Scenario 2: New Mid-rise Building with Sensitive Neighboring Buildings

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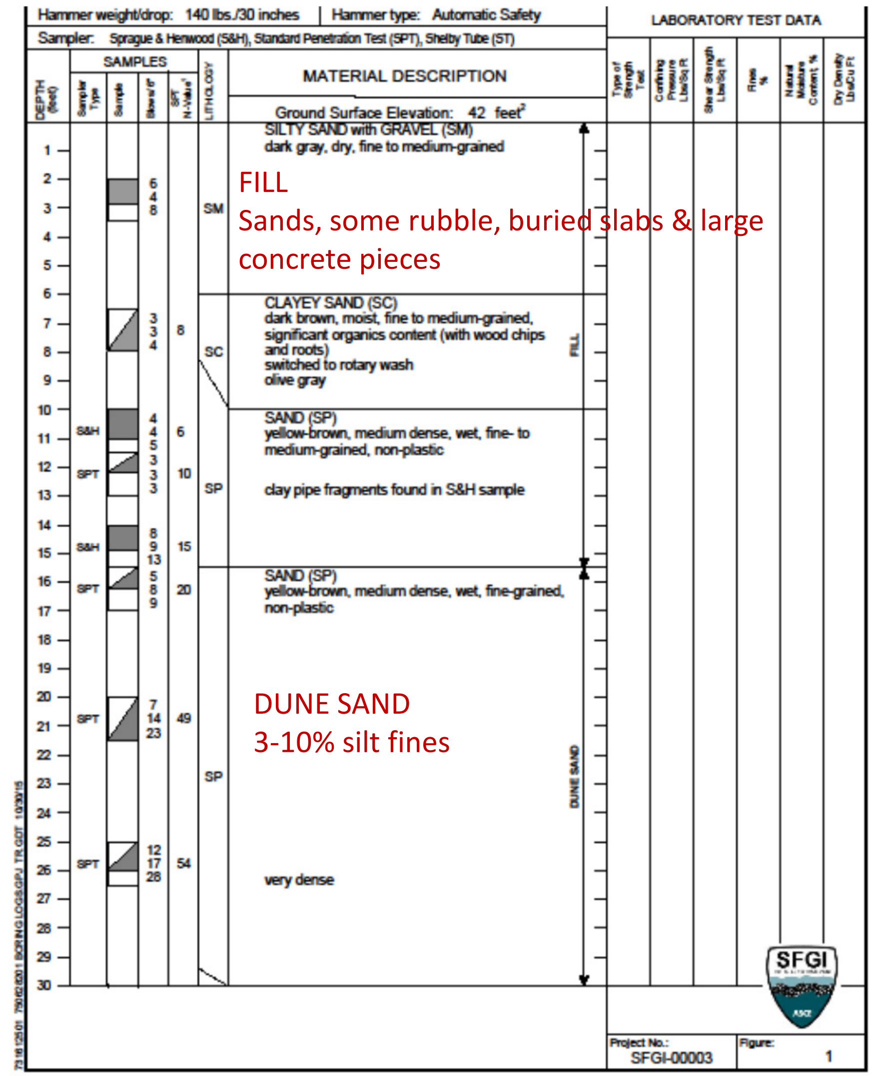
Roberto A. Lopez, P.E.
Chief Engineer, Malcolm Drilling

Scenario 2:
12-story concrete building + 1 Basement Level
P= 2000 to 2500 psf
Surrounding historic buildings

Identified geotechnical challenges:
1. Dry seismic settlement of Fill
2. Widespread liquefaction in Fill, Dune Sand & Marsh deposits
3. Compressible Marsh Deposits



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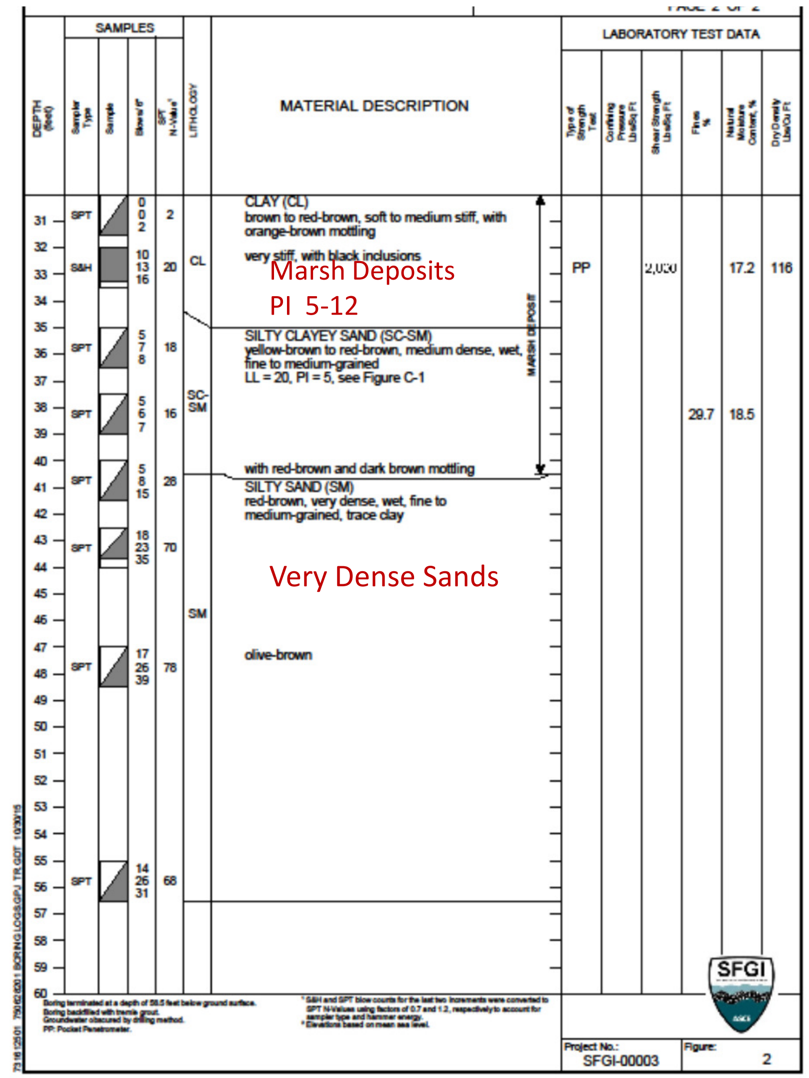
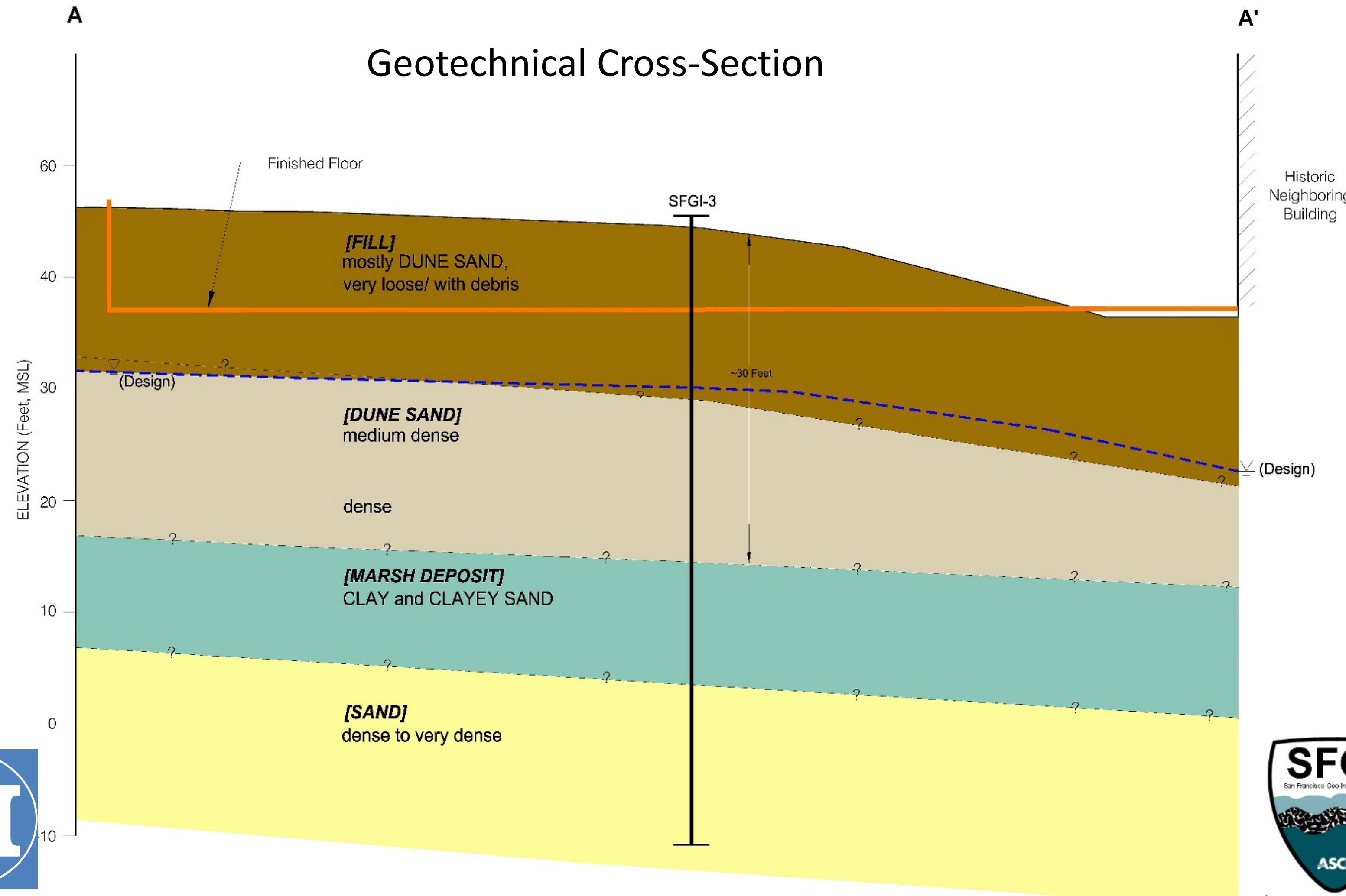
Additional considerations:

1. Surrounding sensitive historic structures
2. Rubble in the fill – concrete, buried foundations
3. Dense lenses within the Dune Sand
4. Sloping ground – lateral spreading?



Geotechnical Cross-Section



Cyclic Resistance Ratio (CRR) Computation

:: Cyclic Resistance Ratio calculation $CRR_{7.5}$ ::

Point ID	Field SPT	C_n	C_e	C_b	C_r	C_s	$N_{1(60)}$	DeltaN	$N_{1(60)cs}$	$CRR_{7.5}$
1	12.00	1.70	0.90	1.00	0.75	1.00	13.77	0.00	13.77	0.15
2	8.00	1.47	0.90	1.00	0.80	1.00	8.46	0.00	8.46	0.09
3	6.00	1.25	0.90	1.00	0.85	1.00	5.75	0.00	5.75	0.07
4	10.00	1.20	0.90	1.00	0.85	1.00	9.18	0.00	9.18	0.10
5	15.00	1.07	0.90	1.00	0.95	1.00	13.76	0.00	13.76	0.15
6	20.00	1.04	0.90	1.00	0.95	1.00	17.76	0.00	17.76	0.19
7	49.00	0.97	0.90	1.00	0.95	1.00	40.57	0.00	40.57	2.00
8	54.00	0.91	0.90	1.00	0.95	1.00	42.03	0.00	42.03	2.00
9	20.00	0.84	0.90	1.00	1.00	1.00	15.20	0.00	15.20	0.17
10	18.00	0.82	0.90	1.00	1.00	1.00	13.29	6.70	19.99	0.22
11	16.00	0.81	0.90	1.00	1.00	1.00	11.59	6.45	18.04	0.20
12	28.00	0.78	0.90	1.00	1.00	1.00	19.76	7.69	27.44	0.33
13	70.00	0.76	0.90	1.00	1.00	1.00	48.16	12.00	60.16	2.00
14	78.00	0.74	0.90	1.00	1.00	1.00	51.99	12.58	64.58	2.00
15	68.00	0.70	0.90	1.00	1.00	1.00	42.77	11.18	53.96	2.00

From LiqIT v.4.7

Cyclic Stress Ratio (CSR) Computation

:: Cyclic Stress Ratio calculation (CSR fully adjusted and normalized) ::

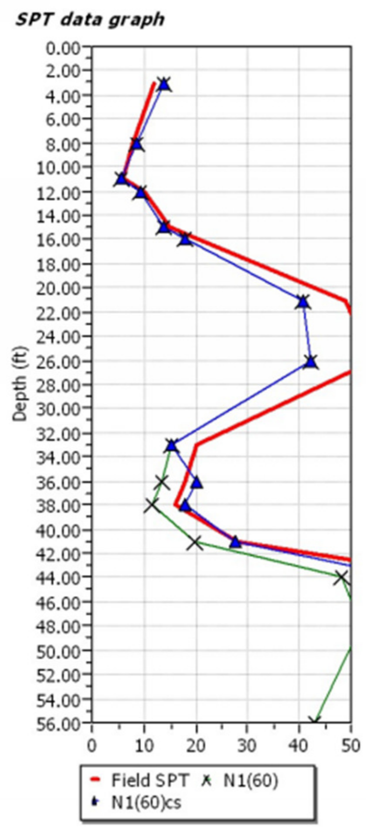
Point ID	Depth (ft)	Sigma (tsf)	u (tsf)	Sigma' (tsf)	r_d	CSR	MSF	$CSR_{eq,M=7.5}$	K_{sigma}	CSR^*
1	3.00	0.18	0.00	0.18	0.99	0.35	0.83	0.42	1.00	0.42
2	8.00	0.48	0.00	0.48	0.98	0.34	0.83	0.41	1.00	0.41
3	11.00	0.67	0.00	0.67	0.97	0.34	0.83	0.41	1.00	0.41
4	12.00	0.73	0.00	0.73	0.97	0.34	0.83	0.41	1.00	0.41
5	15.00	0.91	0.00	0.91	0.97	0.34	0.83	0.41	1.00	0.41
6	16.00	0.97	0.00	0.97	0.96	0.34	0.83	0.41	1.00	0.41
7	21.00	1.27	0.16	1.11	0.95	0.38	0.83	0.46	0.99	0.46
8	26.00	1.57	0.31	1.26	0.94	0.41	0.83	0.49	0.96	0.51
9	33.00	2.00	0.53	1.46	0.91	0.43	0.83	0.52	0.93	0.56
10	36.00	2.18	0.62	1.55	0.88	0.43	0.83	0.52	0.92	0.56
11	38.00	2.30	0.69	1.61	0.87	0.43	0.83	0.52	0.92	0.57
12	41.00	2.48	0.78	1.70	0.84	0.43	0.83	0.52	0.91	0.57
13	44.00	2.66	0.87	1.79	0.82	0.43	0.83	0.51	0.90	0.57
14	48.00	2.90	1.00	1.90	0.78	0.42	0.83	0.50	0.89	0.57
15	56.00	3.39	1.25	2.14	0.72	0.40	0.83	0.48	0.87	0.55

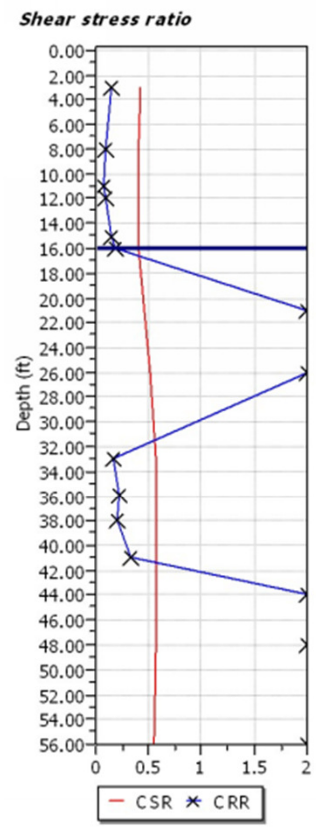
From LiqIT v.4.7

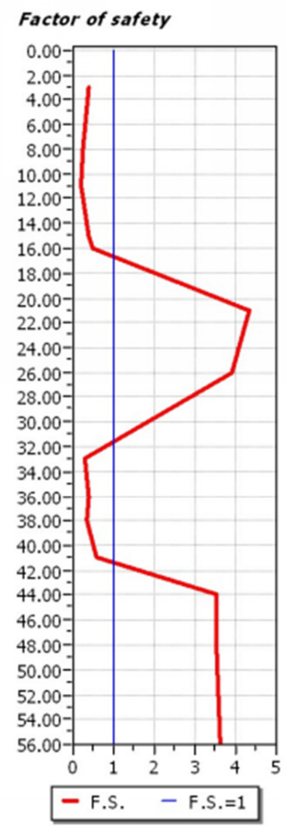
Liquefaction Analysis using LiqIT v.4.7

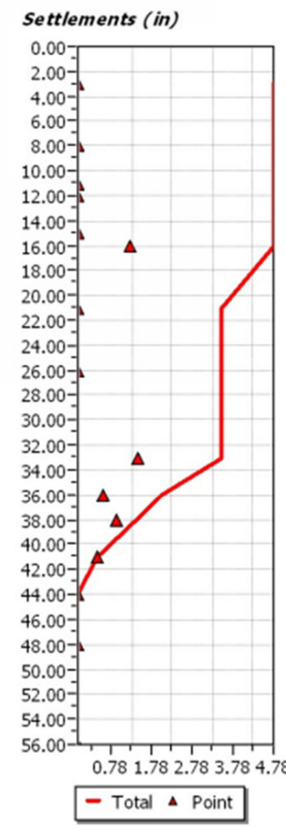
Input parameters and analysis data

In-situ data type:	Standard Penetration Test	Depth to water table:	16.00 ft
Analysis type:	Deterministic	Earthquake magnitude M_w:	8.05
Analysis method:	NCEER 1998	Peak ground accelaration:	0.54 g
Fines correction method:	Idriss & Seed	User defined F.S.:	1.00









Ground Improvement Method Selection Process

1. Obtain liquefaction induced settlement *(5 inches for M=8.05, pga= 0.54 g)*

2. Obtain dry seismic settlement *(additional ½ inch)*

3. Consider strength and settlement of Marsh deposits *(2 blowcount clay, but also 16 blowcount sand)*

4. Consider amount and depth of liquefaction. Two liquefaction zones 10 to 17 ft bgs and 33 to 41 ft bgs

5. Consider at least 10 feet of very dense Dune sands, with liquefaction above and below this layer

6. Consider possible obstructions in the Fill

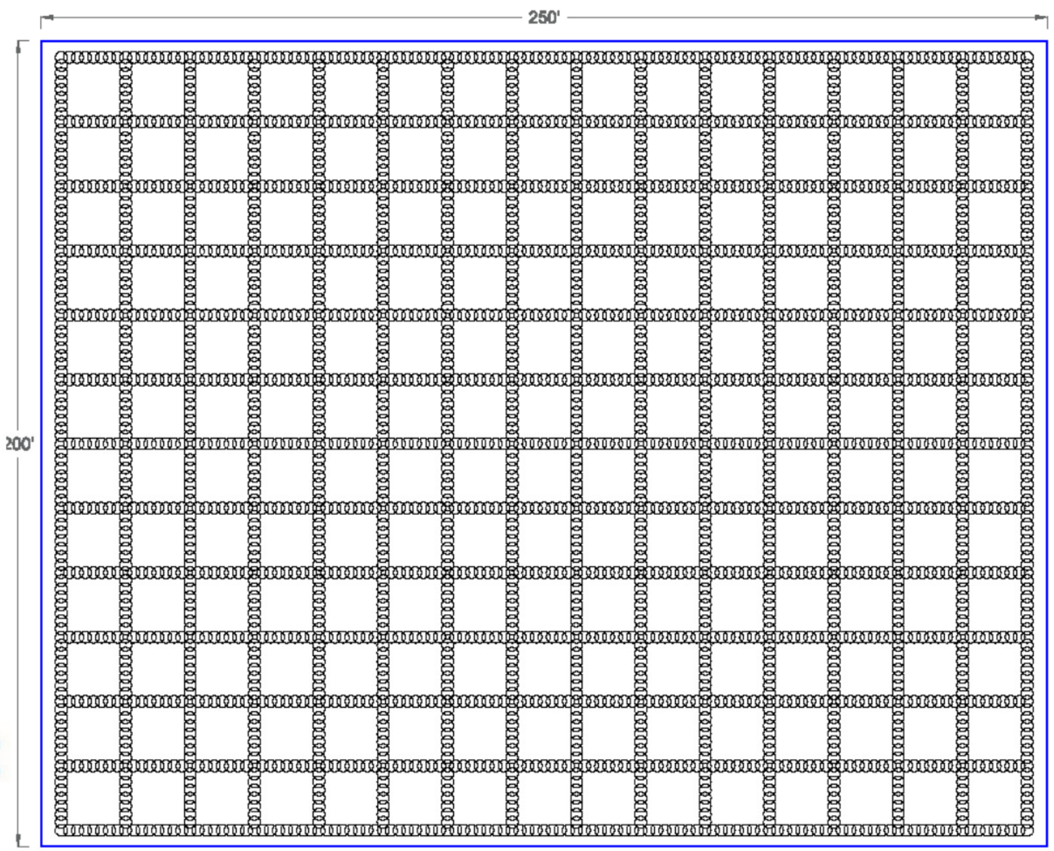
7. Select a ground improvement method out of possible options:
   - A. Stone columns / aggregate piers
   - B. Compaction grouting
   - C. Rigid inclusions
   - D. Soil mixed columns
   - E. **<u>DSM cells</u>**
   - F. Fully reinforced CFA piles or drilled piers – Not a ground improvement solution

Design of DSM Cells

1. How much do we need to reduce the CSR to match the available CRR? Lowest CRR is 0.15. CSR at that depth is 0.41. Required seismic shear stress reduction = 2.7
2. Design for CSR reduction so that soils in between the cells experience no liquefaction.* Seismic shear stress reduction is a function of height of cells, distance between panels, soil shear modulus and soil cement shear modulus.
3. Estimate pressure per ground improvement element: applied bearing pressure/replacement ratio *(2500 psf/0.40 = 6250 psf = 44 psi).*
4. Check bearing capacity in Colma Sand and depth of embedment
5. Check required unconfined compressive strength of soil cement material with proper safety factor *(44 psi X 3 = 132 psi). Seismic design likely to require higher strength than this).*
6. Lateral loads taken in friction between base of mat and transfer platform.
7. Any tension loads can be take with tiedowns, if needed.

* Use procedure in "Design of DSM Grids for Liquefaction Remediation", Nguyen et al, ASCE Journal of Geotechnical and Geoenvironmental Engineering, November 2013

Project Area (250’ x 200’) at 40% Area Replacement Ratio

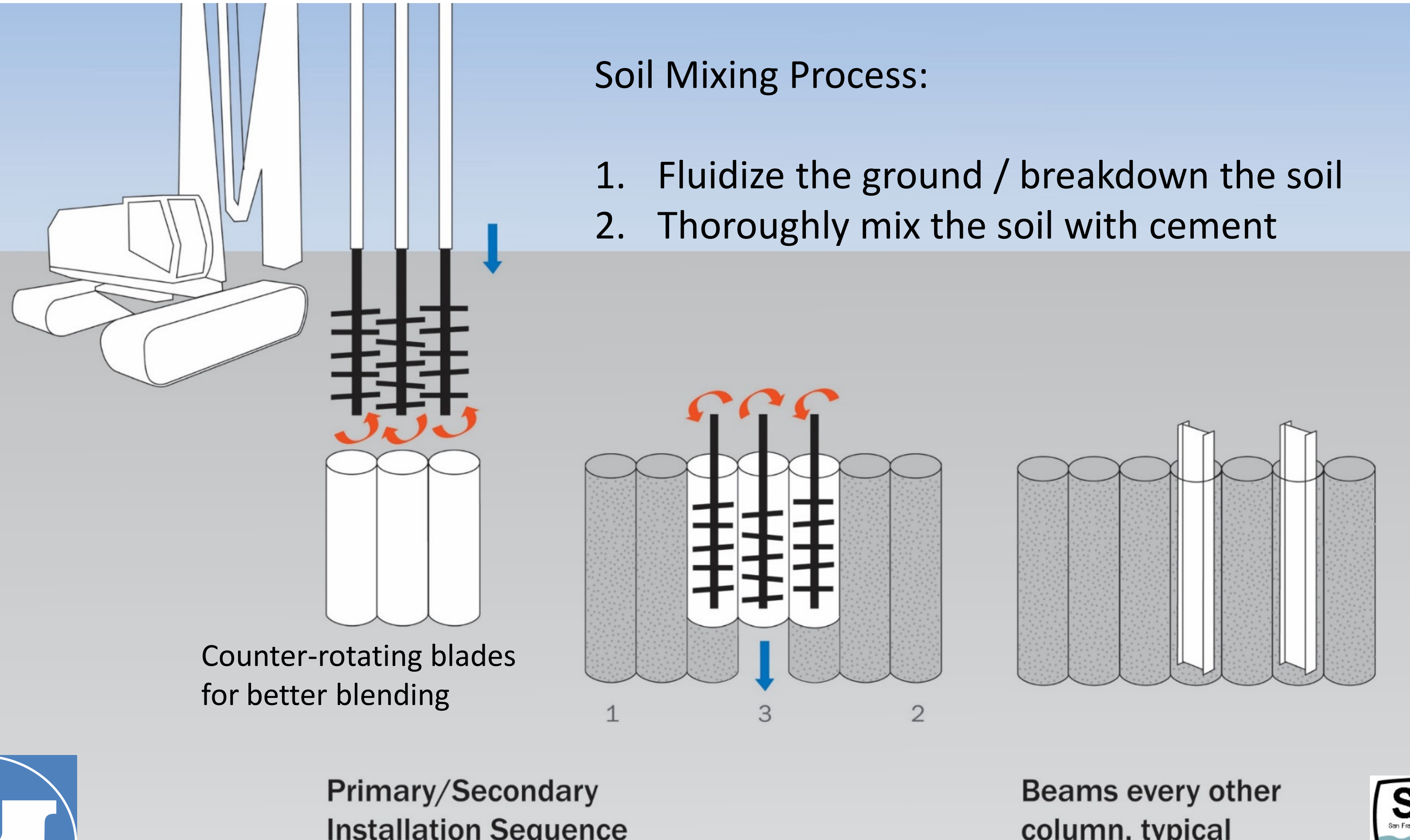


Additional Information We Would Need

1. Additional borings <u>and</u> CPT's, including electronic data
2. Applied pressures across the foundation mat : D+L, D+L+EQ
3. Design Earthquake magnitude and pga, design water table
4. Static total and differential settlement criteria
5. Seismic total and differential settlement criteria
6. QA/QC requirements. Data acquisition system / electronic logs a must for most GI methods
7. Foundation type of adjacent sensitive buildings / survey of adjacent sensitive buildings

Soil Mixing Process:

1. Fluidize the ground / breakdown the soil
2. Thoroughly mix the soil with cement



Applicable Soil Mixing Methods: Multi-Axis Soil Mixing

- 3, 4 and 6 axis systems
- Typically 30 to 48 diameters
- Counter-rotating blades aid in shearing action and blending
- Interlocking cylinders to form panels
- Ideal for walls and cells

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Applicable Soil Mixing Methods: Single-Axis Soil Mixing

- 3 to 9 ft diameters
- Can be lighter equipment
- Very efficient single pile installation
- Can overlap as secants to create continuous wall
- Large diameter, single axis columns are cheapest soil mixing system per installed cubic yard

Applicable Soil Mixing Methods: Cutter Soil Mixing

- Flexible geometry – panel thickness (24”–60”) & length (7’–10’)
- Deep panels – good arching between piles = fewer piles
- Highest quality mixing
- Can advance through obstructions
- Flat rectangular wall (no scalloping)
- Ability to place steel beams right at face of the wall

Project Example: 1400 Mission, San Francisco

10- story and 15-story residential towers and 1-story podium area

Fill / Dune Sand / Marsh Deposits / Dense Colma Sand

Estimated 3 ½ inches of liquefaction

Mat foundations over DSM grids extending into Colma Sands

Mat loads: 6300 psf D+ L, 8500 psf total loads

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Project Example : 1400 Mission St.
San Francisco

Interlocked triple axis panels

Liquefaction mitigation and
bearing capacity

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200 psi design strength

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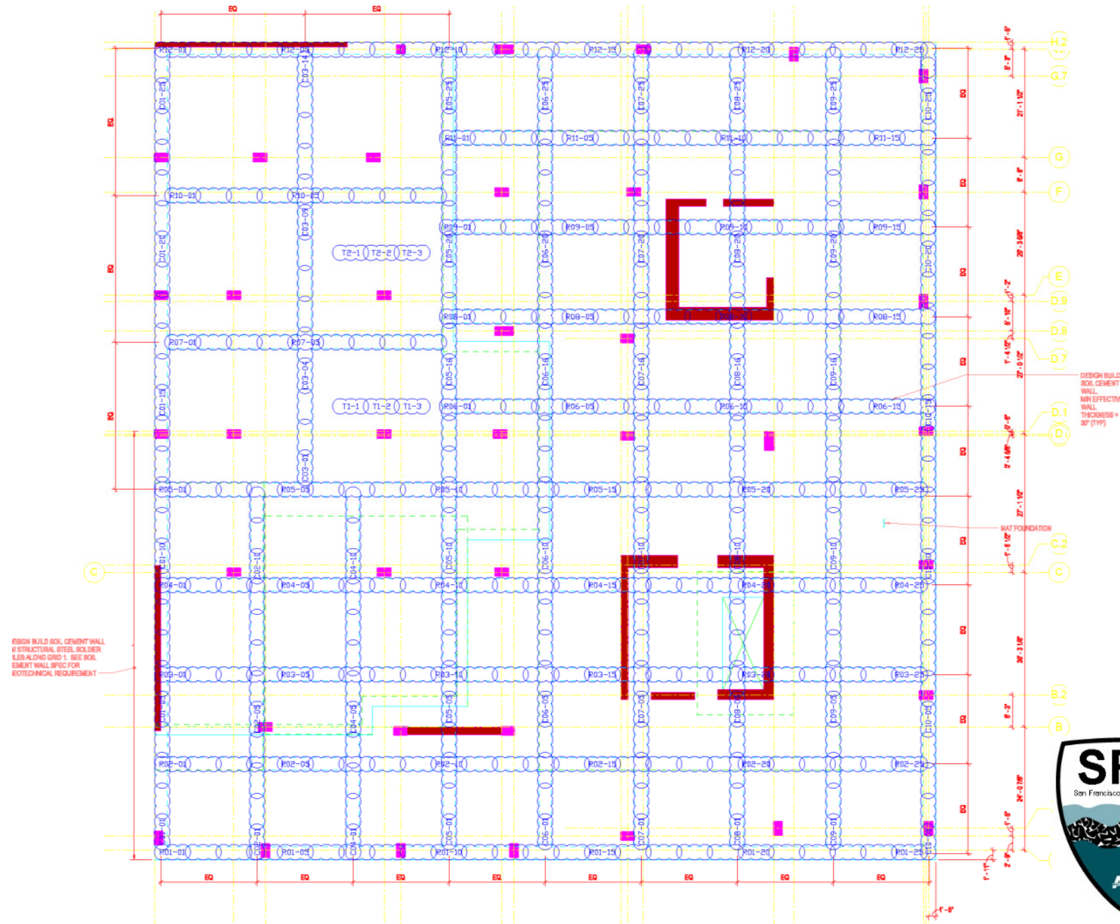
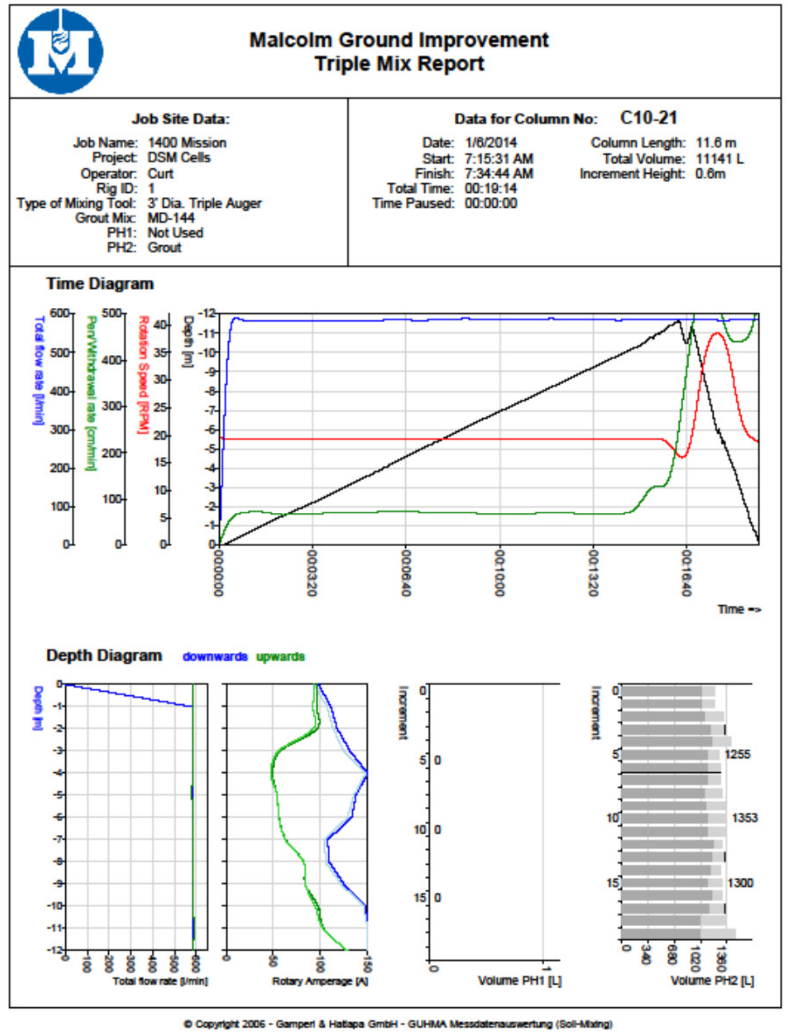


QA/QC: Real Time Data Aquisition

Real time data acquisition in the operator's cab

Daily review by Engineer

- Depth
- Grout volume per increment
- Total grout volume per panel
- Penetration rate
- Withdrawal rate
- Rotation speed (rpm)
- Rotary energy (amperage)



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Soil Mixing QA/QC

Typical:
- Daily wet grab samples for UCS testing at 3, 7 and 28 days
- Continuous coring of selected columns

Can also do:
- Load testing
- Expose the soil mixing

How to Improve Bay Area Practice?

1. For ground improvement applications, always provide SPT <u>and</u> CPT, soil classification, fines content, PI, water content, field shear strength, consolidation test.
2. Conduct investigation to the appropriate depth. Multiple soft or liquefiable layers in the Bay Area. Rock often very deep. Complex profiles.
3. Provide electronic CPT data.
4. Clearly define scope: prescriptive spec vs performance spec vs design-build.
5. Clearly written specification with well defined QA/QC requirements and responsibilities.
6. Make use of contractor's knowledge. Talk to contractors during pre-design phase. Discuss technical feasibility, equipment capabilities and budgeting.

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Thank you!
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