Section 9: GROUTING OPERATION

Grouting of post-tensioned structures has a dual purpose:

1. To protect the strands from corrosion and slippage.
2. To develop the required ultimate moment capacity of the structure.

Grouting is a very important step in the overall stressing operation. There are four essential elements to a successful grouting job:

1. Ducts that are fully encased in well consolidated concrete, free of cracks.
2. Proper materials that have been authorized by METS.
3. Proper equipment in good working order.
4. Procedures that produce good results.

Revisions to the *Standard Specifications*[31] require the Contractor to pressure test each duct with compressed air after stressing and prior to grouting for post-tensioned concrete bridges. The Contractor is required to:

- Seal all inlets, outlets and grout caps.
- Open all inlets and outlets on adjacent ducts.
- Attach an air compressor to an inlet at one end of the duct with an attachment which includes a valve that separates the duct from the air source.
- Attach a pressure gage to the inlet at the end of the duct.
- Pressurize the duct to 50 psi.
- Lock off air source.
- Record the pressure loss after 1 minute.
- If there is a pressure loss exceeding 25 psi, repair the leaks with authorized methods and retest. Compressed air used to clear and test the ducts must be clean, dry and free of oil and contaminants.

Revisions to *Standard Specifications*[32] requires the Contractor to submit a daily grouting report for each day grouting is performed. The report must be submitted within 3 days after grouting. The report must be signed by the technician supervising the grouting activity. The report must include:

- Identification of each tendon.
- Date grouting occurred.
- Time the grouting started and ended.
- Date the prestressing steel was placed in the ducts.
- Date of stressing.
- Type of grout used.
- Injection end and grouting pressure.
- Actual and theoretical quantity of grout used to fill the duct.

[31] 2010 RSS, Section 50-1.01D(4) *Pressure Testing Ducts.*
[32] 07-19-2013 RSS, Section 50-1.01C (5), *Grout*.

- Ratio of actual and theoretical grout quantity.
- Records of air, grout, and structure surface temperatures during grouting.
- Summary of tests performed and results.
    - Except submit compressive strength and chloride ion test results within 48 hours of test completion.
- Names of personnel performing the grouting activity.
- A summary of the problems encountered and corrective actions taken.
- A summary of void investigations and repairs made.

Revisions to the *Standard Specifications*[33] require the use of permanent grout caps. Permanent grout caps for anchorage systems of post tensioned tendons must:

- Be glass-fiber-reinforced plastic with antioxidant additives meeting ASTM D 1693.
- Condition C where the environmental stress-cracking failure time must be a least 192 hours.
- Must completely cover and seal the wedge plate or anchorage head and all exposed metal parts of the anchorage against the bearing plate using neoprene O-ring seals.
- Have a grout vent.

Grout consists of cement conforming to the *Standard Specifications*[34] mixed with not more than five gallons of water per sack of cement. Be sure to check the Contractor's gage or calibration marks to ensure compliance with the five gallons per sack maximum limit. The addition of an authorized admixture is optional, but must be authorized by the Engineer.[35] Admixtures, if used, are generally designed to increase or sustain the fluidity of the grout and may become necessary in order to comply with the maximum water requirements.

The grout mixture, including any authorized admixtures, should be checked in accordance with California Test No. 541.[36] This test is required as a check at both the inlet and outlet ends. The flow cone is plugged, plumbed, and filled with a known quantity of grout. Then the time required to empty is measured with a stopwatch that reads to the nearest 0.1 second or less (a minimum efflux time of eleven seconds is required). A record should be kept of test results. The twenty-minute quiescence test should also be performed when appropriate. Remember that this and all other equipment must be cleaned and maintained regularly.

While the specifications do not currently establish a maximum efflux time, a test resulting in excess of fifteen seconds may be undesirable as this increases the chances of a blockage. A slow efflux time can be attributed to several possible problems:

- Loss of water in the equipment due to poor seals, hose connections, etc.
- Hot weather conditions.
- Insufficient mixing time.

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[33] 2010 RSS, Section 50-1.02F, *Permanent Grout Caps.*
[34] 2010 SS, Section 90-1.02B(2), *Cement*
[35] 2010 SS 50-1.02C, *Grout.*
[36] Appendix F.

- Hot cement or old cement.

The water/cement ratio must not be increased to accommodate grouting. If this is a problem, try to detect and correct the problem before proceeding. Also, be sure to receive a certificate of compliance for the cement used. Cement used for grouting should not contain any lumps or other indication of hydration or "pack set". Pack set can occur when cement is too old and/or exposed to moisture. Lumps in cement and trouble are synonymous.

Equipment used for grouting is generally at the option of the Contractor. Refer to *Standard Specifications*[37] for grouting equipment requirements. The specifications require equipment capable of grouting at least to a pressure of 100 psi (700 MPa), and a pressure gage having a full-scale reading of not more than 300 psi (2000 MPa). Also a screen with 0.07″ maximum clear openings (approx. 14 mesh) must be used prior to pumping to eliminate lumps and foreign material. Grout must be continuously agitated during pumping.

Photo 9-1 – Large Scale Grouting Operation.

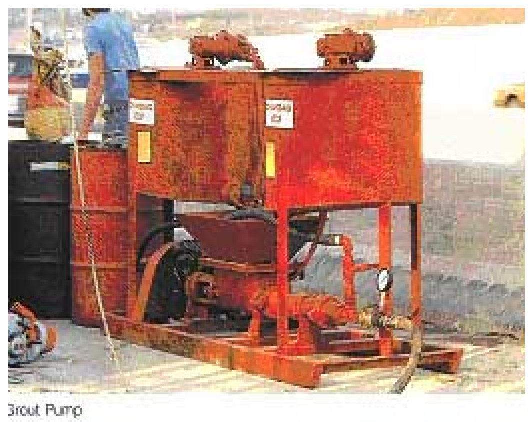


Photo 9-2 – DSI Grout Pump.

Initial pumping pressure should be small (less than 40 psig) and should gradually increase due to friction between the grout and the duct until the duct is filled.

The practice of flushing the prestressing ducts with water prior to grouting is no longer allowed. Flushing with water as a remedial action for blockages is no longer permitted. The grouting plan will have to address procedures for handling blockages[38].

Couplers pose a grout problem inherent to bar systems. If care is not exercised when positioning them in their enlarged duct housing, they can jam against the housing during stressing. If this occurs, it not only produces an incorrect stress distribution in the bar, but also seals the duct.

[37] 2010 SS, Sections 50-1.03B(2)(d)(i), *General* and 5-1.03B(2)(d)(vi), *Grouting Equipment.*
[38] 07-19-2013 RSS, Section 50-1.01C(3)12, *Shop Drawings.*

Blowing air through the ducts after stressing are a means of discovering blockages[39]. An inspection checklist for the grouting operation is available in Appendix C.

Blockage or leakage of a duct during grouting of tendons with strands has become less common since the advent of rigid ducts. However, in the event of blockage or leakage, it is the responsibility of the Contractor to propose and execute a successful solution. Attempting to grout a blocked duct by simply injecting grout from both directions is unacceptable, as this tends to create a pocket of compressed air in the duct. Building up the grout pressure to free a blockage may also be detrimental as the pressure forces out water and the cement particles can form a plug, which cannot be removed by blowing with air.

Upon grouting a tendon, it is necessary to ensure the outlet valve is closed before the inlet valve is closed. Remember, positive shut-off valves are required at injection pipes. Vents and ejection pipes also are required to be fitted with valves capable of withstanding the pumping pressures. Prior to closing the outlet valve, the wasted grout should be checked for equivalent consistency. All vents should be open when grouting begins. Grout should be allowed to flow from each vent until any residual water or entrapped air has been removed. Once a smooth stream of grout is achieved, the vent should be capped or otherwise closed. Remaining vents should be closed in sequence in the same manner.

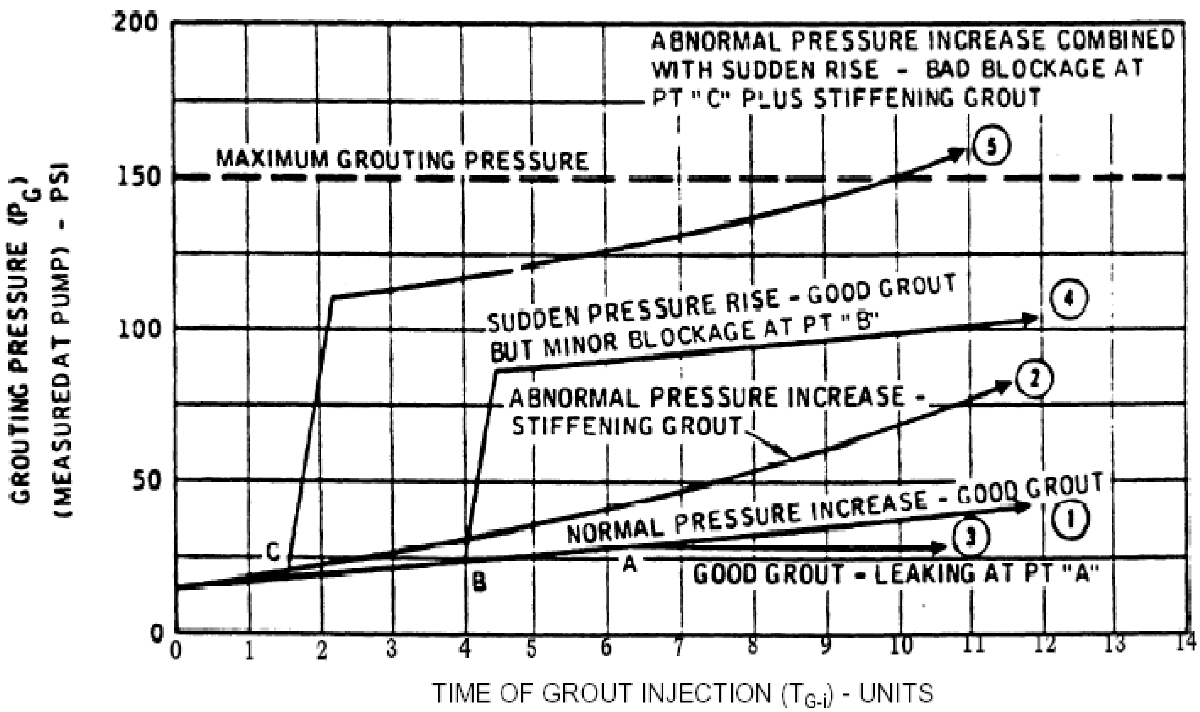
Care should be taken with the wasted grout. Avoid running grout into pervious backfill, traffic, structural or highway drainage, etc. Discuss with the Contractor prior to beginning the grouting operation how the wasted grout and spillage will be cleaned up, and define the location of disposal. The grouting operation, cleanup and disposal, must be in accordance with the authorized Storm Water Pollution Prevention Plan (SWPPP) and Construction Policy Directive CPD 04-5 "*Disposal of Portland Cement Concrete Liquid Residues.*"

A great deal of information can be obtained by monitoring the grout pressure gage and analyzing the information. Grout injection time and the length of duct are interrelated and are dependent on two constants; the duct void volume and the pumping rate, as shown in Figure 9-1. During pumping, grout will conform to known principles of hydraulics. Good grout will exhibit a gradually increasing pumping pressure due to friction in the duct, any head that exists, and normal grout stiffening.[40] A grout that "flash sets" in the duct will still exhibit increasing pressure, but at a greater rate.[41] A relatively constant pressure[42] is a characteristic of a leaky duct. A minor blockage will be indicated by a sudden jump in pressure, followed by a continued gradual increase in pressure.[43] Monitoring the grouting pressure can help determine whether: (a) the entire duct can be filled without exceeding the maximum recommended pressure, (b) the grouting operation should be transferred to a vent, or (c) the grouting operation should be discontinued, and the blockage repaired. An excessive blockage, possibly combined with

[39] 07-19-2013 RSS, Section 50-1.01D(4), *Pressure Testing Ducts.*
[40] Figure 9-1, Curve 1.
[41] Figure 9-1, Curve 2.
[42] Figure 9-1, Curve 3.
[43] Figure 9-1, Curve 4.

stiffening grout, would show up as a large increase in pressure.[44] As illustrated in Curve 5, there is little to be gained by allowing excessive pressure to build and hoping that the problem will correct itself. Grouting should be stopped at a low pressure so the grout can be flushed out easily.

Although grout will conform to known principles of hydraulics, there are too many variables, and not enough test data to establish reliable flow coefficients, thereby allowing pumping pressures to be predetermined by calculation. However, successful grouting on one or more tendons will establish the "normal" pressure vs. time relationship, which can be expected, and thus any "abnormal" conditions existing in other tendons can be detected.



NOTE: GROUTED DUCT LENGTH AND GROUT INJECTION TIME HAVE THE FOLLOWING RELATIONSHIP:

$$T_{G-i} = \frac{V_v \times L}{C_p} \; ; \text{OR} \quad L = \frac{T_{G-i} \times C_p}{V_v}$$

WHERE:

T_{G-i}	=	GROUT INJECTION TIME (MINUTES)
V_v	=	DUCT VOID VOLUME (FT^3/FT)
C_p	=	RATE OF GROUT PUMP (FT^3/MINUTE)
L	=	LENGTH OF DUCT FILLED WITH GROUT (FT)

Figure 9-1 – Pressure vs Rate of Grout Injection.

[44] Figure 9-1, Curve 5.

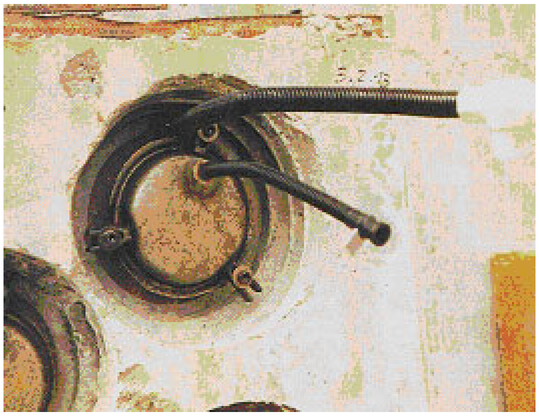


Photo 9-3 – Grout Cap and Tubes in Place.

Photo 9-4 – Grout Vents.