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Ground Improvement for Existing Structures

January 9, 2019

haywardbaker.com

THINK SAFE

Speaker

- **Phillip Gallet, P.E. – Project Manager**
  - Grew up in soils lab
  - 8 Years at HBI, Dallas/Ft. Worth to Denver, CO

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Goal: Zero Injuries

All accidents are preventable	No repeat occurrences	Safety Standards
Job site Daily Task Analysis Meeting to review safety issues related to the day's tasks.	All Incidents investigated, corrective actions implemented and shared in the Weekly Safety Update for awareness.	Safety Standards Document

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THINK SAFE | WORK SAFE | GO HOME SAFE

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Don't be this guy!

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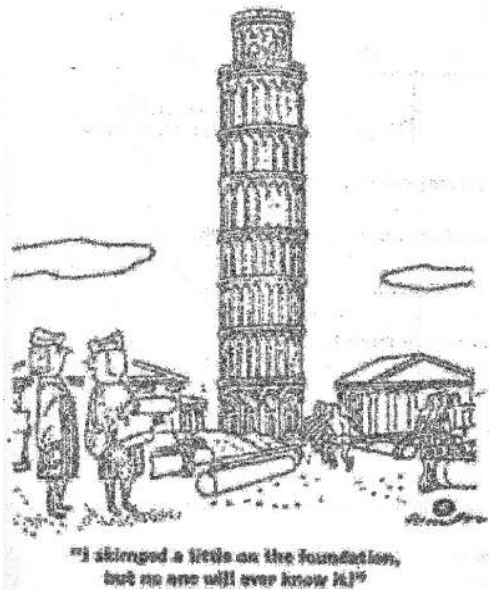
Presentation Topics

- Why Modify the Soil
- Compaction Grouting
- Permeation Grouting
- Jet Grouting
- Injection for Expansive/Collapsible Soils



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http://blog.geotechpedia.com/wp-content/uploads/2013/07/Pizza.jpg

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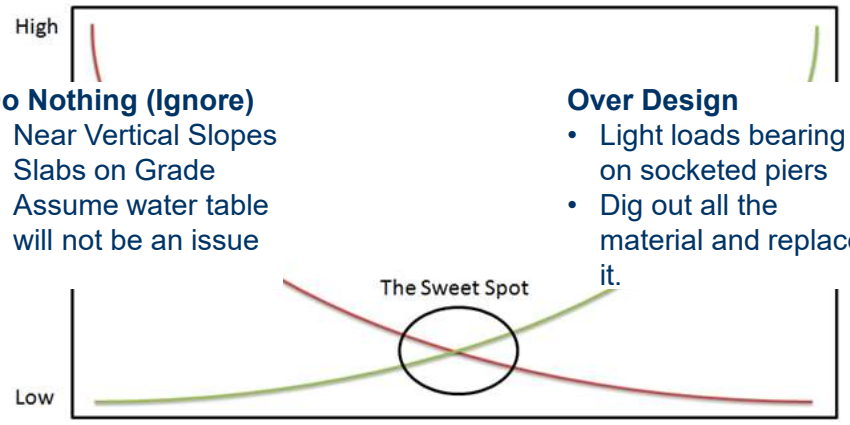
Why Modify the Soil - Cost of Something Happening



Do Nothing (Ignore)
- Near Vertical Slopes
- Slabs on Grade
- Assume water table will not be an issue

Over Design
- Light loads bearing on socketed piers
- Dig out all the material and replace it.

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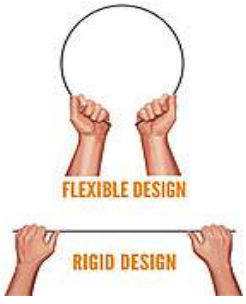
What is Expected?

- **Soil Structure Interactions**
  - Bearing Capacity
  - Settlement Tolerances
- **0 to ¼" Tolerance**
  - Structural Connections
- **2 to 3" Tolerance**
  - Ground Improvement or nothing needed at all



http://www.polygoncomposites.com/products/medical

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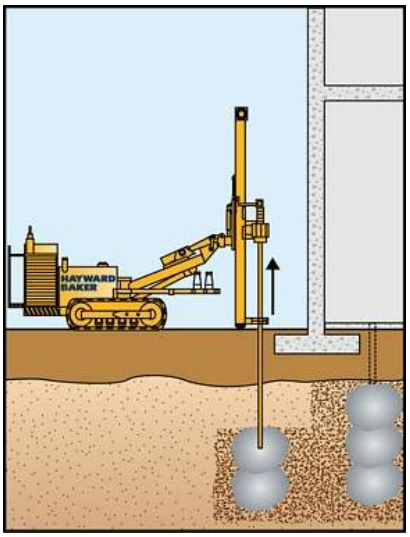

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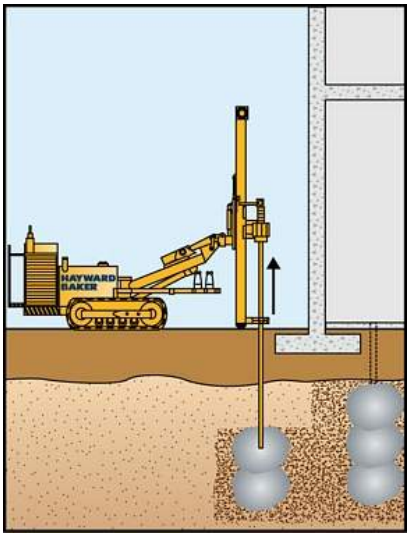
Compaction Grouting

Compaction Grouting uses displacement to improve ground conditions. A very viscous (low-mobility), aggregate grout is pumped in stages, forming grout bulbs, which displace and densify the surrounding soils.

Significant improvement can be achieved by sequencing the grouting work from primary to secondary to tertiary locations.



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Ideal Grout Make-Up

- Pumpable
- Slump less than 2” for pre-treatment and around 1” for underpinning and piles
- 10-20% cement by volume

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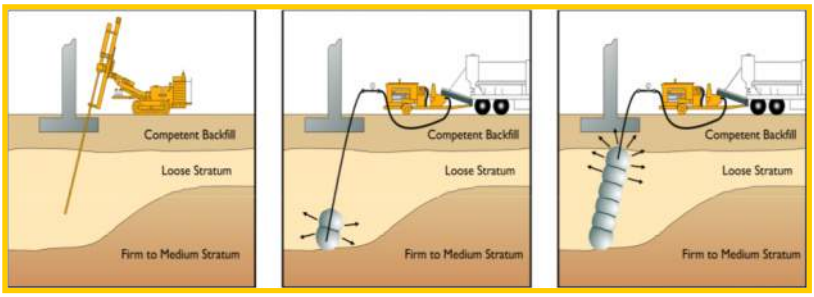
Compaction Grouting Process

Installation of grout pipe:

- Drill or drive casing
- Location very important
- Record ground information from casing installation

Initiation of grouting:

- Typically bottom up but can also be top down
- Grout rheology important (low mobility, not necessarily low slump)
- Usually pressure and/or volume of grout limited slow, uniform stage injection



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Extracted Grout Column – Sand

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Extracted Grout column – Bay Mud

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Extracted Grout columns- Silty Sand

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Grout Batching

Continuation of grouting:

- On-site batching will aid control
- Grout rheology important
- Pressure, grout quantity, injection rate, and indication of heave are controlling factors
- Sequencing of plan injection points very important

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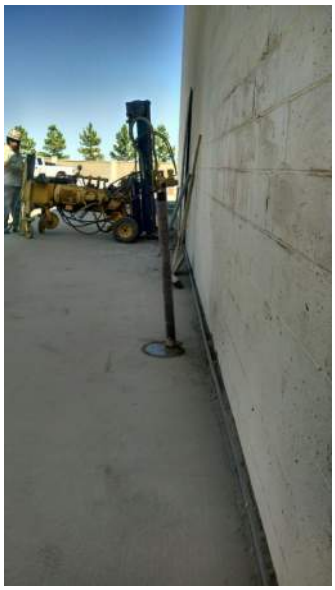
Interior Installation of Grout Pipe with Small Drill



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Interior Installation of Grout Pipe with Very Small Drill

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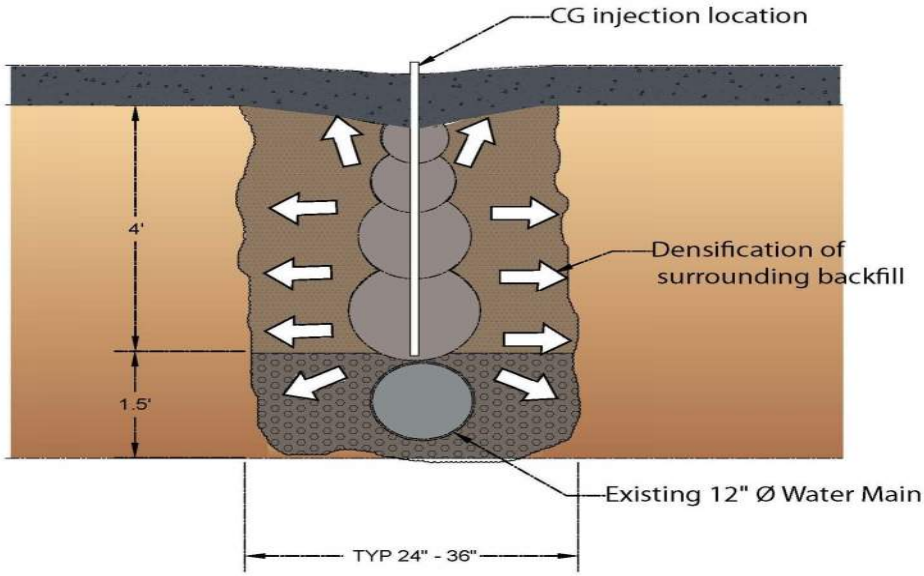
In-situ trench backfill rehab



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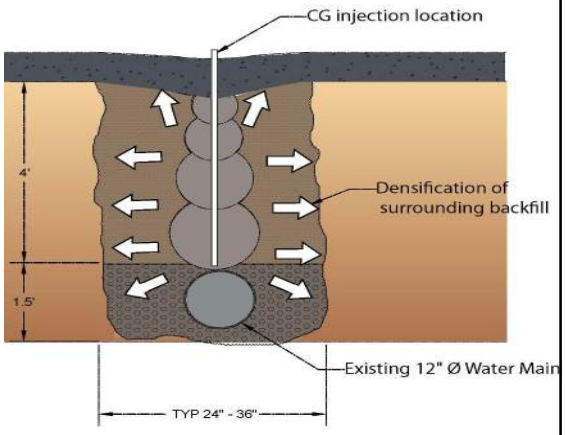
Case Study: Trench Backfill Rehab

Infrastructure Developed in 2005 – 2006

The Issue

- Significant pavement distress & settlement in roadways starting in 2007 – 2008
- Settlement on the order of 3 – 6 inches with multiple areas exhibiting settlement as much as 12 to 24 inches
- Local Geotech determined that settlement was due to poor placement and compaction of sanitary and storm sewer trench backfill
- About 7600 lineal feet of sanitary and storm sewer trench and associated manhole backfill was at risk or exhibiting settlement
- Backfill depth ranged between 13 to 19 feet for sanitary sewer trench
- Storm sewer pipe diameter ranged from 24 to 78 inches. Backfill depth ranged between 9 to 22 feet with isolated areas of 25 to 30 feet depth.



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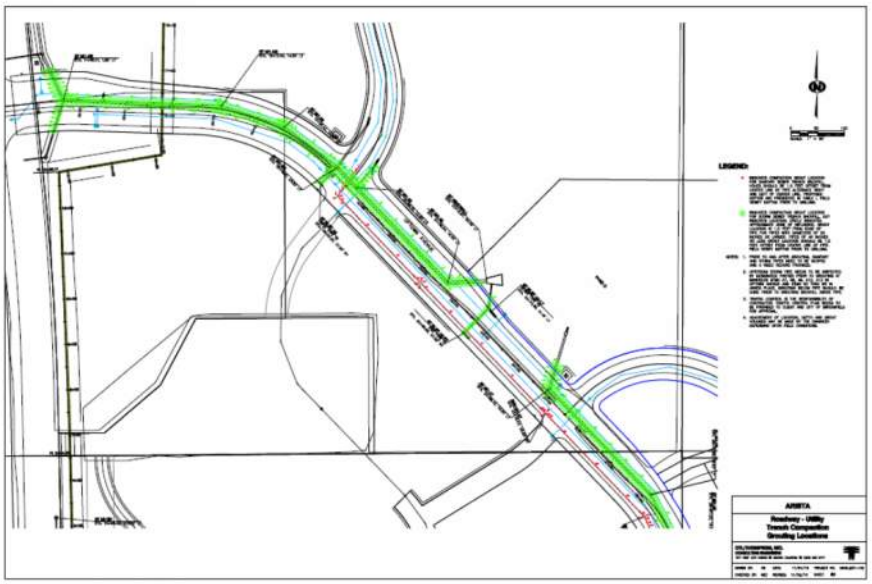

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Photo 1
June 4, 2009
Project No. DN 43,846-145

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Photo 2
June 4, 2009
Project No. DN 43,846-145

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Photo 356
June 8, 2009
Project No. DN 43,846-145

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Photo 63
June 5, 2009
Project No. DN 43,846-145

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Photo 64
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Project No. DN 43,846-145

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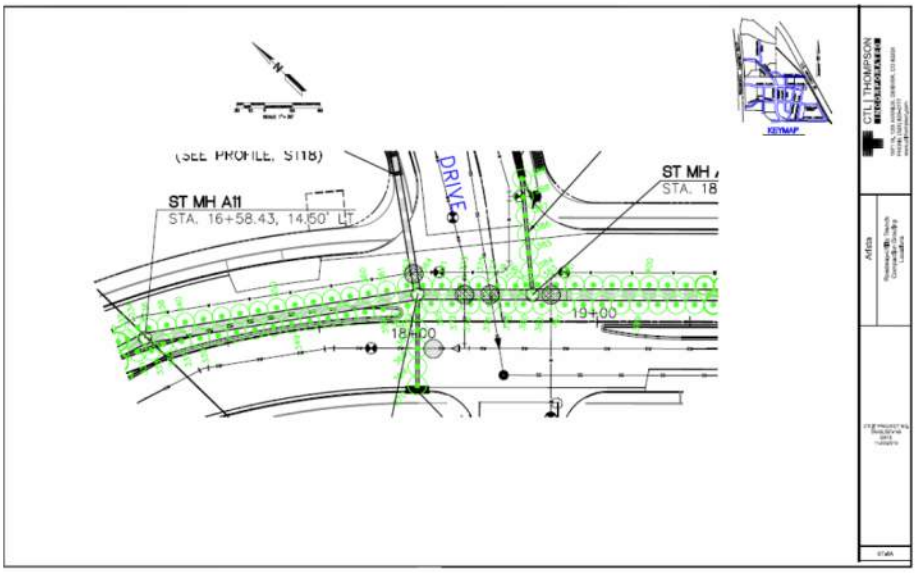

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ARISTA
Roadway Monitoring

PT #	November 27, 2012 HI	Minus	Elevation	PT #	April 3, 2014 HI	Minus	Elevation	Diff.
1	5483.859	3.865	5479.994	1	5483.747	3.760	5479.987	-0.007
2	5483.859	4.295	5479.564	2	5483.747	4.193	5479.554	-0.010
4	5473.687	4.305	5469.382	4	5472.130	2.752	5469.378	-0.004
5	5473.687	5.875	5467.812	5	5472.130	4.323	5467.807	-0.005
6	5473.687	12.300	5461.387	6	5466.319	4.922	5461.397	0.010
11	5447.040	7.840	5439.200	11	5445.661	6.452	5439.209	0.009
12	5447.040	8.825	5438.215	12	5440.233	2.018	5438.215	0.000
30	5446.642	3.393	5443.249	30	5447.752	4.498	5443.254	0.005
31	5446.642	3.198	5443.444	31	5447.752	4.303	5443.449	0.005
32	5446.642	2.862	5443.780	32	5447.752	3.978	5443.774	-0.006
39	5483.859	2.210	5481.649	39	5483.747	2.110	5481.637	-0.012
40	5483.859	2.720	5481.139	40	5483.747	2.618	5481.129	-0.010
41	5483.859	3.968	5479.891	41	5483.747	3.860	5479.887	-0.004
42	5483.859	4.657	5479.202	42	5483.747	4.540	5479.207	0.005
86	5446.642	2.640	5444.002	86	5447.752	3.748	5444.004	0.002
87	5446.642	1.795	5444.847	87	5447.752	2.905	5444.847	0.000

6 Years Later:
Max Deflection = 0.144 Inches

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Case Study: Settling Townhomes

- Hillside in Missoula, MT
- Over historic gully historically used as dump site

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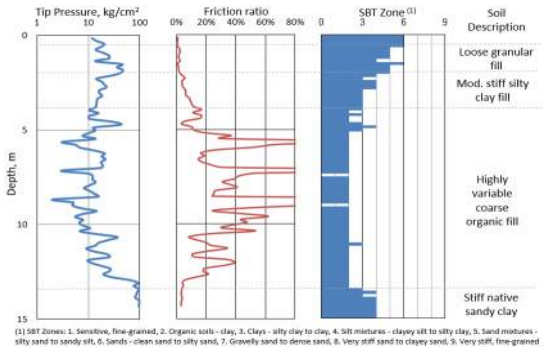
Geotechnical Site Conditions

- Variable depths of undocumented fill up to 13 m
- Gully used as dump area for waste, woody debris and construction waste
- Foundation settlement started shortly after construction

- Silty clay fill over variable organic fill



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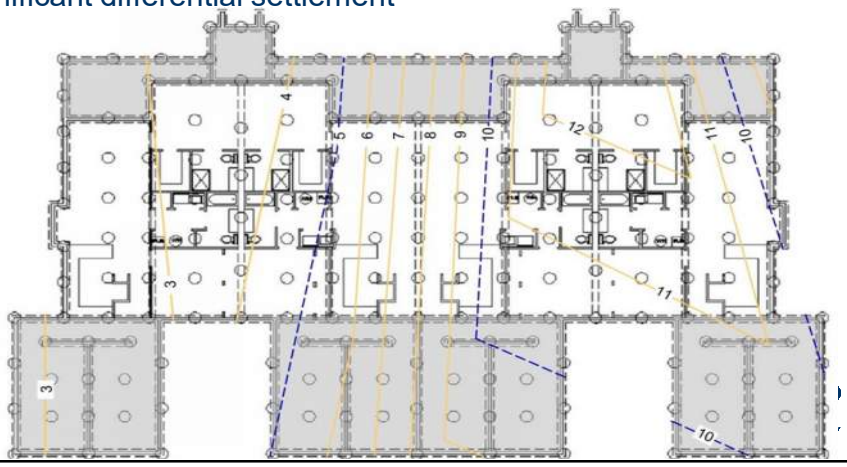
Fill Depth

- Fill depths range from 3 to 12 m
- Contributed to significant differential settlement



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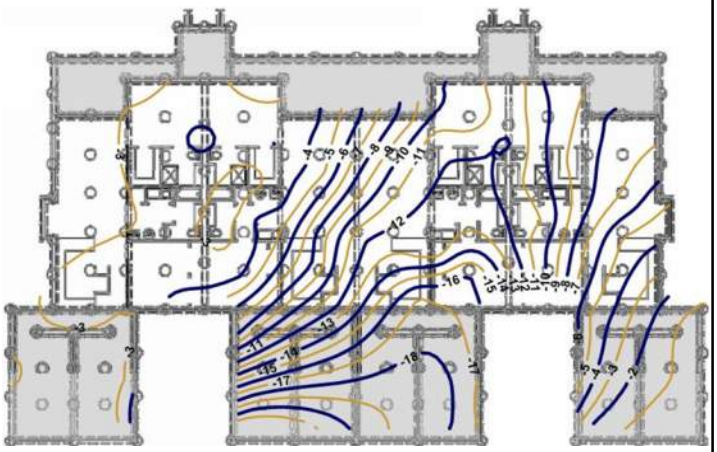
Pre Grouting Level Survey

- Prior to ground improvement survey showed differential settlement of up to 19.5 cm
- Settlement in areas of deeper fill in center of gully



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Examples of Pre Grouting Distress

- Racked doors
- Drywall cracks
- Concrete cracking and settlement
- Cracked windows
- Doors/windows jammed and unserviceable
- High floor slopes
- Negative drainage
- Trip and fire hazards



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Examples of Pre Grouting Distress





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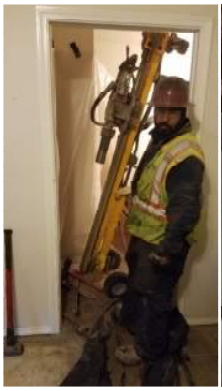
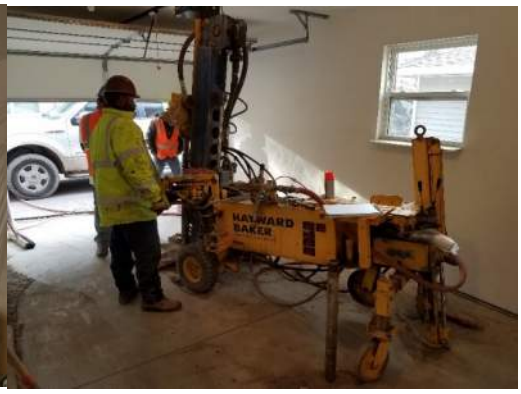
LMG/Compaction Grouting Process

- Casing advanced to termination depth (typically bottom of gully with pneumatic hammer or drill access drill





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LMG/Compaction Grouting Process

- LMG grout batched and pumped onsite. Hydraulic rams used to lift casing for each stage.



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Monitoring During LMG Grouting

- Monitored slabs, walls, asphalt and retaining walls for vertical and lateral movement
- Employed dial gauges and laser targets
- Monitored plumbing for signs of deflection with camera

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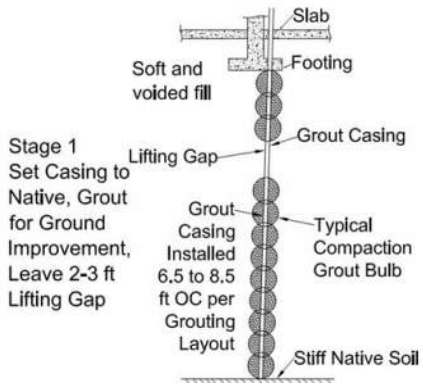
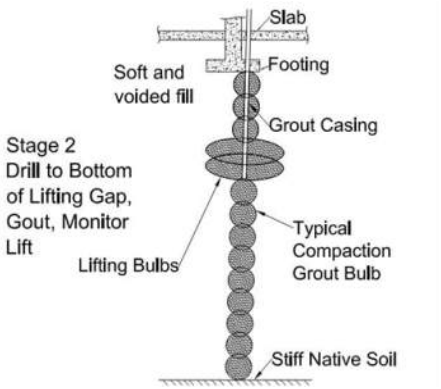
Grouting Process

- Lifting gap process used to generate significant lift of heavily loaded footings.
- Successful in lifting footings along with lightly loaded slab.





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Lifting

- Lifting completed using two crews pumping simultaneously on 4 to 6 holes each to achieve broad distributed lift.

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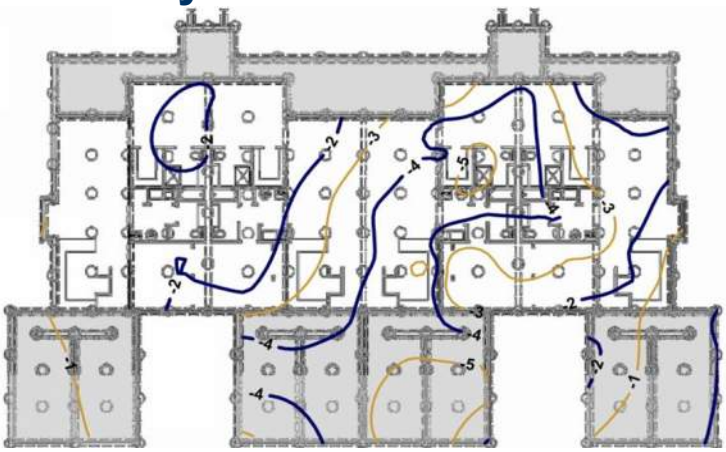
Post Grouting Level Survey

- Lifting with LMG grout able to re-level the building to within 3-5 cm of level. (previous cosmetic repairs prevented full recovery)
- Areas of large floor slope eliminated



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Results of Lifting

- Lifting process closed many structural cracks
- Reduced cost of cosmetic repairs
- Improved racked doors
- Reset stuck windows
- Reduced floor slopes

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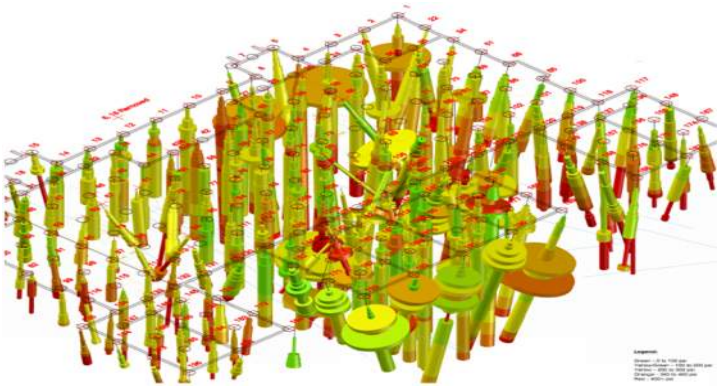
3D As-Built

- 3D As-Built used to evaluate progress, identify soft/voided areas, visualize battered holes and provide visual of ground improvement to clients



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Presentation Topics

- Why Modify the Soil
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- Permeation Grouting
- Jet Grouting
- Injection for Expansive Soils

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Chemical (Permeation) Grouting

Structural Chemical Grouting is the permeation of non cohesive soils with solution grouts to produce weak sandstone like masses to carry loads or increase stand-up time.

Water Control Chemical Grouting is the permeation of sands with fluid grouts to completely fill voids to control water flow.

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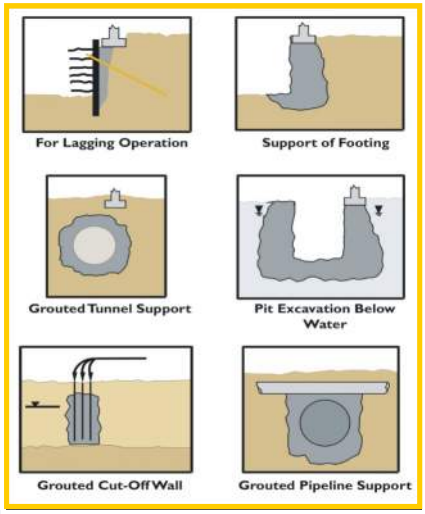
Chemical (Permeation) Grouting Applications



- For lagging or temporary shoring operation
- Permanent Support of footings
- Bearing capacity enhancement
- Grouted tunnel support
- Grouted cut-off wall
- Grouted pipeline support

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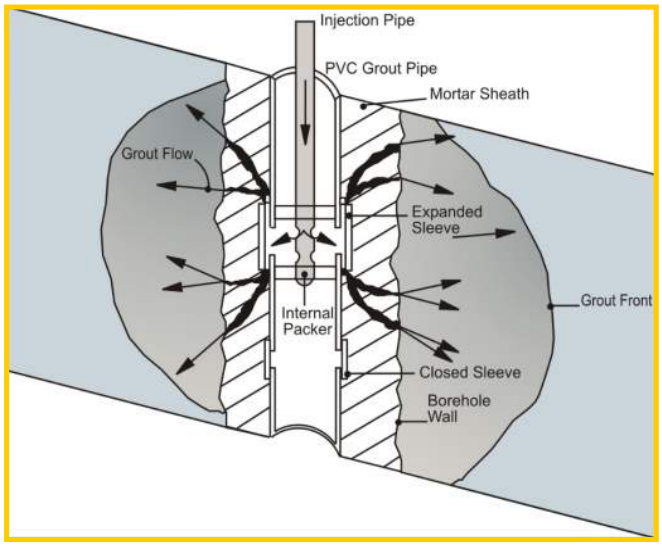
Chemical Grouting



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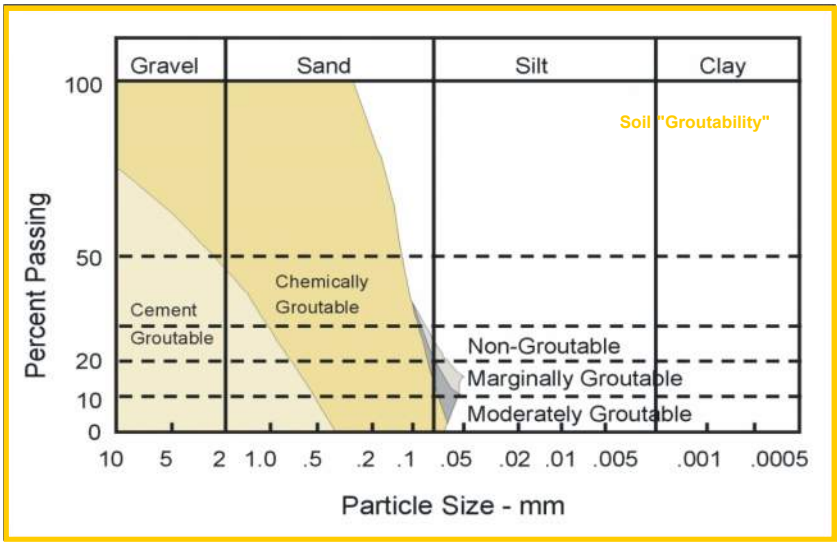
Chemical Grouting - Soils



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Case Study: Georgetown, CO School

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Problem- Settlement

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Options

- Compaction Grouting
- Jet Grouting
- Permeation Grouting
- Underpinning

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Permeation Grouting selected

- Structural Engineer did not want the building to move.

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Chemical Grouting

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Case Study: Aspen, CO

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Problem- Need more space
Solution- Basement

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Creative “staging”

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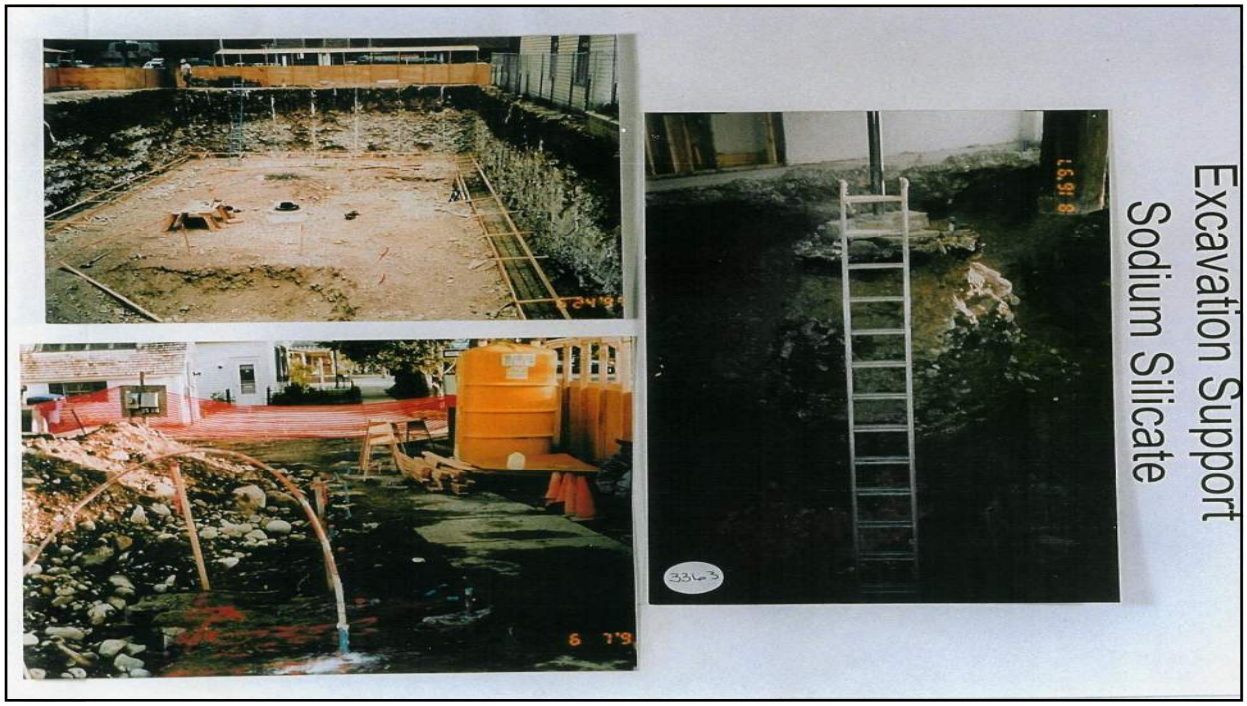
Injection Tubes



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Jet Grouting is . . .

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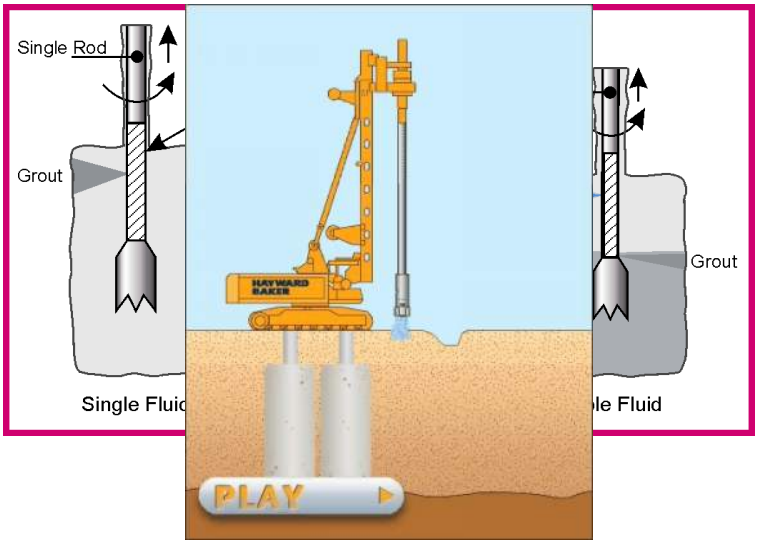
Jet Grouting Systems



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Geometry is a function of:

- Dynamic pressures
  - Velocity of the fluid
  - Air shroud (reduces attenuation)
  - Nozzle focus and condition
  - Injection volume rate
- Erosion time
  - Rotation speed
  - Lift speed (step time and height)
- And most importantly: Soil strength and plasticity

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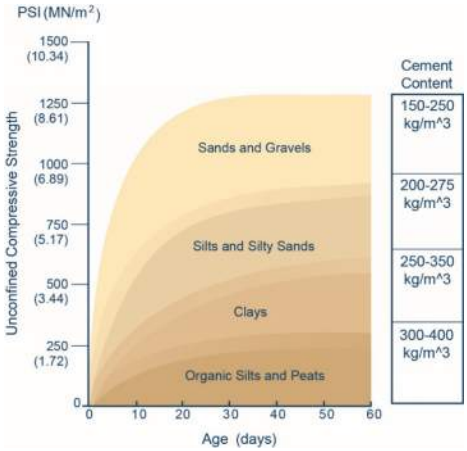
Typical Soilcrete Strengths



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Applications

- Underpinning structures or utilities

Manchester HS

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Applications

- Underpinning structures or utilities
- Scour Protection

Ortega Hwy 74 Bridge

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Jet grouting underpinned and provided earth retention for this wall at the Bayer Healthcare facility in Walpole, MA.

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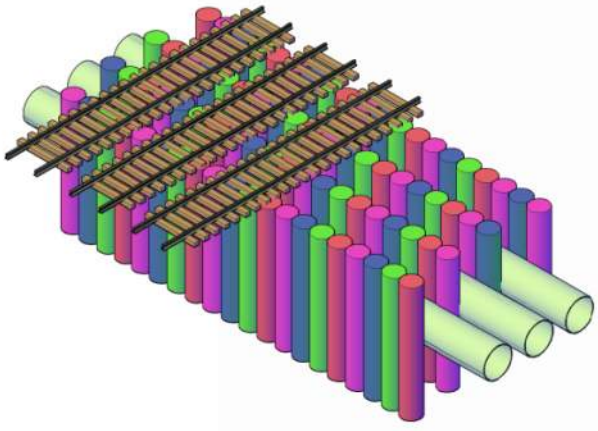
Case Study: Fargo, ND - Frost Heave Mitigation

- Double Main and siding had 3 jack and bored culverts
- Culverts allowed up to 12” of frost heave
- Jet Grouting to limit frost heave



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- Installation of the Test Section
- Verified 4’ diameter columns

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Conclusion

- Three week project
- Frost heave mitigated
- Slow orders cancelled

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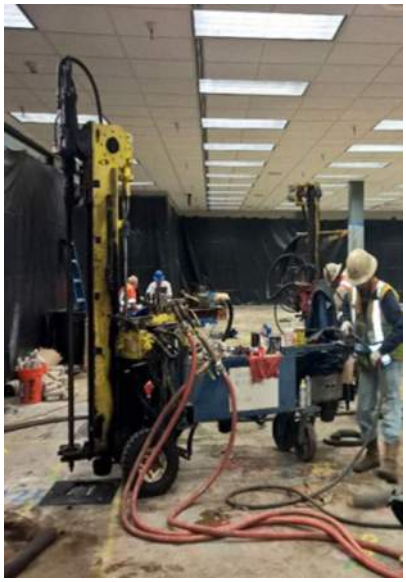
THINK SAFE

Presentation Topics

- Why Modify the Soil
- Compaction Grouting
- Permeation Grouting
- Jet Grouting
- Injection for Expansive Soils



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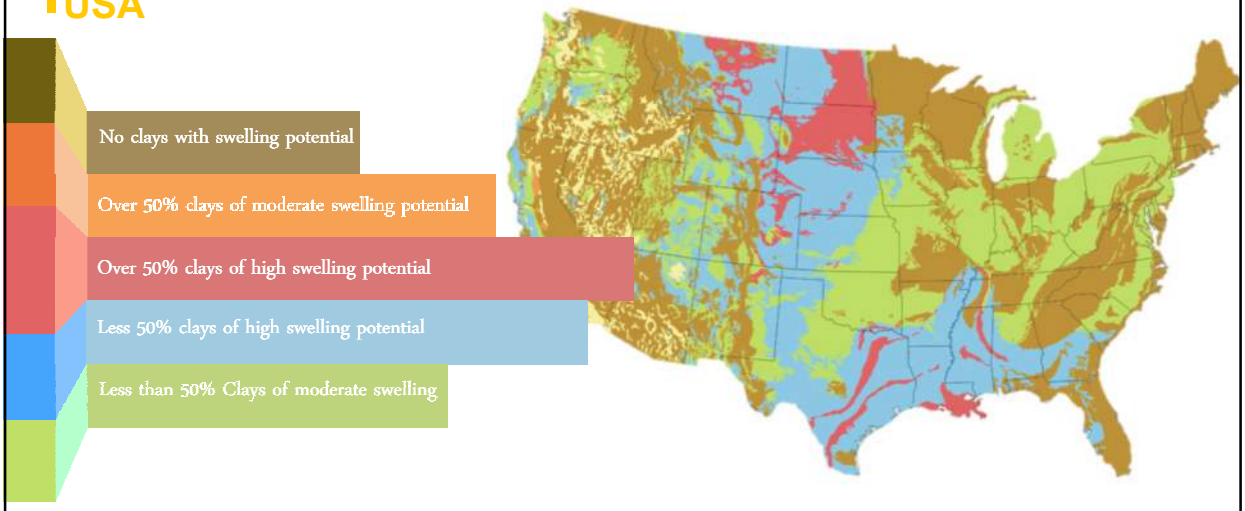
Location of expansive clays
USA



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Expansive clays
New or Existing Structures

1. Remove & Replace
2. Moisture Condition
3. Suspend the Slab
4. Treat the Soil In-Situ

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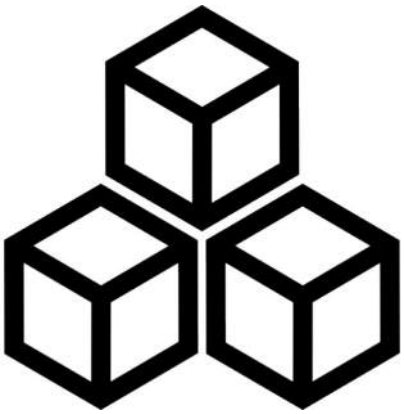
Clay Minerals
Building Blocks

Si

Silica Tetrahedron

Al

Aluminum Octahedron



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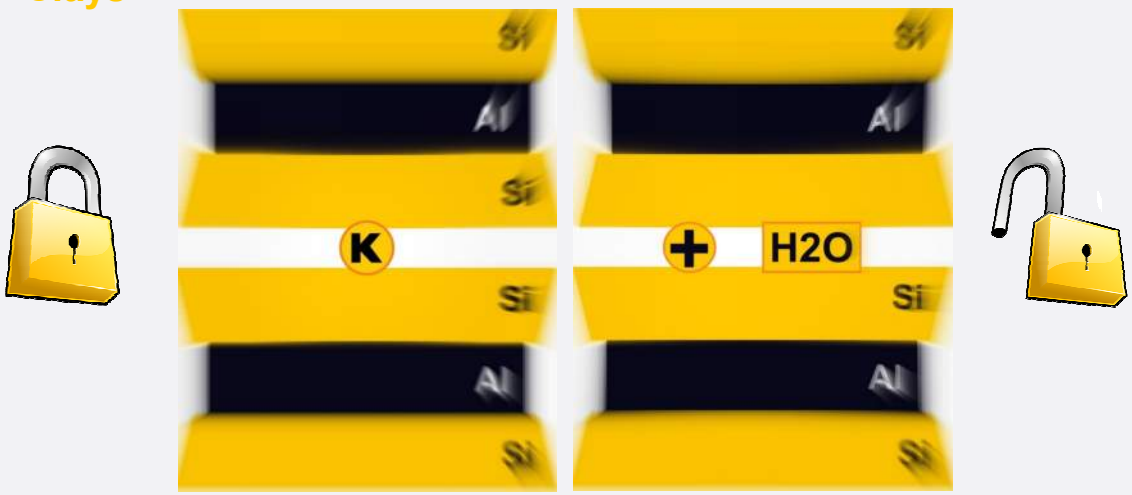
Expansive Clays



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ILLITE SMECTITE

Injection Systems

Single and multi-point push systems which hydraulically force injection probes into the soil mass.

Fluids or slurries are then pumped through the system in order to pre-swell, modify or improve the strength of the soil mass.

Types of Injection Equipment

Outdoor
Multiple rod units, up to 5 rods

Indoor
Single rod units for work in low headroom conditions

Or multiple rod units in warehouse

Deep Injection Units
Injection depth up to 30' deep

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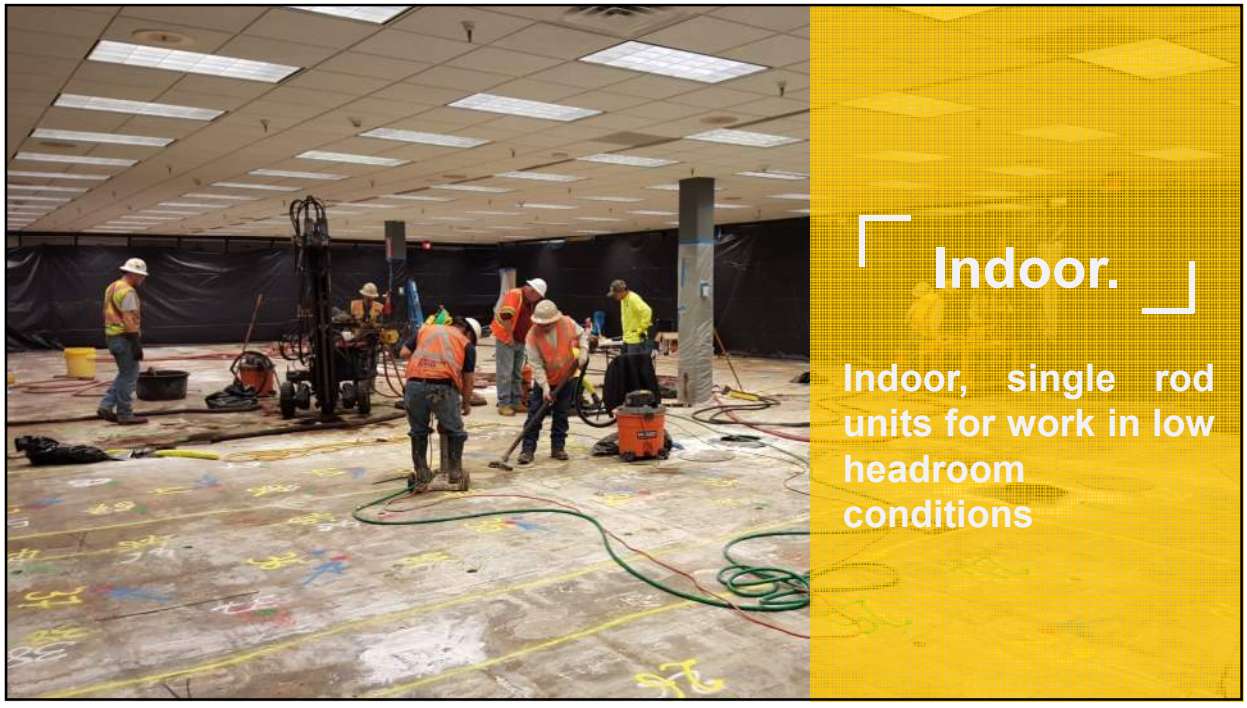

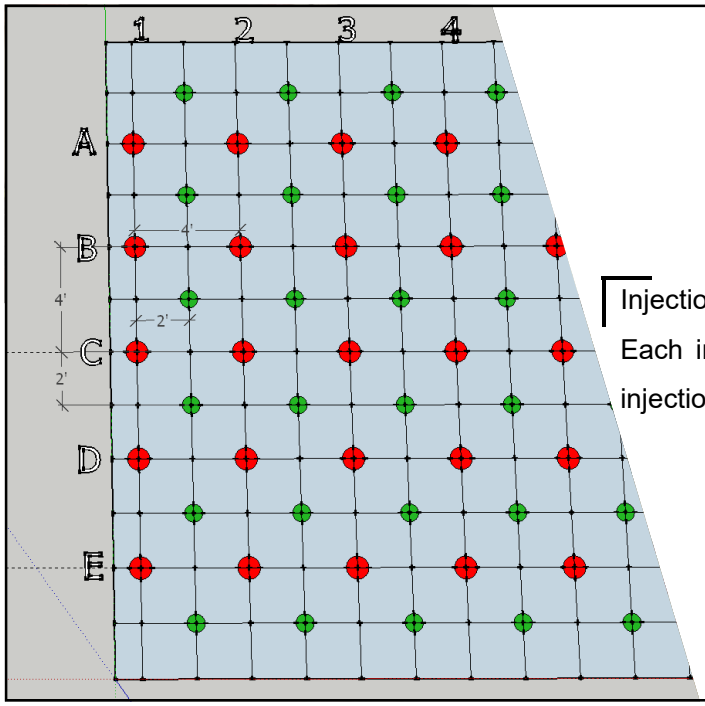

Injection Pattern

Injection Pattern is typically 3’ to 5’ on center. Each injection pass is offset from the previous injection pass resulting in a tighter grid pattern.

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Injection of Expansive Clays

Injection Time

When treating expansive clay, the longer the time period between injections, the better the results.

Testing

Testing of sites after injection should wait until at least 48 hours after the last injection, preferably longer, but not longer than 96 hours.

Swell

Several inches of swell should be expected as a result of the injection. This is usually 2 to 6 inches but in severe cases can be as much as 12 inches.

Passes

Multiple passes are almost always required. The number of passes will vary according to soil type and condition, however, clients should be aware of this and allow for it in the schedule.

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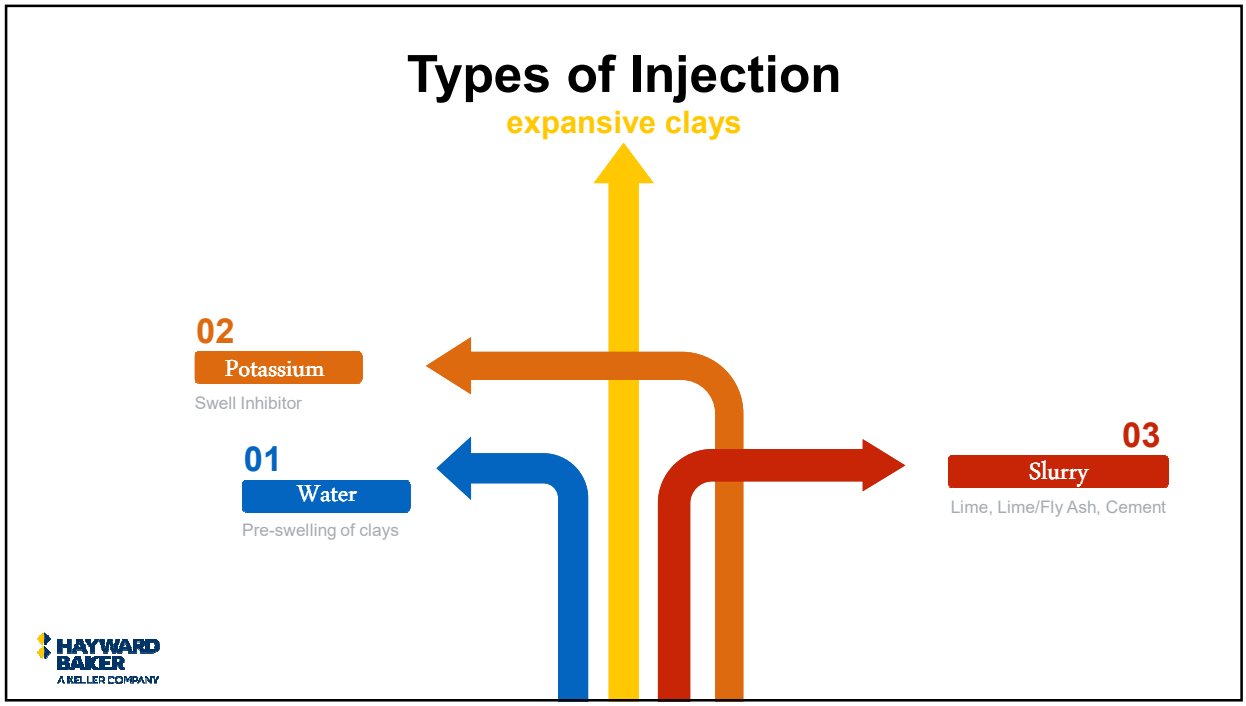
Types of Injection
expansive clays
02
Potassium
Swell Inhibitor
01
Water
Pre-swelling of clays
03
Slurry
Lime, Lime/Fly Ash, Cement
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Water Injection.
• Pre-swelling of clays
• Low-cost method
• Fast and easy
• Existing structures or new building sites
• Alternative to select fill, or pier-and-beam foundation
• Frequently used with post-tensioned slabs

Potassium Injection.

- Greatly limits future heave potential
- Reduce ongoing heave
- Limits the amount of water a clay would absorb
- Satisfies clay particles' charge
- Injected prior to construction as well as through floors and footings of exiting structures

Potassium Injection Mix Design

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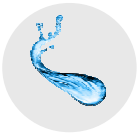
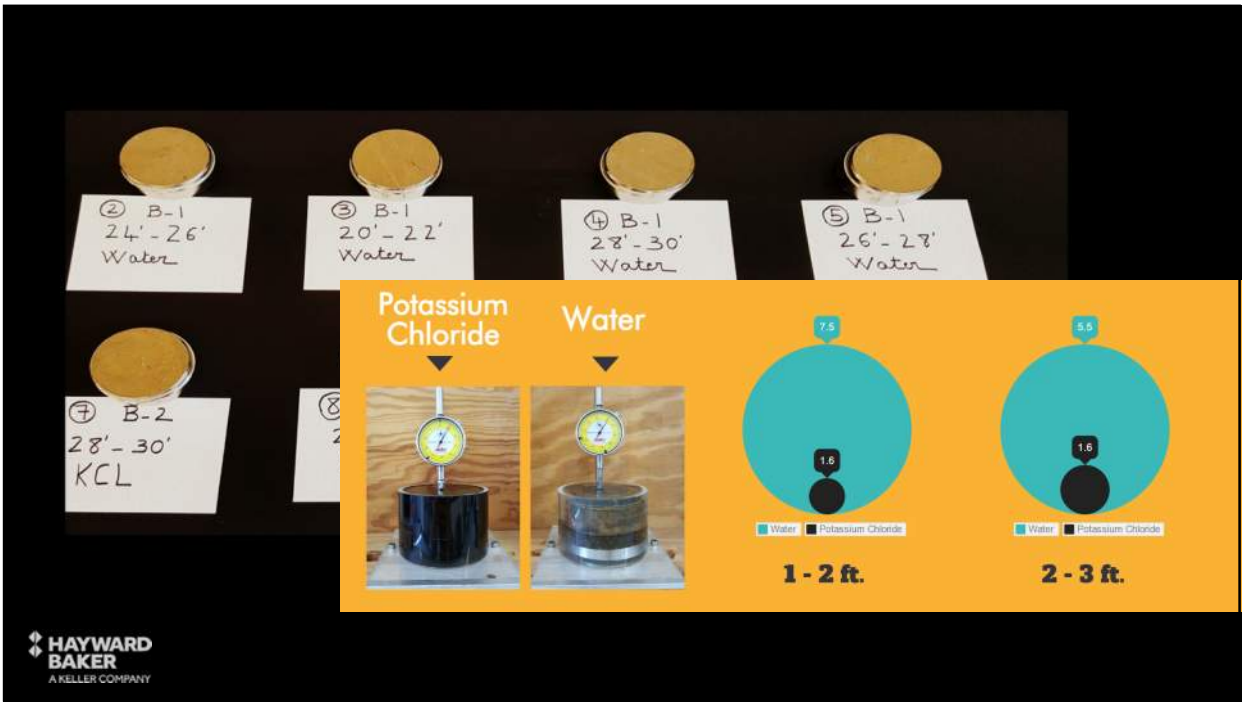


Water

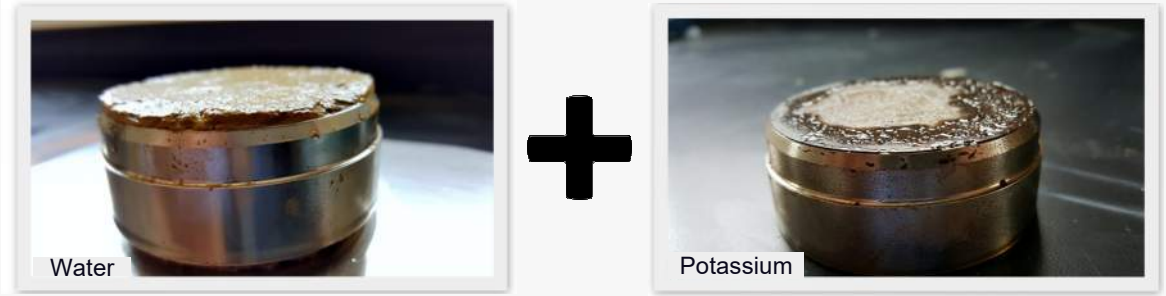
Potash

Lignin

Caustic Soda



Combination of Water and Potassium Injection



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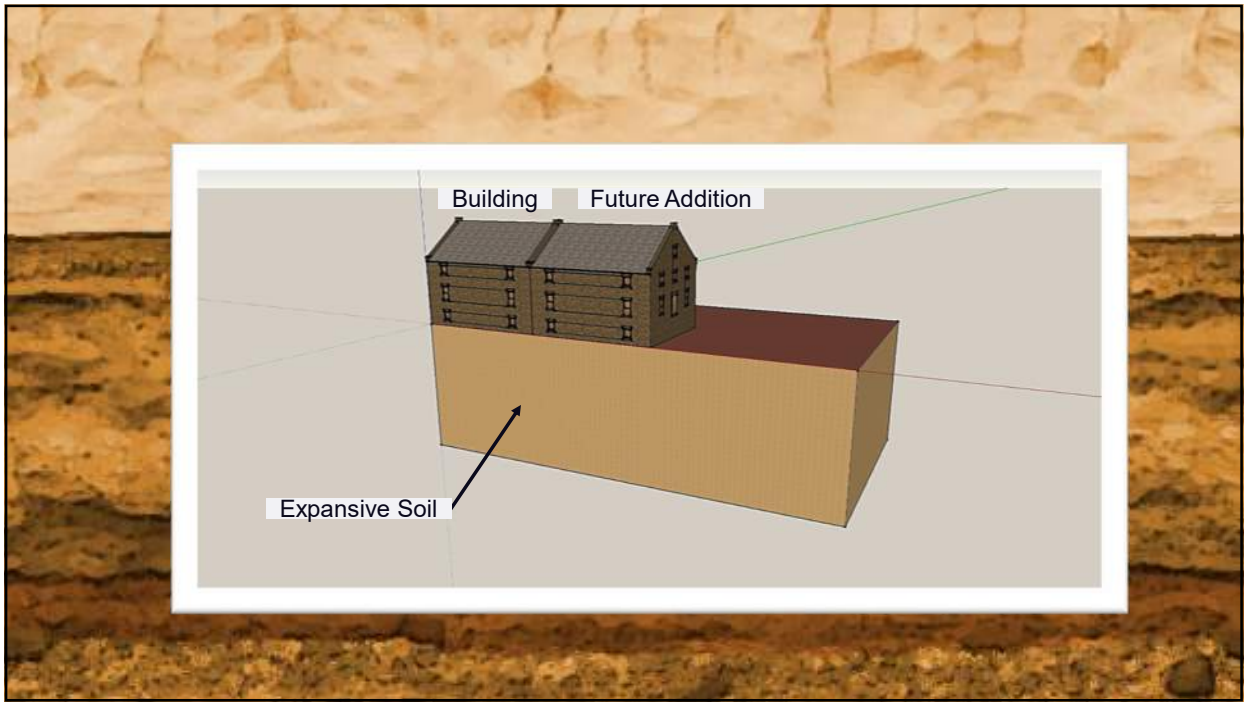
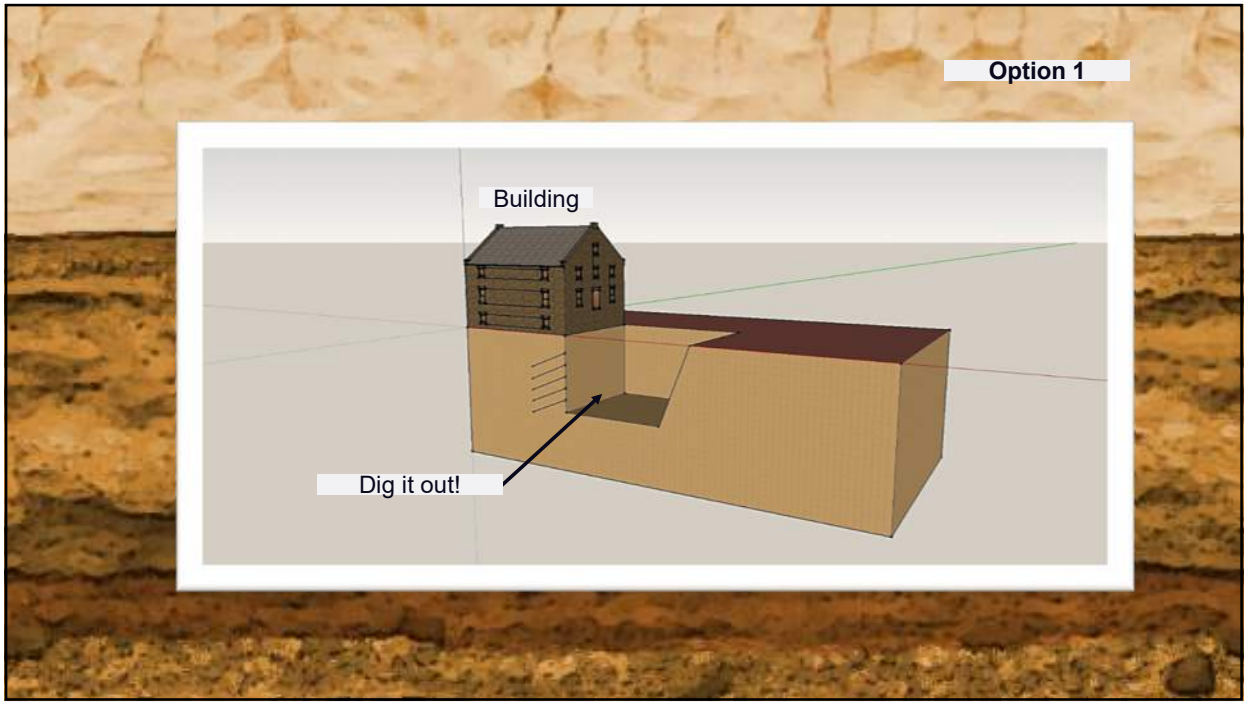
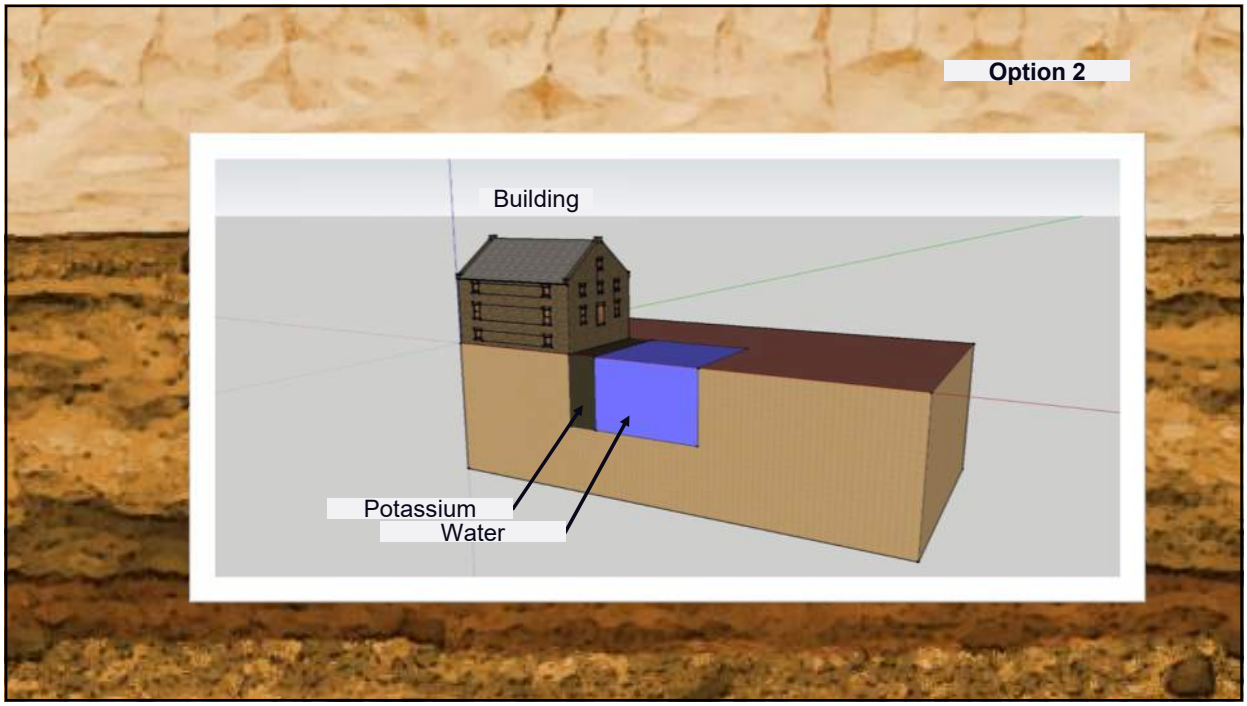

Building
Future Addition
Expansive Soil


Option 1
Building
Dig it out!



Remedial Warehouse Job
Irving, TX

Problem:
The slab in the warehouse of the building experienced heave due to expansive soils located beneath the structure.

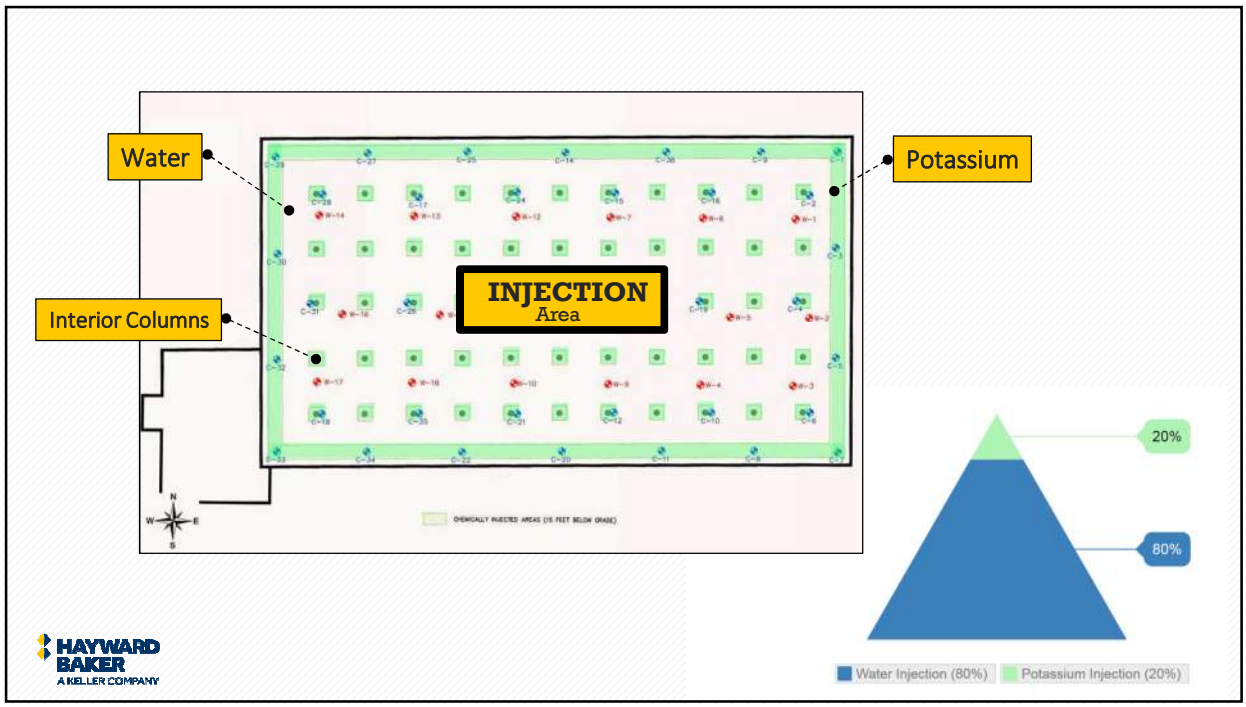
Remedial Warehouse Job
Irving,TX

Injection Area.

- The floor in this area was removed.
- A combination of chemical soil injection and water injection was used to limit the future movement of the soils under the floor slab.

Injection Plan.

The **potassium** was injected in a five (5') wide strip around the perimeter of the inside of the warehouse and in a ten by ten (10' X 10') area at each column location.



Remedial Warehouse Job
Irving, TX

Chemically Injected Areas (15' Below Grade)

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Quality Assurance

- A daily site progress report was completed.
- Includes area treated each day along with the amounts of all material injected into that area.

Test Results.

BORING NUMBER	DEPTH (ft)	INITIAL MOISTURE CONTENT, %	FINAL MOISTURE CONTENT, %	PERCENT SWELL	AVERAGE PERCENT SWELL	HAND PENETROMETER (tsf)
C-15R2	0-1	37.0				X
	1.-2	25.0	26.1	0.34		3.25
	2.-3	22.6	23.4	0.53		2.25
	3.-4	22.9	24.0	0.71		2.5
	4.-5	27.0			0.71%	2.0
	5.-6	25.3	26.7	0.40		2.25
	6.-7	27.2	28.5	0.84		2.75
	7.-8	38.0				0.5
	8.-9	-				-
	9.-10	50.0				X
	10.-11	-				-
	11.-12	-				-
	12.-13	48.0			1.43%	-
	13.-14	28.5	32.3	0.38		4.0
	14-15	29.1	33.1	2.48		4.5

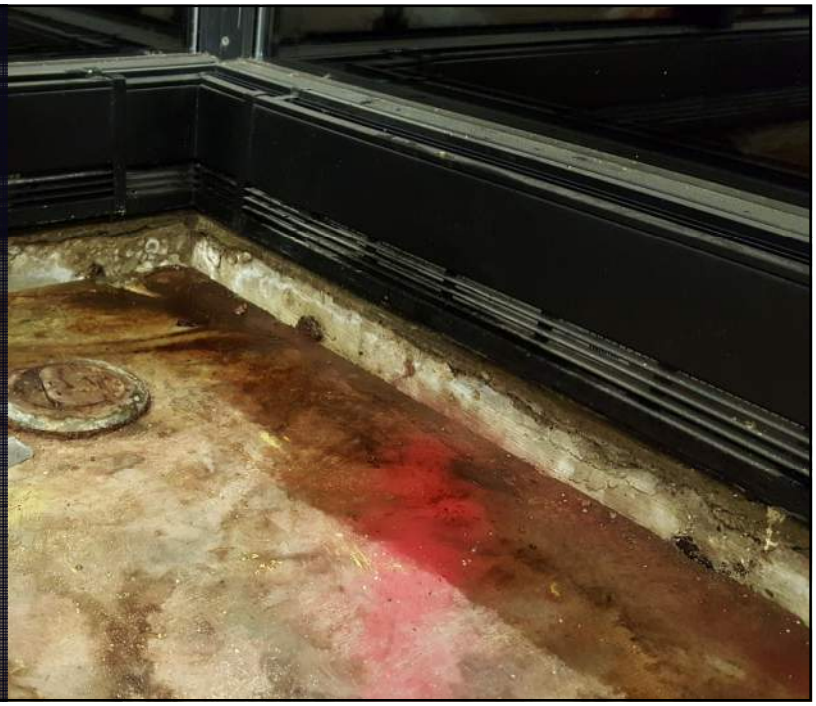
Number of Samples (0 - 10')	4
Number of Samples (10 - 15')	2

Remedial Job
Irving, TX

Problem:
The American Honda training center in Irving Texas experienced significant distress in floor slab and flatwork. The settlement of the floor slab was observed on the south side of the building. The brick paver area settled. Portions of the Honda distribution center, training center and warehouse were settling due to drying of underlying expansive soils.

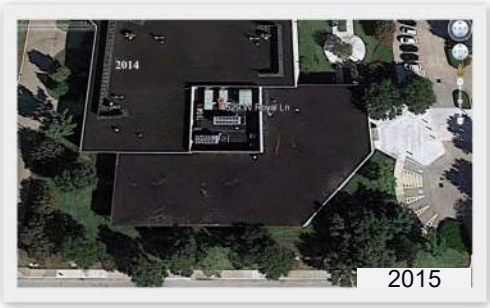
Expansive Clays.

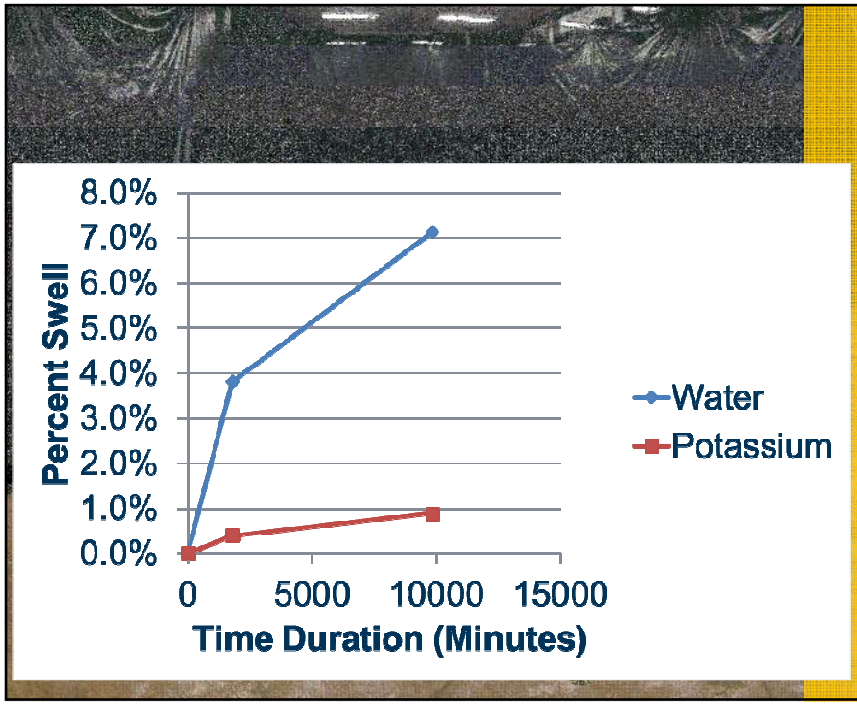
Two borings were drilled to explore subsurface conditions beneath the distressed area. **Highly expansive clays** were present in the borings.



Causes of Distress.

High hand penetrometer and **high swell** potentials were observed in the borings. This indicates that the soil is **dry** and experienced **shrinkage** in the past. This soil shrinkage is considered to be caused by moisture losses due to the presence of **large trees** near the building.





Options.

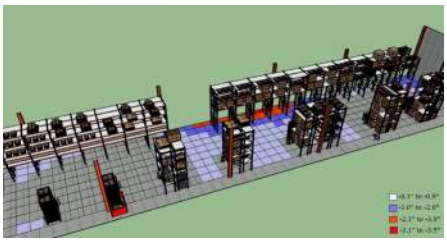
Construction of a structural slab over a void space.
The removal of trees or the installation of root barriers and a new-slab-on-grade after subgrade moisture levels are stabilized.
Coring the slab and injecting potassium chloride.

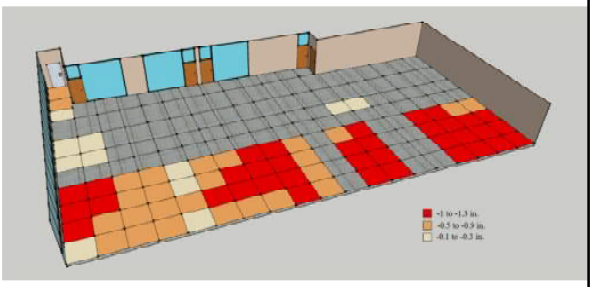
Repair.

Soil Injected to a depth of 10ft with an average chemical take of 0.5 gallons per cubic foot.

Post injection polyurethane grout was used to lift the slab back into place.

Hayward Baker
Polylift®





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Laboratory Test Results
Post-Injection

B-2			Location: See Boring Location Plan		Date Drilled: 12/3/2014	
DEPTH (Feet)			Hand Penetrometer (tsf)	Moisture Content (%)	Load (psf)	Swell (%)
0	to	1	0.5	29	---	---
1	to	2	2.0	35	---	---
2	to	3	1.75	29	250	0.5
3	to	4	2.0	28	---	---
4	to	5	2.0	28	500	0.2
5	to	6	2.0	31	---	---
6	to	7	2.75	30	---	---
7	to	8	2.5	29	850	0.0
8	to	9	2.25	30	---	---
9	to	10	2.5	26	1,125	0.2
10	to	11	3.5	24	---	---

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Thank you!

Questions?

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