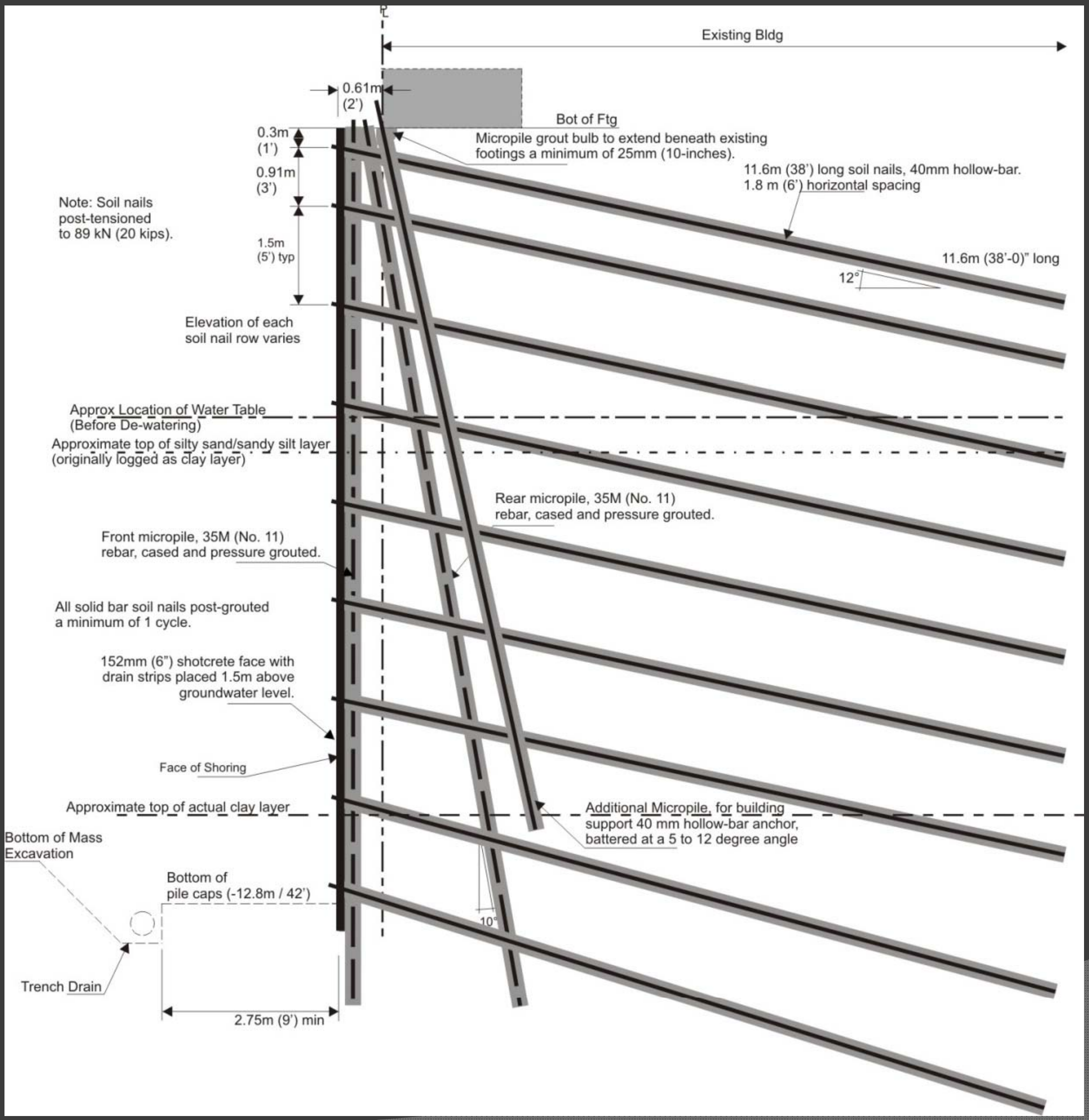
……and ultimately…..

The bottom third of the wall had to support full hydrostatic head

No 4

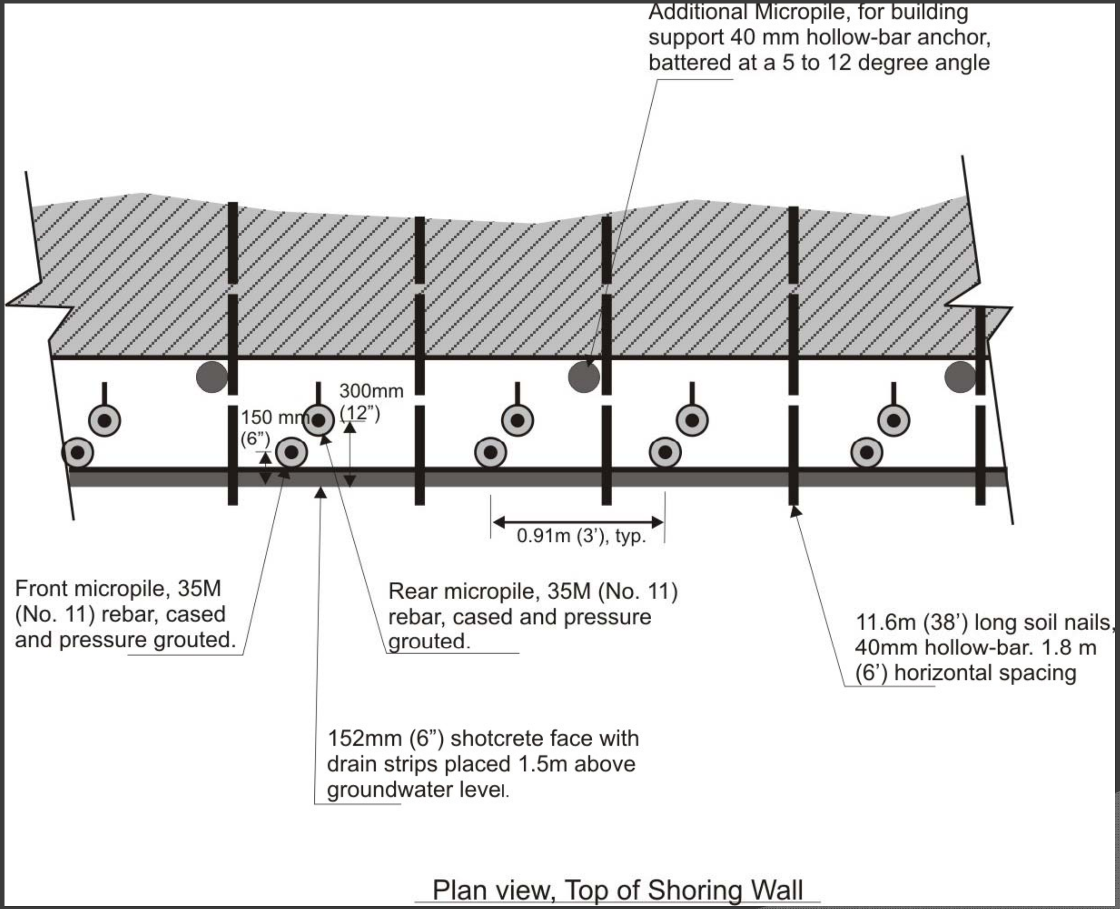

Alcove area
for this portion
of the project
N
Wall B - Case History Wall
Alignment 21meters long
(70 feet) and 13 meters
(42 feet) down to grade.
Property Line
Location of inclinometer
casing for this study
Wall A - Adjacent wall to the
east side of Wall B with
different design.
Wall C - Adjacent wall along
west side of building with
similar design
Existing
Building

No 4



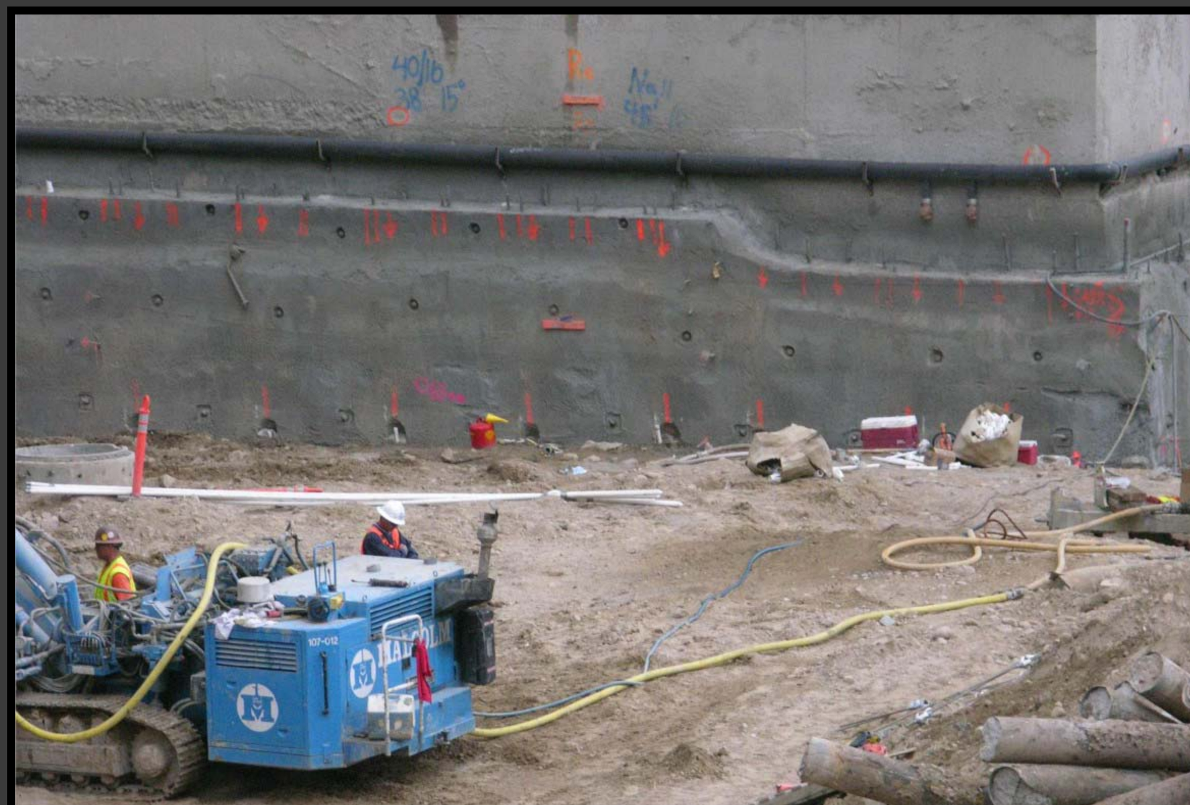
PL
Existing Bldg
0.61m
(2')
Bot of Ftg
Micropile grout bulb to extend beneath existing
footings a minimum of 25mm (10-inches).
0.3m
(1')
0.91m
(3')
1.5m
(5') typ
11.6m (38') long soil nails, 40mm hollow-bar.
1.8 m (6') horizontal spacing
11.6m (38'-0)" long
12°
Note: Soil nails
post-tensioned
to 89 kN (20 kips).
Elevation of each
soil nail row varies
Approx Location of Water Table
(Before De-watering)
Approximate top of silty sand/sandy silt layer
(originally logged as clay layer)
Rear micropile, 35M (No. 11)
rebar, cased and pressure grouted.
Front micropile, 35M (No. 11)
rebar, cased and pressure grouted.
All solid bar soil nails post-grouted
a minimum of 1 cycle.
152mm (6") shotcrete face with
drain strips placed 1.5m above
groundwater level.
Face of Shoring
Approximate top of actual clay layer
Additional Micropile, for building
support 40 mm hollow-bar anchor,
battered at a 5 to 12 degree angle
Bottom of Mass
Excavation
Bottom of
pile caps (-12.8m / 42')
10°
Trench Drain
2.75m (9') min

No 4


Additional Micropile, for building support 40 mm hollow-bar anchor, battered at a 5 to 12 degree angle
300mm (12")
150 mm (6")
0.91m (3'), typ.
Front micropile, 35M (No. 11) rebar, cased and pressure grouted.
Rear micropile, 35M (No. 11) rebar, cased and pressure grouted.
11.6m (38') long soil nails, 40mm hollow-bar. 1.8 m (6') horizontal spacing
152mm (6") shotcrete face with drain strips placed 1.5m above groundwater level.
Plan view, Top of Shoring Wall

No 4

Wall at the beginning of construction – 3 meters down



No 4

Wall down to 6.2 meters, showing micropiles, wells and seepage

No 4

Facing Elements and Soil Layering

No 4

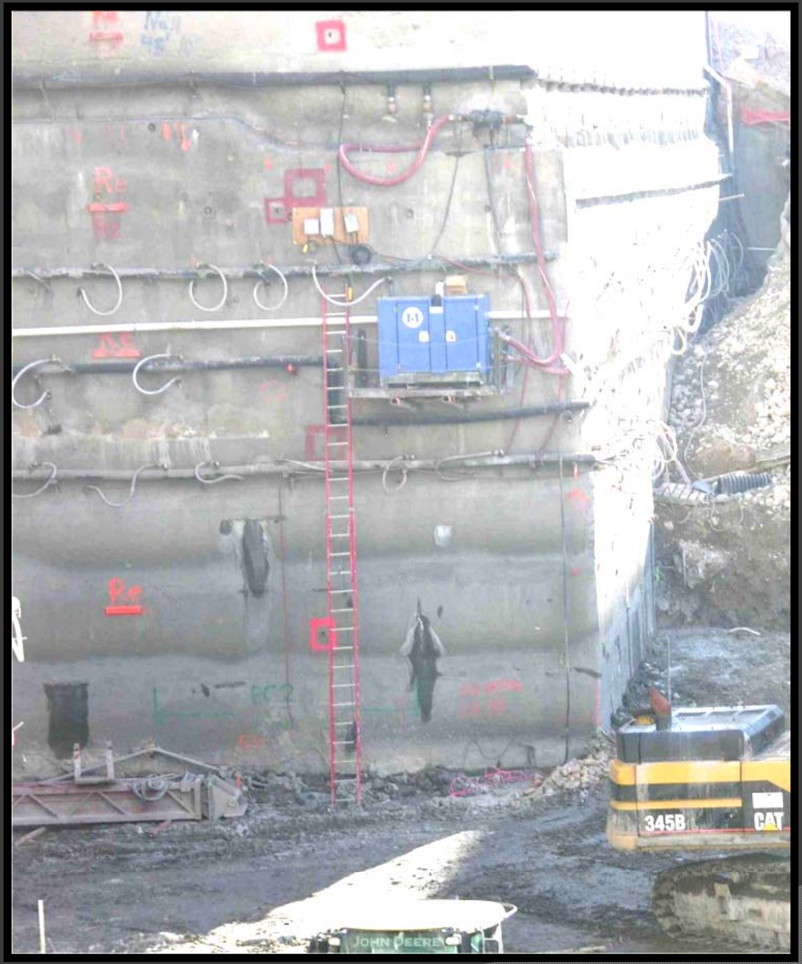
Seepage through shotcrete

No 4

Completion of Supplement Dewatering

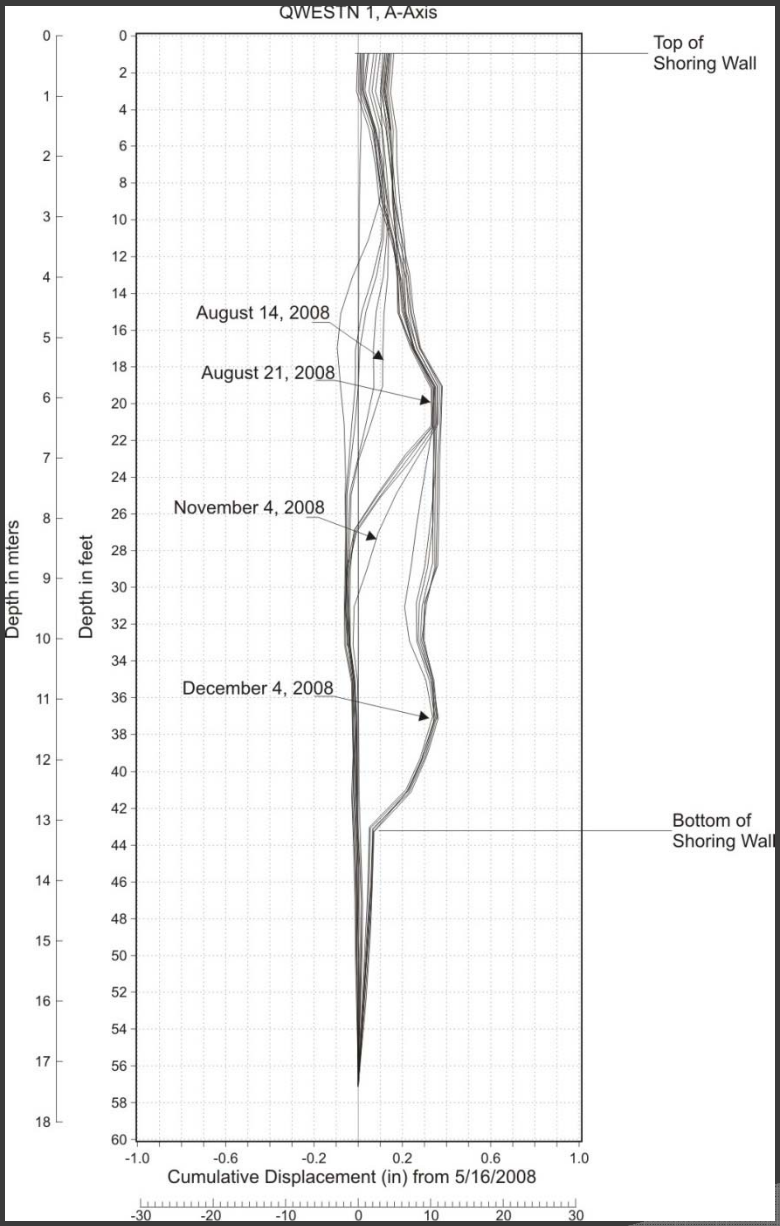
No 4

Near Completion



No 4

Performance



Future Needs...

- Data to Quantify Performance
- Modeling to Predict Performance
- Ultimately a much more Rational Method for Composite Structure Design

Thank You