

Construction Specification 14—Pressure Grouting

1. Scope

The work consists of drilling grout holes, exploratory holes, and check holes; pressure testing, pressure washing, and injecting suspension grout under pressure; and includes furnishing of all materials, labor, and equipment as described and specified.

2. Material

Portland Cement—Portland cement shall conform to the requirements of Material Specification 531, Portland Cement, for the specified type. If the cement contains lumps or foreign material that would clog the grouting equipment or interfere with grout injection, it shall be screened through a 100-mesh screen. Cement shall be furnished in bags (94 lb) unless special equipment is provided for storing, handling, and weighing bulk cement as specified in section 3 of this specification.

Water—Water used shall be clean and free from injurious amounts of oil, acid, organic matter, or other deleterious substances.

Sand—Sand for grout shall conform to Material Specification 522, Aggregates for Portland Cement Concrete, and, unless otherwise specified, the gradation shall be within the numerical limits as follows:

Sieve designation (U.S. std. square mesh)	Percent passing by weight
16	100
50	20 – 50
100	10 – 30
200	0 – 5

Sand included in the mix shall be measured in cubic-foot boxes or other volumetric method approved by the engineer, or by dry unit weight with correction for moisture content.

Bulk fillers—Bulk fillers other than sand shall be of the type and quality specified in section 18 of this specification. Bulk fillers included in the mix shall be measured in cubic-foot boxes or by dry unit weight with correction for moisture content, if applicable.

Admixtures—Admixtures shall be the type and quality specified in section 18 of this specification.

Storage and supply—A sufficient quantity of all materials shall be on hand to ensure that grouting operations will not be interrupted or delayed. Materials shall be stored and protected at all times and at all locations so that the quality of the materials is maintained.

3. Equipment

All drilling and grouting equipment shall be of a type and capacity and in condition to perform the work described.

Drilling equipment—Drilling equipment shall be capable of drilling angle holes up to 45 degrees from vertical unless otherwise specified in section 18 of this specification.

For exploratory holes, all drilling equipment used in rock shall be the rotary type and shall be equipped with hydraulic feed.

Cores shall be drilled with standard ballbearing, swivel type, N-size, double or triple tube split inner core barrels or equivalent size wire-line coring equipment.

Equipment for drilling grout and check holes shall be rotary, percussion, or rotary-percussion type as specified in section 18 of this specification. No core recovery will be required, and the type of bit used shall be optional. Equipment using air alone for flushing cuttings shall not be used. When percussion drilling equipment using water for flushing cuttings is used, the lifting rate of the flushing water shall be not less than 18 inches per second.

Grouting equipment—The equipment shall be capable of mixing and pumping grout having a mix ratio, by volume, of one part water, one part cement, and two parts bulk filler, such as sand or fly ash.

Mixers—Unless otherwise specified, mixers shall be high speed colloidal type and capable of thoroughly mixing water, cement, and bulk fillers to produce a grout of uniform texture and consistency. Mixers shall match the capacity of the pumping plant.

Holdover tank—A holdover tank shall be furnished if a single compartment mixer is used. It shall be equipped with mechanical agitators to prevent segregation of the grout and shall have sufficient capacity to temporarily store the grout and thus provide a continuous supply. The outflow shall pass through a No. 16 wire mesh screen if the grout contains particles or foreign matter that would interfere with its proper flow into the voids it is intended to fill.

Pumps—Grout pumps shall be long stroke, multiple piston or the helical screw type. The capacity shall be not less than 3 cubic feet per minute at 200 pounds per square inch for the maximum grout mix of 1:1:2 (w:c:bf), by volume.

Cement and fly ash-handling equipment—If bulk cement or fly ash is used, it shall be stored in weather tight bins or silos equipped and arranged to discharge directly into a weighing hopper, and hence, directly into the grout mixer without spillage and without intermediate handling.

Air supply—The air supply shall meet the requirement of the pumps and shall not be less than 200 cubic feet per minute per plant.

Water meter—One water meter that has a reset and is graduated in tenths of gallons or hundredths of cubic feet shall be used with each mixer.

Pressure gauges—One pressure gauge shall be installed at the pump and one at the collar of the hole. Gauges shall be nonclogging or use gauge savers or grease to prevent clogging. Spare gauges shall be available at the plant at all times.

Hoses, valves, and fittings—Hoses, valves, and fittings shall be compatible with the maximum pressures specified. Hose from pump to grout header and return shall not be smaller than 1.5-inch (ID), and the pipe between header and packer shall not be smaller than 0.75-inch (ID). Double or single packers may be required for grouting and pressure testing. Packers shall fit tightly in the holes at all testing and grouting pressures.

4. Arrangement of grouting equipment

The arrangement of grouting equipment shall provide a return line from the header back to the mixer or holdover tank. This permits continuous circulation of the grout. The grout pressure shall be controlled at the header or at the end of the return line.

The hose between the takeoff at the grout supply line to the header at the hole shall not be longer than 15 feet.

Grouting several holes simultaneously from the same grout pump (multiple header arrangement) is not permitted.

Each hole shall be equipped with a shutoff valve below the hand coupling union. This permits shutoff at refusal pressure and removal of the header to another hole while still maintaining pressure in the completed hole.

The header arrangement shall include a blowoff valve and a control valve used to check hole back pressure before header removal. It must also have a return line valve. The header shall be connected to the supply line by a U-shaped pipe arrangement or other fashion that prevents fallout of solids into the hole from the bypassing grout during low rates of grout acceptance.

5. Communications

A suitable voice communications system between individuals at the pump units and the holes shall be maintained by the contractor.

6. Grout mixtures

Composition—Grout shall consist of a mixture of portland cement, water, sand, bulk filler, and additives, as specified. Grout mixes and sequences of changes in mix ratio or composition shall be as specified in section 13 of this specification or as approved by the engineer.

Mix ratios—Grout mix ratios are expressed in cubic feet of water to a bag of cement. Bulk fillers are expressed in cubic feet to a bag of cement. Other additives are expressed in percent to a bag of cement and measured in pounds, gallons, or pints.

7. Grout caps and concrete slabs

Concrete for grout caps and slabs, if required, shall be placed as shown on the drawings. The concrete shall be a workable mixture of portland cement, fine and coarse aggregates, and water, containing not less than 6 bags of cement per cubic yard of concrete, and not more than 6 gallons of water per bag of cement, including the free moisture of the aggregates.

Portland cement shall conform to the requirements of Material Specification 531 for the type specified. Aggregates shall consist of sound and durable particles and shall conform to the limitations for deleterious substances and the grading requirements of ASTM Specification C 33. Coarse aggregates shall be size 7, 67, 57, or 467 as defined in ASTM Specification C 33.

Batching, mixing, and placing shall be conducted in a manner that produces a uniform, well-graded, and dense concrete.

When ready-mixed concrete is furnished, the contractor shall furnish the engineer a delivery ticket showing the time of loading and the quantities of materials used for each load of concrete. Concrete shall be placed within 1.5 hours after introduction of the cement to the aggregates or within 45 minutes when the temperature of the concrete is 85 degrees Fahrenheit or greater.

Surfaces against which concrete is to be placed shall be cleaned of all soil, loose rock, and other loose material and shall be moist when the concrete is placed.

Concrete shall be placed only when the engineer is present.

The concrete shall be prevented from drying for a curing period of at least 5 days after it is placed. Exposed surfaces shall be kept continuously moist for the entire period, or shall be coated with an acceptable curing compound as soon as free water has disappeared.

8. Drilling overburden

Unless otherwise specified, holes drilled through overburden shall be cased with steel. Casings shall be removed after completion of the grouting operations unless otherwise approved by the engineer. Holes in overburden shall be backfilled with grout or a sand-cement mixture or by tamping soil into the holes to approximately the bulk density of the surrounding overburden, unless otherwise specified in Section 18 of this specification.

9. Drilling rock

The location, inclination, and depth of holes shall be as shown on the drawings or as directed by the engineer.

Rod dope, grease, and other solid or liquid lubricants are not permitted.

The contractor shall perform such exploratory drilling as may be required to determine the condition of the rock before grouting and the effectiveness of the grouting operation as the work progresses. All exploratory holes shall be cored and shall be pressure tested when directed by the engineer. Exploratory holes shall be drilled with an N-size core barrel as specified in section 3 of this specification. Rock core samples shall be carefully placed in correct sequence in labeled core boxes furnished by the contractor. The contractor shall transport the core boxes to the location designated in section 18 of this specification.

Unless otherwise specified, grout holes shall have a diameter not less than 2 15/16 inches (NX).

10. Washing grout holes

When authorized by the engineer and prior to grout injection, grout holes shall be washed with water and air to remove mud, drill cuttings, and other materials that will interfere with the grout take of the hole. Grout holes to be washed and the sequence of washing shall be approved by the engineer. Washing under pressure using packers or pressure testing shall be performed when specified. Washing time for each hole shall be approved by the engineer.

If mud is moved into a hole by grouting nearby holes after the hole has been washed, the mud will be removed by rewashing the hole.

The air and water pressure will be adjusted to provide the maximum cleaning condition for the holes as determined by the engineer. Water and air shall be introduced simultaneously under pressure and at the same elevation in the hole. The water pump shall be capable of producing 200 gpm of water at a minimum of 100 pounds per square inch. The air supply shall be capable of furnishing a minimum of 200 cubic feet per minute at 100 pounds per square inch.

Unless approved by the engineer, no holes within 100 feet of a previously grouted hole shall be washed unless the grout has been placed for at least 48 hours.

11. Pressure testing

In holes to be pressure tested, the packer or packers shall be set at intervals as directed by the engineer. Each interval shall be tested at water pressures up to the specified design grouting pressure for that interval, unless otherwise directed by the engineer. Pressures exceeding the specified design pressures shall not be applied unless specifically authorized by the engineer.

The flow shall be read at 1 minute intervals. The test is completed when the rate of take is steady for at least 3 consecutive minutes at the maximum pressure for the section being tested. The flow readings shall be recorded on a form supplied by or approved by the NRCS.

Pressure test equipment shall be calibrated at the site to determine the pressure loss in the equipment at various flow rates and test depths. Pressure tests and calibration of pressure test equipment shall be performed in the presence of the engineer.

12. Packer and stage grouting

For packer grouting, the holes shall be drilled to the total depths and shall be grouted in lifts starting at the bottom. If the drill water is lost completely, the hole shall be grouted at that depth and drilling continued not less than 24 hours after grouting. The packer lifts and related pressures shall be as specified except as otherwise directed by the engineer.

If stage grouting becomes necessary, it shall be performed in successive depth intervals (stages) in each hole beginning at the rock surface and progressing to the deeper stages. All of the holes in a specified area shall be drilled and grouted in each stage before grouting of the succeeding stage is begun. The stages and the grouting pressures for each stage shall be as specified unless otherwise directed by the engineer.

Each stage of a hole shall be washed with water and air simultaneously and immediately before grouting. Washing under pressure or pressure testing shall be performed as specified in section 10 of this specification.

13. Grout injection

The pumping rate shall not exceed 3 cubic feet per minute unless otherwise approved by the engineer. Grout pressures shall be as specified in section 18 of this specification, but shall not exceed the refusal pressures shown as follows:

Grout refusal pressures for mix ratios

Rock cover (ft)	----- Gauge pressure at collar in PSI for the mix ratios (by volume) -----							
	1:1:2	1:1:1	1:1:3/5	1:1 W:C	2:1	3:1	5:1	water
5	1	1	1	1	1	1	2	3
10	1	1	2	2	3	3	4	5
20	1	2	3	5	7	8	9	10
40	8	12	14	17	21	23	26	30
60	22	26	28	34	40	43	46	52
80	36	41	44	52	60	64	68	75
100	50	56	60	70	80	84	90	99

- Notes:** (1) 1:1:3/5 = 5 water : 5 cement : 3 sand
 (2) Overburden counts as 50% rock cover (10 feet of overburden = 5 feet of rock cover)
 (3) For depths and mix ratios other than those shown, linear interpolation shall be made to determine maximum pressure.

Grouting, particularly in zones near the surface, shall be accomplished with extreme caution to prevent uplift of the rock or excessive leakage at the surface.

The contractor shall caulk surface cracks that allow excessive loss of grout. Cracks may be caulked by mechanical means or with fast setting mortar. If necessary, grouting shall be temporarily suspended or the pressure shall be reduced to permit the caulking of leaks. Accelerators may be added to the grout for the same purpose if approved by the engineer.

If grout injected into one hole appears in adjacent holes, the interconnected holes shall be plugged temporarily with packers set just above the level at which the grout is entering. Holes grouted by interconnection shall be split spaced.

The quantity of grout prepared in advance shall be kept to a minimum. Grout that has remained in the mixer or holdover tank with or without agitation for more than an hour shall be discarded.

Grout temperatures shall be no lower than 50 degrees Fahrenheit. The grouted soil, rock, or concrete shall be no colder than 40 degrees Fahrenheit when grout is injected and for at least 48 hours thereafter. Insulation or heat shall be applied to the surface for 24 hours before grouting and 48 hours after if required to keep the soil, rock, or concrete above the minimum required temperature.

When the hole shows signs of refusal, a thinner mix shall be used to prevent or remove clogging.

A hole shall be considered grouted when the grout take at the design pressure is less than 1 cubic foot of grout in 10 minutes.

If a hole continues to accept grout after a specified amount of the thickest workable grout mixture has been injected, the engineer may specify a reduced pump speed and/or the use of accelerators, or may direct that the pumping be halted temporarily to permit the grout to set. In which case, the hole shall be flushed with about 5 to 8 cubic feet of water and rested for at least 4 hours.

Grouting shall be discontinued in holes that do not respond to the above procedure. The holes shall be redrilled and regouted later, or the area of high grout absorption shall be grouted from adjacent holes until the design objective has been achieved.

14. Grouting procedure

The procedures and grout mixes described below are general guidelines and may be altered in the field by the engineer to suit the conditions encountered and to meet the design objectives.

Unless on-the-site experience indicates otherwise and in lieu of pressure testing, each stage or lift of a hole to be grouted shall be started with about 15 cubic feet (three batches) of water:cement mix to be no thinner than 5:1 (w:c), by volume, unless otherwise specified in section 18 of this specification.

If the hole continues to take grout at a pumping rate not to exceed 3 cubic feet per minute and at a pressure equal to or less than specified as refusal pressure, the mix ratio shall be changed to 3:1 (w:c). If the majority of the holes accept the 3:1 without signs of slowdown in the rate of take, holes in that stage or location may be started with a 3:1 instead of the 5:1 mix. A change to a different location or stage may require a return to the 5:1 starter mix.

Grout mixes shall be thickened from 5:1 to 3:1 to 2:1 to 1:1 after which sand and/or fly ash shall be added to the mix in a graduated manner (5:5:1S, 5:5:2S, ...). The water-cement ratio shall not be less than one.

15. Records

Unless otherwise specified, the contractor shall keep drilling logs and complete records of all grouting operations. These records include time logs of grout mixes and admixtures used in each stage or lift for each hole, related pressures and pumping rates, back-pressures, and observations on excessive leakage and other nonroutine conditions. The drilling log shall include date, hole location, depth of rock, and depths to various rock features. Rock features shall be described as hard, soft, weathered, cracks, or cavities. The contractor quality control activities are outlined in Construction Specification 94, when applicable.

Unless otherwise specified, the contractor shall cooperate in providing all information related to drilling and grouting activities required by the contract.

Unless otherwise specified, one copy of the records shall be provided the engineer at the completion of each shift.

16. Cleanup

After grouting is completed, the contractor shall remove the grouting plant and all related parts, equipment, and supplies from the site. The cleanup includes unused materials and waste.

17. Measurement and payment

For items of work for which specific unit prices or lump sum prices are established in the contract, measurement and payment for pressure grouting is made as described below. Such payment will constitute full compensation for all labor, materials, equipment, and all other items necessary and incidental to the completion of the work.

Mobilization—Payment for mobilization is made at the contract lump sum price. Such payment will include compensation for moving grouting equipment and supplies to the site of the work, assembling the plant at the site, moving on the site as work progresses, and removal from the site upon completion of the work. Sixty percent of the lump sum price will be paid when the plant is assembled at the site and grouting work is begun. The remaining 40 percent will be paid after the work is completed, the plant is removed from the site, and cleanup is complete.

Drilling overburden—Drilling overburden is measured by determining to the nearest foot the total linear feet of accepted hole drilled in the overburden. Payment for drilling overburden is made at the contract unit price, which will include compensation for placing and removing casings.

Drilling rock—Drilling rock is measured by determining to the nearest foot the total linear feet of accepted hole of each size drilled in rock without coring. Payment for drilling rock is made at the contract unit price for each size of hole.

Coring rock—Coring rock is measured by determining to the nearest foot the total linear feet of accepted hole of each size cored in rock. Payment for coring rock is made at the contract unit price for each core size, which will include compensation for furnishing and handling the core boxes, storing cores, and recording observations as specified.

Pressure tests—Pressure testing is measured by determining the total time to the nearest quarter hour that pressure is applied to the holes in making the required tests. A quarter hour will be added for setting up equipment for each testing period. No extra payment will be made for calibrating pressure test equipment. Payment for pressure tests is made at the contract unit price.

Washing grout holes—Measurement for payment is determined by the total time, to the nearest one-tenth hour, that water is actually applied to the hole. No extra payment will be made for setting up equipment. Payment for washing grout holes is made at the contract unit price.

Connections to grout holes—Connections to grout holes are measured by determining the number of connections made of the grout supply hose to the holes to be grouted. The number of connections for payment will not exceed one per hole for packer grouting or one for each stage for stage grouting. The exception is if grouting is interrupted to permit the grout to set, then one additional connection will be measured for payment each time grouting at the same elevation in the same hole is resumed. Payment for connections to grout holes is made at the contract unit price.

Placing grout—Grout placed is measured to the nearest cubic foot by counting the number of batches of each grout mixture injected in the holes as specified and multiplying by the number of cubic feet per batch. The number of cubic feet per batch for each grout mixture is determined as the average of the measured volumes of at least three batches of the mixture, or it is calculated as the sum of the absolute volumes of water, cement, sand, and bulk fillers used in the mixture. Absolute volume is defined as:

$$\frac{\text{weight (lb) of material}}{\text{bulk specific gravity of material} \times 62.4}$$

Admixtures shall not be considered in determining batch volume. The weight and specific gravity for sand shall be based on saturated surface dry conditions.

Payment for placing grout is made at the contract unit price, which includes compensation for handling all materials for the purpose of mixing and placing grout, sealing surface leaks, and maintaining grout records. Payment is not made for grout lost by failure of the contractor to caulk surface leaks or for grout otherwise wasted because of the actions of the contractor.

Cement—Cement for grout is measured on the basis of the number of bags of cement (94 lb) or equivalent weight of bulk cement used in the grout. Cement used in concrete for capping or other purposes is not included. Payment for cement is made at the contract unit price. Payment is not made for cement in grout wasted because of mechanical failure or the actions of the contractor.

Sand and bulk fillers—Sand and bulk fillers are measured by volume or equivalent weight, adjusted for moisture content where applicable, to the nearest cubic foot of each used in the grouting operation. Payment is made at the contract unit price for sand and each type of bulk filler specified. Payment is not made for sand or bulk filler wasted because of mechanical failure or the actions of the contractor.

Admixtures—Liquid admixtures are measured by volume to the nearest gallon. Dry admixtures are measured by weight to the nearest pound. Payment for admixtures is made at the contract unit price for each type of admixture specified. Payment is not made for admixtures wasted because of mechanical failure or the actions of the contractor.

Grout caps and concrete slabs—Capping and slab concrete are measured to the nearest 0.1 cubic yard by determining the combined weights of cement, aggregates, and water used in concrete mixed and placed as specified, and dividing by a unit weight of 4,000 pounds per cubic yard. Payment for capping concrete is made at the contract unit price, which includes compensation for furnishing and handling all materials (including cement) and for mixing, transporting, placing, and curing the concrete.

Subsidiary items—Compensation for any item of work described in the contract, but not listed in the bid schedule is included in the payment for the item of work to which it is made subsidiary. Such items and the items to which they are made subsidiary are identified in section 18 of this specification.

18. Items of work and construction details