Innovative Use of Compaction Grouting For Ground Improvement and Structure Rehabilitation

October 2016

OTEC
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.
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
- **Cost effective** alternative to removal and replacement or piling
- Time tested and proven
- Site batching allows for necessary adjustments on the fly to maximize results
Geotechnical Compaction Grouting Applications

- Grain Bin, Water and Oil Tank Subgrade Densification and Re-Leveling
- Wind Tower, Power Pole, and Substation Foundation Improvement and Rehabilitation
- Bearing Capacity Improvement for Additional Structure Load
- Railroad Subgrade Stabilization and Improvement
- Sinkhole Stabilization and Karst Grouting
- Trench Backfill Improvement
- Settlement Control and Bearing Capacity Improvement for Retaining Walls and Bridge Abutment/MSE Wall Repair
- Bridge Approach Slab and Sleeper Slab Settlement Mitigation and Re-Leveling
- Historic Structure Subgrade Improvement, Stabilization, and Re-Leveling
Ideal Grout Make-Up

- Aggregate:
  - 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
Day-to-Day Compaction
Grouting Applications
Sinkholes

Karst Related
(nature caused)

Culvert/Tunnel/Utility Collapse
(man caused)
Emergency Sinkhole Stabilization and Repair Typically Consists of Two Components:

- Backfilling the sinkhole from surface with a flowable fill material often from a ready-mix plant, or material produced with on-site batchers.
- Deep compaction grouting into the throat of the sinkhole in order to choke it off so that the flow fill can begin to fill it up.
- Once the sinkhole is stabilized, a pattern of compaction grouting can be performed around the sinkhole in overburden soils in order to find and densify and loosen soils and or voids that may not have yet collapsed or propagated to the surface.
Collapsing Mine Shafts
Roadway Embankment Stabilization

Soft soils on fill side of roadway settle over time
Utility Backfill Settlement Treatment and Ground Loss in Tunneling
Night Work on Roadways Allows Road Reopening During Day
Settlement Reduction From Fill Loads
US HWY 12 - Cooper Creek Bridge Approach Settlement Mitigation
White Sulphur Springs, MT

- Bridge was replaced several years ago
- Approaches started settling immediately afterwards
- Approaches were repaved several times
- Subsequent borings showed loose abutment fill from 10 – 25 ft bgs
• Compaction grouting is being used to densify the soft zones on both approaches to reduce or eliminate additional future settlement
• SPT’s are being used to verify densification
• Roadway surface will be milled and repaved following grouting
Plan View
\[\text{Not to Scale}\]

Treatment Area, Typ.

Abutment

West

Bridge
32' Wide
12' Lane
4' Shoulder

24', typ.

6', typ.

4', typ.
Coal Mine Collapse Mitigation

Norton, VA
38 Road Improvements MSE Wall Repair
38 Road Improvements MSE Wall Repair
MSE Wall Rotated Outward and Settled Immediately After Completion of Construction
First Stability Model Iteration

Existing Condition

<table>
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<tr>
<th>Material Name</th>
<th>Color</th>
<th>Unit Weight (lbs/ft³)</th>
<th>Strength Type</th>
<th>Cohesion (lb/ft²)</th>
<th>Phi</th>
<th>Water Surface</th>
<th>Ru</th>
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</table>
Second Stability Model Iteration
Repair Concept Following Site Evaluation
38 Road Improvements MSE Wall Repair

MSE Wall Was Stabilized In-Place With Soil Nails

Re-Densification of Softened Wall Backfill Material Following Wall Movement

Bearing Capacity Improvement For Wall Load – Original Wall Did Not Bear on Bedrock
• Purpose of the Grouting
  – At top of wall
    • Once the wall had been stabilized, compaction grouting was used to densify softened and voided zones that were created as a result of the slope/wall movement in order to reduce future settlement potential of the roadway surface in the following years (decreasing future maintenance costs)
  – At base of the wall
    • Compaction grouting was used to increase the bearing capacity of the soil under the wall face and wall backfill within approximately 4 ft of the wall face in order to prevent additional wall settlement and potentially resulting rotation leading to further pavement distress thereby decreasing future maintenance costs
Casing Installation
Compaction Grouting — While monitoring injection pressures, quantities, and ground movement
Casing Installation for improvement below existing MSE wall
CNP230 TDOT – Random Fill Grouting Behind Planned Anchored Soldier Pile and Lagging Wall
Chattanooga, TN
CNP230 TDOT – Random Fill Grouting Behind Planned Anchored Soldier Pile and Lagging Wall
Chattanooga, TN

• Anchored Soldier Pile Wall Up to 60 ft Tall
• Portion of Soil Behind Wall is 50 Year Old Backfill, Debris, Concrete, Steel
• Ground Anchors Must Bond in Fill Due to ROW/Easement Restrictions
• Compaction Grouting Will Improve Fill and Increase Anchor/Soil Bond Values
TERTIARY GROUT HOLE SPACING "\(\frac{5}{2}\)" (TYP.)

SECONDARY GROUT HOLE SPACING "\(\frac{5}{2}\)" (TYP.)

CENTER TO CENTER GROUT HOLE SPACING DETAIL

ZONE A - \(S = 3\) FEET OR AS SPECIFIED BY THE ENGINEER
ZONE B - \(S = 5\) FEET OR AS SPECIFIED BY THE ENGINEER
ZONE C - \(S = 3\) FEET OR AS SPECIFIED BY THE ENGINEER

RAMP P
STA. 22+00

NOTE: ALL PRIMARY, SECONDARY, AND TERTIARY GROUT HOLES WILL BE PAID AT THE CONTRACT UNIT RATES.

SPT SPECIMENS AS WELL AS STANDARD PENETRATION TEST (SPT) N-VALUE. SUCCESS CRITERIA SHALL BE NO VOIDS LARGER THAN 1/2 INCH VERTICAL EXTENT, NOT LESS THAN 50% RECOVERY OF SPT SAMPLES, AND SPT N-VALUES NOT LESS THAN 11 BLOWS PER FOOT IN COHESIONLESS SOIL OR 5 BLOWS PER FOOT IN COHESIVE SOIL.