Structures Research Report No. 929
Final Project Report

November 2002

UF Project No. 4504-929-12
Contract No. BC-354 RPWO #73

POST-TENSIONING GROUT BLEED, DUCT, AND ANCHORAGE PROTECTION TEST

Principal Investigator: H. R. (Trey) Hamilton, P.E., Ph.D.

Graduate Research Assistant: Gustavo A. Alvarez

Project Manager: Larry Sessions, P.E.

Department of Civil & Coastal Engineering
College of Engineering
University of Florida
Gainesville, Florida 32611

Engineering and Industrial Experiment Station

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
BC354 RPWO #73		

4. Title and Subtitle	5. Report Date
Post-Tensioning Grout Bleed, Duct, and Anchorage Protection Test	November 2002
	6. Performing Organization Code
	8. Performing Organization Report No. 4910 45 04 929
7. Author(s) H. R. Hamilton III, G. A. Alvarez	
9. Performing Organization Name and Address University of Florida Department of Civil & Coastal Engineering P.O. Box 116580 Gainesville, FL 32611-6580	10. Work Unit No. (TRAIS) 11. Contract or Grant No. BC354 RPWO #73
12. Sponsoring Agency Name and Address Florida Department of Transportation Research Management Center 605 Suwannee Street, MS 30 Tallahassee, FL 32301-8064	13. Type of Report and Period Covered: Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Due to substantial problems with product quality, the Department is revising all specifications concerning post-tensioning corrosion protection. New products for grouting post-tensioning ducts have recently become available. These new products must be thoroughly tested before general application.

Bleed testing was conducted at the FDOT Structures Research Center in Tallahassee using four prepackaged grouts, each from a different manufacturer. The selected grouts were: *Euclid Euco Cable Grout PTX, Master Builders Masterflow GS 1205, Five Star Special grout 400, and Sika Cable Grout.* Vertical pipes were constructed with clear PVC and were injected with grout and monitored for bleed over the next 24 hours. Two inclined tests were performed using the same pipe. Three horizontal corrugated ducts (intended for internal tendons) were also grouted to evaluate the effect of the corrugations on the extent of grout. Finally, laboratory tests were conducted on the bleed properties of the prepackaged grouts used in the grout tests. The tests evaluated the effect of temperature and mixing time on the bleed properties. Some of the major conclusions from this research are: The relative bleed water quantity increases with the height of the duct and number of strands. Wicking action of strand bundles promoted bleeding more than increased height with a single strand. When tested using the Schupack Pressure Test, increasing the grout temperature increased the bleed quantity in several but not all of the grouts. A correlation between the Schupack Test and the Wick-induced test was developed.

A simulated pour-back was constructed and an epoxy grout was placed in the simulated pour-back. The pour-back was then subjected to thermal cycling for approximately two weeks and visually examined for cracking.

17. Kev Words	18. Distribution Statement
Post-tensioned Concrete, Tendons, Grout, Prepackaged Grout, Strand, Pour-back, Corrosion Protection	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA, 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	54	

Form DOT F 1700.7 (8-72)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

The authors would like to acknowledge and thank the Florida Department of Transportation for funding this research project. In addition, the authors would like to thank Frank Cobb, Tony Johnston, David Allen, Paul Tighe and Steve Eudy of the FDOT Structures Research Center in Tallahassee for their hard work and technical input during construction and testing. The authors would also like to acknowledge Mr. Jonathan van Hook for his efforts during the grouting operation. Mr. Richard DeLorenzo and Mr. Charles Ishee from the FDOT Materials Research Laboratory are thanked for sampling and testing the grout during the grout injection operation.

This research would not have been successful without Mr. John Newton and his grouting crew from DSI. The authors would also like to thank Euclid, Five Star, Master Builders, and Sika for donating materials and technical advice. General Technologies and Freyssinet are thanked for their donation of plastic duct.

Many of the tests conducted in this program were Mr. Larry Sessions' ideas and the authors would like to thank him for making this research possible as well as providing valuable technical advice.

1 Introduction

Due to substantial problems with product quality, the Department is revising all specifications concerning post-tensioning corrosion protection. New products for grouting post-tensioning ducts have recently become available. These new products must be thoroughly tested before general application. The testing reported herein was designed to evaluate several of these new products to ensure the that they will perform as expected under conditions as near as possible to field grouting conditions. This testing will help establish the limits of product applicability and facilitate completion of the work required to produce the new specifications. This research project will focus upon three parts of the post-tensioning system: cementitious grout; internal duct; pour-back material.

2 Scope and Objectives

2.1 Grout Testing

The current specification for post-tensioning grout does not differentiate between horizontal and vertical grout applications in regards to limiting bleed. In order to broaden the specification to address both applications, a relationship needs to be developed to associate laboratory test (Schupack) and field-simulated test (wick induced bleed). The laboratory test can then be used with information collected from the testing to quantify the difference between horizontal and vertical applications. If a correlation is established between the vertical or inclined tests and the pressure tests, then the pressure tests can be used in the future to test the bleed properties of new materials.

The majority of the testing for this research was conducted at the FDOT Structures Research Laboratory in Tallahassee, FL on June 28, 2002. Additional laboratory testing was also conducted later at the University of Florida and the FDOT Materials Research Laboratory in Gainesville. The testing conducted in Tallahassee consisted of three grouting tests:

- *Wick-induced bleed test.* Vertical PVC pipes up to 25-ft tall, containing single and bundled strand were erected inside the structures laboratory. Grout from each of the manufacturers was mixed and injected into the vertical pipes. Following injection the grouted pipes were visually inspected, marked, and recorded periodically for bleed at the top and along the length of the grout column. Schupack pressure tests were conducted on the grout used in the injection of the vertical pipes. Fresh and hardened properties of the grout were also determined.
- *Inclined bleed test.* Two inclined bleed test setups were also constructed and injected. One of the prepackaged grouts was used along with a plain grout composed of water and cement.
- *Horizontal corrugated ducts.* Three horizontal plastic ducts with different rib styles were also injected to determine the effect of the corrugations and longitudinal ribs.

Additional laboratory tests were also conducted at the University of Florida as a follow-up to the testing conducted in Tallahassee. Schupack pressure tests were conducted to examine the effect of temperature and mixing time on bleeding.

2.2 Corrugated Duct Testing

Corrugated duct is currently available with three distinct styles of ribs. The first type of duct has ribs that are parallel and oriented perpendicular to the axis of the duct. The second type has spiral ribs. The third type has parallel ribs similar to the first, but with four additional longitudinal ribs that are parallel to the axis of the duct and equally spaced radially around the circumference. This test will examine the effect of the corrugations on the bleed properties of the grout. Three 50-ft long ducts will be grouted with the same prepackaged grout. After acquiring the required strength, the duct will be cut into segments and examined to determine if the corrugations have an adverse effect on the completeness of grouting.

2.3 Epoxy Pour-Back Test

Another area of concern in post-tensioned bridges is the pour-back area around the caps at the anchorages. Traditionally, these areas have been filled with a cementitious non-shrink grout to provide protection to the caps and anchorage. The testing reported herein evaluated an epoxy grout for use in the pour-back area. Specifically, the grout was evaluated under thermal cycling to determine if problems developed because of the difference in coefficient of thermal expansion.

A full scale mock-up of a combined multiple anchorage pour-back was be constructed and subjected to temperature variations. The test will determine if shrinkage and differential volume change between the materials causes cracking of the pour-back.

3 Test Set-up and Procedures

3.1 Post-tensioning Grout

Grout used in the testing was prepackaged grout provided by each manufacturer specifically for this project.

- Euclid - Euco Cable Grout PTX
- Five Star - Special Grout 400
- Master Builders - Masterflow GS 1205
- Sika - Cable Grout

3.2 Mixing and Injection

Grout mixing and injection was performed by a DSI grouting crew experienced in grouting post-tensioned ducts (Figure 1). Grout was mixed in the proportions recommended by the manufacturers as shown in Table 1. The water was placed in the mixing vessel and the mixer was started. Bagged material was added to the mixer as the mixer was running. The grout was mixed for an additional three minutes after the last bag was added. Mixing was terminated and flow cone measurements were taken. If the grout was found suitable, the pump intake was filled with grout and approximately 3 gallons of grout was wasted at the discharge. Flow cone measurements were taken at the discharge before commencement of injection (Table 1 and Figure 2). Detailed procedures used for each grout are recorded in the appendix.

Figure 1 - Collodial Mixer and pump used to mix and inject grout for Wick-Induced Bleed Tests. Photo shows DSI personnel adding bagged grout to mixer during mixing operation.

Table 1 - Mix proportions and fluidity results for wick-induced bleed test

Grout	Materials	Modified Flow Cone at discharge (sec)
Portland cement	3 bags (94 lbs/bag) + 15 gallon water	none
Euco	6 buckets (50 lbs/bucket) + 9.25 gallon water	13
Five Star	6 bag (42 lbs/bag) + 8 gallon	10.9
MB	6 bags (55 lbs/bag) + 11.25 gallon water	10
Sika	6 bags (50 lbs/bucket) + 7.0 gallon water	9

Figure 2 - Flow was checked after mixing and before injection for each grout.

3.3 Wick-Induced Bleed Test

Selected lengths of clear PVC piping were used to mimic post-tensioning duct in the wick induced bleed test (Figure 3). The 4-in diameter, clear, SCH 40, PVC pipes oriented vertically were constructed from 10-ft lengths of PVC connected with standard couplings using PVC solvent welds. The pipes were not flushed with water prior to injections and were maintained dry and free of obstructions or trash. Each grout was injected into a bank of six vertical pipes. Each vertical pipe contained either a single or a bundle of three 0.5-in diameter, 7-wire prestressing strands and ranged in height from 10 to 25-ft (Table 2). The strand was centered in the pipe using plastic rebar chairs placed at a spacing of approximately 5-ft. The base of each pipe was fitted with a PVC reducing “T” to which a ball valve and a quick disconnect, crow’s foot coupler were connected to facilitate injection.

After the batch was mixed and tested for flow, the grout was injected into the vertical PVC pipes starting with the 10-ft pipe and working up to the 25-ft pipe. Grout was injected to fill the pipe to within 6 inches of the top of the pipe (Figure 4).

Figure 3 - Wick Bleed Test Setup. Note strand bundle inside pipe with centering device.

Table 2 – Wick Induced Bleed Test Setup

Test Number	Height (ft)	Number of Strands
1	10	1
2	15	1
3	20	1
4	20	3
5	25	1
6	25	3

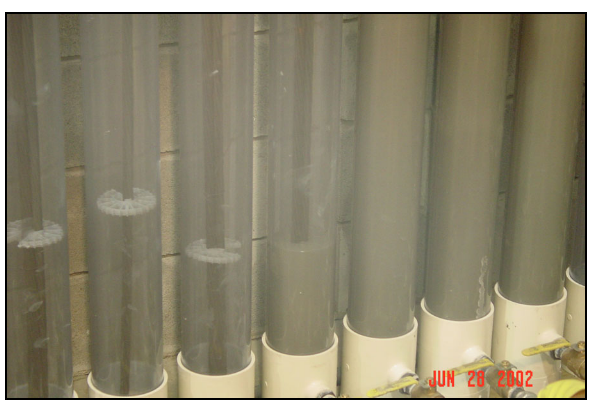


Figure 4 – Wick Induced Bleed Test Specimens During Grout Injection.

After the pipe was grouted, it was visually inspected, marked, and recorded periodically for bleed at the top and along the length of the grout column. The entire bank of pipes for each grout type was inspected at each specified period. The first recorded inspection for each bank occurred ½-hour after initiation of injection for that bank. The second occurred 1-hour following initiation of injection. Two more inspections were made at 2- and 3-hours following the start of injection. Detailed results of the inspection are given in Appendix D. The location and quantity of bleed was recorded (measured along the length of pipe) and photographed. The 10-ft tall duct is shown in

Schupack pressure test and fresh and hardened properties were tested on each of the grouts. The sample for these tests was taken after grouting the 15-ft. tall specimen.

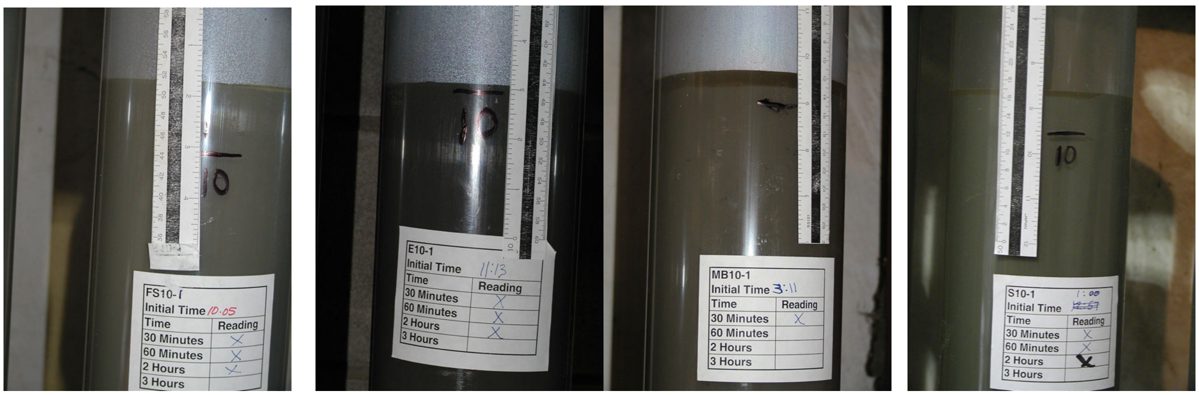


Figure 5 – Typical Bleed Measurement on Wick Induced Bleed Specimens. Photographs show the 10 ft. tall specimens at the 2 hour mark.

3.4 <u>Schupack Pressure Test</u>

The Schupack Pressure Test uses stainless steel pressure filter that is 47mm diameter by 140mm long with removable upper and lower caps at the ends that are threaded on the main body (Figure 6). The upper cap is connected to a pressure tank through a flexible hose equipped with valves and gauges. The lower cap supports a metallic circular screen that in turn supports a mesh filter. The filter is of the type A/E borosilicate glass filter (1µ pore size).

The pressure testing conducted for this research used the following procedures. For each test, the vessel is filled with 200 ml of freshly mixed grout. The grout is allowed to rest in funnel for 10 minutes. The pressure is then increased to 50 psi for 5 minutes and then to 100 psi for five additional minutes. Bleed water quantity is recorded at the end of each period. If a loss of pressure occurs before completion of the test, the test is considered to have failed for the given pressure level. A wire was inserted into the lower stem of the funnel to ensure that all bleed water is removed from the funnel. Bleed volume is reported as a percentage of the original sample volume at the time the reading is taken.

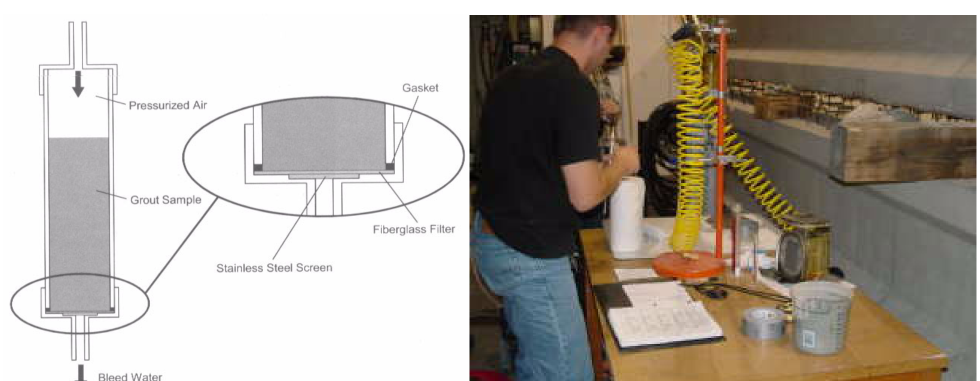


Figure 6 - Laboratory setup for the Schupack Pressure test.

3.5 Corrugated Duct Test

Corrugated duct is currently available with three distinct styles of ribs. The first type of duct has ribs that are parallel and oriented perpendicular to the axis of the duct. The second type has spiral ribs. The third type has parallel ribs similar to the first, but with four additional longitudinal ribs that are parallel to the axis of the duct and equally spaced radially around the circumference.

This test examined the effect of the corrugations on ability of the grout to completely fill the duct. Three 50-ft long ducts, containing no strand, were grouted with the same prepackaged grout. After acquiring the required strength, the duct was cut into segments and examined to determine if the corrugations had an adverse effect on the completeness of grouting.

Three different types of grouted duct to determine if the duct type influences the location, number, and type of void when present. The test set-ups are as follows:

1. 5"Ø x 50 ft long corrugated polypropylene duct with standard ribbed corrugations.
2. 5"Ø x 50 ft long corrugated polypropylene duct with standard corrugations and longitudinal flow channels between corrugations.
3. 4"Ø x 50 ft long corrugated polyethylene duct with spiral corrugation ribs.

The ducts were supported regularly on a slight grade of 1/8" per foot. Before grout was injected, water was circulated through each duct to fill corrugations.

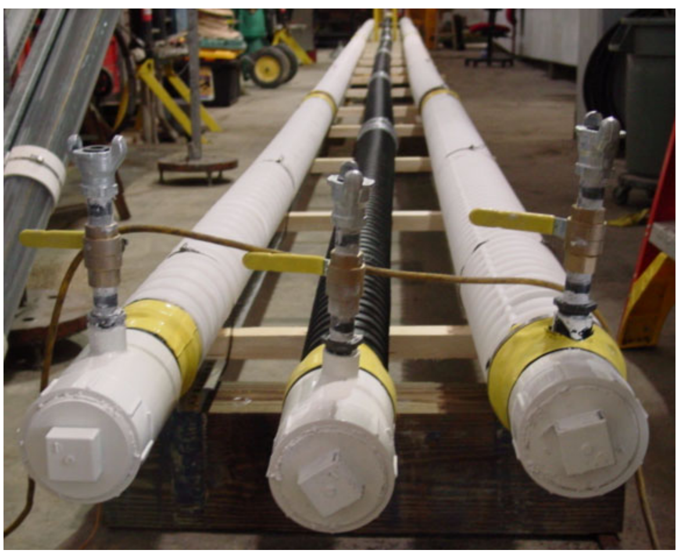


Figure 7 - Corrugated Duct Test Setup.

3.6 Inclined Bleed Test

The inclined bleed test was designed to be similar to a test currently conducted in Europe to determine bleed properties of grout (Figure 8). It is thought that this test is a particularly harsh test in promoting bleed. The set-up consisted of two 4-in diameter clear PVC pipes oriented on an approximately 30° slope. Each pipe contained a bundle of (12) 0.6-in. diameter prestressing strands resting on the bottom of the pipe. The first grout was a portland cement and water mixture. The second was a prepackaged grout *Masterflow GS 1205*. The plain grout was mixed at approximately 0.45 w/c ratio.

Figure 8 - Inclined Bleed Test

3.7 Anchorage Pour-Back Test

Construction of the specimen took place at the FDOT Structures Research Center in Tallahassee. Figure 9. The concrete base was cast from ready-mix concrete in a tub shape to retain the epoxy grout during placement. To ensure that the grout caps did not slip they were bolted to the simulated anchorage using 3/8 inch diameter adhesive anchors and then filled with grout. The caps and concrete surfaces to receive the epoxy grout were lightly sand blasted. Grout caps were fastened to the concrete in the indicated location. Two thermocouples were placed near the center of the pour back to measure temperature during thermal cycling. One was placed in the concrete and one was placed in the epoxy.

Roofing paper was placed against the inside edge of the pour-back to prevent bond between the pour-back material and the concrete. After the concrete was sufficiently cured, the epoxy was mixed and poured according to the manufacturer's directions (Figure 10). The grout used in the pour-back was Masterflow 648 CP plus epoxy grout produced by Master Builders. The grout is a high-performance, three-component, modified epoxy resin-based grout. The manufacturer's literature indicates that the material intended for use in precision alignment of machinery and has good chemical resistance.

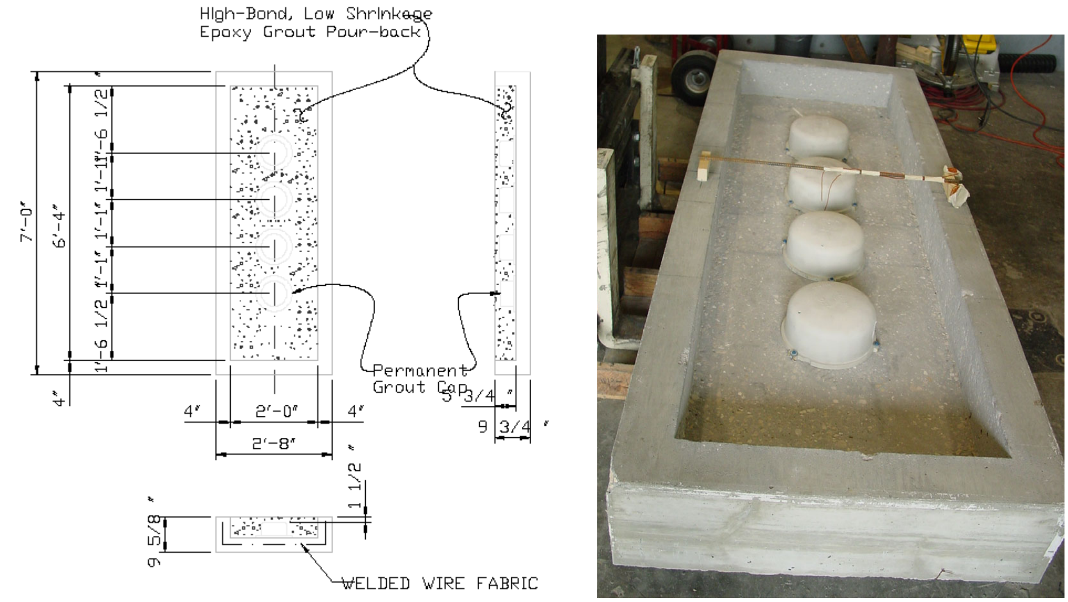


Figure 9 - Epoxy Pour-Back Construction Details

Figure 10 - Mixing and placement of epoxy.

After curing for three weeks the pour-back was transported to UF for thermal cycling. Initially the cycling was made up of 24 hours cold and 24 hours hot. The target temperature range was from 65ºF to 135ºF. However, this range was not reached due to equipment problems (see Appendix E for temperature data). Ambient temperature readings along with the epoxy and concrete were taken every 10 minutes using a datalogger. The specimen was visually inspected for cracking before, during, and after the thermal cycling. In addition, impact-echo nondestructive measurements were taken before and after cycling.

4 Results

4.1 Wick Induced Bleed Test

This section reports the results of the wick induced bleed tests conducted in Tallahassee on June 28, 2002. Table 3 shows the results of the fresh and hardened properties. This testing was conduced by the FDOT Materials Research Office in Gainesville

Table 3 - Fresh and Hardened Properties of Grout

Test	Euclid	Five Star	Master Builders	Sika	Standard Grout	FDOT Specs
Temperture (°C) [°F]	37.0[98.6]	40.1[104]	37.5[99.5]	35.0[95]	30.4[86.7]	n/a
Unit Weight (pcf)	122.7	122.7	127.6	131.0	118.7	n/a
Modified Flow Cone Initial/Hose (sec) ASTM C939	16/13	10/11	11/7 12/10	11/9	?/5	9-20
Expansion (%) ASTM C940	0.0	1.5	0.7	0.6	-2.3	$\leq$ 2.0%
Wick Bleed Water (%) ASTM C940	0.0	0.0	0.0	0.0	1.0	0.0% max
Compressive strength (psi)	10460	10150	8770	11460	n/a	$\geq$7,000psi
Rapid Chloride Permeability (coulombs)	470	508	3410*	2338	10,283	2500 max
Surface Resistivity** (kΩ-cm)	6.5	29.3	5.9	6.5	n/a	n/a

***Subsequent testing of samples mixed in the FDOT Materials Laboratory gave an average value of 1941 coulombs.**
****Surface resistivity was measured with Wenner Probe.**

<u>*Five Star – Special Grout 400*</u>, from Five Star, was the first product injected. Figure 11 shows a plot of the bleed quantity as a percentage of the original sample volume. Bleed water was observed from the first inspection, in the 15-ft-long ducts, 30 minutes after injection. As expected, the maximum bleed volume (0.3%) was observed in the tallest duct, containing the maximum number of strands (FS25-3). The next lowest bleed quantity was found in FS20-3, indicating that the bundle of strand was promoting more bleed at a lower height compared to a single strand with five additional feet of height.

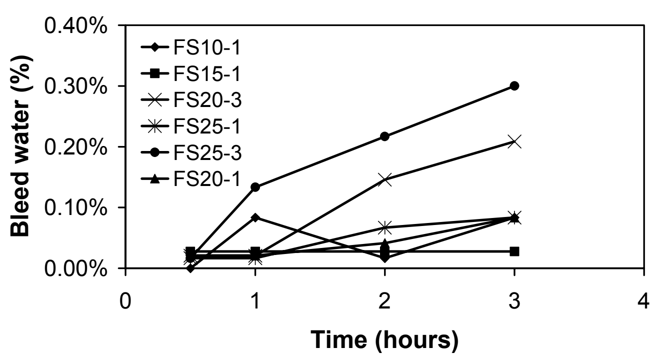


Figure 11 - Bleed quantity for Five Star – Special Grout 400.

<u>*Euco-Cable Grout PTX*</u>, from Euclid, was the second product injected (Figure 12). Bleed water was observed only on the fourth inspection, even for the tallest duct containing the maximum number of strands (E25-3). The maximum registered bleed volume for this product was 0.03%. The next highest quantity of bleed was in E15-1. Differences between bleed quantities are probably not significant since the total quantities were so low, increasing the error in readings.

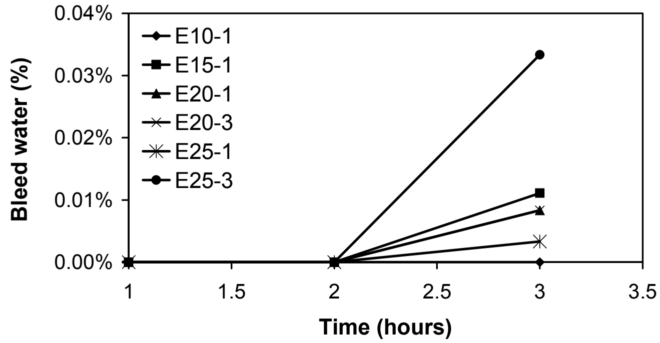


Figure 12 - Wick test - bleed quantity for Euclid.

<u>Sika – Cable Grout</u>, from Sika, was the next product injected (Figure 13). Bleed water was observed during the first inspection 30 minutes after injection. However, at this time, only the tallest ducts (S25-1 & S25-3) contained detectable bleed water. In contrast, in the shorter ducts with the minimum number of strands (S10-1) bleed water was observed only on the third inspection two hours after injection. As expected, the tallest duct containing the maximum number of strands (S25-3) was the one that bled the most rising up to 0.08%. As with the Euclid grout, the Sika grout exhibited significantly higher bleed with the strand bundle at lower heights than the single strand at greater heights.

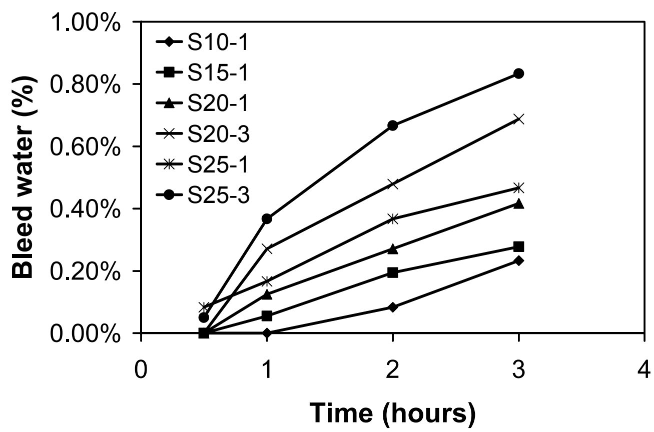


Figure 13 - Wick test - bleed quantity for Sika

<u>Masterflow 1205,</u> from Master Builders, was the last product tested (Figure 13). Bleed water was detected in all specimens during the first inspection. Figure 13 shows the expected increase in bleed from ½ to 1 hr, and from 1 to 2 hours. However, nearly all of the bleed quantities decrease by the third hour. The maximum bleed water of 0.88% was registered from the 20-feet long duct with only one strand.

One explanation for this decrease is permanent enlargement of the PVC that occurred after grout injection (perhaps due to the high temperature of the grout). This enlargement was noted during visual inspection on the following day and may have been due to enlargement of the PVC pipe from high grout temperatures. Figure 15 shows a section of the grouted pipe taken during disassembly of the specimens several days later. This phenomenon was found to occur only in the Master Builders specimens. Unfortunately, no temperature readings were taken on the grout after injection into the ducts. It was noted during the injection process that the injection port on the duct was very hot to the touch, indicating that the temperature of the grout, as injection, was hotter than that of the samples collected for temperature measurement.

The duct was drilled on the day following injection and several samples of the water were collected. The samples were clear with none of the typical discoloration noted in bleed water. The source of this water is uncertain. One explanation is that the bleed from the top of the column leaked into the annular space around the grout. This does not, however, reconcile with the fact that the water was clear and the samples pulled from the top of the column were discolored. Another explanation is that moisture evaporated from the grout column, condensed, and collected in the annular space.

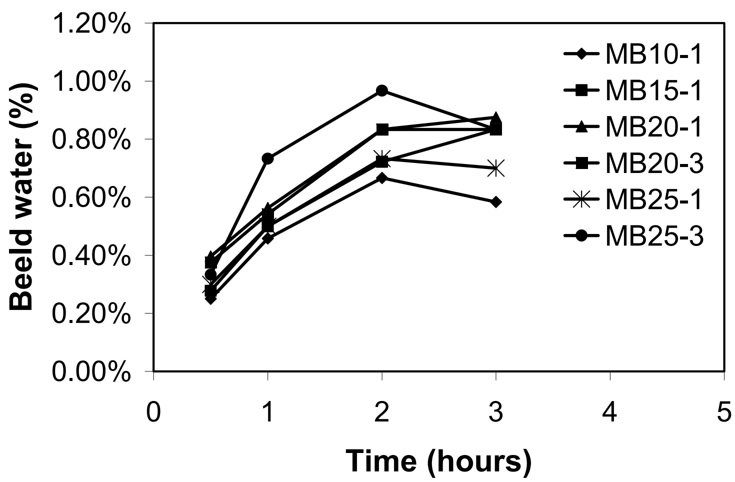


Figure 14 - Wick test - bleed quantity for Masterflow 1205

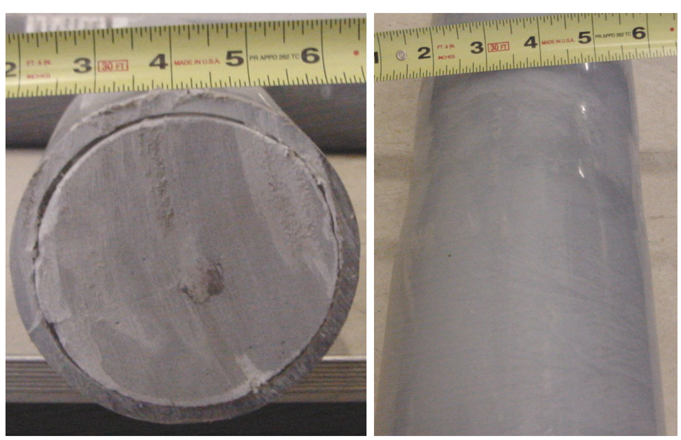


Figure 15 - Permanent Enlargement of PVC Pipe due to high grout temperature.

Figures 8.a, 8.b, 8.c and 8.d, present the results for the Wick Induced Test for Five Star Special Grout 400, Euco Cable Grout 400, Master Flow GS 1205 Grout and Sika Cable Grout respectively. The same scale is used for comparison purposes.

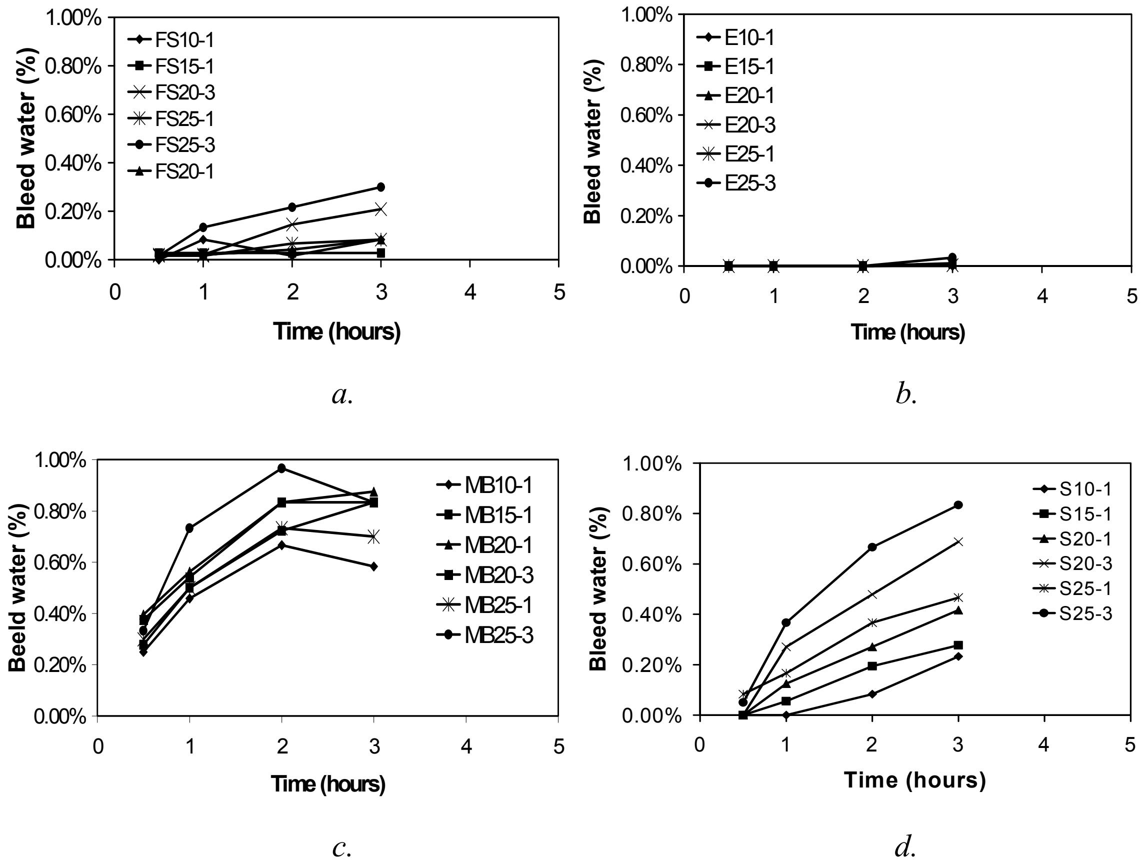


Figure 16 – Wick-induced test results. (a) Five Star (b) Euclid (c) Master Builders (d) Sika.

4.2 <u>Schupack Pressure Test</u>

This section presents the results of the Schupack Pressure Test performed in Tallahassee on June 28, 2002. The grout was taken directly from the hose during injection and tested immediately thereafter. Figure 17 shows two sets of results. The first is the bleed measured after 5 minutes at 50 psi and the second is the total bleed (including that recorded at 50 psi) after an additional 5 minutes at 100 psi. Although the bleed quantities are much larger than those measured on the wick test, the trend and ordering of performance is the same.

4.3 <u>Post-Mortem Examination</u>

The top four feet of the 25-foot ducts with three strands were cut apart and visually examined after the grout had hardened. Figure 18 shows the appearance of the grout surrounding the strand bundle. In general, all of the grouts tested completely filled the spaces around and between the strand, providing adequate coverage for corrosion protection and bond transfer.

Strands in each of the specimens were also examined to determine if grout penetrated the individual strands. Figure 19 shows single strands that have one outer wire removed. As shown in the photo, the grout does not solidly fill the strand interstitial space. All grouts tested demonstrated this behavior.

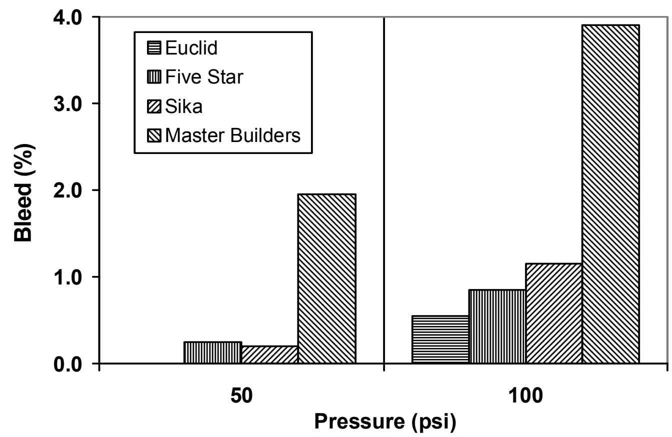


Figure 17 - Pressure test results on grout used in wick induced bleed tests.

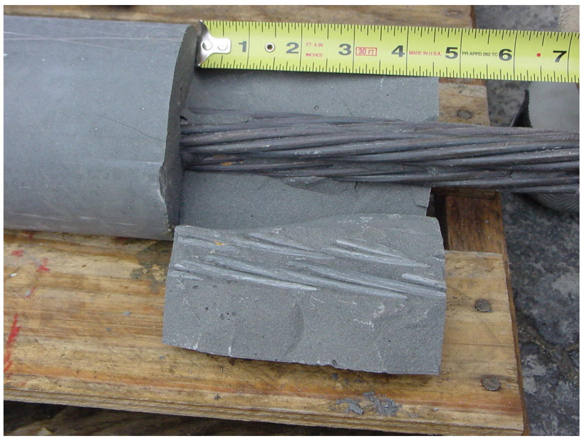


Figure 18 - Three-strand specimen from 25 ft. wick induced bleed test. Grout has filled the space around the strand completely.

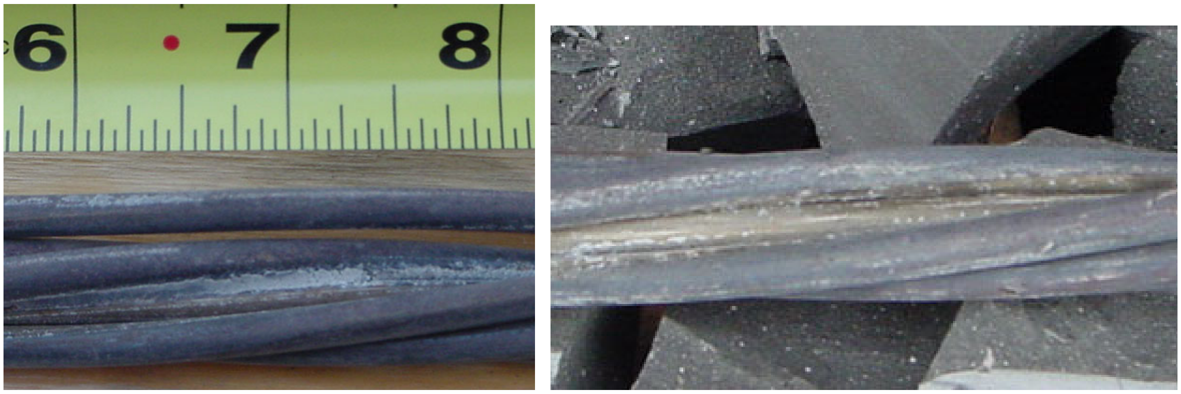


Figure 19 - Strand interstitial space from wick induced grout test specimen.

4.4 Schupack Pressure Tests – UF Laboratory Tests

The results obtained from the tests in Tallahassee called into question the high grout temperatures measured at injection and the long mixing time used with the colloidal mixer. To address this question, a series of laboratory tests were conducted using the Schupack Pressure Test. The tests were conducted varying the mixing time and the grout temperature. The objective was to determine if the bleed properties of the grouts varied significantly when either of these parameters was varied.

4.4.1 Mixing time

The first set of tests was conducted by varying the mixing time. Each grout was mixed using an industrial drill running at 750 RPM and at the same room temperature conditions. Small samples (720 ml) were mixed in a plastic 6-in by 12-in concrete cylinder mold using a jiffy mixer. The only variable induced in this set of tests was the mixing times, which was varied between 1 and 5 minutes (after the final addition of dry materials). Figure 20 and Figure 21 show the results of the pressure test for 50 psi and 100 psi increments, respectively. The pressure test was conducted in a similar manner to those conducted for the grout used in the wick-induced tests.

In all grouts but Sika, increasing the mixing time does not have a significant effect on the bleed volume. This is true at both 50 and 100 psi. Sika, however, shows a marked decrease in bleed as the mixing time is increased. At both pressures, Master Builders remains reasonably constant at approximately 2.0% and 3.0%, respectively. The results of these tests appear to match the results of the tests conducted in Tallahassee.

In conclusion, it does not appear that the long mixing times contribute to excessive bleed. In addition, these results point out the importance of ensuring that the grout has a sufficiently long mixing time to avoid bleed problems.

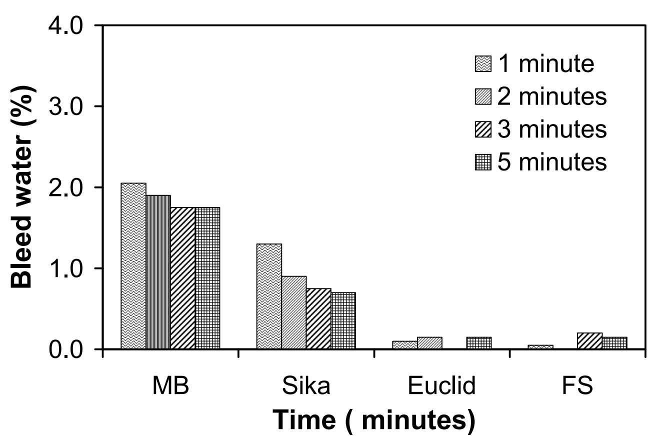


Figure 20 - Effect of Mixing Time on Grout Bleed Properties. Results shown are for bleed quantity measured at end of 50psi period during Schupack Pressure Test.

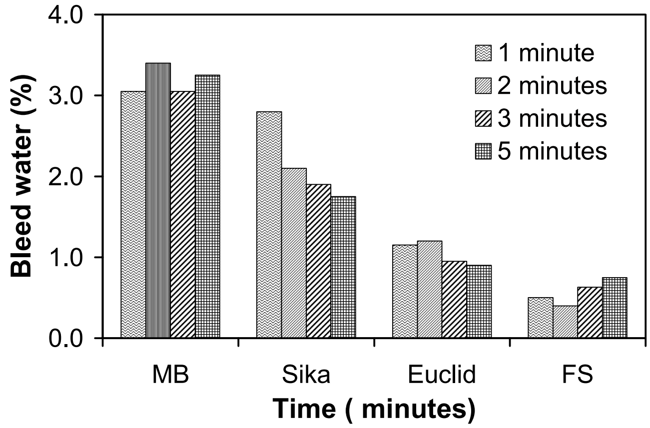


Figure 21 - Effect of Mixing Time on Grout Bleed Properties. Results shown are for bleed quantity measured at end of 100psi period during Schupack Pressure Test.

4.4.2 <u>Temperature</u>

The second set of tests conducted in the laboratory examined the effect of temperature on the bleed properties. Ice and hot water were used to adjust the final temperature of the grout to the three target values of 60, 80, and 100 deg F. The mixing time was held constant at 3 minutes. Figure 22 and Figure 23 show the results of bleed testing at 50psi and 100psi, respectively. The results show varied and somewhat surprising behavior among the grouts. Master Builders appears to have a peak bleed at a temperature of 80 deg F, which decreases when the temperature either falls or rises. Conversely, the Sika grout (and Euclid and Five Star to a lesser degree) bleed appears to decrease to a minimum when the temperature is at 80°F, rather than at 60°F. In summary, Master Builders grout bleed was at a maximum when the temperature was 80°F, Sika was at a maximum when the temperature was 60°F and the remaining grouts were at a maximum when the grout was at 100°F. The expected behavior was that the bleed would be highest at the higher temperature, which was not necessarily the case. Consequently, the testing was conducted twice to ensure that there was no error made during testing. The second set of tests yielded almost exactly the same results.

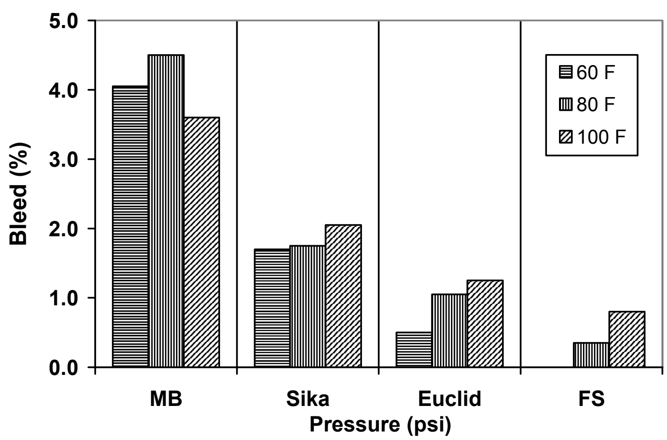


Figure 22 - Effect of Grout Temperature on Grout Bleed Properties. Results shown are for bleed quantity measured at end of 50psi period during Schupack Pressure Test.

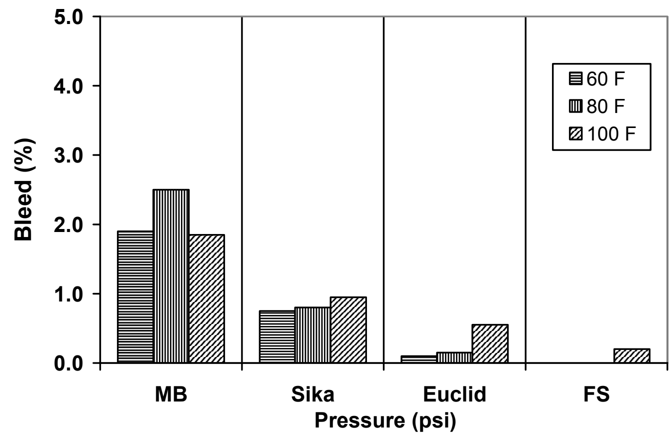


Figure 23 - Effect of Grout Temperature Grout Bleed Properties. Results shown are for bleed quantity measured at end of 100psi period during Schupack Pressure Test.

The temperature measured in the grouts used for the wick-induced bleed test ranged from 95 to 104 deg F. The Master Builders and Five Star grout performed nearly identical between the colloidal mixed grout and that mixed in the laboratory. However, the Sika and Euclid grout performed better overall in the colloidal mixer than in the laboratory mixed grout.

4.5 Corrugated Duct Test

The grout pump was unable to pump a sufficient volume during injection to fully evaluate the differences between the corrugated ducts. Consequently, it was thought that grout front was too shallow (Figure 24). After injection, the ducts were scanned with an infrared camera to determine if voids could be detected. Figure 25 shows the IR image of the grout filled duct. The darker spots at the ribs indicate trapped air.

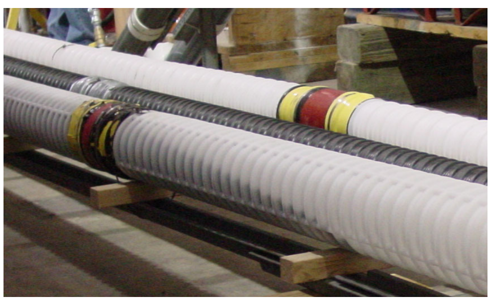


Figure 24 –Grout front in corrugated duct during injection.

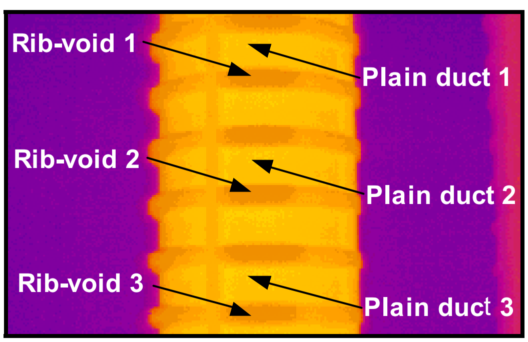


Figure 25 – Thermographic image of corrugated polypropylene duct after injection.

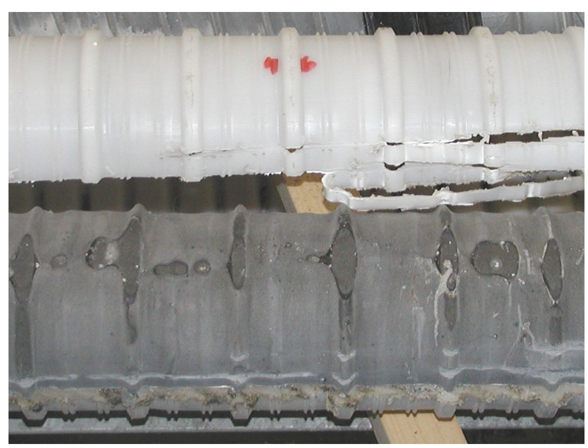
The ducts were cut open following hardening of the grout to determine how well the grout filled the duct. In general, the inspection revealed that the grout filled each duct configuration except for areas near the top of the duct. Figure 26a shows a section of the duct with the spiral corrugation configuration. Air was trapped in the corrugations and in some cases the top of the duct just under the corrugations. Figure 26b shows the corrugated duct with longitudinal ribs. In this location, the ribs were placed to avoid being at the 12 o'clock position. Air bubbles were trapped in the ribs and in some cases just below the ribs. Figure 26c shows the same configuration duct with one of the ribs oriented near the 12 o'clock position. The longitudinal rib is filled solid with grout. The transverse ribs, however, contain voids immediately adjacent to the longitudinal rib. Finally, Figure 26d shows the corrugated duct without longitudinal ribs. This configuration also trapped air in the tops of the longitudinal ribs.

In summary, all ducts performed reasonably well. Had the grout been injected at a higher rate the trapped air would likely have been reduced. Generally, it is expected that some air will be trapped in the ribs during grouting due to air exiting the strand bundle after the grout front passes. This is particularly true for thixotropic grouts that have a higher viscosity than the traditional cement/water mixtures.

(a)

(b)

(c)



(d)

Figure 26 - Post Grouting Inspection of Corrugated Duct.

4.6 Inclined Bleed Test

The inclined bleed test illustrated the significant difference in bleed quantities that prepackaged grouts can make over plain grouts. Figure 27 shows the bleed at the top of the incline for the plain grout and the prepackaged grout. The grout front for the plain grout was nearly parallel with the ground. In contrast, the prepackaged grout was nearly perpendicular to the pipe axis. The prepackaged grout bleed water that appeared in the inclined test gathered on the bottom of the pipe under the grout rather than above. In the plain grout, the bleed water gathered above the grout. The bleed from the prepackaged grout likely came from the wicking action of the strand bundle laying on the bottom of the pipe, while the plain grout bleeding occurred in all segments of the pipe.

The inclined pipe lengths were 15 ft, which allows a direct comparison to the vertical test in which there was a single strand. For the same grout that was used in the inclined test, the 15 ft reading at 3 hours was 1.5 in of bleed. The attempt to measure the bleed water on the inclined test points out one of its disadvantages. The depth of the bleed water will vary depending on the final grout front configuration and characteristics of bleed. However, visually estimating the quantity of grout in the inclined test and comparing the two methods, the vertical tests appear to be at least as harsh as that of the inclined test and perhaps more.

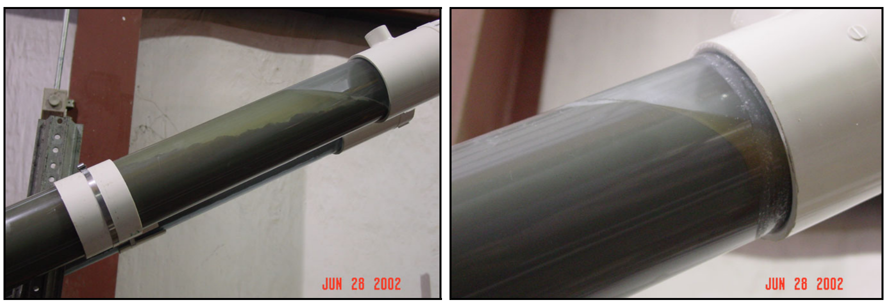


Figure 27 – Results of inclined bleed test

4.7 Anchorage Pour-Back Test

There was no discernable cracking noted on the exterior of the pour-back specimen during or after the thermal cycling. In addition, the impact-echo measurements indicated that there was no change in the bond at the interface between the epoxy and concrete. Cores were taken after completion of the thermal cycling through the epoxy as each of the four corners and near one of the grout caps in the center (Figure 28). No cracking was noted in the epoxy or concrete when the specimens were examined with a microscope.

Figure 28 - Cores taken from epoxy pour-back.

Although the results of this test indicate that the epoxy did not crack or cause cracking in the concrete, the results must be viewed with caution. The large scale of the specimen made monitoring for cracking difficult to impossible. If this material is to be considered for use in pour back application, it is suggested that further study be conducted to ensure that the long-term performance will be adequate.

5 Correlation of Pressure Test and Full-Scale Test

The Schupack Pressure test is a much more convenient way of testing grout for bleed resistance than the full-scale wick test. This is particularly true for very large elevation changes. Figure 29 shows the correlation between the Wick Test and the Pressure Test for the bleed at 2 hours. The results of the 25 and 20-ft wick tests with 3 strands are plotted along with the 50 and 100psi Schupack results. Both sets of data are in terms of percent bleed. The 100-psi test results are also plotted with an exponential trend line using the following equation:

$$S_b = 0.0052e^{181W_b}$$

Where S_b (% bleed/100) is the bleed from the Schupack test and W_b (% bleed/100) is the bleed from the wick-induced bleed test. This equation is based on the data from the 25-3 specimen, but is also plotted in the 20-3 chart for comparison. There were, however, only four data points used to develop the trend equation.

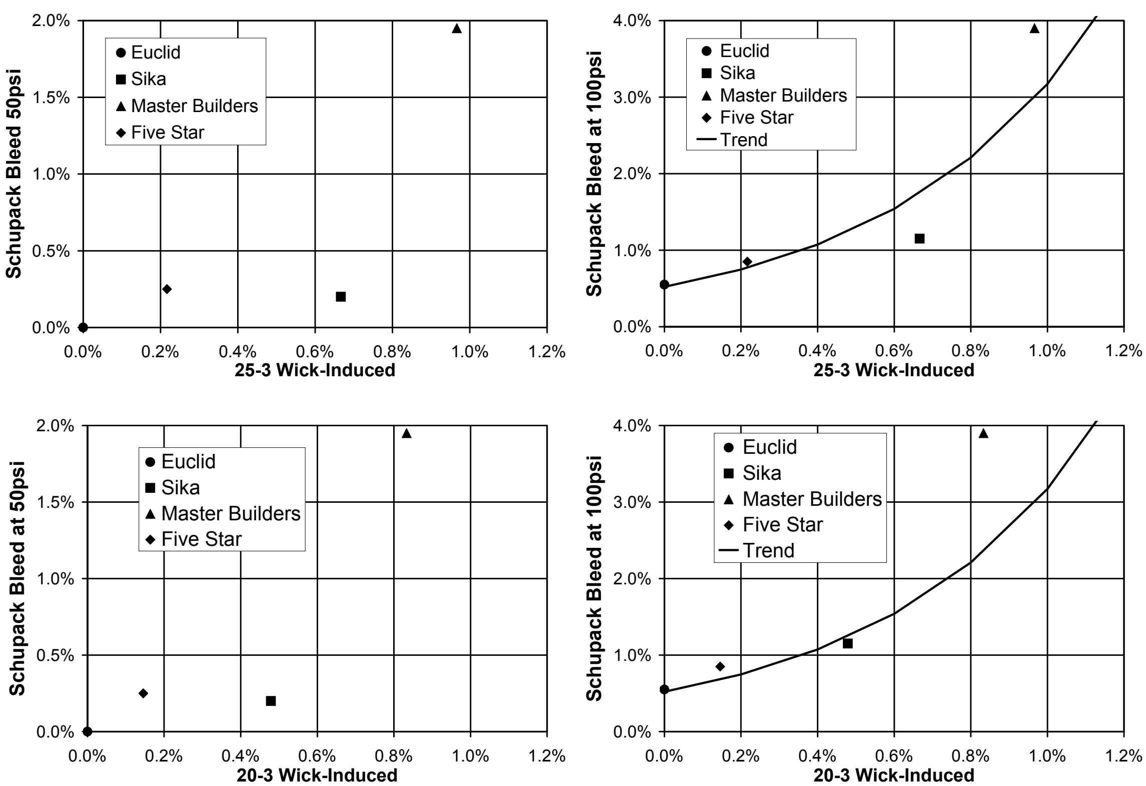


Figure 29 - Correlation between the Wick Test and the Pressure Test

The charts show that the Schupack test gives bleed values of approximately 0.25% for both the Five Star and Sika grouts, even though the performance of these grouts was quite disparate in the wick induced test with one just above 0.2% and the other at nearly 0.7%. Letting the pressure test run longer at a higher pressure provides more separation between the Schupack results, leading to a better correlation.

The underlying assumption in these tests is that the wick-induced test is at least as harsh as actual field conditions. If the desire is to have no bleed in the field (assuming that the wick-induced test is a good indicator) for duct less than 25-ft tall, then the bleed under the 50/100psi should be limited to less than 0.5% or (with less confidence) no bleed under the 50 psi test regime. Unfortunately, this is based on a single prepackaged grout performance (Euclid).

6 Summary and Conclusions

Bleed testing was conducted at the FDOT Structures Research Center in Tallahassee using four prepackaged grouts, each from a different manufacturer. Vertical pipes were constructed with clear PVC and were injected with grout and monitored for bleed over the next 24 hours. Two inclined tests were performed using the same pipe. Three horizontal corrugated ducts (intended for internal tendons) were also grouted to evaluate the effect of the corrugations on the extent of grout. Finally, laboratory tests were conducted on the bleed properties of the prepackaged grouts used in the grout tests. The tests evaluated the effect of temperature and mixing time on the bleed properties.

A simulated pour-back was constructed and Master Builders Masterflow 648 CP plus, an epoxy grout, was placed in the simulated pour-back. The pour-back was then subjected to thermal cycling for approximately two weeks and visually examined for cracking.

The major conclusions from this research are:

Wick-Induced and Schupack Bleed Tests

- The relative bleed water quantity increases with the height of the duct and number of strands.
- Wicking action of strand bundles promoted bleeding more than increased height with a single strand.
- When tested using the Schupack Pressure Test, increasing the grout temperature increased the bleed quantity in all but the Master Builders grout. MB grout showed a decrease in bleed for both increasing and decreasing temperatures. This finding supports the upper limit on grout temperature currently in the FDOT specifications.
- When tested using the Schupack Bleed Test, longer mixing times decreased bleed in both the Sika and Euclid Grouts. Varying mixing time did not significantly affect the Master Builders grout, but did cause an increase in bleed in the Five Star grout.
- A correlation between the Schupack Pressure Test and the Wick-induced test was developed.

Duct Tests

- Air was trapped in all three corrugation configurations tested in the duct test.
- The grout front was thought to be advancing too slowly to adequately evaluate the extent of grouting.

Inclined test

- The bleed was found to be difficult to measure in the inclined test and did not appear to any harsher than the vertical wick induced tests.

Epoxy Pour-Back

- No cracking was noted on the specimen following thermal cycling.
- Impact-echo results indicated no change in the bond between the epoxy grout and concrete.

- Further study of this material is required before adopted for use as a pour-back.

Schupack Pressure Test

- Recommend that the test procedure require the insertion of a wire to break the surface tension and remove trapped water.
- Recommend that the longer times and/or higher pressures be considered for the test method. The test method used in these tests included two pressures (50/100psi) for a total of 10 minutes.

7 Future Research

- Determine the effect of Schupack Test Run time on bleed results. Longer test run times may be useful in evaluating high performance prepackaged grouts.

8 References

1. PTI Committee on Grouting Specifications, "Specification for Grouting of Post – Tensioned Structures", Post – Tensioning Institute, February 2001.

9 Appendix A – UF laboratory grout tests

SCHUPACK TEST- VARIATION IN MIXING TIMES

EUCLID-CABLE GROUT PTX

Mixing time: **1 minute**
Room temp.:

Date :	07/23/02	**Sample Vol. Vo (ml) :**	200	**Grout cement water ratio :**	28.20%
Hour :	14:30	**Additive(s)** :	none	**Weight of Water (gr)** :	141
Test #: :	MT-5	**Density (kg/m^3)** :		**Weight of Cement (gr)** :	500

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.20	0.10	x		
20.00	100.00	2.30	1.15	x		

Mixing time: **2 minute**
Room temp.:

Date :	07/24/02	**Sample Vol. Vo (ml) :**	200	**Grout cement water ratio :**	28.20%
Hour :	15:58	**Additive(s)** :	none	**Weight of Water (gr)** :	141
Test #: :	MT-6	**Density (kg/m^3)** :		**Weight of Cement (gr)** :	500

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.30	0.15	x		
20.00	100.00	2.40	1.20	x		

Mixing time:	**3 minute**
Room temp.:	

Date : 07/24/02 **Sample Vol. Vo (ml)** : 200 **Grout cement water ratio** : 28.20%
Hour : 16:40 **Additive(s)** : none **Weight of Water (gr)** : 141
Test #: : MT-7 **Density (kg/m^3)** : **Weight of Cement (gr)** : 500

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.00	0.00	x		
20.00	100.00	1.90	0.95	x		

Mixing time:	**5 minutes**
Room temp.:	

Date : 07/24/02 **Sample Vol. Vo (ml)** : 200 **Grout cement water ratio** : 28.20%
Hour : **Additive(s)** : none **Weight of Water (gr)** : 141
Test #: : MT-8 **Density (kg/m^3)** : **Weight of Cement (gr)** : 500

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.30	0.15	x		
20.00	100.00	1.80	0.90	x		

SCHUPACK TEST- VARIATION IN MIXING TIMES

FIVE STAR - SPECIAL GROUT 400

Mixing time:	**1 minute**
Room temp.:	95-F

Date : 07/24/02 **Sample Vol. Vo (ml) :** 200 **Grout cement water ratio :** 26.49%
Hour : 18:47 **Additive(s) :** none **Weight of Water (gr) :** 291
Test #: : MT-1 **Density (kg/m^3) :** **Weight of Cement (gr) :** 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.10	0.05	x		
20.00	100.00	1.00	0.50	x		

Mixing time:	**2 minute**
Room temp.:	95-F

Date : 07/24/02 **Sample Vol. Vo (ml) :** 200 **Grout cement water ratio :** 26.49%
Hour : 18:13 **Additive(s) :** none **Weight of Water (gr) :** 291
Test #: : MT-2 **Density (kg/m^3) :** **Weight of Cement (gr) :** 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.00	0.00	x		
20.00	100.00	0.80	0.40	x		

Mixing time:	3 minute
Room temp.:	95-F

Date : 07/24/02 **Sample Vol. Vo (ml) :** 200 **Grout cement water ratio :** 26.49%
Hour : 20:00 **Additive(s)** : none **Weight of Water (gr)** : 291
Test #: : MT-3 **Density (kg/m^3)** : **Weight of Cement (gr)** : 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.40	0.20	x		
20.00	100.00	1.25	0.63	x		

Mixing time:	5 minute
Room temp.:	95-F

Date : 07/24/02 **Sample Vol. Vo (ml) :** 200 **Grout cement water ratio :** 26.49%
Hour : **Additive(s)** : none **Weight of Water (gr)** : 291
Test #: : MT-4 **Density (kg/m^3)** : **Weight of Cement (gr)** : 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.30	0.15	x		
20.00	100.00	1.50	0.75	x		

SCHUPACK TEST- VARIATION IN MIXING TIMES

SIKA-CABLE GROUT

Mixing time:	**1 minute**
Room temp.:	90 F

Date :	07/23/02	**Sample Vol. Vo (ml) :**	**200**	**Grout cement water ratio :**	**19.47%**
Hour :	14:30	**Additive(s) :**	**none**	**Weight of Water (gr) :**	**194.7**
Test #: :	MT-9	**Density (kg/m^3) :**		**Weight of Cement (gr) :**	**1000**

Time (min.)	**Pressure (psi)**	**Bleed Water (nearest 0.1ml)**	**Bleed Volume (% of Vo.)**	**Test Failed No**	**Test Failed Yes**	**Corresponding vertical rise (ft)**
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	2.60	1.30	x		
20.00	100.00	5.60	2.80	x		

Mixing time:	**2 minute**
Room temp.:	

Date :	07/24/02	**Sample Vol. Vo (ml) :**	**200**	**Grout cement water ratio :**	**19.47%**
Hour :	15:58	**Additive(s) :**	**none**	**Weight of Water (gr) :**	**194.7**
Test #: :	MT-10	**Density (kg/m^3) :**		**Weight of Cement (gr) :**	**1000**

Time (min.)	**Pressure (psi)**	**Bleed Water (nearest 0.1ml)**	**Bleed Volume (% of Vo.)**	**Test Failed No**	**Test Failed Yes**	**Corresponding vertical Rise (ft)**
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	1.80	0.90	x		
20.00	100.00	4.20	2.10	x		

Mixing time:	**3 minute**
Room temp.:	

Date :	07/24/02	**Sample Vol. Vo (ml) :**	**200**	**Grout cement water ratio :**	**19.47%**
Hour :	16:40	**Additive(s) :**	**none**	**Weight of Water (gr) :**	**194.7**
Test #: :	MT-11	**Density (kg/m^3) :**		**Weight of Cement (gr) :**	**1000**

Time (min.)	**Pressure (psi)**	**Bleed Water (nearest 0.1ml)**	**Bleed Volume (% of Vo.)**	**Test Failed No**	**Test Failed Yes**	**Corresponding vertical Rise (ft)**
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	1.50	0.75	x		
20.00	100.00	3.80	1.90	x		

Mixing time:	**5 minute**
Room temp.:	

Date :	07/24/02	**Sample Vol. Vo (ml) :**	**200**	**Grout cement water ratio :**	**19.47%**
Hour :		**Additive(s) :**	**none**	**Weight of Water (gr) :**	**194.7**
Test #: :	MT-12	**Density (kg/m^3) :**		**Weight of Cement (gr) :**	**1000**

Time (min.)	**Pressure (psi)**	**Bleed Water (nearest 0.1ml)**	**Bleed Volume (% of Vo.)**	**Test Failed No**	**Test Failed Yes**	**Corresponding vertical Rise (ft)**
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	1.40	0.70	x		
20.00	100.00	3.50	1.75	x		

SCHUPACK TEST- VARIATION IN MIXING TIMES

MASTER BUILDERS-MASTERFLOW 1205

Mixing time:		**1 minute**
Room temp.:		90 F

Date :	07/25/02	**Sample Vol. Vo (ml) :** 200		**Grout cement water ratio :**	28.45%
Hour :	9:27	**Additive(s)**	: none	**Weight of Water (gr) :**	313
Test #: :	MT-13	**Density (kg/m^3) :**		**Weight of Cement (gr) :**	1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	4.10	2.05	x		
20.00	100.00	7.00	3.50	x		

Mixing time:		**2 minute**
Room temp.:		F

Date :	07/24/02	**Sample Vol. Vo (ml) :** 200		**Grout cement water ratio :**	28.45%
Hour :	11:40	**Additive(s)**	: none	**Weight of Water (gr) :**	313
Test #: :	MT-14	**Density (kg/m^3) :**		**Weight of Cement (gr) :**	1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	3.80	1.90	x		
20.00	100.00	6.80	3.40	x		

Mixing time:	**3 minute** _
Room temp.:	F

Date : 07/24/02 **Sample Vol. Vo (ml) :** 200 **Grout cement water ratio :** 28.45%
Hour : 12:23 **Additive(s)** : none **Weight of Water (gr)** : 313
Test #: : MT-15 **Density (kg/m^3)** : **Weight of Cement (gr)** : 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	3.50	1.75	x		
20.00	100.00	6.10	3.05	x		

Mixing time:	**5 minute** _
Room temp.:	F

Date : 07/24/02 **Sample Vol. Vo (ml) :** 200 **Grout cement water ratio :** 28.45%
Hour : 14:10 **Additive(s)** : none **Weight of Water (gr)** : 313
Test #: : MT-16 **Density (kg/m^3)** : **Weight of Cement (gr)** : 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	3.50	1.75	x		
20.00	100.00	6.50	3.25	x		

SCHUPACK TEST- VARIATION IN TEMPERATURE

FIVE STAR - SPECIAL GROUT 400

GROUT TEMPERATURE: 60 F

Date :	08/21/02	**Sample Vol. Vo (ml) :**	200	**Grout cement water ratio :**	26.49%
Hour :	9:00	**Additive(s) :**	none	**Weight of Water (gr) :**	291
Test #: :	VT-1	**Density (kg/m^3) :**		**Weight of Cement (gr) :**	1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.00	0.00	x		
20.00	100.00	0.00	0.00	x		

GROUT TEMPERATURE: 80 F

Date :	08/21/02	**Sample Vol. Vo (ml) :**	200	**Grout cement water ratio :**	26.49%
Hour :		**Additive(s) :**	none	**Weight of Water (gr) :**	291
Test #: :	VT-2	**Density (kg/m^3) :**		**Weight of Cement (gr) :**	1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.00	0.00	x		
20.00	100.00	0.70	0.35	x		

GROUT TEMPERATURE: 100 F			_

Date : 08/21/02 Sample Vol. Vo (ml) : 200 Grout cement water ratio : 26.49%
Hour : Additive(s) : none Weight of Water (gr) : 291
Test #: : VT-3 Density (kg/m^3) : Weight of Cement (gr) : 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.40	0.20	x		
20.00	100.00	1.60	0.80	x		

SCHUPACK TEST- VARIATION IN TEMPERATURE

EUCLID-EUCOCABLE

GROUT TEMPERATURE: 60 F			_

Date : 08/19/02 Sample Vol. Vo (ml) : 200 Grout cement water ratio : 26.49%
Hour : 10:06 Additive(s) : none Weight of Water (gr) : 291
Test #: : VT-4 Density (kg/m^3) : Weight of Cement (gr) : 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.00	0.00	x		
20.00	100.00	1.00	0.50	x		

GROUT TEMPERATURE: 80 F

Date : 08/19/02	**Sample Vol. Vo (ml) :** 200	**Grout cement water ratio :** 26.49%
Hour : 10:50	**Additive(s)** : none	**Weight of Water (gr) :** 291
Test #: : VT-5	**Density (kg/m^3) :**	**Weight of Cement (gr) :** 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	0.30	0.15	x		
20.00	100.00	2.10	1.05	x		

GROUT TEMPERATURE: 100 F

Date : 08/19/02	**Sample Vol. Vo (ml) :** 200	**Grout cement water ratio :** 26.49%
Hour : 11:40	**Additive(s)** : none	**Weight of Water (gr) :** 291
Test #: : VT-6	**Density (kg/m^3) :**	**Weight of Cement (gr) :** 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	1.10	0.55	x		
20.00	100.00	2.50	1.25	x		

SCHUPACK TEST- VARIATION IN TEMPERATURE

SIKA-CABLE GROUT

GROUT TEMPERATURE: 60 F

Date :	07/23/02	**Sample Vol. Vo (ml) :** 200	**Grout cement water ratio :** **19.47**%
Hour :	14:30	**Additive(s) :** none	**Weight of Water (gr) :** 194.7
Test #: :	MT-9	**Density (kg/m^3) :**	**Weight of Cement (gr) :** 1000

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	1.50	0.75	x		
20.00	100.00	3.40	1.70	x		

GROUT TEMPERATURE: 80 F

Date :	07/24/02	**Sample Vol. Vo (ml) :** 200	**Grout cement water ratio :** **19.47**%
Hour :	15:58	**Additive(s) :** none	**Weight of Water (gr) :** 194.7
Test #: :	MT-10	**Density (kg/m^3) :**	**Weight of Cement (gr) :** 1000

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	1.60	0.80	x		
20.00	100.00	3.50	1.75	x		

GROUT TEMPERATURE: 100 F	
	-

Date	**:**	07/24/02	**Sample Vol. Vo (ml) :** 200	**Grout cement water ratio :**	**19.47**%
Hour	**:**	16:40	**Additive(s)** : none	**Weight of Water (gr)** :	194.7
Test #:	**:**	MT-11	**Density (kg/m^3)** :	**Weight of Cement (gr)** :	1000

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	1.90	0.95	x		
20.00	100.00	4.10	2.05	x		

SCHUPACK TEST- VARIATION IN TEMPERATURE

MASTER BUILDERS-MASTERFLOW 1205

GROUT TEMPERATURE: 60 F	
	-

Date	**:**	07/25/02	**Sample Vol. Vo (ml) :** 200	**Grout cement water ratio :**	28.45%
Hour	**:**	9:27	**Additive(s)** : none	**Weight of Water (gr)** :	313
Test #:	**:**	MT-13	**Density (kg/m^3)** :	**Weight of Cement (gr)** :	1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	3.80	1.90	x		
20.00	100.00	8.10	4.05	x		

GROUT TEMPERATURE: 80 F

Date : 07/24/02 **Sample Vol. Vo (ml) :** 200 **Grout cement water ratio :** 28.45%
Hour : 11:40 **Additive(s)** : none **Weight of Water (gr)** : 313
Test #: : MT-14 **Density (kg/m^3)** : **Weight of Cement (gr)** : 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	5.00	2.50	x		
20.00	100.00	9.00	4.50	x		

GROUT TEMPERATURE: 100 F

Date : 07/24/02 **Sample Vol. Vo (ml) :** 200 **Grout cement water ratio :** 28.45%
Hour : 12:23 **Additive(s)** : none **Weight of Water (gr)** : 313
Test #: : MT-15 **Density (kg/m^3)** : **Weight of Cement (gr)** : 1100

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		
10.00	50.00	0.00	0.00	x		
15.00	100.00	3.70	1.85	x		
20.00	100.00	7.20	3.60	x		

10 Appendix B – Schupack Tests on grouts used in wick-induced bleed tests

SCHUPACK PRESSURE TEST RESULTS

FIVE STAR - SPECIAL GROUT 400

Date :	Jun-28-02	**Sample Vol. Vo (ml) :**	200	**Grout water-cement ratio :**	26.50%
Hour :	10:09AM	**Modified flow cone :**	11 sec	**Weight of Water (lbs) :**	66.76
Test #: :	1	**Density (kg/m^3) :**	1950	**Weight of Cement (lbs) :**	252

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical rise (ft)
0.00	0.00	0.00	0.00	x		0.00
10.00	50.00	0.00	0.00	x		121.37
15.00	100.00	0.50	0.25	x		242.74
20.00	100.00	1.70	0.85	x		242.74

EUCLID - CABLE GROUT PTX

Date :	Jun-28-02	**Sample Vol. Vo (ml) :**	200	**Grout water-cement ratio :**	25.04%
Hour :	11:19AM	**Modified flow cone :**	11 sec	**Weight of Water (gr) :**	75.11
Test #: :	2	**Density (kg/m^3) :**	1950	**Weight of Cement (gr :**	300

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Test Failed Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		0.00
10.00	50.00	0.00	0.00	x		121.37
15.00	100.00	0.00	0.00	x		242.74
20.00	100.00	1.10	0.55	x		242.74

SIKA - CABLE GROUT

Date	**:** Jun-28-02	**Sample Vol. Vo (ml):**	200	**Grout water-cement ratio :**	20.86%
Hour	**:** 1:02PM	**Modified flow cone :**	6.6 sec	**Weight of Water (gr) :**	62.59
Test #:	**:** 3	**Density (kg/m^3) :**	1950	**Weight of Cement (gr :**	300

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		0.00
10.00	50.00	0.00	0.00	x		121.37
15.00	100.00	0.40	0.20	x		242.74
20.00	100.00	2.30	1.15	x		242.74

MASTER BUILDERS - MASTERFLOW 1205

Date	**:** Jun-28-02	**Sample Vol. Vo (ml):**	200	**Grout water-cement ratio :**	28.45%
Hour	**:** 3:00PM	**Modified flow cone :**	11 sec	**Weight of Water (gr) :**	93.89
Test #:	**:** 4	**Density (kg/m^3) :**	1950	**Weight of Cement (gr :**	330

Time (min.)	Pressure (psi)	Bleed Water (nearest 0.1ml)	Bleed Volume (% of Vo.)	Test Failed No	Yes	Corresponding vertical Rise (ft)
0.00	0.00	0.00	0.00	x		0.00
10.00	50.00	0.00	0.00	x		121.37
15.00	100.00	3.90	1.95	x		242.74
20.00	100.00	7.80	3.90	x		242.74

11 Appendix C – Observations taken during grout injection for wick-induced bleed test

Manufacturer	**N/A**
Grout	**Water/Portland Cement**
Mixing	
Mix design (Batch 1)	3 bags (94 lbs/bag) + 15 gallon water
Mix procedures	Water added, mixer started, bags added one at a time while mixing, 3 minutes after last bag
Batch 1	1:40 pm
Modified flow cone	5 sec
Injection	
Waste ~3 gal from hose	
Inject inclined specimen	1:45 pm

Manufacturer	**Five Star**
Grout	**Special Grout 400**
Representative	Bob Carlson, Marshall
Mixing	
Mix design	6 bag (42 lbs/bag) + 8 gallon
Mix procedures	Water added, mixer started, bags added one at a time while mixing, 3 minutes after last bag
Batch 1- Discarded	9:13 am
Modified flow cone	11 sec
Batch 2	9:42 am
Modified flow cone	10 sec
Batch 3	9:50 am
Modified flow cone	None taken
Batch 4	?
Modified flow cone	None taken
Injection	
Waste ~3 gal from hose	
Flow cone at discharge	10.9 sec
10-ft. single strand	10:03 am
15-ft single strand	10:06 am
Sample taken from hose	10:09 am
20-ft single strand	10:10 am
20-ft triple strand	10:15 am
25-ft triple strand	10:18 am
25-ft single strand	10:25 am

Manufacturer	**Euclid**
Grout	**Euco Cable Grout PTX**
Representative	William “Bud” Earley
Mixing	
Mix design (Batch 1)	6 buckets (50 lbs/bucket) + 9 gallon water
Mix design (Batch 2)	6 buckets (50 lbs/bucket) + 9.25 gallon water
Mix procedures	Water added, mixer started, bags added one at a time while mixing, 3 minutes after last bag
Batch 1	10:49 am
Modified flow cone	11 sec
Batch 2	11:00 am
Modified flow cone	?
Batch 3	11:18 am
Modified flow cone	None taken
Injection	
Waste ~3 gal from hose	
Flow cone at discharge	13 sec (11:10 am)
10-ft. single strand	11:11 am
15-ft single strand	11:16 am
Sample taken from hose	11:19 am
20-ft single strand	11:20 am
20-ft triple strand	11:25 am
25-ft triple strand	11:30 am
25-ft single strand	11:34 am

Manufacturer	**Sika**
Grout	**Sika Cable Grout**
Representative	Tim Gillespie
Mixing	
Mix design (Batch 1)	6 bags (50 lbs/bag) + 7.5 gallon water
Mix design (Batch 2)	6 bags (50 lbs/bucket) + 7.0 gallon water
Mix procedures	Water added, mixer started, bags added one at a time while mixing, 3 minutes after last bag
Batch 1 – Discarded	11:59 am
Modified flow cone	6.6 sec
Batch 2	12:19 pm
Modified flow cone	11 sec

Batch 3 through 5	12:30 pm, 12:50 pm, 1:03 pm
Modified flow cone	None taken
Injection	
Waste ~3 gal from hose	
Flow cone at discharge	9 sec (12:24 pm)
Compressor problems	
Waste ~2 gal from hose	
10-ft. single strand	12:55 pm
Grout recirculated	12:59 pm
15-ft single strand	1:00 pm
Sample taken from hose	1:02 pm
20-ft single strand	1:03 pm
20-ft triple strand	1:06 pm
25-ft single strand	1:10 pm, injection interrupted
Grout recirculated	1:13 pm
25-ft single strand	1:16 pm injection completed
25-ft triple strand	1:18 pm

Manufacturer	**Master Builders**
Grout	**Masterflow GS 1205**
Representative	Bob Gulyas, Walt Hanford
Mixing	
Mix design (Batch 1-12)	6 bags (55 lbs/bag) + 11.25 gallon water
Mix procedures	Water added, mixer started, bags added one at a time while mixing, 3 minutes after last bag
Batch 1	2:12 pm
Modified flow cone	11 sec
Batch 2 through 12	2:20pm through 3:20 pm
Modified flow cone	None taken
Injection	
Waste ~3 gal from hose	
Flow cone at discharge	7 sec (2:25 pm)
Inject horizontal specimens	
Ribbed with channel	Start 2:32pm, stop 2:40pm
Ribbed	Start 2:50pm, stop 2:55pm
Spiral	Start 2:55pm, stop 2:59pm
Flow cone at discharge	10 sec (3:00pm)
Sample taken for pressure test	3:00pm
Inclined specimen injected	3:08pm
10-ft. single strand	3:10 pm
15-ft single strand	3:15 pm

Sample taken from hose	3:16 pm
20-ft single strand	3:17 pm
20-ft triple strand	3:20 pm
25-ft single strand	3:22 pm
25-ft triple strand	3:26 pm

12 Appendix D – Wick-Induced Bleed Test

12.1 Recorded Data

Wick Induced Bleed Test for Vertical Tendons with 1 and 3 - 0.6" dia. Strands

Friday, June 28, 2002

Grout Manufacturer	Initial Time	30 Min Expansion (in)	30 MIN Bleed (in)	30 MIN Bleed (%)	1 Hour Expansion (in)	1 Hour Bleed (in)	1 Hour Bleed (%)	2 Hour Expansion (in)	2 Hour Bleed (in)	2 Hour Bleed (%)
Euclid										
E10-1	11:13	0.05	0.00	0.00%	0.05	0.00	0.00%	0.10	0.00	0.00%
E15-1	11:16	0.02	0.00	0.00%	0.05	0.00	0.00%	0.10	0.00	0.00%
E20-1	11:20	0.02	0.00	0.00%	0.05	0.00	0.00%	0.05	0.00	0.00%
E20-3	11:26	0.05	0.00	0.00%	0.05	0.00	0.00%	0.05	0.00	0.00%
E25-1	11:37	0.05	0.00	0.00%	0.10	0.00	0.00%	0.10	0.00	0.00%
E25-3	11:34	0.10	0.00	0.00%	0.10	0.00	0.00%	0.10	0.00	0.00%
Sika										
S10-1	1:00	0.10	0.00	0.00%	0.20	0.00	0.00%	0.30	0.10	0.08%
S15-1	1:01	0.20	0.00	0.00%	0.30	0.10	0.06%	0.35	0.35	0.19%
S20-1	1:05	0.20	0.00	0.00%	0.25	0.30	0.13%	0.30	0.65	0.27%
S20-3	1:07	0.20	0.00	0.00%	0.10	0.65	0.27%	0.20	1.15	0.48%
S25-1	1:15	0.20	0.25	0.08%	0.30	0.50	0.17%	0.35	1.10	0.37%
S25-3	1:19	0.05	0.15	0.05%	0.00	1.10	0.37%	0.00	2.00	0.67%
Master Builders										
MB10-1	3:11	0.30	0.30	0.25%	0.35	0.55	0.46%	0.40	0.80	0.67%
MB15-1	3:15	0.25	0.50	0.28%	0.30	0.90	0.50%	0.30	1.30	0.72%
MB20-1	3:20	0.20	0.95	0.40%	0.45	1.35	0.56%	0.40	2.00	0.83%
MB20-3	3:22	0.30	0.90	0.38%	0.60	1.30	0.54%	0.50	2.00	0.83%
MB25-1	3:24	0.20	0.90	0.30%	0.30	1.50	0.50%	0.40	2.20	0.73%
MB25-3	3:26	0.50	1.00	0.33%	0.10	2.20	0.73%	0.10	2.90	0.97%
Five Star										
FS10-1	10:05	0.80	0.00	0.00%	1.00	0.10	0.08%	1.25	0.02	0.02%
FS15-1	10:07	1.15	0.05	0.03%	1.45	0.05	0.03%	1.60	0.05	0.03%
FS20-1	10:13	1.55	0.05	0.02%	2.00	0.05	0.02%	2.10	0.10	0.04%
FS20-3	10:17	1.60	0.05	0.02%	1.85	0.05	0.02%	1.85	0.35	0.15%
FS25-1	10:26	2.60	0.05	0.02%	3.00	0.05	0.02%	3.00	0.20	0.07%
FS25-3	10:24	1.70	0.05	0.02%	1.80	0.40	0.13%	1.85	0.65	0.22%
MAX		2.60	1.00		3.00	2.20		3.00	2.90	
MIN		0.02	0.00		0.00	0.00		0.00	0.00	

Wick Induced Bleed Test for Vertical Tendons with 1 and 3 - 0.6" dia. Strands

Grout Manufacturer	3 Hour Expansion (in)	3 Hour Bleed (in)	3 Hour Bleed (%)	Saturday, June 29, 2002 Bleed Reading Time	Bleed Captured (in)	Monday, July 1, 02 Reading (in)	Bleed (in)	Tuesday, July 2, 2002 Additional Bleed in annulus between grout and duct Time	(oz)
Euclid									
E10-1	0.10	0.00	0.00%			0.00	0.00		
E15-1	0.00	0.02	0.01%			0.00	0.00		
E20-1	0.05	0.02	0.01%			0.05	0.00		
E20-3	0.05	0.02	0.01%			0.00	0.00		
E25-1	0.05	0.01	0.00%			0.10	0.00		
E25-3	0.10	0.10	0.03%			0.10	0.00		
Sika									
S10-1	0.30	0.28	0.23%			0.15	0		
S15-1	0.40	0.50	0.28%			0.30	0.20		
S20-1	0.30	1.00	0.42%			0.10	0.00		
S20-3	0.20	1.65	0.69%			0.10	0.40		
S25-1	0.30	1.40	0.47%	3:30 p.m.	1.10	0.20	Drill		
S25-3	0.05	2.50	0.83%	3:30 p.m.	1.50	-0.05	Drill		
Master Build.									
MB10-1	0.40	0.70	0.58%			0.30	0.50	11:00 a.m.	0.0
MB15-1	0.30	1.50	0.83%			0.30	0.90	11:00 a.m.	12.0
MB20-1	0.30	2.10	0.88%			0.40	1.80	11:00 a.m.	21.8
MB20-3	0.25	2.00	0.83%			0.10	1.40	11:00 a.m.	7.0
MB25-1	0.30	2.10	0.70%	3:30 p.m.	1.90	0.40	Drill	11:00 a.m.	20.0
MB25-3	0.10	2.50	0.83%	3:30 p.m.	2.00	0.15	Drill	11:00 a.m.	10.0
Five Star									
FS10-1	1.20	0.10	0.08%			0.15	0.00		
FS15-1	1.60	0.05	0.03%			1.70	0.00		
FS20-1	2.00	0.20	0.08%			1.90	0.00		
FS20-3	1.90	0.50	0.21%			1.80	0.00		
FS25-1	3.00	0.25	0.08%			3.00	0.00		
FS25-3	1.85	0.90	0.30%			1.90	0.00		

MAX	3.00	2.50		0.00	2.00	3.00	1.80
MIN	0.00	0.00		0.00	1.10	-0.05	0.00

12.2 Bleed water (%) vs time (hr)

EUCLID

Time (hours)	0.5	1	2	3
E10-1	0.00%	0.00%	0.00%	0.00%
E15-1	0.00%	0.00%	0.00%	0.01%
E20-1	0.00%	0.00%	0.00%	0.01%
E20-3	0.00%	0.00%	0.00%	0.01%
E25-1	0.00%	0.00%	0.00%	0.00%
E25-3	0.00%	0.00%	0.00%	0.03%

SIKA

Time (h)	0.5	1	2	3
S10-1	0.00%	0.00%	0.08%	0.23%
S15-1	0.00%	0.06%	0.19%	0.28%
S20-1	0.00%	0.13%	0.27%	0.42%
S20-3	0.00%	0.27%	0.48%	0.69%
S25-1	0.08%	0.17%	0.37%	0.47%
S25-3	0.05%	0.37%	0.67%	0.83%

MASTER BUILDERS

Time (hours)	0.5	1	2	3
MB10-1	0.25%	0.46%	0.67%	0.58%
MB15-1	0.28%	0.50%	0.72%	0.83%
MB20-1	0.40%	0.56%	0.83%	0.88%
MB20-3	0.38%	0.54%	0.83%	0.83%
MB25-1	0.30%	0.50%	0.73%	0.70%
MB25-3	0.33%	0.73%	0.97%	0.83%

FIVE STARS

Time (h)	0.5	1	2	3
FS10-1	0.00%	0.08%	0.02%	0.08%
FS15-1	0.03%	0.03%	0.03%	0.03%
FS20-1	0.02%	0.02%	0.04%	0.08%
FS20-3	0.02%	0.02%	0.15%	0.21%
FS25-1	0.02%	0.02%	0.07%	0.08%
FS25-3	0.02%	0.13%	0.22%	0.30%

12.3 Bleed water (%) vs height (ft)

h=10 ft, 1 strand

grout	bleed (%)
Euclid	0.00%
Sika	0.23%
Master Builders	0.58%
Five Star	0.08%

h=20 ft, 1 strand

grout	bleed (%)
Euclid	0.01%
Sika	0.42%
Master Bu	0.88%
Five Star	0.21%

h=25 ft, 1 strand

grout	bleed (%)
Euclid	0.00%
Sika	0.47%
Master Builde	0.70%
Five Star	0.08%

h=15 ft, 1 strand

grout	bleed (%)
Euclid	0.01%
Sika	0.28%
Master Builders	0.83%
Five Star	0.03%

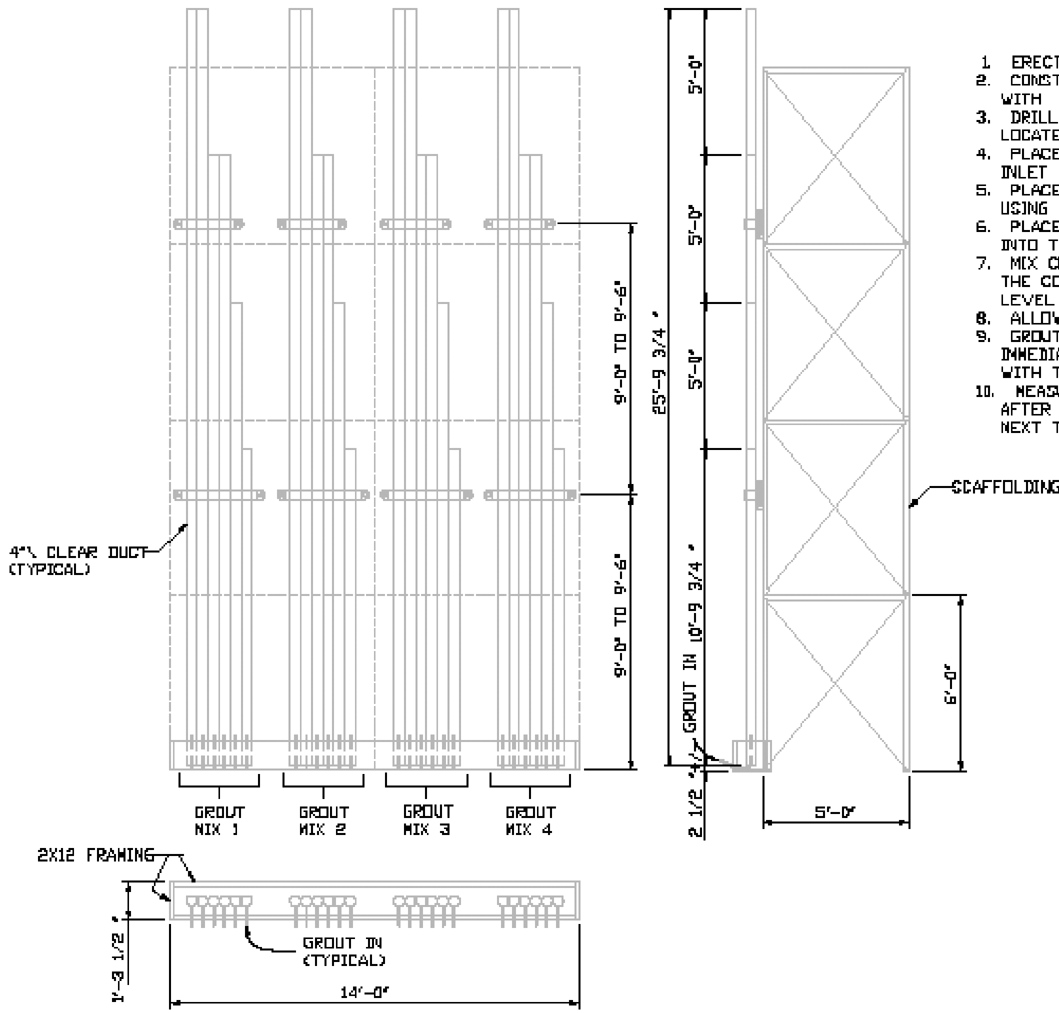
h=20 ft, 3 strands

grout	bleed (%)
Euclid	0.01%
Sika	0.69%
Master Bu	0.83%
Five Star	0.21%

h=25 ft, 3 strands

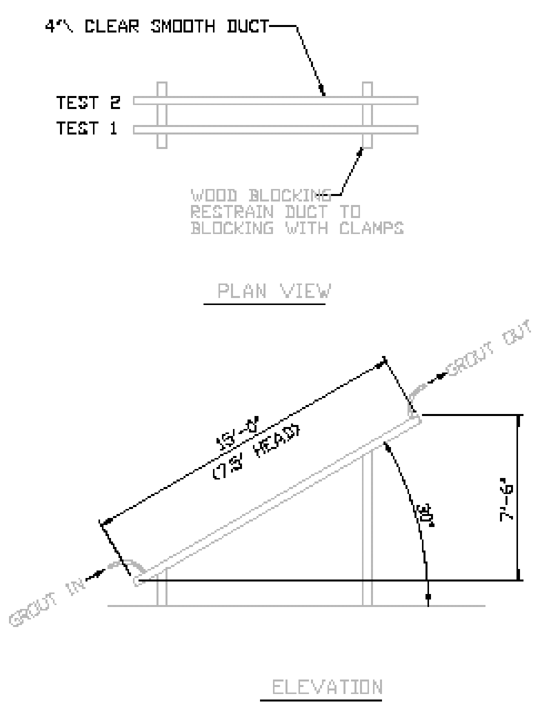
grout	bleed (%)
Euclid	0.03%
Sika	0.83%
Master Builde	0.83%
Five Star	0.30%

12.4 Test Set-up Details

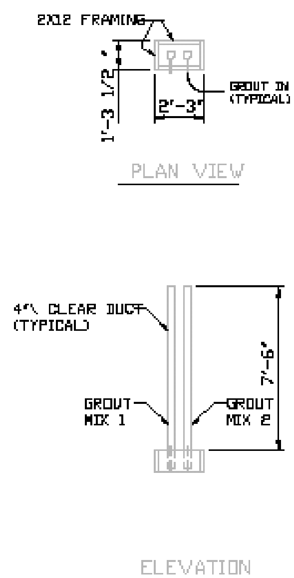


1. ERECT SCAFFOLDING
2. CONSTRUCT 1'-3 1/2 " X 14'-0" 2X12 BOX WITH 1/4 " OR 1/2 " PLYWOOD ATTACHED TO BOTTOM
3. DRILL 24- 3/4 " DIA HOLES FOR GROUT INLETS. LOCATED AT THE BOTTOM OF THE 2X FRAMING.
4. PLACE GROUT INLET THROUGH HOLE. THE GROUT INLET SHOULD EXTEND 6" ABOVE THE FRAMING
5. PLACE 4"\ CLEAR DUCT AND ATTACH TO SCAFFOLDING USING BAND CLAMPS AND SCREWS. DUCT MAY REST ON SMALL BLOCKS.
6. PLACE REQUIRED AMOUNT OF PRESTRESSING WIRE INTO THE CENTER OF THE DUCT.
7. MIX CONCRETE AND POUR INTO FORMWORK ENSURING THAT THE CONCRETE DOES NOT POUR INTO THE GROUT INLET. LEVEL THE CONCRETE WITH THE TOP OF THE FORMWORK.
8. ALLOW THE CONCRETE TO CURE BEFORE GROUTING.
9. GROUT DUCT TO THE FULL HEIGHT OF THE DUCT. IMMEDIATELY AFTER GROUTING, CORK THE TOP OF THE DUCT WITH THE PT STRAND CENTERED IN THE CORK
10. MEASURE BLEED WATER EVERY 15 MINUTES FOR THE FIRST HOUR AFTER THE FIRST HOUR, MEASURE BLEED EVERY HOUR FOR THE NEXT TWO HOURS.

Wick Induced Bleed Test



INCLINED GROUT DUCT TEST



Wick Induced Bleed Test

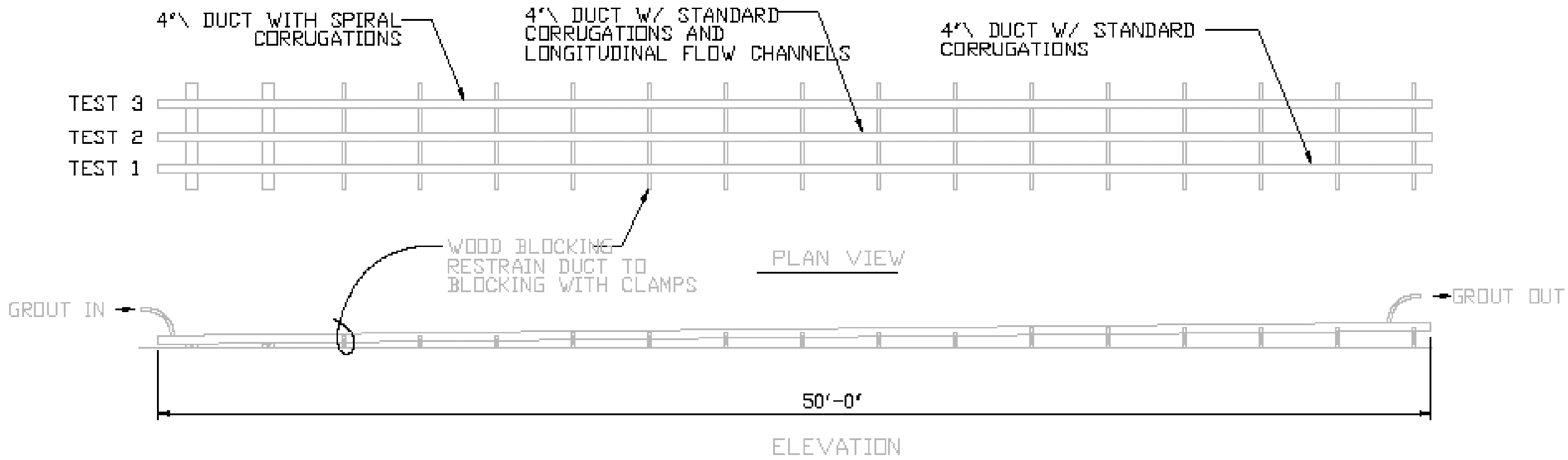
SET UP AND PERFORM THE FOLLOWING TWO TESTS TO DEVELOP A CORRELATION BETWEEN THE INCLINED AND THE WICK INDUCED BLEED TEST.

PROCEDURE: INCLINED GROUT DUCT TEST

1. PLACE WOOD BLOCKING OR OTHER UNDER DUCT.
2. PLACE 2 CLEAR DUCTS (BOTH 15'-0" IN LENGTH) ON BLOCKING AND ATTACH WITH CLAMPS. PLACE ONE 12X0.5 TENDON IN EACH DUCT AND CENTER IN DUCT.
3. ATTACH GROUT INLET ON THE LOW SIDE AND GROUT OUTLET ON THE HIGH SIDE.
4. PLACE CAPS AT THE END OF THE 4"\ DUCTS. ENSURE THAT CAPS ARE SEALED TIGHTLY TO DUCTS.
5. PERFORM GROUTING OPERATION. GROUT ONE DUCT WITH STANDARD GROUT (CEMENT & WATER @ WC RATIO OF 0.45) AND THE OTHER WITH MB MORTAR-FIRM GS120S)

WICK INDUCED BLEED TEST (12X6 TENDON)

1. CONSTRUCT 1'-3 1/2 " X 2'-3" 2X12 BOX WITH 1/4 " OR 1/2 " PLYWOOD ATTACHED TO BOTTOM
2. DRILL 2- 3/4 " DIA HOLES FOR GROUT INLETS LOCATED AT THE BOTTOM OF THE 2X FRAMING.
3. PLACE GROUT INLET THROUGH HOLE. THE GROUT INLET SHOULD EXTEND 6" ABOVE THE FRAMING.
4. PLACE 4"\ CLEAR DUCT AND ATTACH TO SCAFFOLDING (AS IN PREVIOUS TEST) USING BAND CLAMPS AND SCREWS. DUCT MAY REST ON SMALL BLOCKS.
5. PLACE 1-12X0.5 TENDON IN EACH DUCT (LOCATED IN THE CENTER OF THE DUCT).
6. MIX CONCRETE AND POUR INTO FORMWORK ENSURING THAT THE CONCRETE DOES NOT POUR INTO THE GROUT INLET. LEVEL THE CONCRETE WITH THE TOP OF THE FORMWORK.
7. ALLOW THE CONCRETE TO CURE BEFORE GROUTING.
8. GROUT DUCT TO THE FULL HEIGHT OF THE DUCT. GROUT ONE DUCT WITH STD. MIX AND THE OTHER WITH MB GROUT. IMMEDIATELY AFTER GROUTING, CORK THE TOP OF THE DUCT WITH THE PT STRAND CENTERED IN THE CORK
9. AFTER GROUTING, RECORD BLEED AS DEFINED IN THE SPECIFICATION SECTION 938.



1. PLACE WOOD BLOCKING AT 3'-0" O.C.
2. PLACE 50'-0" LONG DUCTS ON BLOCKING AND ATTACH WITH CLAMPS.
3. ATTACH GROUT INLET ON THE LOW SIDE AND GROUT OUTLET ON THE HIGH SIDE.
4. PLACE CAPS AT THE END OF THE 4"\ DUCTS. ENSURE THAT CAPS ARE SEALED TIGHTLY TO DUCTS.
5. PERFORM GROUTING OPERATION AS PER SPECIFICATIONS.
6. ALLOW 24 HOURS TO CURE.
7. ONCE CURED, CUT GROUTED DUCTS AT 1'-0" O.C. ALONG THE CORRUGATIONS AND INSPECT FOR VOIDS.

HORIZONTAL CORRUGATED DUCT TEST

13 Appendix E – Epoxy Pour-Back Temperature Data