Report on Treatment of Fort Lewis Soil: Baseline Soil Characteristics, Treatment Effectiveness, and Geotechnical Properties

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Background/Purpose

Ft. Lewis, in western WA, has numerous sites with soil contaminated with lead bullets, bullet fragments and pellets stemming from firing range usage. A team of AMEC Earth & Environmental Inc. (AMEC), Brice Engineering (Brice), Doyle-Ellis, Encapco, and ERDC are developing a treatment approach based on separation of lead from the bulk soil, and, if required, stabilization lead in fine soil material.

On August 18 and 19, 2003, representatives from AMEC, Brice, and ERDC collected samples from Ft. Lewis to conduct preliminary studies, which will be used to design a treatment system for the soils. The sample collection, and the subsequent testing, followed the AMEC workplan titled "Collaborative Treatability Study: Engineer Bluff (AOC 4-1) and Miller Hill (AOC 4-2), Fort Lewis Washington". ERDC received two bulk soils samples from the Fort Lewis sampling effort: Range 61 (composite), which was from the Engineer Bluff area, and Range 62/67 (composite), which was from the Miller Hill location. The following analyses were conducted on each bulk sample:

- Atterburg Limits (Liquid Limit, Plastic Limit, Plasticity Index) by American Society for Testing and Materials (ASTM) D4318.
- Size Distribution – ASTM D422
- Specific Gravity on < 10 mesh fraction
- Percent Moisture – ASTM D2216
- Soil pH – EPA SW 846 - on <10 mesh fraction

Afterwards, ERDC received approximately 70 lbs of soil from Brice. This soil had undergone Brice's size treatment procedure. Brice reported the total lead of the soil to be 20,222 mg/kg and reported TCLPs ranging from 198 to 218 mg/L (as reported in ENCAPCO Submittal TO-0001-03). The resulting soil was very fine, almost powdery.

ERDC treated the soil, then evaluated the treatment by TCLP. The treatments included various treatments with lime, encapco solution and Enviro 50:50. In addition, treatments with apatite and apatite with Enviro 50:50 were also conducted.

A successful treatment was chosen for geotechnical testing. This was 3% lime and 15% asphalt encapco (which was mixed with 5g of water per 15g of asphalt emulsion to promote better mixing). The following tests were performed:

- Unconfined compressive strength
- Marshall

Permeability tests are being conducted and additional Marshall testing is planned upon receipt of new emulsion. These will be reported as an addendum to this report.

Results

Atterburg Limits

The Atterberg Limits test is used to determine if particles finer than a #40 sieve are plastic or non-plastic, and was conducted on two samples: Range 61 (composite) and Range 62/67 (composite). Both samples were non-plastic (NP). Therefore, it was not possible to determine liquid and plastic limits. Range 61 was approximately 60% sand and gravel after being washed through a #40 sieve. Range 62/67 was approximately 30% sand and gravel after being washed through a #40 sieve. Both soils were classified as silty sand (SM).

Size Distribution

Figures 1 and 2 are pie graphs summarizing the results of the size distribution analysis. Both soils had remarkably similar distributions. Attachments 1 & 2 provide the raw data for the size distribution analysis.

Figure 1. Grain Size Distribution for Range 61 (Composite)

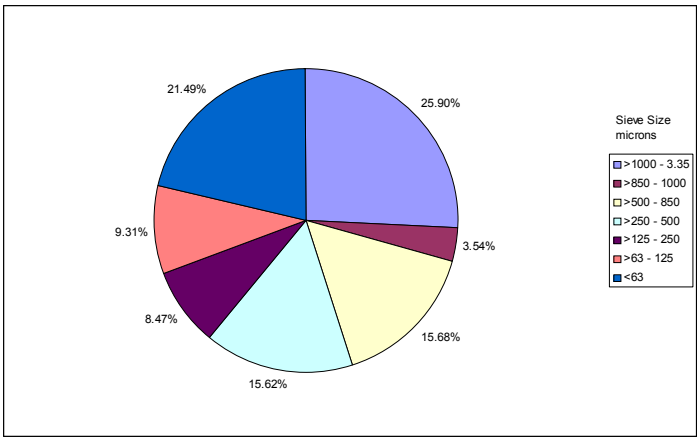
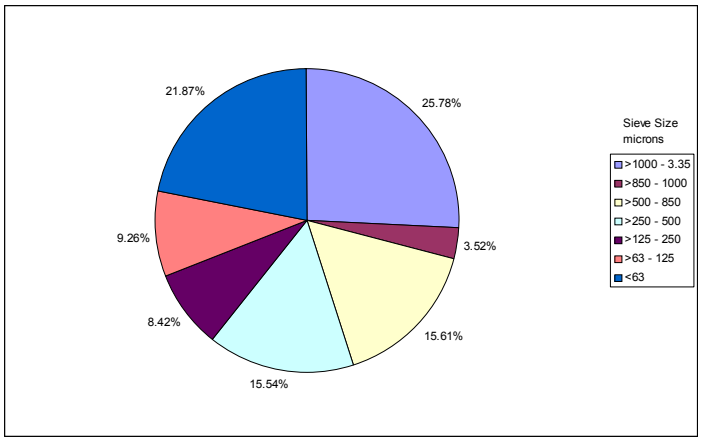


Figure 2. Grain Size Distribution for Range 62/67 (Composite)



Specific Gravity, Percent Moisture, Soil pH

Table 1 summarizes specific gravity, percent moisture, and soil pH

Table 1. Summary of Specific Gravity, Percent Moisture and Soil pH

Sample	Specific Gravity	Percent Moisture	pH
Range 61 (composite)	2.48 ± 0.03	4.55 ± 0.02	5.37 ± 0.02
Range 62/67 (composite)	1.25 ± 0.00	3.62 ± 0.24	5.50 ± 0.02

Soil Treatment Results

Soil treatment with Encapco Asphalt emulation results are presented in Table 2. Generally, the treatments worked well. We did discover that a key factor in the asphalt treatments was to add enough water to facilitate even mixing of the emulsion. Lime also appeared to be a key factor in treatment performance. Asphalt with no lime greatly reduced the TCLP, but did not meet the treatment goal. 1% treatments did not meet the goal either, however, these were the first treatments conducted and we later determined that water addition greatly improved mixing, so better performance may have been possible. In any case, treatments with 3% and 5% achieved the desired results.

Table 3 summarizes results for apatite treatments. Treatments with apatite alone reduced concentrations, but did not meet the 5-mg/L goal. However, the addition of 5% Enviro 50:50 resulted in effective treatment.

Table 2. Summary of Asphalt Treatments and Treatment Results for Ft. Lewis Soils (Output of Brice Treatment)

Treatment ID	% Lime	% Enviro 50:50	% Asphalt	TCLP (mg/L)
Untreated Soil (Brice Measurements)	0	0	0	205 ± 11.3
Untreated Soil (ERDC Measurements)	0	0	0	608.8 ± 23.9
Encapco only	0	0	10	9.47 ± 0.82
Encapco/Lime 1*	1	0	6	38.92 ± 2.20
Encapco/Lime 2*	1	0	8	17.27 ± 1.93
Encapco/Lime 3*	1	0	10	14.40 ± 4.24
Encapco/Lime 4	3	0	10	1.12 ± 0.15
Encapco/Lime 5	5	0	10	1.04 ± 0.26
Encapco/Lime 6	5	0	12	1.07 ± 0.75
Encapco/Lime/Enviro	1	5	10	0.39 ± 0.03

Table 3. Summary of Apatite Treatments for Ft. Lewis Soils

Treatment ID	% Apatite	% Enviro 50:50	TCLP (mg/L)
Apatite 1	5	0	306 ± 10.1
Apatite 2	8	0	107 ± 30.4
Apatite 3	10	0	56 ± 35.2
Apatite/Enviro 1	5	5	0.41 ± 0.02
Apatite/Enviro 2	8	5	0.41 ± 0.03
Apatite/Enviro 3	10	5	0.42 ± 0.02

Geotechnical Results

Table 4 summarizes the compressive strength results. Attachment 3 contains the raw data. Table 5 summarizes Marshall test results.

Table 4. Summary of Compressive Strength Testing

	Chamber Pressure (TSF)			Average
	0.50	1.00	2.00	
Compressive Strength (TSF)	2.36	3.17	5.00	3.51

Table 5. Summary of Marshall Test Results

Condition	Marshall Result (lbs)	Flow
Standard Test Temperature (140^{o}F)	793	11
Ambient Temperature	2130	12

Attachment 1. Size Distribution Data for Range 61 (Composite)

Table I. Mass of Soil Used for Sieving

Sample ID	Wt. of Cont. (kg)	Wt. of Cont. + Soil (kg)	Wt. of Soil (kg)
Range 61 Composite	0.019	3.019	3.000

Table II. % Moisture of Soil Before Dry Sieving

Sample ID	wt. of empty pan (g)	wt. of wet soil (g)	wt. of cont. + wet soil (g)	Oven dry wt. + cont. (g)	Oven dry wt. (g)	% moisture
Range 61 Composite: Rep 1	0.9382	10.0032	10.9414	10.4841	9.5459	4.57
Range 61 Composite: Rep 2	0.9365	10.0011	10.9376	10.4837	9.5472	4.54
Range 61 Composite: Rep 3	0.9360	10.0009	10.9369	10.4843	9.5483	4.53

Table III. Mass of Soil in each Fraction (Dry)

Sieve Size (mm)	Wt. of Empty Pan (kg)	Dry Wt. + Pan (kg)	Dry Wt. (kg)
>6.7-3.35	0.011	1.134	1.123
>3.35	0.011	0.309	0.298
Total			1.422

Table IV. Final Weight (<3.35mm)
Initial Mass of Soil Used for Wet Sieving

Wt. of Empty Cont. (kg)	Wt. of Pan + Soil (kg)	Wt. of Wet Soil (kg)	Dry Wt. (kg)
0.019	1.597	1.578	1.507

Table V. Mass of Soil in each Fraction (Wet)

Sieve Size (micron)	Wt. of Pan Cont. (kg)	Dry Wt. + Pan (kg)	Dry Wt. (kg)	Percentage
>1000 - 3.35	0.011	0.374	0.363	25.90%
>850 - 1000	0.011	0.060	0.050	3.54%
>500 - 850	0.011	0.231	0.220	15.68%
>250 - 500	0.011	0.230	0.219	15.62%
>125 - 250	0.011	0.129	0.119	8.47%
>63 - 125	0.011	0.141	0.130	9.31%
<63	0.016	0.318	0.301	21.49%
Total			1.402	100.00%

Attachment 2. Size Distribution Data for Range 62/67 (Composite)

Table I. Mass of Soil Used for Sieving

Sample ID	Wt. of Cont. (kg)	Wt. of Cont. + Soil (kg)	Wt. of Soil (kg)
Range 62/67 Composite	0.019	3.019	3.000

Table II. % Moisture of Soil Before Dry Sieving

Sample ID	wt. of empty pan (g)	wt. of wet soil (g)	wt. of cont. + wet soil (g)	Oven dry wt. + cont. (g)	Oven dry wt. (g)	% moisture
Range 62/67 Composite: Rep 1	0.9397	10.0003	10.9400	10.6243	9.6846	3.16
Range 62/67 Composite: Rep 2	0.9378	10.0010	10.9388	10.5871	9.6493	3.52
Range 62/67 Composite: Rep 3	0.9378	10.0007	10.9385	10.5767	9.6389	3.62

Table III. Mass of Soil in each Fraction (Dry)

Sieve Size (mm)	Wt. of Empty Pan (kg)	Dry Wt. + Pan (kg)	Dry Wt. (kg)
>6.7-3.35	0.011	1.191	1.181
>3.35	0.011	0.311	0.300
Total			1.481

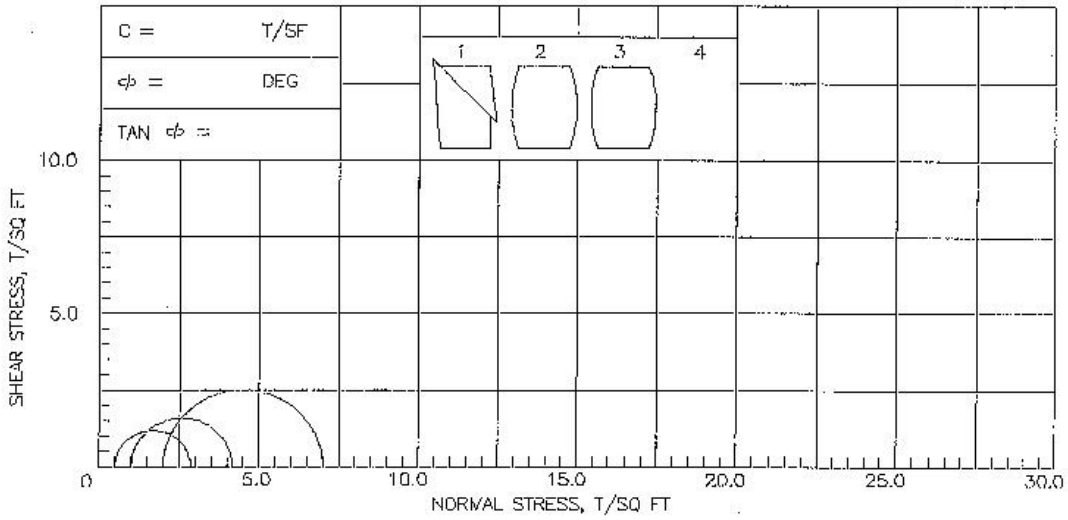
Table IV. Final Weight (<3.35mm)
Initial Mass of Soil Used for Wet Sieving

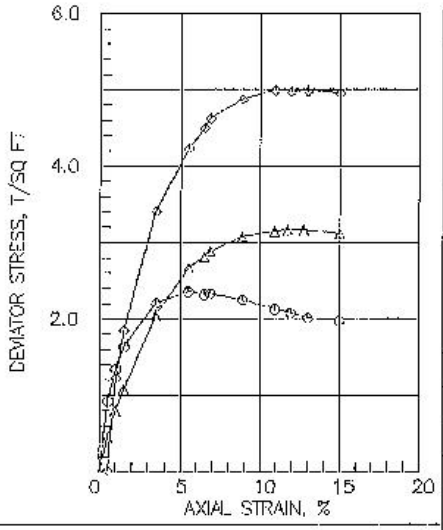
Wt. of Empty Cont. (kg)	Wt. of Pan + Soil (kg)	Wt. of Wet Soil (kg)	Dry Wt. (kg)
0.019	1.538	1.519	1.467

Table V. Mass of Soil in each Fraction (Wet)

Sieve Size (micron)	Wt. of Pan Cont. (kg)	Dry Wt. + Pan (kg)	Dry Wt. (kg)	Percentage
>1000 - 3.35	0.011	0.374	0.363	25.78%
>850 - 1000	0.011	0.060	0.050	3.52%
>500 - 850	0.011	0.231	0.220	15.61%
>250 - 500	0.011	0.230	0.219	15.54%
>125 - 250	0.011	0.129	0.119	8.42%
>63 - 125	0.011	0.141	0.130	9.26%
<63	0.010	0.318	0.308	21.87%
Total			1.408	100.00%

Attachment 3. Report on Compressive Strength Test.





SPECIMEN NO.		φ 1	Δ 2	φ 3	4
INITIAL	WATER CONTENT, %	16.2	15.8	15.4	
	DRY DENSITY, PCF	90.1	91.7	92.9	
	SATURATION, %	51.0	51.7	51.7	
	VOID RATIO	.850	.817	.794	
BEFORE SHEAR	WATER CONTENT, %				
	DRY DENSITY, PCF				
	SATURATION, %				
	VOID RATIO				
	BACK PRESSURE, TSF				
CHAMBER PRESSURE, TSF		.50	1.00	2.00	Ave.
MAX. DEV. STRESS, TSF		2.36	3.17	5.00	3.51
TIME TO FAILURE, MIN.		12	28	27	
STRAIN RATE INCR., %					
INITIAL DIAMETER, IN.		1.32	1.31	1.31	
INITIAL HEIGHT, IN.		3.00	3.00	3.00	

CONTROLLED—STRAIN TEST

DESCRIPTION OF SPECIMENS: SILTY SAND (SM), GRAY

LL	PL	PI	GS 2.67 (ESTIMATED)	UNDISTURBED SPECIMEN	Q TEST

REMARKS: 15% ASPHALT ; 5% WATER

PROJECT FT. LEWIS

BORING NO. SAMPLE NO.

DEPTH/ELEV TECH. JH

LABORATORY USAE WES -- STF/GL DATE 02 DEC 03

TRIAXIAL COMPRESSION TEST REPORT