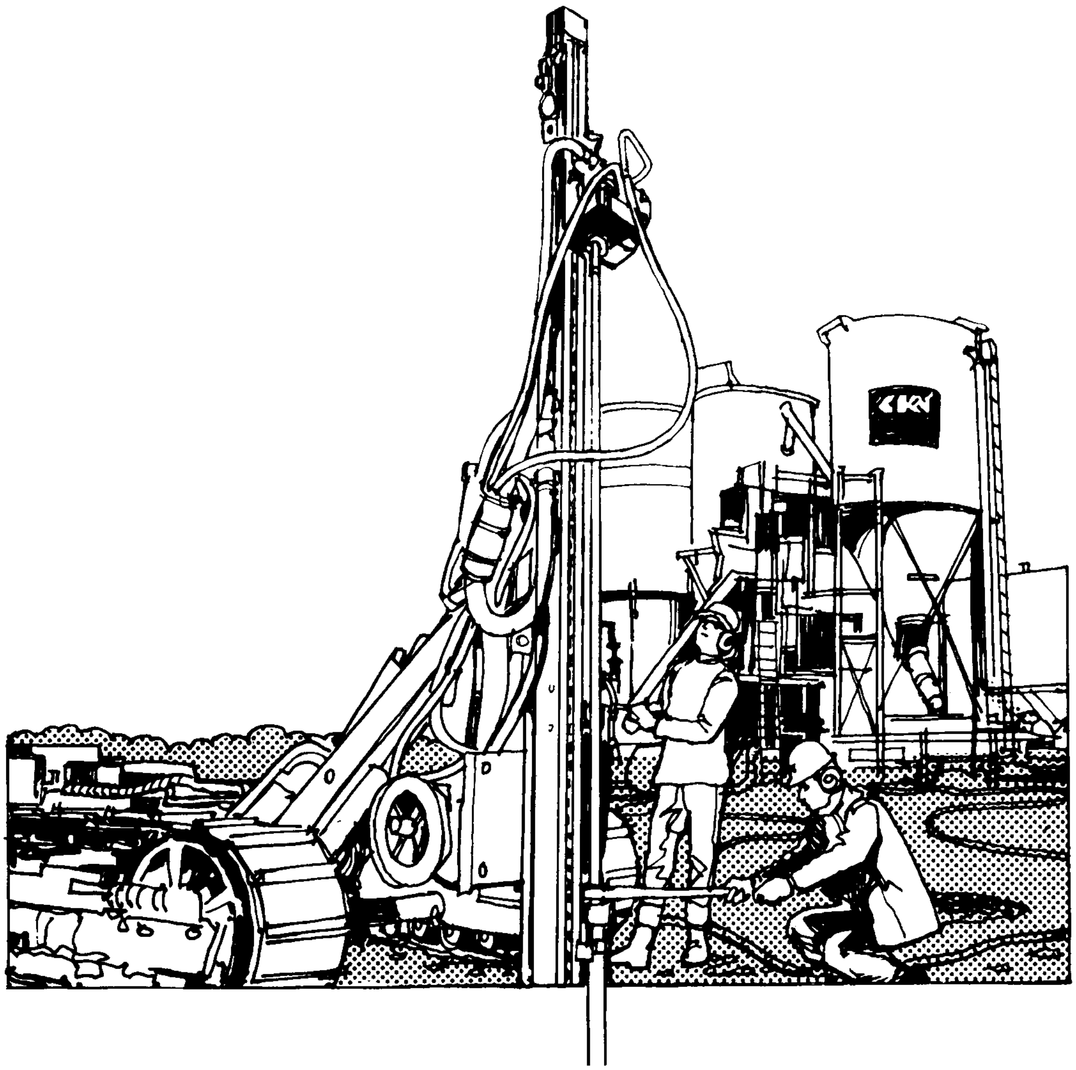
CRREL
REPORT 79-5

Grouting silt and sand at low temperatures
A laboratory investigation



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Grouting silt and sand at low temperatures

A laboratory investigation

Robert Johnson

March 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents data from an experimental program undertaken to develop information on proposed and existing chemical grout solutions to provide engineering properties in connection with grouting of soils in ambient temperatures of 39° ±1° F (3.88°C) and below. Twelve grout solutions were investigated, including organic chemicals, sodium silicates, cements, and clay (bentonite). Set or gel tests were performed on each chemical solution, in the center of which a thermocouple was placed for measuring the rates of heat of reaction, except those of the cements and the clay. These solutions consisted of the mixing portions of the chemicals and were placed into 4-in.-diam by approximately 6-in.-long cylinders at an ambient temperature of 39°F. The components of each chemical were also

PREFACE

This study was conducted and this report was prepared by Robert Johnson, formerly Research Civil Engineer, Geotechnical Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

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The technical reviewers of this report were Dr. R. Torence Martin, Massachusetts Institute of Technology, and Dr. Omar T. Farouki, Queen's University of Belfast, Northern Ireland.

The author wishes to thank Frederick Crory of CRREL for his professional advice and review of the manuscript.

TABLES

CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

These conversion factors include all the significant digits given in the conversion tables in the ASTM *Metric Practice Guide* (E 380), which has been approved for use by the Department of Defense. Converted values should be rounded to have the same precision as the original (see E 380).

Multiply	*By*	*To obtain*
gallon (U.S. liquid)	0.003785412	$meter^3$
centipoise	0.001*	pascal second
stokes	0.0001*	$meter^2$/second
pound/inch^2	6894.757	pascal
pound-force/foot^2	47.88026	pascal
gram-force/centimeter^2	98.06650*	pascal
dyne/centimeter^2	0.1*	pascal
ton (short, 2000 lb)	907.1847	kilogram
degrees Fahrenheit	$t_K = (t_{°F} + 459.67)/1.8$	kelvins
degrees Fahrenheit	$t_{°C} = (t_{°F} - 32)/1.8$	degrees Celsius

*Exact.

GROUTING SILT AND SAND AT LOW TEMPERATURES
A Laboratory Investigation

Robert Johnson

INTRODUCTION

In the northern states, including Alaska, a sizeable amount of construction engineering must be carried out under low temperature conditions because of the short summer season. Under these climatic conditions, unless grout materials produce required heat for grout setting properties, viscosity and setting problems of fluid and grout slurry materials will result. The need to exclude the application of heat, which is important in conserving energy, leads to the requirement for grouts to which heat will not have to be added before or during their use. The grout materials covered in this paper were tested for use in the stabilization of naturally or artificially thawed soils at low temperatures.

Previous to this paper, a literature search was conducted (Johnson 1977) to develop information on methods and grout materials for low temperature use. The literature search produced information on a variety of soil grout materials that could be used in warm climates, but it did not produce information on the effects of low temperatures on the properties of these grout materials.

The data reported here contain the results of tests conducted on grout materials at low temperatures and are preliminary to further laboratory testing as well as field testing in soils above the permafrost table.

MATERIALS TESTED

Grout materials

The grout materials and chemical solutions tested are listed in Table I. The soils used were sand and silt, as described in the following sections.

The base grout or chemical solution of successfully pressure-injected and set or gelled soil samples investigated, and the unconfined compressive strengths are listed in Table II.

The manufacturers of the materials used in this investigation, with addresses and points of contact, are listed in Appendix A.

Sand

Farrel sand. The sand used for these tests measured 5.6×10^{-3} cm/sec hydraulic conductivity (permeability) at 39°F (3.9°C). Its gradation curve is shown in Figure 1.

Silt

Jenks silt. The silt used for these tests is a sandy silt that measured 5.15×10^{-4} cm/sec permeability at 39°F. Its gradation curve is also shown in Figure 1.

DESCRIPTION OF EQUIPMENT

Coldroom

The equipment and materials were maintained and used in coldrooms in which the ambient temperatures were 39° ± 1°F, 33° ± 0.9°F, and 20° ± 1°F, unless otherwise stated.

Water-bath

A water-bath was maintained in the 39°F coldroom for soaking injected samples (Fig. 2). Samples were immersed in water for 7 days, unless otherwise stated, to determine whether the initial set product would dissolve or otherwise be affected by complete immersion of the samples.

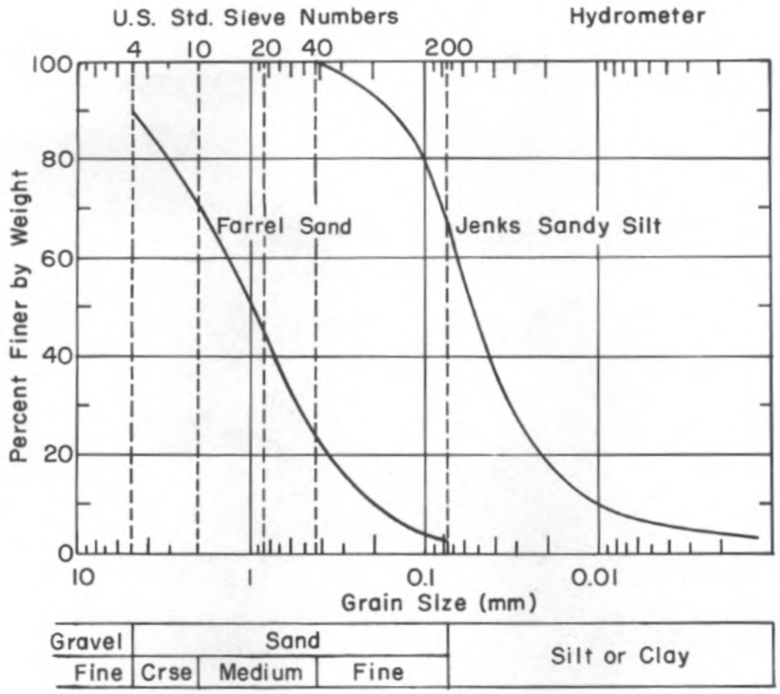
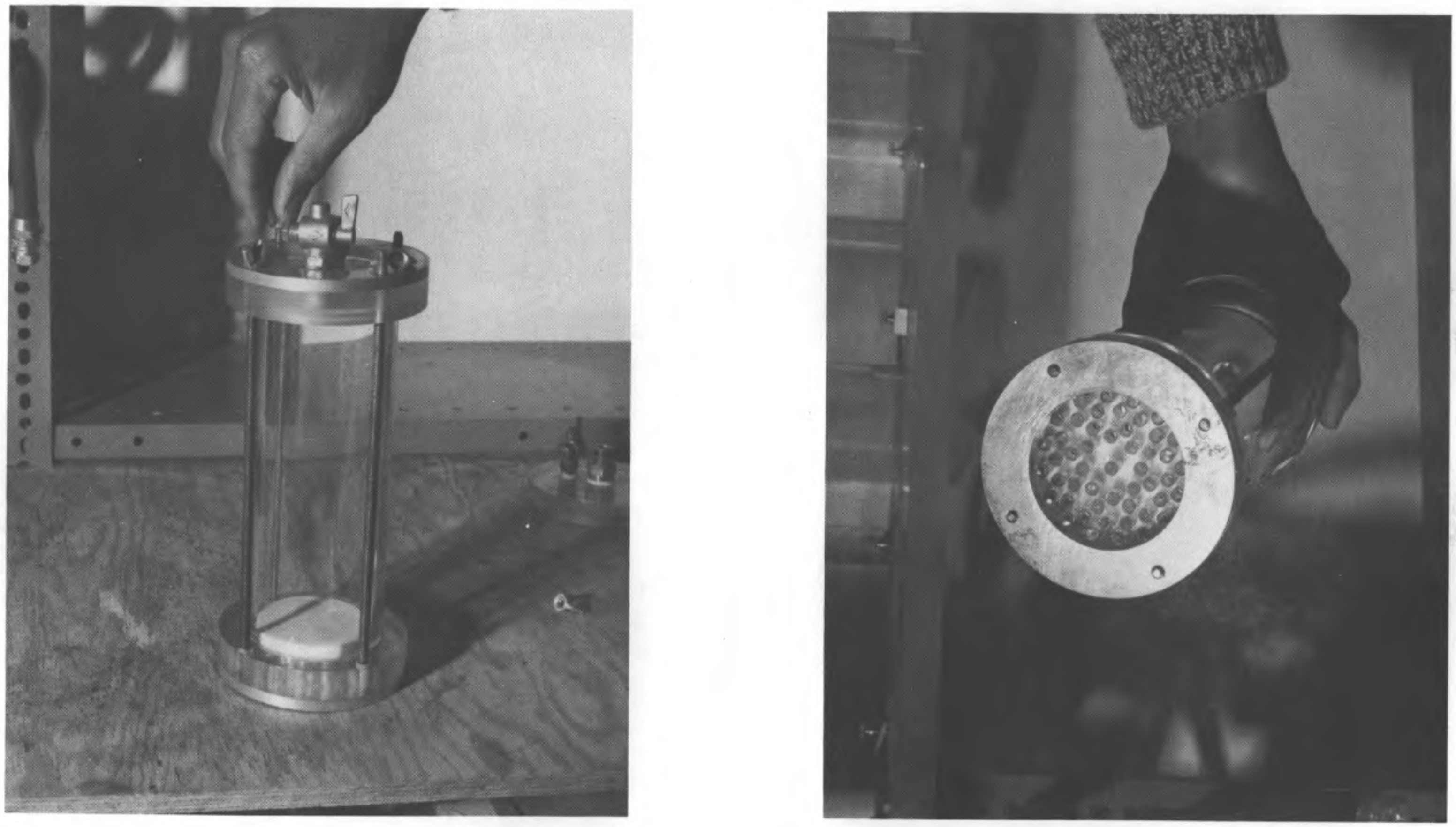


Figure 1. Gradation curves of soils used.

Figure 2. Water-bath maintained in coldroom.



c. *Rings and clamps (wing nuts).*

d. *Bottom view of test cylinder with solution exit holes.*

Figure 3. Assemblage of test mold.

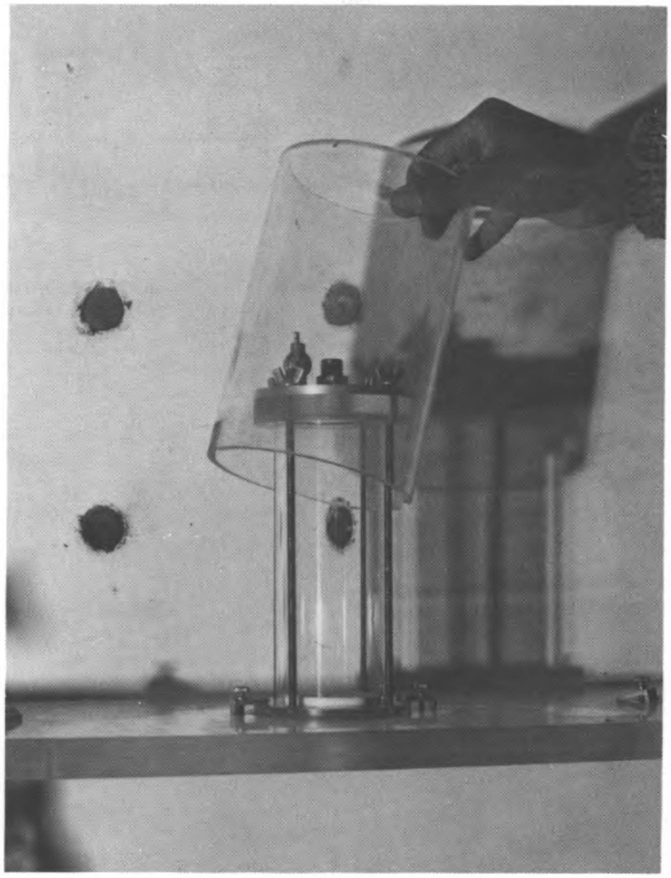


Figure 5. Placement of scatter shield.

Figure 6. Setup of injection apparatus, excluding soil.

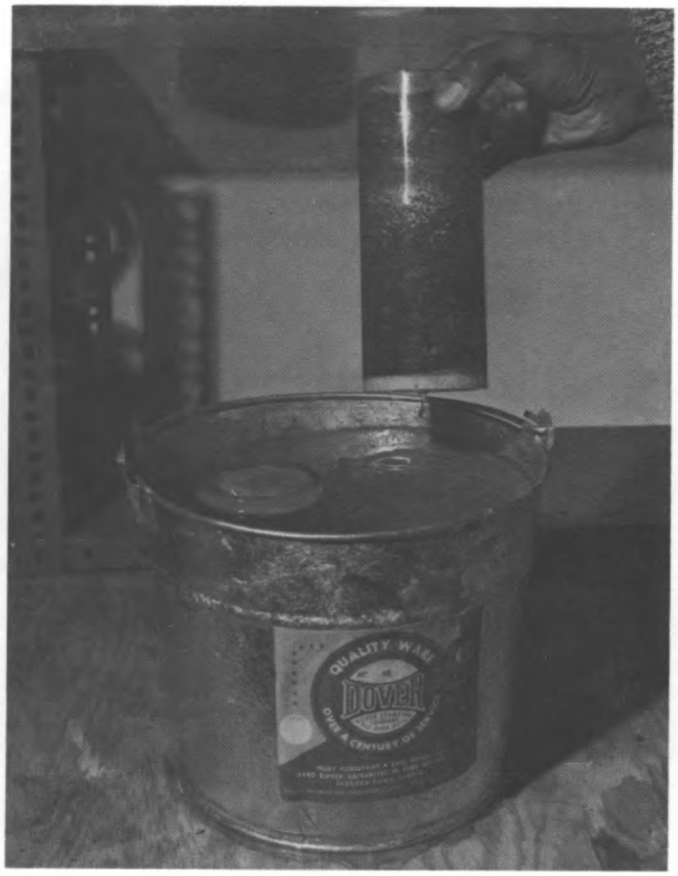


Figure 8. Sample being placed into pail of water before being injected.

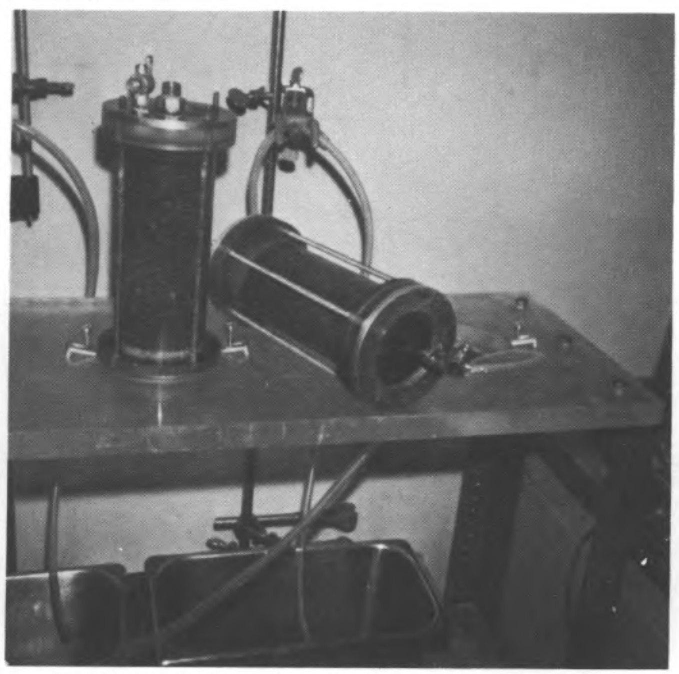


Figure 9. Sample cylinder including soil.

Figure 12. Cylinder molds with thermocouples centered in mixed chemical or grout solutions.

Many of the samples were injected with 20-psi injection pressure. However, at times the injection pressures were higher or lower, as is indicated in the sections on the respective chemical or grout solution.

The samples were unmolded by using the apparatus described in Figure 10 and photographed in Figure 11.

All samples remained in the ambient temperature of 39°F (3.9°C) or 33°F (0.5°C) throughout the period of sample preparation and testing to the end of the 7-day period, at which time they were trimmed for the unconfined compression test.

A table model blender was used for mixing samples.

METHODS OF TEST

Penetration test

Penetration tests (ASTM - C403) were performed on set test samples to measure hardness of setting samples. However, samples were measured for hardness only when the set or gel was not produced immediately.

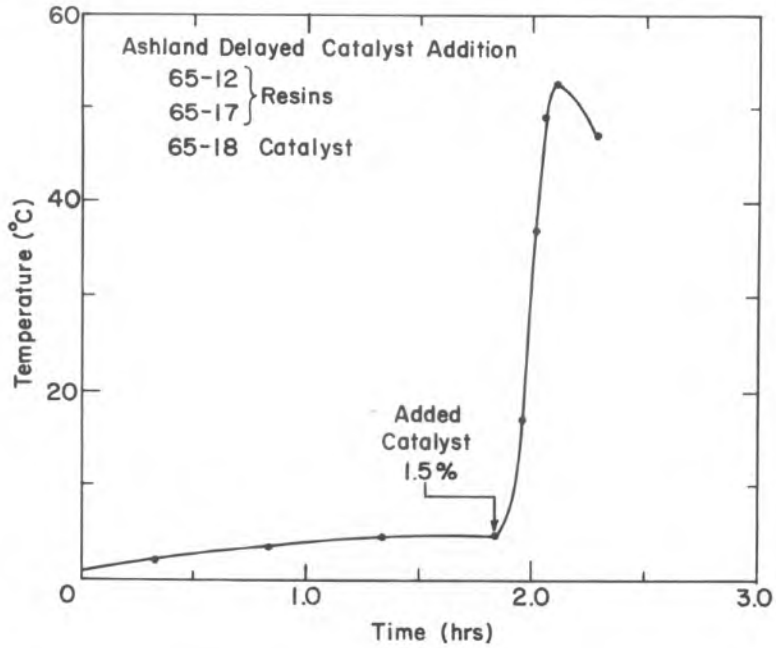
Set test

Set tests were performed to determine if the grout material would set or gel at 39°F (3.9°C). Further set tests were conducted at lower temperatures on the materials that showed potential after being pressure injected at 39°.

The set tests were performed in 4-in.-diam by approximately 6-in.-long cylindrical molds with thermocouples centered in the mixed chemical or grout solutions (Fig. 12). The thermocouples were wired to a data retrieval system which records or logs temperatures at controlled set intervals of 1 minute to 24 hours. In the tests conducted, the usual procedure was to initiate the test with the setting at 1-minute intervals, changing these gradually to 30-minute intervals as the liberation reaction heat began to fall slowly. For the chemical reactions that were not initiated until some preset time, data log setting time intervals were begun at every 1 minute and after a brief period were then reduced to every 5 minutes, until near reaction gel time, when 1-minute intervals were again selected.

Unconfined compressive test

Unconfined compressive strength tests were run on each sample after being immersed in 39°F or 33°F water for a period of 7 days. The samples were trimmed, using a concrete saw, to a 6-in.-long cylinder with 2.75- or 2.85-in. diameter, depending on the size of the cylinder mold. All samples were strained at 0.1 cm/min.



c.

Figure 13 (cont'd.). Set test temperature vs time.

TESTS OF CHEMICALS OR GROUT SOLUTIONS

Urethane resins

EP resin system (urethane)

This system includes urethane resins EP 65-92, EP 65-93, EP 65-12, EP 65-17, and catalysts EP 65-94 (fast), EP 65-18 (slow), and A-11.

According to the manufacturer, the EP resin system is a low viscosity urethane system suitable for soil consolidation in arctic environments, but may be obtained in more concentrated forms of higher viscosities. At the manufacturer-suggested percentage of 1% catalyst based on the mixed resin system, set tests were conducted at 39°F (3.9°C) ambient temperature using the formula below (see Fig. 13b).

This resin system (Ashland Chemical formula) by weight was as follows:

65-92	65-93	Catalyst
50 parts	50 parts	added %

Test results at 39°F (3.9°C) ambient temperature:

Set test temperature graphs (Fig. 13b) show that with the slow catalyst the sample produced a maximum temperature of 128.8°F (53.8°C) in 20 minutes, and that with the fast catalyst the sample gained a maximum temperature of 126.1°F (52.3°C) in 18 minutes.

It was desired to obtain a longer time to initial set than 20 minutes, and because of the short periods of initial set or gel, further set tests were conducted using a simple cup test method and the slow catalyst; this consisted of set testing by adding various percentages of slow catalyst to 50-ml (cup) of the resin mix, and recording the set time. The time measurements began when the catalyst was added to the base solution and ended when the solution color began to change, indicating beginning of set, which occurred within seconds.

the 65-18 "slow" catalyst, was further set tested. Results are presented in Figures 13a and 13c.

Injection of frozen sample with urethane

The resin system used for the frozen injected soil sample was EP 65-12 and EP 65-17 (50-50 by volume), including the 65-18 "slow" catalyst at ½%.

An oven-dried sand sample I-66 was molded at 110 lb/ft³ dry density, as were all other sand samples. The sample weighted 1255.7 g, was saturated to zero, and 198 g of water was added to saturate it. The sample was allowed to drain for 30 minutes, at the end of which time it weighed 104 g, consisting of water. It was then put into a −18.4°F (−28°C) ambient temperature, along with the resin system solutions (components), for five hours. The coldroom ambient temperature was then turned to −10°F (−23.3°C), which remained overnight. The following morning the coldroom ambient temperature was raised to 20°F (−6.7°C), and when the resin system solutions rose to 20°F (as measured by thermocouple), the solutions were mixed and pressure injection of the sample was successfully accomplished. The injected sample remained at the 20°F ambient temperature until the next morning after the injection.

The next day, after the sample had been placed in the 39°F water-bath for four hours, it was surface-dried, tempered to room temperature, and an unconfined compression strength test was conducted [see sample in photos, Fig. B31, B32, B33 (App. B)]. The stress-strain curve and the results of the strength tests are given in Figures 15d and 16, respectively. As shown in Figure 16, this resin (EP 65-12 and 17 with EP 65-18 catalyst), injected at 20°F, measured 305.5 psi (22 tons/ft²).

XB-2403 Mud Lock (hydrophilic urethane)

According to the 3 M Company, XB-2403 is a liquid, water reactive polymer solution designed to react with saturated soil. In general, the application rate should be in proportion equal to the weight percentage of water in the soil. It is a brown liquid with 65 ± 2.0% solids by weight, at 8.7 ± 0.2 lb/gal. Acetone is a solvent of this material, and the material flash point is given as 0°F [Tag Closed Tester (Cup) — ASTM D56]. The XB-2403 solution is mixed with water, 50-50 by volume, before use. It was found in this investigation that attempting to pressure inject a soil sample using this formula was unsuccessful.

Test results at 39°F (3.9°C) ambient temperature. Mud Lock was tested for set at the 39°F ambient temperature using the 50-50 by volume (water-Mud Lock solution) formula. The product expanded and bulged, quickly set upon mixing, and was resilient to finger compressive pressure. However, upon cooling, the sample exhibited a shrinkage to less than the initial mixed volume. (See Fig. 13b, temperature-time curve D-1.)

Test results at 33°F (0.5°C) ambient temperature. Because of the complication of quick setting when using the Mud Lock 3M formula, previous attempts to pressure inject soil samples had failed. Therefore, it was decided to attempt an injection at the 33°F ambient temperature without mixing the Mud Lock with water.

This urethane resin solution reacts immediately upon mixing with water. Therefore, the only way a sample could be injected was by using the 100-part solution of XB-2403 Mud Lock. This solution injected into sand sample 69 successfully. However, the injection process forced the majority of the pore water ahead of the injection solution, leaving the soil grains moist for the water reactant hydrophilic urethane solution. The resin solution was injected under 20-psi pressure and moved through the sample with ease.

When sample 69 was unmolded, it appeared to be porous, which was evident by the emergence of small bubbles when it was immersed in the 33°F water-bath. At the end of the soaking period, the 7-day unconfined compression strength test measured 115 psi (8.28 tons/ft²); the stress-strain graph is shown in Figure 15b.

Epoxy resin

Epotuf resin system

The epoxy resin solutions are Epotuf 37-130 (a modified diglycidyl ether of bisphenol A — epoxy resin family) and Epotuf 37-052 (previously 37-149, a butyl glycidyl ether — aliphatic monepoxide family). The properties are:

	37-130	37-052
Specific gravity	1.12-1.15	0.89-0.92
Density, lb/gal.	9.3-9.6	7.4-7.7
Epoxide equivalent	175-195	130-150

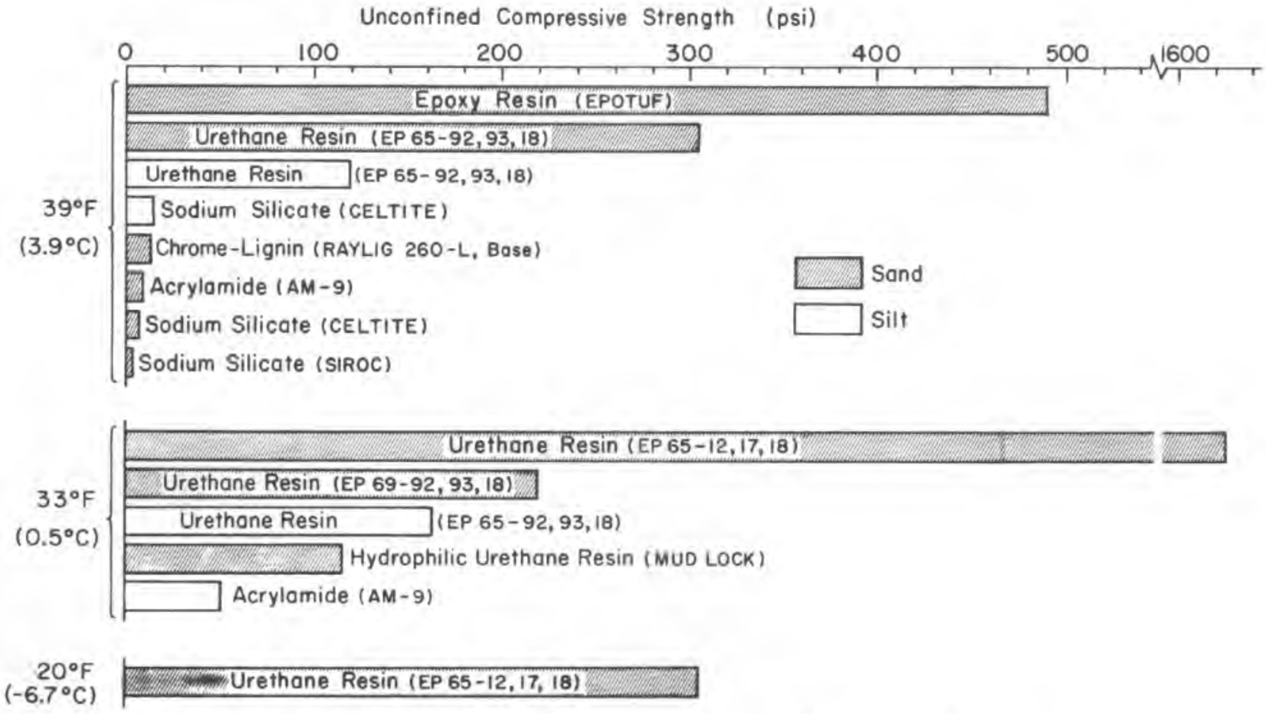


Figure 16. Unconfined compressive strength bar graph of injected samples.

Hardeners/reactants (used with above epoxy resins)

Ancamine AD is a curing agent for liquid and semi-solid epoxy resins, a blend of amines and hardening accelerators, and is capable of curing under cold damp conditions (Pacific Anchor data sheet CA/35).

Ancamine LT is an amine-based curing agent designed to operate down to -5°C, effective under water as well as in air (Pacific Anchor data sheet CA/24).

Ancamine MCA is a modified amine of high reactivity and cures are possible at low temperatures (down to 5°C) and under water (Pacific Anchor data sheet CA/37).

Epotuf was formulated as recommended by Pacific Anchor Chemical Corporation:

Component	Parts by weight
37-130	20
37-052	80
MCA	30
AD	30

However, the 37-052 component was a very low viscosity solution (approximately that of water) and was added to the 37-130 component (20% by weight) to lower the overall viscosity of the mix, as recommended by Reichhold Chemicals, Inc.

Test results at 39°F (3.9°C) ambient

During set tests, the Epotuf components mixed well at this ambient temperature and the heat of reaction rose immediately. Within five minutes, the sample temperature was 43.3°F (6.3°C), and within one hour the temperature was 75.2°F (24°C). Immediately following this, the sample began to liberate heat at a high rate and produced a temperature of 341.6°F (172°C) within the next 26 minutes. The temperature versus time graph is presented in Figure 13b, curve A-1.

Injecting Epotuf into sand sample 37, with 20-psi injection pressure, was without problem. The injected sample [see sample in Fig. B14 (App. B)] was not hard when unmolded the next morning. However, within 15 minutes of exposure to air, at the 39°F ambient temperature, the sample became hard.

At the end of the 7-day period, the sand sample had an unconfined compressive strength of 488.88 psi (35.2 tons/ft^2).

An attempt to inject a silt sample failed when the resin solution would not penetrate the soil.

Test results at 33°F (0.5°C) ambient temperature.

Set tests were conducted at 33°F (0.5°C). This temperature did affect the mixing property of

Test results at 39°F (3.9°C) ambient temperature

The AM-9 set test indicated that this grout solution rose to 28.1°C once the preset gelling period occurred. This grout solution was successfully injected into sand sample 7 (see Fig. B2, App. B). The 7-day unconfined compression strength test measured 8 psi (0.61 tons/ft²).

Test results at 33°F (0.5°C) ambient temperature

Because of the low viscosity (near water) of AM-9, a silt soil sample was successfully injected.

The unconfined compressive strength test of the silt injected sample 70 produced 51.11 psi (3.68 tons/ft²) with a significant amount of deformation of the distortion and volumetric type as described by Lambe and Whitman (1969). [See sample 70 in Fig. B28, B29, B30 (App. B)].

Sodium silicates

Sodium silicate (Hayward Baker Formula)

The Hayward Baker's grout material is a sodium silicate with GELOC-3 reactant (ethyl acetate-amide).

As recommended by the manufacturer, this sodium silicate was formulated by volume as follows:

60%	Sodium silicate
8%	GELOC-3 (reactant)
32%	Water

Test results at 39°F (3.9°C) ambient temperature

Set tests were performed that showed a temperature gain of 44.06°F (6.7°C) in 103 minutes; this temperature remained for 50 minutes before beginning to cool to the 39°F ambient temperature within 15 hours. The set sample measured 300 psi penetration resistance after this 15-hour period.

Pressure injecting this sodium silicate grout presented problems. It displayed quick initial setting or gelling when attempts were made to inject the soil samples.

Further tests were conducted at the 39°F ambient temperature to determine if a lower-percentage catalyst would lengthen the time to initial set of the grout solution and provide a formula which could be used for pressure injection of soil samples. Therefore, 5, 6, and 7% catalyst formulations were made. The 7% catalyst produced a gel instantly; the 6% catalyst produced visual signs of gelling in approximately 15 minutes; and the 5% catalyst produced visual signs of gelling in approximately 1-1½ hours, contrary to previous test results using the 8% catalyst. The present samples remained at the 39°F ambient temperature for 3 days. Perhaps the component has a short shelf life that affects the control of setting. Penetration resistance measurements were then made. The results are as follows:

Catalyst (%)	Penetration resistance stress (psi)
5	280
6	450
7	470

Using a 5% catalyst, three samples were pressure injected. The 5% catalyst was chosen because time was needed to mix and inject the samples. The first sample (22) held together and was immersed in the water-bath for four days, before it was found dissolved. The other two samples did not seem to have set and fell apart.

SIROC (sodium silicate)

The SIROC grout is a sodium silicate system with chloride-amide components. Sodium silicate is the gel-forming material with the amide being the primary gel-producing reactant. The accelerators for controlling the rate of initial set for this system are chloride, aluminate, and bicarbonate.

The SIROC sodium silicate formula (as recommended by Mr. Peeler, SIROC chemist) is as follows:

Percent by weight	
11.65	SIROC #1 (Silicate)
9.5	SIROC #2 (Formamide)
0.156	Water
8.337	SIROC #3 (Chloride)

Test results at 39°F (3.9°C) ambient temperature

This grout solution produced a set or gel which appeared to be of a fine sponge texture and which would not offer any penetration resistance. See Figure 13b for temperature-vs-time graph of set test. However, a SIROC injected sand sample (20) did produce a 3-psi unconfined compressive strength.

cement then added upon injection pressure feasibility. Another reference for w/c ratio is Department of the Army TM 5-818-6 (1970, p. 27 and 28).

Type III Portland cement was used at w/c ratios between 2 and 5. This cement, a finer grind, also failed to penetrate the sand samples.

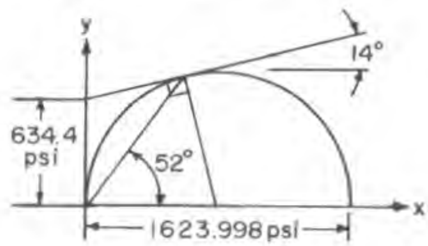
DISCUSSION

The tests conducted on sand and silt yielded strength values that can be compared with those of injected soil samples prepared, in this investigation, under the same conditions. Included in the tests were the chemicals that are intended not to add strength to the soils but to make them impermeable, for example, the acrylamide gel AM-9. However, tests of silt samples injected with the AM-9 gel gave higher unconfined compressive strength results than those of sand samples injected with the gel. This is shown in the stress-strain graphs of Figure 15a and 15c, and in Table II. These tests showed that a silt sample successfully injected with AM-9 gained a significant unconfined compressive strength, as evidenced by the 17.5% strain at 51.11 psi (3.67 tons/ft^2) of the silt sample at 33°F versus the 8.472 psi (0.6 ton/ft^2) sand sample at 39°F. Celtite 55 Terraset, brittle in nature, also gave higher strengths for the injected silt sample (14.583 psi -1.05 tons/ft^2) in contrast with the injected sand sample (7.222 psi - 0.52 ton/ft^2), both at 39°F (see Table II).

The Ashland Chemical Co. urethane resin (EP 65-12, 17 and 18) resulted in the product with the strongest set which maintained a low viscosity as the temperature lowered; and, according to visual inspection, all of the EP series injected soil samples were impervious (not porous). This product was successfully injected at 20°F and set. Set test data showed this urethane solution mixed at temperatures lower than 20°F and produced a set. This solution is capable of being mixed at −26°F, still fluid, and is capable of producing a set at approximately 17°F and below. This product shows promise for grouting and stabilizing fine-grain soils at lower temperatures. It has set at -4°F (-20°C) in a recent construction materials test program.

The results of the investigation on the unconfined compressive strength tests show that the injected urethane resin (Ashland Chemical Co.)

Sample 65 Urethane Resin, Sand



$$\theta = 52^\circ$$

$$45^\circ + \frac{\phi}{2} = 52^\circ$$

$$\therefore \phi = 14$$

Figure 17. Mohr's Circle of stress for the highest strength gained by pressure injecting (33°F ambient temperature).

produced the highest strength (1623.99 psi — 117.575 tons/ft^2, 33°F) and the injected epoxy resin (Reichhold Chemicals, Inc.) the second highest (448.88 psi — 32.319 tons/ft^2, 39°F) (see Fig. 16 and 17). However, the epoxy resin exhibited problems and a significant increase in viscosity as the temperature was lowered to 33°F, as opposed to the urethane resin that did not. The Mud Lock XB-2403, which is water reactive, maintained a low viscosity and was successfully injected into a sand sample at 33°F, resulting in an unconfined compressive strength of 115.22 psi (8.295 tons/ft^2). Mud Lock, being injected into frozen soil, would perhaps remain stable until thaw, at which time it might consume water and react, becoming solid.

For soil injection purposes, the Mud Lock with water reacted too quickly for a one-solution system. It worked very well concentrated, when pressure injected into a 100% (approximate) water-saturated soil sample, by displacing the great majority of water and reacting with the moist soil. However, the set sample was porous.

The epoxy resin tested (Epotuf) gave a high unconfined compressive strength, but as the resin temperature was lowered, the viscosity of the solution increased noticeably, and at the 39°F set test, the heat of reaction increased the temperature to 341.6°F; this must be considered if the material heat would disturb or melt the materials is also needed for structural purposes.

The hydrophilic urethane Mud Lock XB-2403, which is water reactant, should be tested for soil stabilization by mixing water and soil down to the freezing point of the water portion. Further, Mud Lock should be investigated for its use as an injection grout for various percentage-saturated frozen soils samples. The samples should then be allowed to thaw to create the water for reacting. Depending on the shelf life of this material, it may have stabilization potential for injections in-situ previous to thaw.

Acrylamide AM-9 should be further tested for structural foundation purposes in low temperatures where water exists continuously around foundations, including those subject to vibratory loads. The silt AM-9 sample exhibited great resilience when examined by hand and should be tested for this property using injected silt or fine-grained soils with a variety of loading conditions.

Urea-formaldehyde such as Cyanaloc 62, which did set at a low temperature (39°F) with the lowest heat liberation rate, should be investigated for further low temperature set information as well as unconfined compressive strength of the material. This grout may show promise for other pressure injection purposes (cavity and jacking) or placement on permafrost for structural purposes, without melting or disturbing the normal balance of the substrate.

2. *Field evaluation.* An in-situ test site of sufficient size and proper soil conditions should be chosen so that an adequate number of samples can be produced to validate the laboratory test. This test site should be in a field environment where grouting can be performed with the ambient temperatures at 39°F and below. This would allow an in-depth evaluation of grouting procedures and materials.

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APPENDIX A. GROUTS AND CHEMICAL SOLUTIONS, MANUFACTURERS AND PERSONNEL CONTACTED

Name and/or no. of grout or chemical solution	*Company firm or manufacturer*	*Personnel contacted (1977)*
EP Systems and A-11	Ashland Chemical Co. Division of Ashland Oil Inc. Columbus, Ohio 43216	Dr. Robert Shafer Dr. G.L. Linden John Lundberg (614) 889-3333
XB-2403 Mud Lock	3 M Company 3 M Center St. Paul, Minn. 55101	John Simpson Paul Denuccio (612) 733-1110
Epotuf 37-130 and 37-052	Reichhold Chemicals, Inc. RCI Building White Plains, N.Y. 10602	Scott C. Raswyck Andover, Mass. 01810 (617) 475-6600
Ancamine AD, LT and MCA	Pacific Anchor Chemical Corp. (PVO International Inc.) Richmond, Calif. 94804	Colin G. Hull, President (415) 529-1020
Raylig-260 L	ITT Rayonier, Inc. New York, N.Y. 10016	E.K. Millette (212) 687-7880 F.W. Herrick (206) 426-4461 Shelton, Wash. 98584
AM-9	American Cyanamid Co. Berdan Avenue Wayne, N.J. 07470	Roger Nowell (201) 831-1234
Cyanaloc 62	American Cyanamid Co. Berdan Avenue Wayne, N.H. 04740	Roger Nowell (201) 831-1234
Hayward Baker Sodium Silicate	Hayward Baker Co. 1875 Mayfield Road Odenton, MD 21113	Wallace H. Barker (301) 551-8200 or (301) 621-9400 Washington, D.C.
SIROC	Raymond International Inc. Cherry Hill, N.J. 08034	E.R. Colle (609) 667-3323
Celtite 55 Terraset	Celtite, Inc. Cleveland, Ohio 44133	Tony Plaisted (216) 237-3232
Bentonite Clay	Federal Bentonite Aurora, Ill. 60538	Robert F. Waterloo (312) 896-4142
Portland cement Type I		
Portland cement Type III		

APPENDIX B. TEST SAMPLES

The samples shown in this appendix are listed as *before, during,* and *after* unconfined compressive strength testing. The samples designated as *before* testing had been soaked for 7 days in the water-bath.

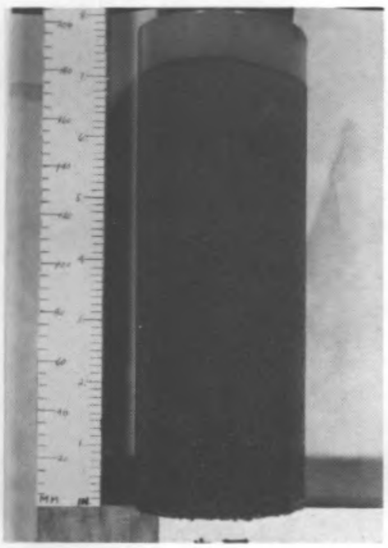

Figure B1. No. 7 before.

Figure B2. No. 7 after.

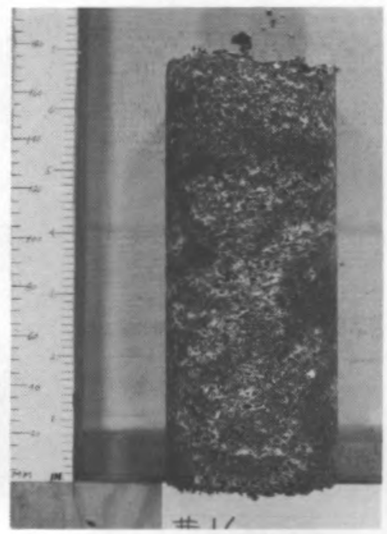

Figure B3. No. 16 before.

Figure B4. No. 16 after.

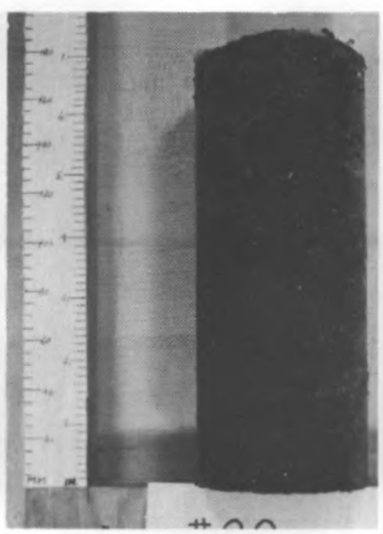

Figure B5. No. 20 before.

Figure B6. No. 20 during.

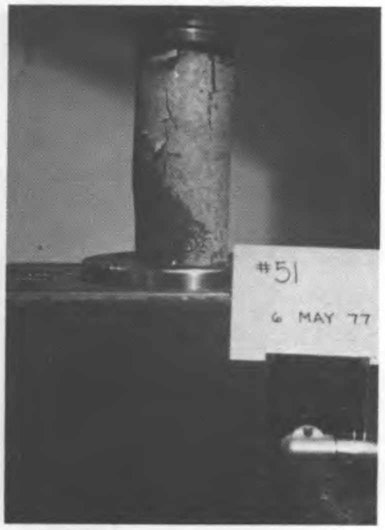

Figure B16. No. 51 after.

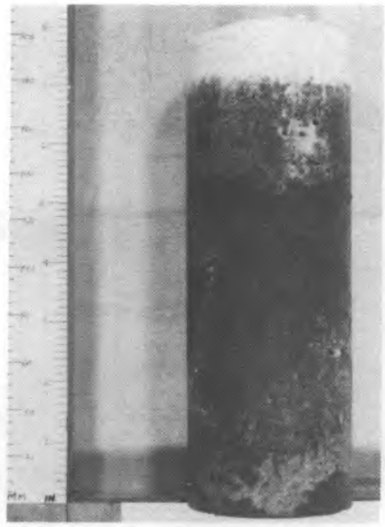

Figure B17. No. 53 before.

Figure B18. No. 53 after.

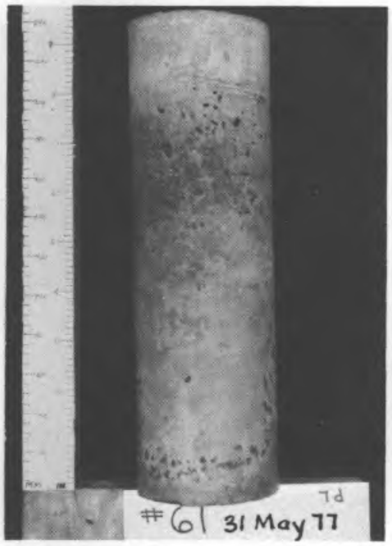

Figure B19. No. 61 before.

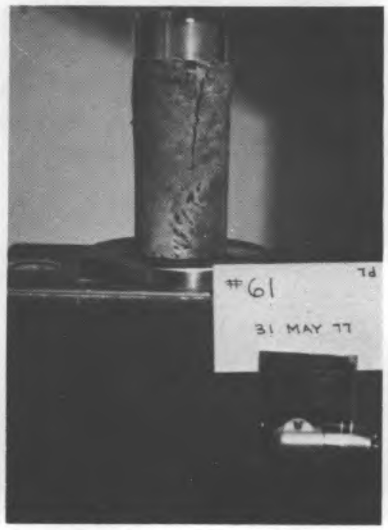

Figure B20. No. 61 after.

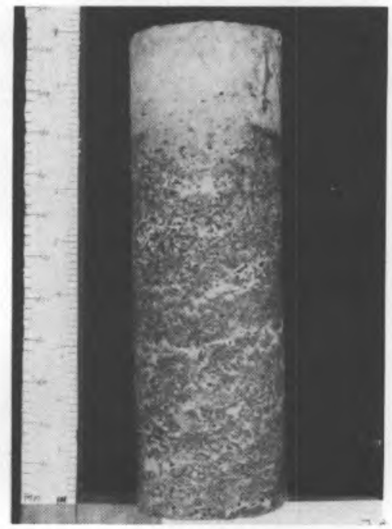

Figure B21. No. 63 before.

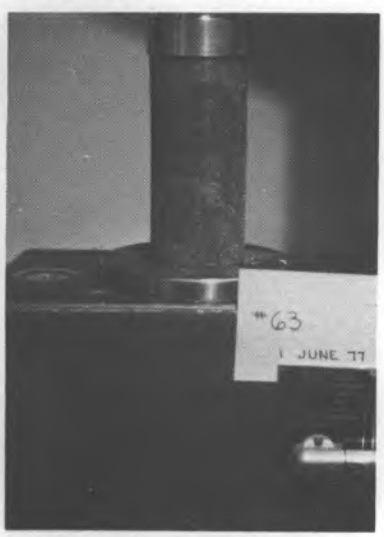

Figure B22. No. 63 during.

Figure B23. No. 63 after.

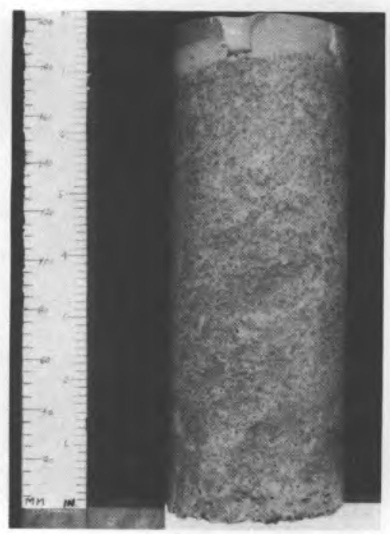

Figure B24. No. 65 before.

APPENDIX C. GROUT OR SOLUTION COST INFORMATION

Solution no.	*Price/pound*	*Flash point*
Urethane resin (Ashland Chemical Co.)		
EP 65-92	$ 0.4968	105°F
EP 65-93	0.5393	
EP 65-12	0.7060	130°F
EP 65-17	0.5195	120°F (PM)
EP 65-18*	4.7237	276°F (PM)
EP 65-94*	7.0350	198°F (PM)
A-11*	1.5217	130°F (TCC)
Hydrophilic urethane resin (3M Company)		
XB-2403 Mud Lock	$13.00/gal.	0°F (TCC)
Epoxy resin (Reichhold Chemical Inc.)		
Epotuf 37-130	$ 0.78 (truck load)	200°F (TCC)
Epotuf 37-052	1.08 (truck load)	130°F (TCC)
Hardners/Reactant (Pacific Anchor Chemical Corp.)		
Ancamine AD	$ 1.60	180°F (TCC)
Ancamine LT	1.40	213°F (TCC)
Ancamine MCA	1.70	230°F (TCC)
SIROC (Raymond International)		
Silicate	$ 0.93/gal.	
Amide	4.74/gal.	
Chloride	0.30/10 lb. bag	
Celtite 55 Terraset (Celtite Inc.)		
Part A	$ 0.91/gal.†	281°F (TCC)
Part B	0.91/gal.†	
Lignosulfonate (ITT Rayonier Inc.)		
Raylig-260 L	$20.00/short ton F.O.B. Hoquiam, Wash.	

* Catalyst
† Price from Paul Rausch
(PM) = Pensky - Martens Closed Tester (ASTM D93)
(TCC) = Tag Closed Tester (Cup) (ASTM D56)

CYANALOC® 62 chemical grout

Effective Date: June 7, 1976

Delivery: F.O.B. Wallingford, Conn.
Terms: Net 30 days to app'vd. credit or cash with order
Freight: Collect.
Packing: Cyanaloc 50 gal. non-returnable steel drums
Net – 575 lbs., Tare – 41 lbs., Gross – 616 lbs.

Pounds Per Gallon: 10.4
50 Gallon Fibre Pak: Sodium Bisulfate – Net 400 lb.
Tare – 28 lb. Gross – 428 lb.

		INDIVIDUAL SHIPMENTS PRICES PER POUND					
	Product Code	*Tank Cars or Tank Trucks*	*Minimum 24,150 lbs. and over*	*10,350 lbs. to 23,575 lbs.*	*5,175 lbs. to 9,775 lbs.*	*2,300 lbs. to 4,600 lbs.*	*1,725 lbs. or Less*
Drum Quantity			*42 - Up*	*18 - 41*	*9 - 17*	*4 - 8*	*1 - 3*
Selling Price $/lb.	26202-01	$0.19	$0.23	$0.25	$0.27	$0.29	$0.31
Selling Price $/gal.		1.97	2.39	2.60	2.81	3.01	3.22

		INDIVIDUAL SHIPMENTS PRICES PER POUND				
	Product Code	*3,200 lbs. 3,200 lbs. to*	*2,400 lbs. to 2,800 lbs.*	*1,600 lbs. to 2,800 lbs.*	*800 lbs. to 1,200 lbs.*	*400 lbs.*
Drum Quantity		*8 - Up*	*6 - 7*	*4 - 5*	*2 - 3*	*1*
Sodium Bisulfate	95184-01	$0.19	$0.21	$0.23	$0.25	$0.28

® trademark