The Use of Compaction Grouting for Ground Improvement; Karst and Beyond

Tom Szynakiewicz, PE, D.GE
Compaction grouting, otherwise known as Low Mobility Grouting (LMG) is the injection of low slump (typically less than 1”) cementitious grout into weak or soft soil layers throughout a weak soil profile in a primary/secondary pattern in order to **densify the soils for the purpose of increasing bearing capacity, decreasing settlement potential or general improvement**.
1. **(Step 1)** Hole is drilled or casing is driven to bottom of proposed treatment zone.

2. **(Step 2)** Compaction grout is then pumped through the casing until one of several refusal criteria have been reached.

3. **(Step 3)** Casing is lifted to the next stage and Steps 1 & 2 are repeated.
Geotechnical Compaction Grouting Applications

- Karstic Regions
- Rubble Fill
- Poorly Placed Fill
- Loosened Soil: Pre-Treatment
- Loosened Soil: Post-Treatment
- Liquefiable Soils
- Collapsible Soils

- Emergency Structure Settlement and Stabilization
- Karst Grouting
- Increasing Load Carrying Capacity of Existing Foundations
- To Compensate for Ground Loss During Tunneling
Advantages of Compaction Grouting

- Precise treatment
- Fast installation
- Can be performed in very tight access and low headroom
- No waste spoil disposal
- Wide applications range
- Non-destructive and adaptable to existing foundations
- Economic alternative to removal and replacement or piling
- Time tested and proven
- Site batching allows for necessary adjustments on the fly to maximize results
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
Grout Batching

- 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
Ideal Grout Make-Up

- 100% passing 3/8"
- 15-25% passing #200
- Rounded pea gravel helps
- 10-20% cement by volume
- Slump is very important – typically less than 2” for pre-treatment and around 1” for underpinning and piles
Compaction Grouting QA/QC

- Grout logs for every hole at every one ft stage during production
- Pre-production test program can evaluate improvement
- Pre and Post SPT’s
- CPT’s
- Primary/Secondary nature of the method “notices” improvement between primary and secondary holes
  - Higher pressures
  - Lower grout takes
Limitations

Like Any Ground Improvement Technique You Must Consider All Factors When Choosing A Remedial Technique

• The in situ vertical stress must be sufficient to enable the grout to displace the soil horizontally (if ground surface heave occurs densification will be minimized).
• The grout injection rate should be slow enough to allow pore pressure dissipation.
• Sequencing of grout injection is also important.
• Soils that lose strength during remolding (saturated, fine-grained soils; sensitive clays) should be avoided.
• Greater displacement will occur in weaker soil strata. Exhumed grout bulbs confirm that compaction grouting focuses improvement where it is most needed.
• Collapsible soils can usually be treated effectively with the addition of water during drilling prior to compaction grout injection.
• Stratified soils, particularly thinly stratified soils, can be cause for difficult or reduced improvement capability.
Geotechnically Problematic Conditions Where Compaction Grouting Can Be Effective
Collapsible Soils on Alluvial Fans
Karst
Culvert Washout or Sewer Line Collapse
Differing Soil Conditions Under Existing Structures

If footings are designed for sandy soil, then footings for the portion of the house over silty soil may be undersized. This could lead to differential settlement.

Sandy soil -- good bearing capacity

Silty soil -- poor bearing capacity
Urban Fills
Collapsing Mine Shafts
More mine mitigation needed beneath Rock Springs

Workers use a drilling rig to access an abandoned mine along Loop Road in Rock Springs. Concrete pillars will be poured to shore up the mine.

ROCK SPRINGS — Sweetwater County has a history of not sitting on stable ground.
Loess Deposits In Arid Areas
Day-to-Day Compaction Grouting Applications
Night Work on Roadways Allows Road Reopening During Day
Roadway Embankment Stabilization

Soft Soils On Fill Side Of Roadway Settle Over Time
Sleeper Slab Re-Leveling and Stabilization
MSE Wall Subgrade Stabilization
Utility Backfill Settlement Treatment and Ground Loss in Tunneling
Trench Backfill Densification
Gas Compressor Station
Vibration Induced Settlement
4” Total Settlement
ECIS Compaction
Grouting
Grouting Operations and Surface Heave Monitoring