IN SITU GROUTING TREATABILITY STUDY FOR THE IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY SUBSURFACE DISPOSAL AREA—TRANSURANIC PITS AND TRENCHES

Guy G. Loomis, Jim J. Jessmore
Idaho National Engineering and Environmental Laboratory
P.O. Box 1625 (MS 3710), Idaho Falls, ID 83415
(208) 526-9208, guy@inel.gov

Al L. Sehn, Chris M. Miller
University of Akron

ABSTRACT

At the Idaho National Engineering and Environmental Laboratory (INEEL), a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) treatability study is being performed to examine the technology of in situ grouting for final in situ disposal of buried mixed transuranic (TRU) waste. At the INEEL, there is over 56,000 cubic meters of waste commingled with a similar amount of soil in a shallow (3-5 m) land burial referred to as Waste Area Group 7-13/14. Since this buried waste has been declared on the National Priorities List under CERCLA, it is being managed as a superfund site. Under CERCLA, options for this waste include capping and continued monitoring, retrieval and ex situ management of the retrieved waste, in situ stabilization by vitrification or grouting, in situ thermal dissorption, or some combination of these options. In situ grouting involves injecting grout at high pressures (400 bars) directly into the waste to create a solid monolith. The in situ grouting process is expected to both stabilize the waste against subsidence and provide containment against migration of waste to the Snake River Plain Aquifer lying 150-200 m below the waste. The treatability study involves bench testing, implementability testing, and field testing. The bench testing was designed to pick three grouts from six candidate grouts for the implementability field testing in full scale which were designed to down-select from those three grouts to one grout for use in a full-scale field demonstration of the technology in a simulated test pit. During the bench testing, grouts were evaluated for durability using American Nuclear Society 16.1 Leach Protocol as well as evaluating the effect on physical parameters such as hydraulic conductivity and compressive strength due to the presence of interferences such as soil, organic sludge, and nitrate salts. During full-scale implementability testing, three grouts were evaluated for groutability and monolith formation, which resulted in a single grout for use in field testing that evaluated the entire concept of in situ grouting including not only grouting performance and monolith formation but also contamination control during grouting.

INTRODUCTION

At the INEEL, a CERCLA treatability study is being performed to examine the technology of in situ grouting for final disposal of buried mixed TRU waste. At the INEEL, there are 56,000 cubic meters of mixed TRU waste commingled with a similar amount of soil in a shallow (3-5 m deep) landfill consisting of pits and trenches. The source of the waste was the Rocky Flats Plant and consists of containerized cloth, paper, metal, concrete, asphalt, inorganic and organic sludge, and nitrate salts contaminated with small micron sized particles of plutonium. The waste has been buried 30-50 years and considerable deterioration of the containers is certain. One of the options being considered for this waste is to employ a technology developed at the INEEL called in situ grouting to both stabilize the waste against subsidence and provide containment against migration of waste to the Snake River Plain Aquifer lying 150-200 m below the waste.

In situ grouting was developed at the INEEL first as an aid to the retrieval process (ref 1,2) and finally as a stand-alone application to facilitate in situ disposal (ref 3,4).

In situ grouting as developed at the INEEL involves high-pressure (400 bar [6,000 psi]) nonreplacement jet grouting into the waste to create, once cured, a solid monolith out of the waste pit or trench. Nonreplacement means that the jet grouting is accomplished with minimal to no grout returns to the surface, thus minimizing contamination spread. The grout is delivered via a rotating drill string that is first driven through the waste to the desired depth. At this point, the high-pressure grout is injected through small (2-3 mm) nozzles at the bottom of the drill string. During grouting, the drill string is raised in precise increments or steps (nominally 5 cm) with a predetermined "dwell" time on a step. By injecting grout on an approximately 50-cm triangular pitch, the resultant circular columns are interconnected to form a solid monolith. One of the key elements of in situ grouting is the contamination control features, which involve grouting in an essentially glove-box environment as shown in Fig. 1 and Fig. 2. The technology uses a thrust block to contain grout returns and along with the shroud around the drill steel creates a glove-box like environment for the grouting process. Each hole through the thrust block has a removable lid and a plastic diaphragm, which is penetrated during the grouting process. The thrust-block and glove-port assemblies shown in Fig. 1 and Fig. 2 are under negative pressure using a high-efficiency particulate air (HEPA) filtration system and a shroud assembly around the drill stem, which is also HEPA filtered. Once a hole is grouted, the drill steel is withdrawn into the shroud and the glove port is taped and cut. The cut portion is placed down into the thrust block, and the removable lid is replaced.

The CERCLA treatability study involves three phases. Phase 1 is a bench study involving six promising grout materials. During the bench study, the various grouts were tested against a number of standard testing protocols to study tolerance of the grout to expected interferences, physical and chemical properties of the grouts to suggest durability, and the implementability of the grout for jet grouting. Phase 2 is a full-scale field study examining injecting grout into INEEL typical soils to examine the injectability and handling of the grouts in larger scale than the bench studies as well as monolith formation. Phase 3 is a full-scale field study involving injecting grout in a simulated INEEL TRU waste pit.

BENCH TESTING RESULTS

During the bench testing (described in ref 5), six grouts were evaluated with the goal of picking three grouts to be tested during implementability testing in the field. Additionally, data were obtained to aid modelers in determining the expected migration of contaminants from the grouted buried waste site. The six grouts were:

- US GROUT—a proprietary pozzolanic/cement grout
- TECT-HG—a proprietary cementitious grout
- Enviroblend—a phosphate-based grout
- GMENT-12—a modified Savannah River Site tank closure grout
- Saltstone—from the Savannah River Site
- WAXFIX—a molten wax-based grout

SCREENING TEST RESULTS

The cementitious grouts were first screened for implementability parameters including time for initial and final gel (greater than 2 hours), pressure filtration (less than 0.1 [-.5]), viscosity (less than 7 minutes in a Marsh funnel), temperature of set (less than 100°C). All of the grouts except Saltstone passed the screening. Saltstone exhibited initial gellation time of 1.8 hours and therefore was unacceptable. Table I summarizes the results of the initial screening.

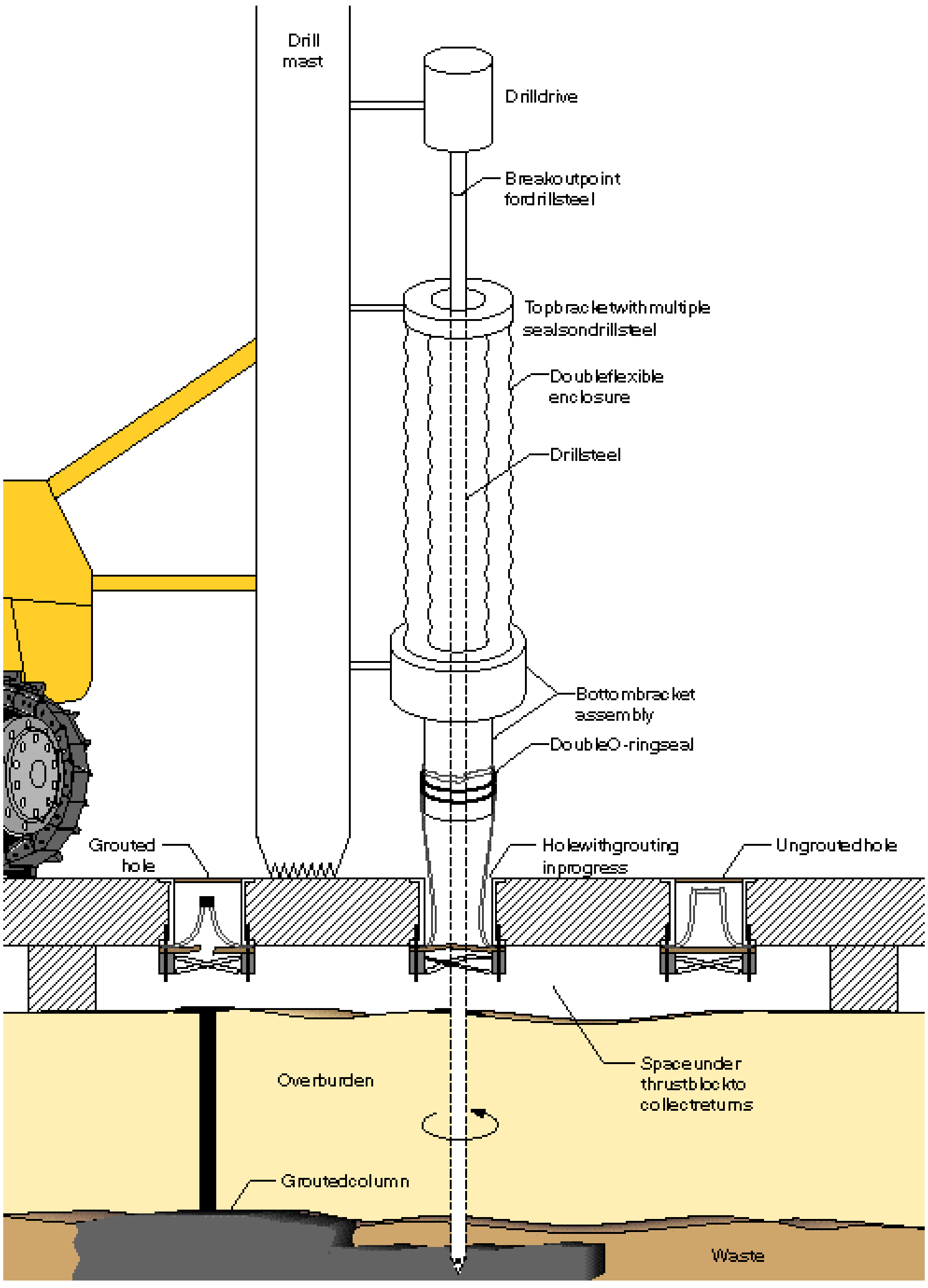

Fig. 1. Contamination control system during grouting.

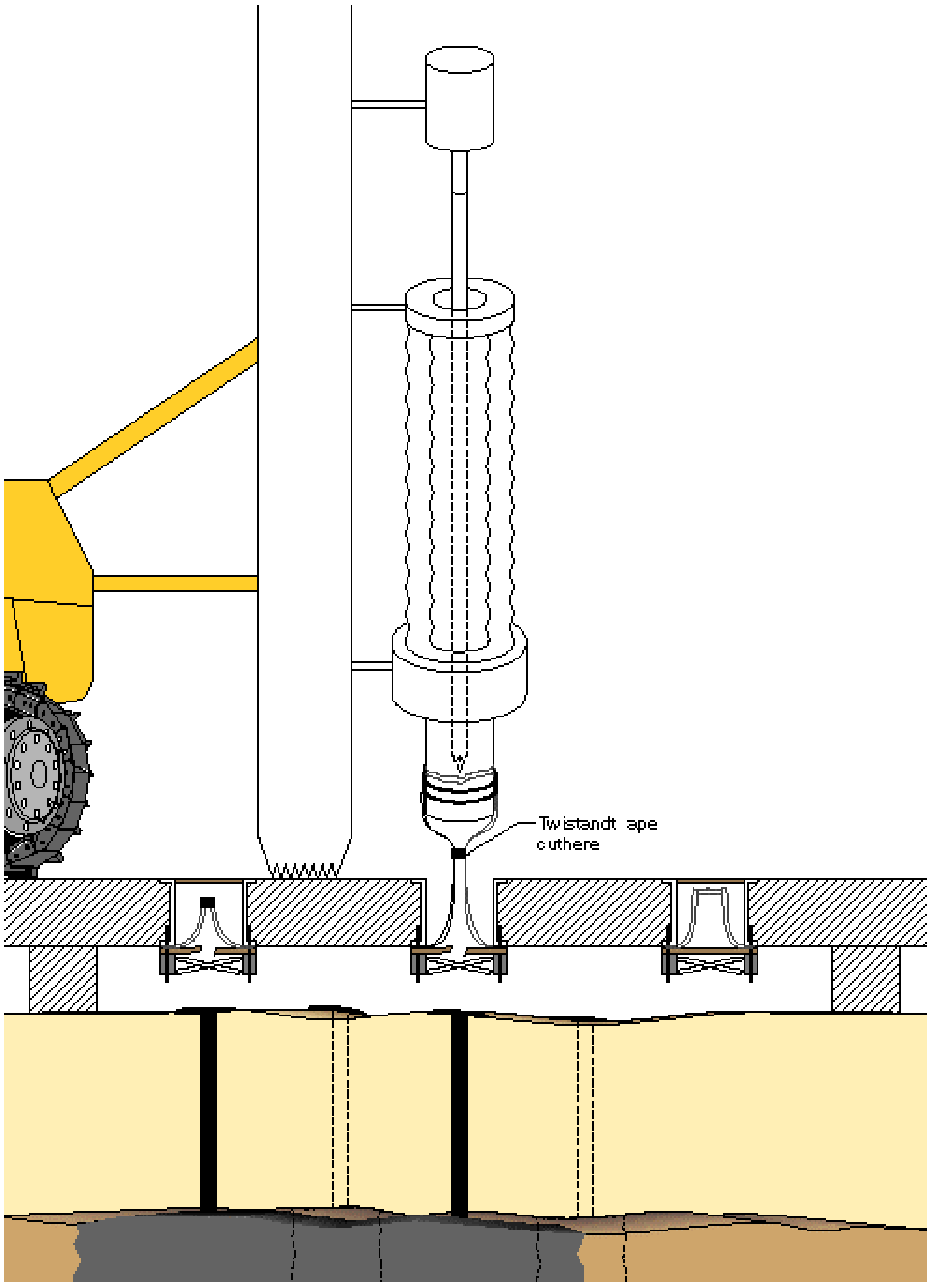

Fig. 2. Drill steel withdrawn—preparing for move to a new hole.

Table I. Implementability test results and screening criteria.

	Grout Product					
	C75	E	S	T	U	
Grout Property	GMENT-12	Enviro-blend	Salt Stone	TECT-HG	US Grout	Screening Criteria
Specific Gravity (ASTM D 4380-84)	1.84	1.78	1.60	2.16	1.65	
Viscosity (Marsh Funnel Time) (sec.)	56	165	110	113	58	< 420
Initial Gelation Time (hours) Wally Baker Shear Vane	4.9	9.4	1.8	6.0	4.7	> 2
Final Gelation Time (hours) Wally Baker Shear Vane	10.7	27.5	8.3	17.9	7.6	> 2
Pressure Filtration Coefficient (min $^{-0.5}$)API Procedure RP-10B	0.072	0.077	0.023	0.008	0.033	0.1 to 0.6
Maximum Set Temperature (deg. C)	59	32	28	62	46	< 100
Settlement/Shrinkage (%)	1.82	3.16	0.25	0.44	0.84	

The remaining grouts were then tested for neat grout compressive strength, neat grout leaching using American Nuclear Society protocol 16.1, eH (ASTM D 1498-93) and pH (ASTM D 1293-95) of the leachate, and interference tolerance evaluated by the effect on physical parameters and leaching.

Leaching Results

ANS 16.1 was performed for cured neat grout samples in triplicate while measuring eH and pH of the leachate as an indicator of buffering of the grout. The evaluation of each leachate sample for the 90-day testing was performed for grout specific elements (aluminum, silica, calcium) as well as for a nonradioactive tracer strontium placed in the grout as a 0.1 wt% of grout mixture strontium carbonate. The final report for this work will give a complete summary of the leaching data including mg/L leached, diffusion coefficient, and Leach Index on a day-by-day basis for the various elemental constituents. As an example, a summary of this testing using diffusion coefficient for the nonradioactive strontium tracer as an indicator of durability is shown in Table II. All grouts exhibited relatively low diffusion coefficients (e-10 to e-15 cm2/s) for all constituents in the grout (aluminum, strontium, calcium, and silicon) with the phosphate containing American Minerals Enviroblend having the lowest coefficients.

Table II. Summary of ANS 16.1 leach data for strontium tracer (0.1 wt% added to wet mix).

GROUT NAME	Range De cm2/s	Range Ph	Range Eh mv
US GROUT	e-11 to e-13	9.7 to 11.2	Less than 390
TECT-HG	e-10 to e-11	9.6-11.4	Less than 384
Enviroblend	e-12 to e-15	9.6 to 11.1	Less than 375
GMENT-12	e-10 to e-12	10.6 to 11.2	Less than 313

Physical Testing for Both Neat Grouts and Grouts Mixed with Interferences

Interferences that might affect the monolith formation during jet grouting include soil (roughly 50% of the excavated volume), organic sludge (at approximately 5% of the excavated volume), and nitrate salts (about 5% of the excavated volume). The INEEL soil is a silty clay soil; the organic sludge is a mixture of volatile organics, Texaco Regal Motor Oil, and absorbents; and the nitrate salts consists of granulated sodium and potassium nitrate.

Monolith formation in areas containing this material may be compromised, and interference tolerance testing was designed to determine the effect on parameters such as compressive strength and hydraulic conductivity.

Table III summarizes the compressive strength results using ASTM C-39-96 of applying a range of interferences with the neat grout. Using neat grout as a baseline, the grouts showed a marked difference in degradation as a result of inclusion of interferences. For instance, the Enviroblend grout had a very poor neat grout compressive strength (150 psi) and basically no tolerance to any interferences. On the other extreme, TECT-HG and GMENT-12 had an excellent neat grout compressive strength (6,320 and 7,639 psi respectively) and excellent tolerance to all three interference types. For instance, both GMENT-12 and TECT-HG monoliths had robust compressive strength (greater than 1,500 psi) even with 50 wt% soil and 25 wt% nitrate salts. However, both grouts exhibited less by mass tolerance to the organic sludge material, which is a mixture of volatile organics such as carbon tetrachloride and Texaco Regal Motor Oil and calcium silicate absorbents (tolerance for GMENT-12 was 9 wt% organic sludge and for TECT-HG 12 wt%). The US GROUT had an overall lower compressive strength for both neat grout and for the grout with interferences; however, across the board showed higher tolerance to the interferences. For instance, US GROUT could still produce stand-alone monoliths with 75 wt% soil and 75 wt% nitrate salts.

Table III. Average compressive strength in psi for the interference tolerance testing specimen groups.

		Grout Product			
		C75	E	T	U
Interference Type	Interference Percentage	GMENT-12	Enviroblend	TECT-HG	US GROUT
None-Neat Grout		7,639	150	6,320	2,582
INEEL Soil	12	5,884	62	4,150	3,896
INEEL Soil	25	6,048	26	3,654	3,098
INEEL Soil	50	2,529	43	1,924	1,278
INEEL Soil	75	NA	NA	NA	805
Nitrate Salts	12	3,171	39	3,239	4,801
Nitrate Salts	25	2,885	4	1,193	1,383
Nitrate Salts	50	3	NA	NA	1,813
Nitrate Salts	75	104	11	NA	869
Organic Sludge	3	7,349	133	4,296	3,276
Organic Sludge	5	6,100	132	3,706	2,878
Organic Sludge	7	6,215	102	2,820	2,644
Organic Sludge	9	6,083	105	2,618	3,136
Organic Sludge	12	NA	116	2,347	NA
Organic Sludge	25	NA	NA	204	NA
Organic Sludge	50	NA	52	7	NA

Table IV shows the average hydraulic conductivity as measured in monoliths formed by the neat grouts and neat grout mixed with interferences. The testing protocol followed the essence of ASTM D 5084-90. Although there was a marked degradation for samples containing 12 wt% nitrate salts (as much as a two order degradation), there was little degradation in hydraulic conductivity for up to 9 wt% organic interference and 50 wt% soil. It is noted here that a soilcrete mixture of grout and soil at 50 wt% soil is similar to what is expected in a jet-grouted monolith for the INEEL TRU pits and trenches. In all cases shown on Table IV, the hydraulic conductivities are extremely low and definitely show an improvement over the ungrouted pits and trenches of around E-5 cm/s (ref 3).

Table IV. Average hydraulic conductivity values in cm/second for mixtures of each grout with the various interferences.

Test Specimen	Interference Amount and Type	GMENT-12	Enviroblend	TECT-HG
Neat Grout	None	7.3E-09	1.5E-07	5.8E-09
A	12% Nitrate Salts	5E-07	7.5E-06	1.3E-09
A	9% Organic Sludge	3.5E-09	6E-08	3E-09
A	50% INEEL Soil	8E-09	8.5E-07	1.4E-08

SPECIAL BORON CONCENTRATION TESTING FOR WAXFIX

Since WAXFIX is considered a moderator for neutrons relative to criticality concerns in the buried transuranic waste, and since it had been jet grouted before, there was only one basic criterion to pass to the field and that was the capability to have sodium tetraborate solution remain uniformly suspended such that there is 1g/L of boron-10 in the solution during a 5-day cooldown, thus simulating conditions expected in a buried waste environment following jet grouting of the molten (160°F) wax. The uniform presence of the boron-10 in the sodium tetraborate at 1g/L was mandatory for INEEL criticality considerations. In repeated tests, the sodium tetraborate solution separated such that there was a 10-fold reduction in B-10 concentration in the top compared with the bottom of the container, and therefore, WAXFIX was eliminated from further testing.

GROUT DOWN-SELECTION

The down-selection for the cementitious grouts were based on the physical properties of the grout such as compressive strength, hydraulic conductivity, and leach resistance, and jet grouting properties such as set history, temperature of set, viscosity, density and pressure filtration, all applied to a weighting criteria defined in the test plan (ref 5). For instance, items that affect implementability (Table V) shows the relative ranking of the four grouts based on a fairly complex criteria.

Table V. Relative ranking of cementitious grouts.

Grout	Relative Rank
TECT-HG	4184
GMENT-12	3862
US GROUT	4150
Enviroblend	3010

Comparison of the four cementitious grouts that passed the initial screening (recall that Saltstone did not meet the minimum screening criteria) show that the relative scoring for US GROUT (4150), TECT-HG (4184), and GMENT-12 (3862) was relatively close while the Enviroblend (3010) was clearly a distant fourth. As expected, Enviroblend achieved a better leach index than any of the other grouts because of the presence of phosphate, but the other grouts were high enough in leach index and yet still have all the other desirable properties that the scoring came out higher for the other grouts. In fact, Enviroblend had virtually no resistance to interference tolerance and a relatively high shrinkage number such that a zero score was achieved for those parameters. Also, evaluation of the WAXFIX paraffin-based grout was halted due to difficulties in achieving a reasonable distribution of the B-10 during a 5-day cooling period and therefore was also dropped. Therefore, using the agreed upon scoring system established in the test plan, three grouts were recommended for testing in the implementability phase including US GROUT, TECT-HG, and GMENT-12.

IMPLEMENTABILITY TESTING

Implementability testing of TECT-HG, US GROUT, and GMENT-12 was performed in specially constructed soil pits simulating INEEL soil as described in ref 6. In this testing, monoliths were created at full scale by jet grouting inner connected triplex columns on a 20-in. grid. For this testing, the CASA GRANDE JET-5 pump and C6S drill rig were used along with simulated thrust blocks (in this case simply concrete boxes providing a volume for grout returns). Grouting in soil is the worst case for nonreplacement jet grouting from a grout return standpoint in that there are much fewer voids present in the soil than the waste (30-40% for soil and up to 70% for the waste). Results of the implementability testing showed that all three grouts exhibited field implementability and would be considered for jet grouting TRU pits and trenches; however, data were sufficient to choose a single grout for testing in later field testing.

CREATING A TRIPLEX COLUMN USING THE THRUST BLOCK

A series of three connected holes were grouted in a 20-in. triangular pitch for each of the three grouts. For each of the cases, the grout was prepared in a special vortex mixing system that allowed mixing at least enough grout for a single column such that the grouting was essentially performed as one operation with no curing of the grout between grout holes. Grouting was performed using a thrust block to collect any grout returns. The first grout injected was the GMENT-12, followed by the US GROUT and finally the TECT-HG. Table VI summarizes the volume of grout injected in forming the grout columns. What follows is a description of the grouting operation and data obtained during grouting.

Table VI. Volume of grout injected during the implementability tests (gallons).

Grout Type	Hole Number	Grout Flow (Jean-Lutz Flow Meter)	Total Grout Injected
GMENT-12	1 2 3	93 139 128	360
US GROUT	1 2	156 104	260
TECT-HG	1 2 3	90 158 83	331

GMENT-12

A triplex column was successfully created using the GMENT-12 grout and two opposing 2.4-mm nozzles. The grouting parameters were set at 5.1 seconds/step, 2 revolutions per step and a 5 cm step size, with grouting pressure at 400 bars (6,000 psi) for all three positions grouted. Three gallons of water were mixed with each 60-lbm bag of dry ingredients. Basically, during grouting, no grout returns to the surface of the thrust block were observed; however, when grouting the final hole 3-5 gal of grout returns flowed from the side of the thrust block as the final inches of the third hole were grouted. Table VI summarizes the volume of grout injected in forming the columns using the Jean Lutz metering system and shows that a total of 360 gal of grout were injected with no returns to the surface. This equated to about 15 gal per ft delivered to each hole during grouting.

US GROUT

Only two holes of the planned triplex column were grouted, because excessive grout returns to the surface of the thrust block during the grouting of the second hole precluded grouting any further. The parameters for grouting the US GROUT using two opposing 2.4-mm nozzles were 5.5 seconds per step, 5 cm step size, and 400 bars (6,000 psi) pressure at the high-pressure pump, with a mud balance taken on the grout at 13.1 lbm/gal. The US GROUT was found to be easy to mix in that there was a reduction in lumps of solid material that had to be mixed relative to mixing the GMENT grout. With the US GROUT, there was an initial plugging of a nozzle. This plugging was not attributed to the grout; rather, it was the first grout hole of the day, and debris in the lines could have accounted for the plugging. A total of 260 gal of grout were delivered in the two holes during the grouting operation, which essentially filled the thrust block with returns. In fact, the first hole had 156 gal of grout in the 8-ft column grouted and in the second hole only 104 gal was injected (the column was between 4-5 ft deep) when grouting was suspended because of the excessive return. Because of this complete filling of the thrust block with grout returns, it was decided to not grout the third hole. Either the grouting action had completely filled the voids in the soil under the thrust block or the relatively low density (SG=1.6) US GROUT simply did not impart enough kinetic energy to the soil and could not overcome the resistance of the soil and came to the surface.

TECT-HG

TECT-HG was successfully injected in a total of five positions (two limited length-field trials and three holes using the thrust block). Initially, it was desired to inject a similar volume of grout for the TECT-HG as the GMENT-12 so that a valid comparison could be made relative to column development in conditions of similar soil voids. To set these desired parameters and to maximize the availability of grout material, the field trials only involved 2-ft high columns in an iterative approach. These field trials were also necessary because the TECT-HG grout is of higher density than the GMENT grout (specific gravity of 2.16 g/cc for TECT-HG and 1.8g/cc for GMENT-12). The 3-mm nozzle was used and the mud balance reading on the TECT-HG grout was 17.5 lbm/gal. In addition, the initial field trial was at 400 bars (6,000 psi), 5 cm/step and 5.0 seconds/step. In 1.15 ft of column, 24.8 gal of grout were injected or 21.56 gal/ft, which was much higher than the average of 15 gal/ft injected in the GMENT-12 triplex columns. In the second field trial, the time on a step was adjusted to 3.5 seconds/step and the result was 17.2 gal for 1.15-ft column or about 15 gal/ft. Therefore, the first 8-ft column of the triplex under the thrust block was grouted at 3.5 seconds/step, with the result that 90 gal of grout was injected for 11.2 gal/ft, which was short of the goal of 15 gal/ft. Therefore, using proportioning, the next hole was grouted using 4.5 seconds/step, with the result of 158 gal of grout injected or 19.7 gal/ft. This action overshot the desired 15 gal/ft so the last hole was grouted at 4 seconds/step with a total of 83.75 gal in a 5.7-ft hole (the system ran out of grout before the total length of 8 ft could be grouted), which resulted in a net amount of grout of 14.7 gal/ft, which was close to the desired 15 gal/ft average seen in the GMENT-12 triplex column. Overall, in the three holes, the total amount of grout injected was within 10% of that injected into the

GMENT-12 pit. During grouting of these three holes under the thrust block, there were copious returns of grout pouring out of the field trial holes located just off the side of the thrust block.

EASE OF GROUT MIXING AND CLEANOUT

Following grouting of the three types of grout, the grouting contractor was interviewed as to ease of use for the grouts to determine which of the three grouts (TECT-HG, GMENT-12, US GROUT) was the easiest to mix and following grouting to clean out. During grouting, the down time to clean out plugged nozzles was basically the same for all grouts. This was due to debris in the system but not the fault of the TECT-HG. The grouting contractor claimed that US GROUT mixes easier than GMENT-12, and TECT-HG is the hardest to mix because of the required liquid component. In addition, GMENT-12 is medium difficult to mix, with minor clods that have to be mixed. Mixing GMENT-12 all dry product is easier than mixing TECT-HG. When mixing US GROUT, superplasticizer must be put in very soon to allow mixing.

During cleanout, the grouting contractor evaluated on a scale of 1-10—with 10 the most difficult—how hard is the cleanout for the three grouts:

- TECT-HG is hardest by far (some filter caking)—8
- GMENT-12 is second hardest with no filter caking—4
- US GROUT displayed some filter caking—4

These qualitative observations from the grouting contractor apply to using the small batch (approximately 1 cubic yard) vortex mixer used in the implementability testing; however, even in a batch plant mode the comments are still valid and especially the comments about cleanout.

In summary, US GROUT is the easiest to mix followed by GMENT-12. The hardest was TECT-HG. TECH-HG is by far the most difficult to clean out, with GMENT-12 and US GROUT similar but fairly easy to clean out.

EVALUATION OF GROUT RETURNS UNDER THE THRUST BLOCK

A special mixture of bentonite (Wyoming Bentonite—Billings, Montana) and water was prepared in the first vortex mixing system. The idea was to fill the thrust block with the bentonite slurry and then subtract the known design volume under the block. Bentonite was used in the slurry so that leakage paths under the block would quickly seal. A special test block was created in the local sand and the bentonite slurry mix effectively sealed the sand from slurry flow using a ratio of about 12-lbm bentonite per 40 gal of water. Using the flow meter on the vortex mixer, the slurry was pumped under low pressure into each of the thrust blocks. Because all of the holes in the thrust block used for US GROUT were sealed with grout returns (indicating a completely full thrust block), it was impossible to fill the US GROUT block. For the TECT-HG thrust block, a total of 25 gal of slurry was placed in the thrust block. For the GMENT-12 thrust block, a total of 70.8 gal of slurry was placed. Therefore, for the TECT-HG grout, there were a total of 119 minus 25 gal or 94 gal of grout returns and for GMENT-12, a total of 119 minus 70.8 gal or 48 gal of returns.

In summary, US GROUT had the most grout returns at 119 gal of grout returns, even with only two holes grouted with a total of 260 gal injected, meaning 45% of what was injected came up to the surface. Next, TECT-HG had the second most grout returns at 94 gal with a total of 331gal injected, meaning a 28%

volumetric return, and finally, GMENT-12 had the least grout returns at 48 gal, with 360 gal injected for a 13% return. Comparing the amount of grout returns with the amount of grout injected in each of the blocks shows that GMENT-12 clearly had the best results of the three grouts tested.

EVALUATION OF TEMPERATURE OF CURE FOR THE MONOLITHS

The time/temperature profile at mid-axial location for TECT-HG, GMENT-12, and US GROUT was taken using a data logger and a specially inserted temperature probe (thermocouple on a copper rod). The thermocouples were inserted immediately following injection of each type of grout. US GROUT reached a maximum center-line temperature of set of 118°F, 12 hours following insertion of the thermocouple. GMENT-12 reached a maximum temperature of set of 168°F, 14.3 hours after insertion. Finally, TECT-HG reached a maximum temperature of set of 165°F, 17.6 hours after insertion of the thermocouple. Therefore, all three grouts met the curing criteria in that the maximum temperature of set is below 212°F (100°C).

DESTRUCTIVE EXAMINATION OF THE RESULTANT COLUMNS

The destructive examination of the columns created under the thrust blocks first involved removing side burden material until the monolith was exposed. The thrust blocks were then toppled over into the created pit and the interior of the thrust block examined for sticking of the cured returned grout/soil on the interior surface of the thrust block (the interior surface of the thrust block was lined with closed cell foam liner). This was followed by complete excavation of the monoliths and removal in one piece for a photographic record. All thrust blocks were removed. As expected, the US GROUT thrust block was completely full of cured grout with only partial filling of the GMENT-12 and TECT-HG thrust block.

Examination of the GMENT-12 Monolith

The GMENT-12 monolith was isolated on three sides and photographed and measured. Using a front-end loader, the monolith was completely removed in one stand-alone piece of soilcrete, which is basically just a mixture of soil and grout. The monolith was measured at 8 ft high by roughly 48 in. in diameter. This represents a volume of 751 gal, with 360 gal of grout injected and 48 gal of returns, giving a net 312 gal into the monolith. This equates to a void filling of 41%. An attempt was made to break up the monolith using a standard backhoe bucket by raising the bucket above the monolith about 2 ft and striking the monolith, but only small fragments could be obtained after dozens of blows, suggesting a strong cohesive monolith.

Examination of the TECT-HG Monolith

The monolith created by the injection of TECT-HG grout in a triplex column was a solid cohesive stand-alone monolith. The dimensions of the monolith averaged about 43 in. throughout the length of 7 ft 10 in., with a reduced section or ledge in the top portion caused by running out of TECT-HG grout during grouting of the last hole. A total of 331 gal of grout was injected with 94 gal of returns, giving a net volume injected into the monolith of 237 gal. The size of monolith equates to an approximate volume of 516 gal of column (accounting for an approximately 2 ft diameter by 2 ft high reduction due to the region not grouted because of running out of grout), which means that the void filling was 45%, which is in good agreement with the GMENT-12 monolith creation. An attempt was also made to break up the stand-alone monolith with the backhoe. After repeated attack, only small chunks could be broken off, again suggesting a solid cohesive monolith.

Examination of the US GROUT Monolith

The US GROUT monolith also was a cohesive stand-alone piece of soilcrete. The monolith was irregular shaped in that only one full column and one-half column was grouted prior to filling the block with grout returns. The approximate volume of the column was that 4 ft of the column had a mean diameter of 43 in., and the other half had a mean diameter of 33 in., which equates to an approximate volume of column of 478 gal of soilcrete. This compares with the amount of grout injected into the column of 141 gal, meaning that the injection process filled 29% of the voids. This is considerably lower void filling than for the TECT-HG and GMENT-12 grouts and is attributed to the lower density for the US GROUT compared with the TECT-HG grout and GMENT-12 grout (US GROUT specific gravity=1.65, GMENT-12 SG=1.84, and TECT-HG=2.16). With a lower density, the grout impacts less energy to the soil for similar nozzle velocities.

DOWN-SELECTION OF GROUTS

Based on implementability testing of the three grouts, GMENT-12 was chosen as the single grout to carry forward for field testing. GMENT-12:

1. Displayed the lowest grout returns/grout delivered ratio.

2. Displayed the best ease of operation using simple dry ingredients and displayed a fairly straightforward cleanup.

3. Was cost competitive with the other grouts.

4. Produced a good monolith soil.

5. Laboratory results for hydraulic conductivity, leach, physical strength, set conditions, where competitive.

FIELD TESTING

Field testing is currently under way, with only preliminary results available. The testing as described in ref 6 is being performed in a simulated waste pit that contains containers and simulated waste with up to 200 g of terbium oxide tracer in each container. The terbium oxide is a stand-in for the plutonium oxide found in the actual TRU pits and trenches at the INEEL. The testing involves an elaborate contamination control apparatus including a thrust block over the pit and drill string shrouds that provide for "glove bag" like operations for protection from potential contaminant spread during and after grouting (see Fig. 1 and Fig. 2). This testing will focus on measuring the contamination spread (terbium) during grouting. Following curing of the pit, the hydraulic conductivity will be evaluated and the robustness of the resultant monolith will be assessed by destructive examination and leach testing of select fragments. These results will be reported in future symposia articles.

CONCLUSIONS

Bench and implementability testing have been completed as part of a CERCLA treatability study, and full-scale field testing is under way. The bench data allowed down-selecting from six grouts to three grouts for further consideration in field implementability studies. The three grouts chosen from the bench testing include TECT-HG, GMENT-12, and US GROUT. The three grouts were field tested for jet grouting in the implementability testing and were all found to be applicable and formed good monoliths.

Based on a predetermined selection criteria, the grout of choice for use in the field testing currently under way was GMENT-12. Data from all three phases of this treatability study will be used in forming the Record of Decision for the INEEL buried TRU pits and trenches.

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