I. Project Description

The bump at the beginning or end of a bridge is a serious safety issue and a common problem on North Carolina Department of Transportation (NCDOT) bridges. Several years ago there was even a traffic fatality in eastern North Carolina attributed to a settling bridge approach slab. This STIC project involved deep compaction grouting to stabilize settling bridge approach embankments and slabs and restore the grade of the approach slabs for the dual bridges on Cary Parkway over the Norfolk Southern Railroad in Cary, NC. The bridges were constructed in 2001 and the failing bridge approach slabs continued to settle creating maintenance issues and citizen complaints.

Compaction grouting was developed in the U.S. in the 1950’s as a remedial measure for foundation settlement. Compaction grouting has only recently been used for bridge approach slab settlement by some state DOTs in the western U.S. Compaction grouting is an in-situ subsurface soil treatment that can improve and remediate a wide range of subsurface conditions. This process strengthens and/or stiffens the subsurface soils by pumping a relatively low slump low mobility grout under pressure to a deep supporting layer. Homogenous grout bulbs are formed that displace and densify the surrounding soils and grout bulb support columns are created as the process continues (see attached Hayward Baker Compaction Grouting Brochure).

The ongoing settlement of the bridge approach slabs for Wake County bridge nos. 911208 and 911209 carrying Cary Parkway (NC Secondary Route 3112) over Norfolk Southern Railroad in Cary, NC created several maintenance problems including failed bridge joints, cracked bridge approach pavements and inadequate drainage. In addition, the substantial “bump at the end of the bridge” was significant enough that NCDOT was receiving complaints from the public about it. The purpose of compaction grouting is to stabilize and raise the approach slabs in order to eliminate future maintenance issues and the bump at the beginnings and ends of the bridges. Previous conventional corrective action attempts were ineffective in the long term because these attempts only included void filling and slab jacking by pumping cementitious grout immediately below the bridge approach slabs. The embankment fill soils continued to settle with a total settlement of approximately 8 inches over a period of 15 years.
The compaction grouting contract was executed August 30, 2016 and the work was completed in the fall of 2016. The bid amount was $197,780.00 which was partially funded by the $75,000 STIC grant. The total project cost was approximately $300K which included costs for compaction grouting, traffic control, paving and marking, surveying and specification development. The compaction grouting was monitored during injection by recording the grout pressure and volume and ground surface movement on grout logs. The approaches and departures were scanned for movement with Light Detection and Ranging (LiDAR) before and after compaction grouting as well as about every 3 months since completion with the most recent scan done November 27, 2017 (see attached LiDAR Results from Cary Parkway Bridges). It should be noted that the approaches and departures have been repaved twice since the work was completed; once right after compaction grouting and about a year later as part of a larger paving project.

II. Project Results

NCDOT has used other types of deep grouting for bridge approach slabs such as permeation grouting and Uretek’s patented Deep Injection Process with varying degrees of success and numerous problems including significant cost overruns due to excessive quantities of polyurethane foam. The documented benefits of compaction grouting include economical costs, deep injection, minimal traffic interruption and controlled, reliable and verifiable results. Compaction grouting is significantly less expensive than remove and replace or alternative types of grouting when comparing equivalent injection depths and grout quantities can typically be reasonably estimated. Compaction grouting minimizes lane closures due to the speed of installation, has no waste disposal and can be done in tight areas at night. Compaction grouting is more effective than other types of deep grouting because grout is injected through sectional casings to deeper depths in order to reach stiffer soil layers. Compaction grouting is effective in a variety of soil types, relatively nondestructive as it is injected through core holes in the pavement and monitored by recording grout parameters.

This STIC project has been very successful as compaction grouting has proven to be an effective solution for the problem of settling approach slabs. The actual grout pay quantities were within 20% of the proposal grout bid quantities which allowed for a reasonably accurate cost estimate. The LiDAR results show minimal settlement has occurred over the last year indicating that movement has significantly slowed or stopped. The ride has substantially improved and NCDOT is no longer receiving complaints from the public about a bump at the beginnings or ends of the Cary Parkway bridges.

In addition to the Cary Parkway bridges, NCDOT has completed 3 other compaction grouting projects with two different contractors. All four compaction grouting projects have covered a wide variety of subsurface conditions, grouting depths and compaction grouting applications. These three additional projects are summarized below.

- US 70 Goldsboro Bypass in Wayne County, NC – Underpinning a sleeper slab for a bridge approach slab
US 321 Blowing Rock Bypass in Watauga County, NC – Stabilizing a roadway embankment above a soil nail wall

SR 1187 (Sanders Road) in New Hanover County, NC – Stabilizing a roadway subgrade with a sinkhole

As a result of this STIC project, the use of compaction grouting is becoming common across the state to stabilize subgrades, embankments and bridge approach slabs. A fifth compaction grouting project is scheduled to be let in January, 2018 to stabilize 6 settling bridge approach slabs for 3 bridges on US 70 Clayton Bypass in Johnston County, NC.

NCDOT had not used compaction grouting in any ground improvement application prior to this STIC project. Previously, NCDOT used deep grouting for approach slabs primarily by contracting with a single contractor due to patent restrictions or contractor availability. As a result of this project, NCDOT will be able to competitively bid deep grouting for approach slabs because of the number of readily available compaction grouting contractors around the southeast. NCDOT has gained a lot of experience with compaction grouting over the last 18 months. The Geotechnical Engineering Unit (GEU) has used this experience to develop a standard compaction grouting provision as well as incorporate a low slump low mobility grout (Type 5) into the NCDOT Standard Specifications for Roads and Bridges (see attached Grout Specification and Compaction Grouting Provision). With this innovative application of compaction grouting for settling approach slabs, NCDOT has gained experience with and developed specifications for compaction grouting of bridge approach slabs and other future ground improvement applications. These standards will make using compaction grouting easier in the future as opportunities arise. The GEU has also learned numerous lessons about compaction grouting from the projects completed to date. Some of the more apparent lessons learned are summarized below.

- Compaction grouting can be very expensive depending on the grouting depth but is typically about 2 to 3 times the cost of slab jacking. However, if settlement has not stopped, slab jacking is only a temporary fix while compaction grouting can be a long term solution if grouting depths are deep enough.
- Subsurface investigations (borings) are very beneficial for determining grouting depths and estimating grout takes.
- Grout logs from compaction grouting consisting of grout volumes and pressures and ground heave measurements can provide valuable information about how stiff or dense the subsurface is and give an indication of where loose or soft zones are.
- Volumetric concrete mixers are best suited for typical compaction grouting conditions and situations.
- Low slump low mobility grout mixes can vary greatly depending on local aggregate sources available but aggregate gradation has the greatest effect on the pumpability of the grout.
- Movement monitoring is critical to prevent damage to slabs, structures, drains, utilities or walls.
- As with all grouting, compaction grouting plans and criteria will probably be revised in the field as grouting proceeds based on monitoring results and contractor experience.
so it is important to have a qualified and experienced grouting contractor (most subsurface grouting is “more art than science”).

- After compaction grouting is completed, slab jacking and void filling with either cementitious grout or polyurethane foam are usually still required to lift the slab back to original grade and ensure the slab is fully supported by the subgrade. Therefore, the GEU also developed specifications for slab jacking and polyurethane foam for future use on compaction grouting projects.

For additional information about NCDOT's experience with compaction grouting, please contact Scott Hidden of the Geotechnical Engineering Unit at (919) 707-6856 or shidden@ncdot.gov.

Attachments:

- Hayward Baker Compaction Grouting Brochure
- LiDAR Results from Cary Parkway Bridges
- Grout Production and Delivery (Section 1003) Specification
- Compaction Grouting Provision
Compaction grouting improves a wide range of ground conditions by displacement, for a variety of site improvement and remedial applications.

Compaction grouting was used to seal this 160-foot diameter sinkhole that extended down to the Floridan aquifer.

When a properly designed compaction grout is injected into loose soils, homogeneous grout bulbs are formed that displace, densify and thus strengthen the surrounding soil.

The technique was originally developed in the 1950's as a remedial measure for the correction of building settlement, and used almost exclusively for that purpose for many years. Over the past twenty years, however, compaction grouting technology has evolved to treat a wide range of subsurface conditions for new and remedial construction. These include rubble fills, poorly placed fills, loosened or collapsible soils, sinkhole sites, and liquefiable soils.

Hayward Baker’s compaction grouting techniques, which include the internationally respected Denver System, offer an economic advantage over conventional approaches such as removal and replacement or piling. Compaction grouting can be accomplished where access is difficult and space is limited. Since compaction grouting’s effectiveness is independent of structural connections, the technique is readily adaptable to existing foundations.
Compaction grouting improves ground conditions by displacement. A very viscous (low-mobility), aggregate grout is pumped in stages to displace and densify the surrounding soils. By sequencing the grouting work from primary to secondary to tertiary locations, this densification process can be performed to achieve significant improvement. Hayward Baker’s compaction grouting capability, spanning more than 25 years, is enhanced by the control features provided by the Denver System: batching-on-demand, and specialized, high pressure injection.

Site Investigation
For successful compaction grouting, comprehensive knowledge of subsurface conditions is important. In order to prepare a suitable program, a geotechnical engineering consultant will develop a site investigation report, which will generally contain site geology and history, soil gradation, and the in situ horizontal permeability of each treatment stratum. Type and condition of nearby structures and utilities, together with plan and elevation locations, will further assist program development.

Geotechnical Considerations
Conditions necessary for optimum compaction grouting results:

1. The in situ vertical stress in the treatment stratum must be sufficient to enable the grout to displace the soil horizontally (if uncontrolled heave of the ground surface occurs, densification will be minimized).

2. When compaction grout is injected into saturated soils, a pore pressure increase occurs as a result of ground displacement. This increased pressure must dissipate for effective densification to take place. Therefore, the grout injection rate should be slow enough to allow pore pressure dissipation. Sequencing of grout injection is also important.

3. Compaction grouting can usually be effective in most silts and sands, provided that the soil is not near saturation.

4. Soils that lose strength during remolding (saturated, fine-grained soils; sensitive clays) should be avoided.

5. Greater displacement will occur in weaker soil strata. Excavated grout bulbs confirm that compaction grouting focuses improvement where it is most needed.

6. Collapsible soils can usually be treated effectively by adding water during drilling prior to compaction grout injection.

7. Stratified soils, particularly thinly stratified soils, can be cause for difficult or reduced improvement capability.

The grout mix must have specific characteristics: a very low mobility (low slump) mixture that is "pumpable" but, upon installation, exhibits an internal friction enabling it to remain intact and displace the surrounding soil without fracturing it.

![Range of soils that will show improvement by post-testing. Compaction grouting can also be used to reinforce soils beyond this guideline, provided that drainage is enhanced.](image-url)
Compaction Grouting Delivery Methods

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 be top down
- Grout quality important
- Pressure and/or volume of grout is usually limited
- Slow, uniform stage injection

Continuation of grouting:
- On-site batching can aid control
- Grout quality important
- Pressure, grout quantity and indication of heave are controlling factors
- Sequencing of plan injection points very important

Improvement Conditions
Typically greater than 1,500 psf overburden stress is required to maximize densification. Limited densification can be achieved with less overburden. This stress can come from overburden soils, surcharge loads and/or foundation loads. When densification is the primary intent, a replacement ratio and pressure criterion is applied to each stage of compaction grouting. This ratio is determined based on the existing density, the soil density range, and the amount of displacement necessary to affect the improvement.

\[
\text{CG Volume} = \frac{\text{Replacement Ratio (RR)}}{\text{Treatment Volume}} \approx 5\text{ to }15\% \text{ (typical)}
\]

Experience has proven that treatment spacing should not exceed 6 to 10 ft. From this, a compaction grouting volume can be calculated. The maximum pressure criterion prevents fracture and ground heave and compensates for stiff zones in the treatment area. Vertical stages are usually set at 2- to 3-ft intervals; tighter grid spacing will generally lead to better results.

Quality Control/Quality Assurance
Quality control includes procedural inspection and documentation of the work activity, testing to ensure proper mix design and injection rates, and verification of ground improvement where applicable. Ground improvement can be assessed by Standard Penetration Testing, Cone Penetrometer Testing, or other similar methods. Data recording of important grouting parameters has been utilized on sensitive projects.

"The design and application of compaction grouting is always site-specific, considering the entire above- and below-ground conditions."
Case Histories . . .

Karstic Regions

Pre-treatment for prevention of potential sinkholes is common. This usually involves drilling down to and into the limestone surface to locate and fill any cavities, followed by improvement of the loose soil above the rock surface. A denser, less erodible soil results, better able to arch over any sinkhole that might develop in the future.

**Summit Office Building**

**Maitland, Florida**

Maitland is an active sinkhole area and also a desirable commercial real estate market. Development proceeds with a significant risk of sinkhole-related structural damage. To reduce the high risk of sinkhole development at the Summit Office Building site, compaction grouting was used to improve the soils at each stone column location. A total of 14,350 cu yds of compaction grout was injected at 340 grout point locations at depths of 80 to 120 ft. Grade beams were incorporated into the foundation design to span between columns. After completion of the grouting program, an irrigation well triggered three sinkholes on the site, but not within the treated areas.

**Active Sinkholes**

Where this condition develops, injection casing is installed around the perimeter of the depression, and aimed at the throat of the limestone opening. The compaction grouting program includes first filling the void at depth, followed by staged treatment to densify the loosened soil in and above the cavity. Due to the inverted cone shape of loosened soil, structures that exist near the cone can often be lifted back to near original elevation.

**Dalesford Lake Development**

**Berwyn, Pennsylvania**

A luxury, four-unit townhouse structure founded on timber piles had exhibited structural distress related to sinkhole activity. Subsurface investigation revealed 5 to 30 ft of miscellaneous construction fill, including wood chips and building materials, overlying clay soil. Beneath this, pinnacled karstic limestone was encountered at depths ranging between 10 and 30 ft. Compaction grouting was performed to stabilize the driven pile foundation, re-establish ground contact with the structure, and halt the soil piping that resulted from sinkhole activity. Grout pipes were installed at 68 interior, low headroom locations, and 90 exterior locations, to average depths of 16 to 21 ft. The work was successfully completed while the building remained occupied.
Rubble Fill
Construction debris and other similar fills are often placed in an uncontrolled manner. This results in a very porous, voided matrix that can deform and settle over time due to the migration of soil into the voids. To close the void spaces and minimize potential settlement impact, compaction grouting is applied in a regular pattern.

One Woodway Plaza
Houston, Texas
Over several years, a four-story office building's foundation element had undergone major settlement. Built in the early 1970s on spread footings, deep grade beams and drilled caissons, the structure sits on 30 ft of construction rubble fill, beneath which are competent soils. A significant part of the rehabilitation program involved compaction grouting 33 ft deep to stabilize the fill and lift spread footings back to the original elevation. Work was accomplished at night, with more than 3,600 cu yds of grout pumped through 467 low-headroom, interior locations. The settled footings were raised up to 8 inches. In addition, drilled caissons were underpinned with micropiles, and an anchored retaining wall was constructed to stabilize a failed MSE wall.

Poorly Placed Fill
Provided sufficient overburden stress exists, a proper program of compaction grouting can treat the poorly placed fill material. This is often utilized when structure deformation alerts the owner to the problem, and an unobtrusive approach to foundation restoration is needed.

WMATA Station Platforms
Rockville and Landover, Maryland
Areas of poorly compacted granular fill beneath two Washington Metro Area Transportation Authority subway platforms had resulted in up to three inches of settlement. Consolidation of the fill was achieved through compaction grouting by the Denver System. Over 150 grout points were established for the 2 platforms. Following coring through the concrete platforms, 2-inch ID casing was pneumatically driven in 3-ft, battered sections to between 9 and 17 ft. Low mobility grout was delivered via the specially designed, on-site mobile batching and pumping unit that typifies the Denver System. Limited station access required this unit to operate across the tracks from the platforms. Although casing installation was accomplished during station operating hours, grouting was limited to line shut-down hours of 1 to 4 a.m.
Case Histories...

Loosened Soil: Pre-Treatment

Construction-generated ground disturbance can often be the cause of soil loosening near the work area. This can affect nearby structures. The injection of compaction grout soon after the disturbance occurs can compensate for the disturbance by re-establishing the original stress state and prevent deformations beyond the work area.

La Reina Building
Hollywood, California

The La Reina Building is a six-story glass and steel office complex founded on large spread footings. The building sits 80 to 90 ft directly above the alignment of a new, twin-tube subway tunnel. Compaction grouting was used to protect the building against settlement resulting from foundation soils being loosened during tunneling. As the tunneling machine passed beneath the building, grouting was initiated just following the advancement of the tunnel shield and expansion of the tunneling precast segments. The complex array of 150, precisely angled compaction grout pipes were positioned within 5 ft of the tunnel crown. Gyroscopic survey of installed pipe tip locations and as-built CAD drawings aided the critical sequencing of tunneling and grouting.

Loosened Soil: Post-Treatment

This is often a man-made condition resulting from nearby construction...subsurface utility backfill, tunneling, poorly stabilized excavations. Knowledge of how the condition occurred is useful, as the treatment zone must be accurately located to provide the desired benefit. Ground improvement is usually undertaken to re-establish the previous stress state, instead of providing improvement beyond.

Industrial Plant
Northwestern Georgia

The combination of a high water table, leaking water pipe and a loose soil profile had initiated settlement beneath a 300-ft long rail siding structure. Over time, these settlements had been compounded by heavy, dynamic train loads that induced slab cracking. This was aggravated when fines pumping through the cracks further loosened the subsurface soils. Compaction grouting was performed on 2- to 4-ft centers in a primary/secondary sequence to depths of up to 18 ft to reinforce and densify the loosened soils. Careful scheduling of the grouting program allowed the facility to remain operational around the clock. This enabled the owner to keep the plant fully on-line an extra four weeks before a scheduled repair shutdown, thus limiting major plant disruption.
Liquefiable Soils

For these conditions, ground improvement consists of density increase, cellular containment, and/or reinforcement. In all cases, soil permeability is an important parameter in determining the rate of compaction grouting so that improvement results.

LRT Extension, Morena Segment
San Diego, California

In the Mission Valley area of San Diego, three light rail transit bridges are supported by individual piers. The piers bear on 9-ft diameter caissons up to 130 ft deep. These caissons are founded in dense sands and gravels underlying potentially liquefiable soils. Although the caissons are founded below the zone of liquefaction, they rely on support from the surrounding soils for lateral stability. Prior to bridge construction, compaction grouting was performed to depths of between 45 and 115 ft around 6 abutments and 68 caissons to densify and reinforce the soils, mitigating their liquefaction potential and thereby ensuring the long-term protection needed for the caissons and the bridge superstructure in the event of an earthquake.

Collapsible Soils

Collapsible soil conditions exist in specific regions where wind-blown sills have accumulated or intermittent stream flow deposition has occurred. Treatment of these soils is possible by forcing a restructuring of the fine grains into a tighter configuration. The replacement quantity of compaction grout by volume can be higher than normal for sites like this, as the pretreatment condition can be very loose.

Hampton Inn, Albuquerque, New Mexico

In the five years since construction, a Hampton Inn had settled almost 2.5 inches. Data indicated that the moisture contents of the upper 20 ft of soils were now higher than at the time of construction. Modeling tests indicated a soil collapse potential of 5 to 7 inches. Compaction grouting was performed to varying depths at 150 locations to target the higher moisture content soils, with the majority of the work done in limited headroom within the occupied building. Total grout take for the project represented 14.5 percent of soil volume for the treated zone. Post-grouting survey results indicate that movement of the structure has slowed to a rate of less than .0025 inches per year.
Advantages of Hayward Baker’s Compaction Grouting

- Pinpoint treatment
- Speed of installation
- Wide applications range
- Effective in a variety of soil conditions
- Can be performed in very tight access and low headroom conditions
- Non-hazardous
- No waste spoil disposal
- No need to connect to footing or column
- Non-destructive and adaptable to existing foundations
- Economic alternative to removal and replacement or filing
- Able to reach depths unattainable by other methods
- Enhanced control and effectiveness of in situ treatment with Denver System

Why Should You Choose A Hayward Baker Compaction Grouting Solution?

As North America’s largest geotechnical contractor, Hayward Baker has the resources to build your project. We manufacture much of our own equipment, ensuring the best performance and reliability in the industry.

From job start-up to job end, our attention to quality control ensures project specifications are achieved. Our network of offices and full-service equipment yards means fast mobilization and reduced start-up costs.

Hayward Baker is committed to providing the most economical solution that satisfies the technical requirements of each project.

Whether a situation is typical or unique, we have the experience and innovation to assist engineers, contractors and owners with identifying and implementing the best solution. For a variety of subsurface conditions, compaction grouting may be the answer.
Profile View of Initial and Final LiDAR Scans along NW Approach - Wheel Lane 1
(From the beginning of bridge deck to 50 ft beyond beginning of slab)

- End of Approach Slab (Beginning of Bridge Deck)
- End of Pavement (Beginning of Approach Slab)

Elevation (ft)

Station

08/09/16 - Initial Scan (Before Deep Compaction)
11/16/16 - 1st Rescan (After Deep Compaction and Paving)
11/27/17 - Final Rescan

Note: 2/20/17, 5/30/17, and 8/30/17 Rescans not shown for clarity

Profile View of Initial and Final LiDAR Scans along NW Approach - Wheel Lane 4
(From the beginning of bridge deck to 50 ft beyond beginning of slab)

- End of Approach Slab (Beginning of Bridge Deck)
- End of Pavement (Beginning of Approach Slab)

Elevation (ft)

Station

08/09/16 - Initial Scan (Before Deep Compaction)
11/16/16 - 1st Rescan (After Deep Compaction and Paving)
11/27/19 - Final Rescan

Note: 2/20/17, 5/30/17, and 8/30/17 Rescans not shown for clarity
Profile View of Initial and Final LiDAR Scans along NE Departure - Wheel Lane 1
(From the beginning of bridge deck to 50 ft beyond beginning of slab)

Profile View of Initial and Final LiDAR Scans along NE Departure - Wheel Lane 4
(From the beginning of bridge deck to 50 ft beyond beginning of slab)

Note: 2/20/17, 5/30/17, and 8/30/17 Rescans not shown for clarity
Profile View of initial and Final LiDAR Scans along SW Departure - Wheel Lane 1
(From the beginning of bridge deck to 50 ft beyond beginning of slab)

Note: 2/20/17, 5/30/17, and 8/30/17 Rescans not shown for clarity

Profile View of Initial and Final LiDAR Scans along SW Departure - Wheel Lane 4
(From the beginning of bridge deck to 50 ft beyond beginning of slab)

Note: 2/20/17, 5/30/17, and 8/30/17 Rescans not shown for clarity
Profile View of Initial and Final LiDAR along SE Approach - Wheel Lane 1
(From the beginning of bridge deck to 50 ft beyond beginning of slab)

Profile View of Initial and Final LiDAR along SE Approach - Wheel Lane 4
(From the beginning of bridge deck to 50 ft beyond beginning of slab)

Note: 2/20/17, 5/30/17, and 8/30/17 Rescans not shown for clarity
the same shooting position and at the same time as shotcreting is done. Do not disturb
test panels for the first 24 hours after shotcreting.

(H) Handling and Storing Test Panels

Notify the Area Materials Engineer when preconstruction or production test panels are
made within 24 hours of shooting the panels. Field cure and protect test panels from
damage in accordance with ASTM C1140. The Contractor shall core the panels in the
presence of the Engineer. The Department transports core to a Materials and Tests
Regional Laboratory for testing.

SECTION 1003
GROUT PRODUCTION AND DELIVERY

1003-1 DESCRIPTION

This section addresses cement grout to be used for structures, foundations, retaining walls,
concrete barriers, embankments, pavements and other applications in accordance with the
contract. Produce non-metallic grout composed of Portland cement and water and at the
Contractor’s option or as required, aggregate and supplementary cementitious materials.
Include chemical admixtures as required or needed. Provide sand cement or neat cement
grout as required. Define “neat cement grout” as grout without aggregate.

The types of grout with their typical uses are as shown below:

Type 1 – A cement grout with only a 3 day strength requirement and a fluid consistency that
is typically used for filling subsurface voids.

Type 2 – A nonshrink grout with strength, height change and flow conforming to ASTM
C1107 that is typically used for foundations, ground anchors and soil nails.

Type 3 – A nonshrink grout with high early strength and freeze-thaw durability requirements
that is typically used in pile blockouts, grout pockets, shear keys, dowel holes and recesses for
concrete barriers and structures.

Type 4 – A neat cement grout with low strength, a fluid consistency and high fly ash content
that is typically used for slab jacking.

Type 5 – A low slump, low mobility cement grout with minimal strength that is typically
used for compaction grouting.

1003-2 MATERIALS

Refer to Division 10.

<table>
<thead>
<tr>
<th>Item</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Admixtures</td>
<td>1024-3</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>1014-1</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>1024-5</td>
</tr>
<tr>
<td>Ground Granulated Blast Furnace Slag</td>
<td>1024-6</td>
</tr>
<tr>
<td>Portland Cement</td>
<td>1024-1</td>
</tr>
<tr>
<td>Silica Fume</td>
<td>1024-7</td>
</tr>
<tr>
<td>Water</td>
<td>1024-4</td>
</tr>
</tbody>
</table>

Do not use grout that contains soluble chlorides or more than 1% soluble sulfate.

At the Contractor’s option, use an approved packaged grout instead of the materials above
except for water. Use packaged grouts that are on the NCDOT APL.

Use admixtures for grout that are on the NCDOT APL or other admixtures in accordance with
Subarticle 1024-3(E) except do not use concrete additives or unclassified or other admixtures
in Type 4 or 5 grout. Use Class F fly ash for Type 4 grout and Type II Portland cement for
Type 5 grout.
Section 1003

Use well graded rounded aggregate with a gradation, liquid limit (LL) and plasticity index (PI) that meet Table 1003-1 for Type 5 grout. Fly ash may be substituted for a portion of the fines in the aggregate. Do not use any other supplementary cementitious materials in Type 5 grout.

<table>
<thead>
<tr>
<th>TABLE 1003-1</th>
<th>AGGREGATE REQUIREMENTS FOR TYPE 5 GROUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation</td>
<td>Liquid Limit</td>
</tr>
<tr>
<td>Sieve Designation per AASHTO M 92</td>
<td>Percentage Passing (% by weight)</td>
</tr>
<tr>
<td>3/8”</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>70 – 95</td>
</tr>
<tr>
<td>No. 8</td>
<td>50 – 90</td>
</tr>
<tr>
<td>No. 16</td>
<td>30 – 80</td>
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<td>25 – 70</td>
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</tr>
<tr>
<td>No. 100</td>
<td>15 – 40</td>
</tr>
<tr>
<td>No. 200</td>
<td>10 – 30</td>
</tr>
</tbody>
</table>

1003-3 COMPOSITION AND DESIGN

When using approved packaged grout, a grout mix design submittal is not required. Otherwise, submit proposed grout mix designs for each grout mix to be used in the work. Mixes for all grout shall be designed by a Certified Concrete Mix Design Technician or an Engineer licensed by the State of North Carolina. Mix proportions shall be determined by a testing laboratory approved by the Department. Base grout mix designs on laboratory trial batches that meet Table 1003-2 and this section. With permission, the Contractor may use a quantity of chemical admixture within the range shown on the current list of approved admixtures maintained by the Materials and Tests Unit.

Submit grout mix designs in terms of saturated surface dry weights on Materials and Tests Form 312U at least 35 days before proposed use. Adjust batch proportions to compensate for surface moisture contained in the aggregates at the time of batching. Changes in the saturated surface dry mix proportions will not be permitted unless revised grout mix designs have been submitted to the Engineer and approved.

Accompany Materials and Tests Form 312U with a listing of laboratory test results of compressive strength, density and flow or slump and if applicable, aggregate gradation, height change and durability from a certified laboratory. List the compressive strength of at least three 2 inch cubes at the age of 3 and 14 or 28 days per Table 1003-2 for Type 1 through 4 grouts. List the compressive strength of at least three 6 inch x 12 inch cylinders at the age of 3 and 28 days for Type 5 grout.

The Engineer will review the grout mix design for compliance with the contract and notify the Contractor as to its acceptability. Do not use a grout mix until written notice has been received. Acceptance of the grout mix design or use of approved packaged grouts does not relieve the Contractor of his responsibility to furnish a product that meets the contract. Upon written request from the Contractor, a grout mix design accepted and used satisfactorily on any Department project may be accepted for use on other projects.
Perform laboratory tests in accordance with the following test procedures:

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Gradation A</td>
<td>AASHTO T 27</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>AASHTO T 106</td>
</tr>
<tr>
<td>Density (Unit Weight)</td>
<td>AASHTO T 121 AASHTO T 133 B, ANSI/API RP C 13B-1 B (Section 4, Mud Balance)</td>
</tr>
<tr>
<td>Durability A</td>
<td>AASHTO T 161 B</td>
</tr>
<tr>
<td>Flow</td>
<td>ASTM C939 (Flow Cone)</td>
</tr>
<tr>
<td>Height Change E</td>
<td>ASTM C1090 E</td>
</tr>
<tr>
<td>Slump</td>
<td>AASHTO T 119 (Except do not rod grout)</td>
</tr>
</tbody>
</table>

A. Applicable to grout with aggregate.
B. Applicable to Neat Cement Grout.
C. American National Standards Institute/American Petroleum Institute Recommended Practice.
D. Procedure A (Rapid Freezing and Thawing in Water) required.
E. Moist room storage required.

1003-4 GROUT REQUIREMENTS

Provide grout types in accordance with the contract. Use grouts with properties that meet Table 1003-2. For Type 1 through 4 grouts, the compressive strength of the grout will be considered the average compressive strength test results of three 2 inch cubes at the oldest age per Table 1003-2. Make cubes that meet AASHTO T 106 from the grout delivered for the work or mixed on-site. Make cubes at such frequencies as the Engineer may determine and cure them in accordance with AASHTO T 106. For Type 5 grout, the compressive strength of the grout will be considered the average compressive strength test results of three 6 inch x 12 inch cylinders at the age of 28 days. Make cylinders in accordance with AASHTO T 23 except do not rod grout. Make cylinders at such frequencies as the Engineer may determine and cure them in accordance with AASHTO T 23.

<table>
<thead>
<tr>
<th>Type of Grout</th>
<th>Minimum Compressive Strength at 3 days</th>
<th>Minimum Compressive Strength at 14 days C</th>
<th>Minimum Compressive Strength at 28 days</th>
<th>Height Change at 28 days</th>
<th>Flow A/Slump B</th>
<th>Minimum Durability Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,000 psi</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10 – 30 sec</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>5,000 psi</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Fluid Consistency D</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>5,000 psi</td>
<td>5,000 psi</td>
<td>-</td>
<td>0 – 0.2%</td>
<td>Per Accepted Grout Mix Design/ Approved Packaged Grout F</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>600 psi</td>
<td>1,500 psi</td>
<td>-</td>
<td>10 – 26 sec</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>100 psi</td>
<td>250 psi</td>
<td>-</td>
<td>&lt; 2&quot;</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Section 1005

A. Applicable to Type 1 through 4 grouts.
B. Applicable to Type 5 grout.
C. Not applicable to Type 2 grout
D. ASTM C1107.
E. Minimum compressive strength at 3 days is only required to approve Type 3 grout mix
designs or evaluate Type 3 packaged grouts for the NCDOT APL.
F. Add mixing water to Type 3 packaged grout at the manufacturer’s recommended rate to
produce grout with the designed consistency and required 3 day strength.
G. Use Type 4 grout with proportions by volume of 1 part cement and 3 parts fly ash.

1003-5 TEMPERATURE REQUIREMENTS

When using an approved packaged grout, follow the manufacturer’s instructions for grout and
air temperature at the time of placement. Otherwise, the grout temperature at the time of
placement shall be not less than 50°F nor more than 90°F. Do not place grout when the air
temperature measured at the location of the grouting operation in the shade away from
artificial heat is below 40°F.

1003-6 ELAPSED TIME FOR PLACING GROUT

Agitate grout continuously before placement. Regulate the delivery so the maximum interval
between the placing of batches at the work site does not exceed 20 minutes. Place grout
before exceeding the times in Table 1003-3. Measure the elapsed time as the time between
adding the mixing water to the grout mix and placing the grout.

<table>
<thead>
<tr>
<th>Air or Grout Temperature, Whichever is Higher</th>
<th>Maximum Elapsed Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Retarding Admixture Used</td>
</tr>
<tr>
<td>90°F or above</td>
<td>30 minutes</td>
</tr>
<tr>
<td>80°F through 89°F</td>
<td>45 minutes</td>
</tr>
<tr>
<td>79°F or below</td>
<td>60 minutes</td>
</tr>
</tbody>
</table>

1003-7 MIXING AND DELIVERY

Use grout free of any lumps and undispersed cement. When using an approved packaged
grout, mix grout in accordance with the manufacturer’s instructions. Otherwise, comply with
Articles 1000-8 through 1000-12 to the extent applicable for grout instead of concrete.

SECTION 1005

1005-1 GENERAL

Obtain aggregates from sources participating in the Department’s Aggregate QC/QA Program
as described in Section 1006. Obtain aggregates from pre-approved sources, or have the
source approved before use. Approval of such sources is based not only on the quality of the
aggregate, but also on satisfactory production facilities and procedures. A list of approved
aggregate sources participating in the Department’s Aggregate QC/QA Program in North
Carolina and adjoining states is available from the Materials and Tests Unit. This list includes
aggregates meeting Specification requirements but whose use is restricted due to history of
unsatisfactory service performance. Use of aggregates is allowed in the work provided they
have been properly stockpiled in units of not less than 300 tons, tests of representative
samples of these aggregates indicate satisfactory compliance with the Specifications and the
source meets all the requirements of the Aggregate QC/QA Program.
COMPACTION GROUTING:

Description
Compaction grouting is a ground improvement method that consists of injecting low mobility grout into the ground to displace and compact the surrounding soil without permeating or fracturing the soil. Grout is pumped through steel sectional casings, i.e., “grout pipes” installed to required depths. As grout pipes are withdrawn, columns of grout “bulbs” are formed below the ground surface. Compaction grouting is required to stabilize subgrades and embankments and prevent future subsidence at locations shown in the plans or as directed. Use a prequalified Subsurface Grouting Contractor to perform compaction grouting.

If a minimum grout replacement ratio is shown in the plans, inject enough grout to achieve this replacement ratio which is defined as the ratio of the injected grout volume to the volume of treated soils. Depending on the compaction grouting results in the field, the Engineer may adjust the grouting requirements shown in the plans which could include more or less holes, revised hole grouting sequence or different hole depths or locations.

Materials
Refer to Division 10 of the Standard Specifications.

<table>
<thead>
<tr>
<th>Item</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grout</td>
<td>1003</td>
</tr>
</tbody>
</table>

Use Type 5 grout for compaction grouting and Type 3 grout for patching holes in pavements. Provide a Type 5 grout mix with at least 400 lb of cement per cy. In some subsurface conditions, the Engineer may approve grout mix designs that deviate from Type 5 grout requirements in order to improve grout take or pumpability.

Pregrouting Requirements
(A) Compaction Grouting Plan
Submit a PDF copy of a compaction grouting plan at least 14 days before mobilizing to the site. Do not begin grouting until a grouting plan submittal is accepted. Provide detailed project specific information in the compaction grouting plan that includes the following:

1. Overall description and schedule of work and traffic control operations,
2. List of personnel with descriptions of experience and qualifications,
3. Details of drilling and coring, grout pipe installation, hole layout and grouting sequence, equipment and procedures,
4. Methods and equipment for mixing grout and monitoring and recording grout volumes and pressures with calibration certificates dated within 1 year of the submittal date,
5. Detailed description of movement monitoring including device locations, specific things to be monitored and measuring equipment with calibration certificates dated within 1 year of the submittal date,
6. Grout volume and pressure and movement criteria for raising grout pipes,
Example of drilling, grouting and monitoring logs,
Grout mix design that meets Section 1003 of the Standard Specifications and
Other information shown in the plans or requested by the Engineer.

If alternate grouting procedures are proposed or necessary, a revised compaction grouting plan submittal may be required. If the work deviates from the accepted submittal without prior approval, the Engineer may suspend compaction grouting until a revised plan is accepted.

(B) Compaction Grouting Equipment

Mobilize equipment to the site capable of installing grout pipes to the depths required and through whatever pavement and subsurface materials that are encountered including concrete approach and sleeper slabs, asphalt pavements, debris, obstructions, etc. Use equipment capable of drilling round and plumb holes of the required diameter through pavements for grout pipe installation. For concrete slabs, use a core barrel with an outside diameter 1" to 2" larger than the casing outside diameter to core holes completely through concrete and reinforcing steel. Use grout pipes consisting of flush joint steel sectional casing with an inside diameter of at least 2" and sufficient strength to maintain grout holes and withstand pumping, drilling and jacking pressures.

Provide mobile equipment as necessary to transport, proportion, mix and batch materials and pump grout for compaction grouting. A volumetric concrete mixer is required to produce Type 5 grout. Do not use grout from a concrete ready mix or batch plant. Produce grout with volumetric mixer equipment that is certified by the Volumetric Mixer Manufacturers Bureau (VMMB) signified by a VMMB registered rating plate attached to the equipment. Use a mixer that can continuously produce grout with a slump of less than 2" at pressures of up to 1,000 psi and flow rates up to 5 cf per minute. An operator with at least 3 years of experience within the last 5 years operating volumetric mixer equipment for compaction grouting is required.

Use a riser elbow with a radius of at least 1 ft. Provide an elbow and grout hoses with an inside diameter equal to or larger than the inside diameter or the casings. Use hoses of sufficient strength for the pressures anticipated and couplings that do not restrict grout flow. Monitor grout pressures with an in-line calibrated pressure gauge that is protected from grout contamination and mounted near the riser elbow.

(C) Monitoring Equipment

Monitor ground surface heave with digital electronic devices. For jointed pavements, use devices with the ability to simultaneously detect the movement of two adjacent slabs. Monitor vertical and horizontal movement of nearby structures, drains, utilities and walls with dial gauges on rigid supports. Use monitoring devices and gauges that can measure to the nearest 0.01". For concrete slabs, structures, drains, utilities and walls, take digital pictures of existing cracks or damage and mark the locations of cracks or damage on slabs, structures, drains, utilities and walls. Provide an electronic copy of this photographic information to the Engineer before pumping grout.

(D) Pregrouting Meeting

Before starting compaction grouting, hold a pregrouting meeting to discuss the grouting,
movement monitoring, criteria for raising grout pipes and other aspects of the work. Schedule this meeting onsite and during daylight hours before mobilizing to the site. The District or Bridge Maintenance Engineer, Geotechnical Operations Engineer or Grouting Supervisor and Grouting Contractor Superintendent will attend pregrouting meetings.

**Compaction Grouting Methods**

A Grouting Supervisor or Engineer with at least 3 years of experience within the last 5 years working on compaction grouting projects is required to remain on-site for the duration of the work. Use equipment and methods accepted in the compaction grouting plan or approved by the Engineer. Air temperature restrictions in Article 1003-5 of the *Standard Specifications* do not apply to Type 5 grout for compaction grouting. Do not drill more holes than can be cased or grouted full depth during a single shift.

Install grout pipes as required in the plans or if an alternate plan is approved, follow the compaction grouting plan accepted by the Engineer. Install casings for and grout primary holes before secondary holes. Use methods to drill holes and advance grout pipes that prevent casings from plugging or ejecting during grouting or grout escaping through annular space between the casings and the ground. Install grout pipes within 5° of vertical or the batter accepted in the compaction grouting plan.

Remove oil, rust inhibitors, residual fluids and similar foreign materials from holding tanks/hoppers, mixers, pumps, hoses and all other equipment in contact with grout before use. Discard the first 2 cf of grout produced by the volumetric concrete mixer when grout production begins for each shift. Verify the flow rate initially before grouting and weekly after that by filling a 1 cf container. Take precautions as necessary to prevent grout, drill cuttings and fluids from drilling or equipment from defacing the site.

Continuously monitor and record grout take and pressure near the grout pipe head while injecting grout into the ground through grout pipes. Control pumping so grout injection rate is between 0.25 cf and 5 cf per minute. Inject grout in holes from the bottom up unless otherwise approved by the Engineer. Provide hard copies of logs to the Engineer at the end of each shift and a PDF copy of all logs upon completion of compaction grouting.

Withdraw grout pipes in 1 ft increments unless otherwise approved. At each increment, inject grout until criteria for raising grout pipes in the compaction grouting plan is met or unacceptable or undesirable movements occur in nearby structures, drains, utilities or walls as directed by the Engineer. Limit total ground surface heave from compaction grouting to 1/4".

It is crucial to monitor movement closely to prevent damage to nearby structures, drains, utilities or walls. Take precautions to avoid breaking or cracking concrete slabs. Slabs, structures, drains, utilities and walls will be considered damaged if damage is due to compaction grouting as determined by the Engineer based on crack patterns and locations.

The Contractor is responsible for any damage to slabs, structures, drains, utilities or walls caused by compaction grouting. Acceptance of the compaction grouting plan does not relieve the Contractor of responsibility for damage or liability in accordance with Article 107-11 of the *Standard Specifications*.

If damage occurs, submit a proposed remediation or repair plan for review. Ensure remediation submittals are designed, detailed and sealed by an engineer licensed in the state of North Carolina. Do not begin remediation or repair work until plans are approved. No extension of
completion date or time will be allowed for repair of damaged slabs, structures, drains, utilities or walls.

When drilling through existing pavements and the roadway will not be resurfaced or the concrete slab will not be lifted after completing compaction grouting, remove excess grout, drill cuttings and fluids from holes and fill holes with Type 3 grout. Collect and dispose of any debris, waste and excess grout before leaving the site and opening lanes to traffic.

**Measurement and Payment**

*Compaction Grouting* and *Grout Pipes* will be measured and paid in cubic feet and linear feet, respectively. Compaction grouting will be measured as the cubic feet of grout injected into the ground through grout pipes. Grout pipes will be measured as the linear feet of casings installed equal to the maximum casing depth achieved below the ground surface. The contract unit price for *Compaction Grouting* and *Grout Pipes* will be full compensation for submittals, monitoring, logs, labor, tools, equipment, materials, installing grout pipes, mixing and injecting grout, cleanup, patching holes and any incidentals necessary to complete the work.

No additional payment will be made due to changing the number, location or depth of holes or the order for grouting holes. No payment will be made for discarded grout or casing ejected during grouting. No payment will be made for remediation or repair of damaged slabs, structures, drains, utilities or walls.

*Mobilization* will be measured and paid in accordance with Section 800 of the *Standard Specifications*.

Payment will be made under:

<table>
<thead>
<tr>
<th>Pay Item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compaction Grouting</td>
<td>Cubic Foot</td>
</tr>
<tr>
<td>Grout Pipes</td>
<td>Linear Foot</td>
</tr>
</tbody>
</table>