

Section 02431

TUNNEL GROUT

PART 1 GENERAL

1.01 SUMMARY

This Section includes:

- A. Mix design requirements, testing, furnishing, and production of grout for:
 - 1. Pressure grouting of bolted liner plates for shafts
 - 2. Pressure grouting of primary tunnel liner
 - 3. Pressure grouting of jacked-pipe
 - 4. Annular grouting of cased or uncased sewer pipe
 - 5. Grouting of annular space between carrier pipe and primary tunnel liner
 - 6. Grouting voids in ground resulting from caving, loss of ground, or settlement
 - 7. Grouting of manholes constructed in shafts
- B. Compaction grouting is not part of this specification.

1.02 MEASUREMENT AND PAYMENT

- A. Unit Prices.
 - 1. No separate payment will be made for Work performed under this Section. Include cost of such Work in contract unit prices for Work of which it is component part.
 - 2. Refer to Section 01270 – “Measurement and Payment” for Unit Price procedures.
- B. Stipulated Price (Lump Sum). If Contract is Stipulated Price Contract, payment for Work in this Section is included in total Stipulated Price.

1.03 REFERENCES

- A. ASTM C 138. Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
- B. ASTM C 144. Standard Specification for Aggregate for Masonry Mortar.

- C. ASTM C 150. Standard Specification for Portland Cement.
- D. ASTM C33ASTM C 494. Standard Specification for Chemical Admixture for Concrete.
- E. ASTM C 618. Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.
- F. ASTM C 869. Standard Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete.
- G. ASTM C 937. Standard Specification for Grout Fluidifier for Preplaced-Aggregate Concrete.
- H. ASTM C 942. Standard Test Method for Compressive Strength of Grout for Preplaced-Aggregate Concrete in the Laboratory.
- I. ASTM C33ASTM C 1017. Standard Specification for Chemical Admixture for Use in Producing Flowing Concrete.

1.04 SUBMITTALS

- A. Conform to requirements of Section 01330 – “Submittal Procedures”.
- B. Submit description of materials, grout mix, equipment, and operational procedures to accomplish each grouting operation. Description shall include sketches as appropriate, indicating type and location of mixing equipment, pumps, gauges, injection points, venting method, flow lines, pressure measurement, volume measurement, grouting sequence, schedule, and stage volumes, as well as procedures to resist movement and counteract floating the carrier pipe during grouting operations. Tests and certifications shall have been performed within last 12 months prior to date of submittal.
- C. Grouting contractor shall provide a project history showing a minimum of 5 years of work and at least 10,000 linear feet of experience in grouting tunnels.
- D. Submit grout mix design report, including:
 - 1. Grout type and designation
 - 2. Grout mix constituents and proportions, including materials by weight and volume
 - 3. Grout densities and viscosities, including wet density at point of placement
 - 4. Initial set time of grout
 - 5. Bleeding, shrinkage/expansion

6. Compressive strength
 7. Detailed description of grout pressure limiting equipment
 8. For annular space grouting, buoyant force calculations and bulkhead designs (See Section 02517 – “Water Line in Tunnel” for further requirements)
- E. For cellular grout, also submit the following:
1. Foam concentrate supplier's certification of product application for foam concentrate.
 2. A description of proposed cellular grout production procedures.
- F. Maintain and submit logs of grouting operations indicating pressure, density, and volume for each grout placement.

1.05 RELATED REQUIREMENTS

- A. Section 01270 – “Measurement and Payment”
- B. Section 01330 – “Submittal Procedures”
- C. Section 02517 – “Water Line in Tunnel”
- D. Section 03315 – “Concrete for Utility Construction”

1.06 – 1.09 NOT USED

1.10 DEFINITIONS

- A. **Pressure Grouting.** Filling void behind liner or pipe with grout under pressure sufficient to ensure void is properly filled but without overstressing temporary or permanent ground support, or causing ground heave to occur.
- B. **Back Grouting.** Secondary pressure grouting to ensure that voids have been filled between primary tunnel or shaft liners and surrounding ground.
- C. **Annular Grouting.** Filling annular space between carrier pipe and primary tunnel liner, casing, or ground, by pumping.
- D. **Ground Stabilization Grouting.** Filling of voids, fissures, or under-slab settlement due to caving or loss of ground by injecting grout under gravity or pressure to fill void.
- E. **Carrier Pipe.** Sewer or water line installed inside primary tunnel support.

1.11 – 1.13 NOT USED

PART 2 PRODUCTS

2.01 MANUFACTURER(S) (NOT USED)

2.02 MATERIALS AND/OR EQUIPMENT

- A. Grouting materials: Conform to Section 03315 – “Concrete for Utility Construction”, except as modified in the following paragraphs.
- B. Grout Type Applications:
 - 1. Grout for pressure grouting, backfill grouting, and annular grouting: Sand-cement mortar mix.
 - 2. Alternative grout for annular grouting of water line: Low density (cellular) grout.
 - 3. Grout for annular grouting of sanitary sewer: Low density (cellular) grout, unless otherwise approved by Project Manager.
 - 4. Grout for filling space around manholes in shafts: Sand-cement mortar mix.
 - 5. Ground stabilization: Sand-cement mortar mix.
- C. Do not include toxic or poisonous substances in grout mix or otherwise inject such substances underground.
- D. Grout
 - 1. Develop one or more mixes based on following criteria as applicable and provide test reports from a professional laboratory for each mix design:
 - a. Size of annular void between carrier pipe and liner, or size of void between primary liner and surrounding soil
 - b. Absence or presence of groundwater
 - c. Adequate retardation
 - d. Non-shrink characteristics
 - e. Pumping distances
 - 2. Prepare mixes that satisfy required application. Provide materials conforming to the following standards:
 - a. Cement: ASTM C 150

- b. Fly Ash: ASTM C 618. Do not use fly ash in amounts to exceed 25 percent by weight of cementitious material in mix design.”
 - c. Water: Potable
 - d. Foam: ASTM C 869. The foaming agent shall maintain stability until the cement sets to form a self-supporting matrix comprising closed cells and low water absorptive characteristics.
 - e. Slurry: ASTM C 138
 - f. Cellular Grout: ASTM C 138
 - g. Sand for sand-cement mortar mix: ASTM C 144
 - h. Retarder/water reducer: ASTM C494, Type D
 - i. Plasticizer/water reducer: ASTM C494, Type A
 - j. Fine aggregate: ASTM C33
3. Provide grout meeting the following minimum requirements:
- a. Low Density Cellular Grout
 - 1) Cement content shall be no less than 200 lb/cubic yard.
 - 2) Water content shall be no more than 65 percent.
 - 3) Wet density shall be no less than 65 lb/cubic foot.
 - 4) Minimum compressive strength shall be 100 psi after 7 days and 300 psi after 28 days.
 - b. Conventional (Mortar) Grout
 - 1) Conventional grout shall consist of a pumpable mix of 1-part cement, 2-part clean sand, water free from organics and deleterious materials, and a small amount of bentonite for pumpability and stability. The unit weight shall not be less than 130 lb/cubic foot.
 - 2) Minimum 28-day unconfined compressive strength shall be 1,500 psi for water lines and 1,000 psi for other carrier pipes.
 - 3) Determine strength by ASTM C942.

4. Fluidifier. Provide fluidifier, meeting ASTM C 937 that holds solid constituents of grout in colloidal suspension and is compatible with cement and water used in grouting operations.
5. Admixtures.
 - a. Use admixtures meeting ASTM C 494 and ASTM C 1017 as required, to improve pumpability, control time of set, hold sand in suspension and reduce segregation and bleeding.
 - b. For cellular grout, do not use foam or admixtures that promote steel corrosion
 - c. Ensure that admixtures used in mix are compatible. Provide written confirmation from admixture manufacturers of their compatibility.
 - d. Admixtures shall not contain chlorides, and shall be non-toxic after 30 days.
 - e. Amount of admixture added to concrete shall be in accordance with the manufacturer's recommendations.

2.03 – 2.04 NOT USED

PART 3 EXECUTION

3.01 GENERAL / MANUFACTURER(S) (NOT USED)

3.02 PREPARATION

- A. Notify Project Manager at least 24 hours in advance of grouting operations.
- B. Select and operate grouting equipment to avoid damage to new or existing underground utilities and structures.
- C. In selection of grouting placement consider pipe flotation, length of pipe, length of tunnel, depth from surface, type of pipe, type of pipe blocking and bulkheading, grout volume and length of pipe to be grouted between bulkheads.
- D. Operate dewatering systems until grouting operations are complete and grout has reached initial set.
- E. Verify that locations where grout is to be placed are clean and free of standing or running water.
- F. A bulkhead designed by the Contractor shall be placed in the annular space at each end of tunnel section that is to be grouted. Provide an opening in the crown in addition to other required vent outlets. Provide an opening for the tunnel invert drain and at the

casing invert to facilitate draining water away from the Work during grouting operations.

3.03 ERECTION/INSTALLATION APPLICATION AND/OR CONSTRUCTION

A. Equipment

1. Batch and mix grout in equipment of sufficient size and capacity to provide necessary quality and quantity of grout for each placement stage.
2. Use equipment for grouting of type and size generally used for work, capable of mixing grout to homogeneous consistency, and providing means of accurately measuring grout component quantities and accurately measuring pumping pressures. Use pressure grout equipment which delivers grout to injection point at steady pressure.
3. Foam Generator for Cellular Grout: Foam shall be generated by combining controlled quantities of air, water, and foaming agent under pressure in accordance with the foaming agent manufacturer's recommendations. The temperature of water used in generating the foam shall be maintained below 80°F, or as recommended by the foaming agent manufacturer. Foam shall be discharged into the mixer and blended with the cement slurry.
4. Mixing: The mixer shall be configured for compatibility with the pump to ensure continuous and uniform flow at the point of placement. The mixer shall be capable of providing a super-wetted, homogenized mix. The mixer shall be fitted with a meter with an accuracy of ± 1 gallon to measure the volume of water added to dry mix ingredients. An automated system shall be provided capable of delivering a neat cement grout to the mixer and pump in the tunnel where grouting is to be performed.
5. Pumping: Pumping equipment shall be capable of pumping concrete without pulsation or segregation. Pumping equipment shall be operated to convey a continuous and uniform stream of concrete without air pockets. Pumping equipment shall be equipped with a water connection for flushing the system and a device to limit pumping pressure as required to prevent damage to pipe.
6. Agitator: A separate agitator shall be provided to serve as a holding tank between the mixer and the pump. The agitator shall be equipped with baffles to induce turbulence and rotating paddles to ensure thorough mixing of the grout before and during injection.
7. Piping, Injection Hoses, Ports, Valves and Connections: Concrete shall be conveyed to placement points using piping or rubber hoses, with all components having an internal diameter of at least 2 inches. Do not allow hardened grout or concrete to obstruct or coat pipe or hose internally. A system of valves shall be furnished in the line at or near the points of injection

to facilitate sample collection. Suitable stop valves shall be furnished at injection points for use in venting air or maintaining pressure, as required.

8. Provide certified oil-filled gauges scaled to not more than 150% of the maximum allowable pressure, accurate to within 0.5% over the full range of the gauge. Pressure gauges shall be certified and calibrated in accordance with ASME B40.1, Grade 2A. Pressure gauges shall be oil-filled type gauges attached to a saddle-type diaphragm seal (gauge saver) to prevent clogging with grout.

B. Pressure Grouting for Primary Tunnel and Shaft Liner

1. Perform grouting operations to fill voids outside of primary tunnel or shaft liner.
2. For nonexpendable primary liners installed behind shield or tunnel boring machine (TBM), fill voids with sand-cement grout promptly after each ring of liner is out of shield. Keep grout pressure below value that may cause damage or distortion to installed liner plate rings. Provide seals on tail of shield or TBM which shall prevent grout from spilling.
3. For nonexpendable primary liners installed by hand mining or in shafts, grout once every 4 feet but no later than the end of each, or more frequently when conditions dictate. Upon completion of each grouting operation, sound tunnel liner and immediately correct voids discovered by necessary means.
4. Use care in grouting operations to prevent damage to adjacent utilities or other properties. Keep grout pressure below value that may cause damage or distortion to installed tunnel liner or shaft liner. Control grout pressures so that tunnel or shaft liner is not overstressed, and ground heave is avoided.
5. For liner requiring grout, perform back grouting once each shift, or more often when required to ensure that all voids are filled.
6. Grout shall only be pumped to one hole at a time.
7. Grouting shall be performed in a progressive, methodical manner, moving from hole to hole, starting at one end of the tunnel and working to the other end. Grouting shall be from lower holes to higher holes as the case may be.
8. To the extent possible, air and groundwater shall be relieved through valved, open, and ungrouted holes downstream of the hole being grouted. Valved, open, and ungrouted holes shall not be closed until grout of the same consistency as that being injected issues forth.
9. Contractor shall remove grout valves and shall cap the grout ports after grout has reached initial set.

- C. Annular Grouting for Water and Sewer Line in Tunnels and Augers
1. Methods employed shall completely fill the annular space between tunnel liner and carrier pipe with grout.
 2. Placement
 - a. Placement Limits: Predetermine limits of each grout placement stage by size and capacity of batching equipment and initial set time of proposed grout. Under no circumstances shall placement continue at grout port longer than that period of time for mix to take initial set. Locate grout hole spacing and locations according to number of stages necessary to grout tunnel liners. Stage or lift cannot be installed on another lift until proper set has been attained. Have placement procedures approved by admixture or additive manufacturer.
 - b. Limit pressure on annular space to prevent damage or distortion to pipe or liner. Define limiting and estimated required pressure range. Provide an open ended, high point tap or equivalent vent and monitor it at bulkhead opposite to point of grouting.
 - c. Pump grout until grout within 5 percent of specified density discharges from end opposite injection point, to ensure grout is not diluted by extraneous water in annulus.
 - d. For sewer line in primary lined tunnel, limit length of pipe installed to 200 feet or less before grouting same length of sewer line. Repeat this cycle until all pipe is installed and grouted.
 - e. Use methods as required to avoid pipe flotation and damage to pipe. Complete each lift for a particular section of tunnel being grouted before starting the next lift. Lift heights shall be limited to avoid pipe flotation and to maintain cellular grout parameters within specified limits. There shall be no fewer than 2 lifts per annular grouting operation.
 3. Remove temporary bulkheads installed for grouting.
 4. Batch and mix cellular grout mechanically with a colloidal mixer at the project site to ensure consistency of mix. Wet solids thoroughly before introduction of foaming agent. Operate batching system to maintain slurry density with the requirements of Paragraph 3.05.B.3. Shear foam into slurry in accordance with manufacturer's recommendations.
 5. Control ground water as necessary to permit completion of grouting without separation of grout materials.

D. Pressure Grouting for Jacked Sewer Pipe

1. For jacked pipe 60 inches in diameter or greater, pressure grout annulus after installation, displacing bentonite lubrication. Jacked pipes less than 60-inch diameter may be left ungrouted unless excavated diameter exceeds external pipe diameter by more than one inch.
2. Inject grout through grout holes in sewer pipe. Drilling holes from surface or through carrier pipe walls is not allowed. Perform grouting by injecting it at pipe invert with bentonite displacement occurring through high point tap or vent.
3. Control ground water as necessary to permit completion of grouting without separation of grout materials.
4. Limit pressures to prevent damage or distortion to pipe or to keep flexible pipe within acceptable tolerances.
5. Pump grout until material discharging is similar in consistency to that at point of injection.

E. Ground Stabilization Grouting

1. Completely fill voids outside limits of excavation caused by caving or collapse of ground with sand-cement grout. Perform second grouting to fill soft spots or voids which may be detected, no later than 24 hours after initial grouting of tunnel liner.
2. Take care in grouting operations to prevent damage to adjacent utilities or public or private property. Grout at pressure that shall not distort or imperil portion of Work or existing installations or structures.
3. Verify that void has been filled by volumetric comparisons and visual inspection. In case of settlement under existing slabs, take cores as directed by Project Manager, at no additional cost, to demonstrate that void has been filled.

3.04 REPAIR/RESTORATION (NOT USED)

3.05 FIELD QUALITY CONTROL

A. Pressure Grouting for Primary Tunnel and Shaft Liners.

1. For each shaft, make one set of four compressive test specimens for each 30-foot depth and one set for remaining portion less than 30-foot increment.
2. Make one set of four compressive test specimens for every 200 feet of primary lined, (non-expandable) tunnel requiring grout.

- B. Annular Grouting for Water and Sewer Line in Tunnels and Augers.
1. Make one set of four compressive test specimens for every 200 feet of pipe installed in primary lined tunnel.
 2. For augers, make one set of four compressive test specimens for each grouting operation, or for each 100 feet of pipe installed, whichever is more frequent.
 3. For cellular grout, check slurry density both at point of batching and placement at least twice each hour in accordance with ASTM C 138. Record density, time, and temperature. Density must be within 3 percent of design density at point of batching and 5 percent of design density at point of placement.
 4. Measure and record the volume of grout placed. Compare actual volume placed for each length of tunnel being grouted with the theoretical volume for that length of tunnel being grouted. Collect samples of fresh cellular grout at the injection point or discharge point.
 5. Wet Density Test for Cellular Grout: Sample at the injection point every 30 minutes, after a change in the mix batched, and whenever compression test cylinders are made.
 6. Compression Tests: Take two sets of two cylinders for every 200 cubic yard batched, but no less than two sets per day, two sets per annulus between carrier pipe and tunnel liner grouted, or two sets per lift. Test two cylinders at 28 days and test the additional two cylinders at 56 days, if fly ash is used. For testing, cylinders shall be capped with plaster of Paris; sulfur caps are not permitted.
- C. Pressure Grouting for Jacked Pipe. Make one set of four compressive test specimens for every 400 feet of jacked pipe pressure grouting.
- D. Ground Stabilization Grouting. Make one set of four compressive test specimens for every location where ground stabilization grouting is performed.

3.06 – 3.10 NOT USED

END OF SECTION