CHAPTER 4 – PHYSICAL ANALYSIS

LABORATORY ANALYSIS

Source material from a nearby local stream wash was used as the select borrow for the roadway topping. Samples from three different locations at this borrow source were taken to determine its soil properties. The three samples were physically combined and tested as one sample. Based on laboratory analysis of particle size distribution, liquid limit and plasticity index, the soil type can be described a granular non-plastic material.

Classification Tests

The following test methods were performed to determine the characteristics of the borrow material:

- AASHTO T 11, Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregates
- AASHTO T 89, Determining the Liquid Limit of Soils
- AASHTO T 90, Determining the Plastic Limit and Plasticity Index of Soils
- AASHTO T 180, Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and 457-mm (18-in) Drop, Method D
- AASHTO T 190, Resistance R-Value and Expansion Pressure of Compacted Soils
- ASTM D 1883 Test Method for CBR (California Bearing Ratio) of Laboratory Compacted Soils

Classification systems

Two systems are routinely used to classify soil. Under the American Association of State Highway and Transportation Officials (AASHTO)(14) system, this borrow material classifies as an A-1-b group soil. Under the American Society for Testing and Materials (ASTM)(15) system, this borrow material classifies as a poorly graded sand, or SP. While there is some overlap in the classification definitions of these systems for the range of coarse to fine, and level plasticity, there is not a direct one-to-one correspondence. These classifications are discussed below in a general overview of the two classification systems.

AASHTO

AASHTO M 145, Classification of Soil-Aggregate Mixtures for Highway Construction Purposes, divides soils into the two major groups of granular materials and silt-clay materials. The granular materials are those soils with 35% or less passing the 75 µm (No. 200) sieve consisting of:

A-1-a – Well-graded coarser stone fragments, gravel, and sand; plasticity index maximum of 6,

A-1-b – Well-graded finer stone fragments, gravel, and sand; plasticity index maximum of 6,

A-2-4 – Silty or clayey gravel or sand with higher portions of silt, lower liquid limit, plasticity index maximum of 10,
A-2-5 – Silty or clayey gravel or sand with higher portions of silt, higher liquid limit, plasticity index maximum of 10,
A-2-6 – Silty or clayey gravel or sand with higher portions of clay, lower liquid limit, plasticity index maximum of 10,
A-2-7 – Silty or clayey gravel or sand with higher portions of clay, higher liquid limit, plasticity index maximum of 10, and
A-3 – Clean, poorly graded sands; non-plastic,

The silty-clayey materials are those soils with more than 35% passing the 75 µm (No. 200) sieve consisting of:

A-4 – Silty soils, lower liquid limit, plasticity index maximum of 10,
A-5 – Silty soils, higher liquid limit, plasticity index maximum of 10,
A-6 – Clayey soils, lower liquid limit, plasticity index maximum of 10, and
A-7 – Clayey soils, higher liquid limit, plasticity index maximum of 10.

ASTM

ASTM D 2487, Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), divides soils into three major groups of coarse-grained soils (sands and gravels, fine-grained soils (silts and clays), and highly organic soils (peat and other highly organic soils). The coarse-grained soils are those with 50% or less material passing the 75 µm (No. 200) sieve consisting of:

GW – Well-graded gravel,
GP – Poorly-graded gravel,
GM – Silty gravel,
GC – Clayey gravel,
SW – Well-graded sand,
SP – Poorly-graded sand,
SM – Silty sand, and
SC – Clayey sand.

The fine-grained soils are those with more than 50% passing the 75 µm (No. 200) sieve consisting of:

ML – Low liquid limit silt,
CL – Low liquid limit clay,
OL – Low liquid limit organic,
MP – Poorly graded silt,
CH – High liquid limit clay, and
OH – High liquid limit organic.

The highly organic soils are classed as

Pt – Peat.

Borderline instances can occur in these classifications when the material properties fall between the limits such that some soils can be classified for instance as:

GM-ML – Low liquid limit silty gravel,
SC-SM – Silty clayey sand, or
SP-SM – Poorly graded sand with silt.

Table 12 is a summary of the soil characteristics for the select borrow prior to placement and treatment.

Table 12. Untreated borrow soil samples.

Attribute		**Value**
AASHTO Soil Classification		A-1-b (0)
ASTM Soil Classification		SP
Optimum Moisture, %		6
Maximum Dry Density, pcf		129
Liquid Limit		NV
Plastic Limit		NP
R-Value		66
CBR @ 0.1 in penetration		32.6 (sample 1) 30.2 (sample 2)
Sieve Size, % Passing	**2-1/2 in**	100
	1-1/2 in	93
	1 in	87
	3/4 in	83
	1/2 in	77
	3/8 in	74
	No. 4	64
	No. 10	52
	No. 16	41
	No. 40	21
	No 100	8
	No. 200	4.4

In addition to sampling the borrow source, borrow material samples were also taken from each test section during the initial product application and from each test section at the 6-month evaluation. This was done to determine if any borrow material properties changed after it was processed and placed on the roadway. As discussed below, the evaluation team saw no significant variations.

Comparison of Data

Tables 13 and 14 summarize the soil characteristics at initial treatment and after 6-months, respectively. Some observations can be made concerning several of the parameters.

Soil Classification

No significant differences exist in the soil classification and grouping among the borrow stockpile results in Table 12, after initial treatment in Table 13, and after 6 months in Table 14. Under both systems the soils are placed into the same divisions described as coarse grained and granular materials, with AASHTO classified as A-1-b and ASTM classified as SW-SM and SP-SM.

Table 13. Borrow soil values after initial treatment.

Product	Test Section					
	I	II	III	IV	V	VI
	Mag/Lig	Caliber	Soil Sement	Permazyme	Terrazyme	Lignosulfonate
Field Sample Number	1b	2c	3b	4a	5c	6b
Milepost (within each section)	0.60	0.60	0.42	0.08	0.91	0.43
AASHTO Soil Classification	A-1-b (0)	A-1-b (0)	A-1-b (0)	A-1-b (0)	A-1-b (0)	A-1-b (0)
ASTM Soil Classification	SW-SM	SP-SM	SP-SM	SW-SM	SP-SM	SP-SM
Dry Density, pcf	AASHTO T 180 Method D = 131 pcf					
Moisture, %	10.5	11.0	10.4	11.0	7.0	10.0
Liquid Limit	NV	NV	NV	NV	NV	NV
Plastic Limit	NP	NP	NP	NP	NP	NP
R-Value	55	74	73	71	76	67
CBR, computed	5	14	10	11	7	10
Sieve Size	Gradation, % Passing					
3 in	100	100	100	100	100	100
2-$^1/_2$ in	100	100	98	100	100	100
1-$^1/_2$ in	97	96	92	98	93	93
1 in	93	92	87	94	87	89
$^3/_4$ in	90	87	82	89	84	85
$^1/_2$ in	86	81	77	84	79	79
$^3/_8$ in	82	76	73	79	75	76
No. 4	70	64	64	71	66	65
No. 10	57	52	50	56	53	53
No. 16	48	42	41	47	43	43
No. 40	30	23	24	29	25	24
No 100	17	11	12	16	13	12
No. 200	12	7.6	7.7	10	9	8.8

Table 14. Treated borrow soil values at 6-month evaluation.

Product	Test Section						
	I	II	III	IV	V	VI	VII
	Mag/Lig	Caliber	Soil Sement	Permazyme	Terrazyme	Lignosulfonate	Mag/Cl
Field Sample Number	1	2	3	4	5	6	7
Milepost (within each section)	0.60	0.60	0.42	0.08	0.91	0.43	1.00
AASHTO Soil Classification	A-1-b (0)	A-1-b (0)	A-1-b (0)	A-1-b (0)	A-1-b (0)	A-1-b (0)	A-1-b (0)
ASTM Soil Classification	SW-SM	SW-SM	SW-SM	SM	SP-SM	SW-SM	SP-SM
Dry Density, pcf	138	--	137	--	138	--	--
Moisture, %	6	--	6	--	6	--	--
Liquid Limit	NV	NV	NV	NV	NV	NV	NV
Plastic Limit	NP	NP	NP	NP	NP	NP	NP
R-Value	81	81	84	81	78	90	90
CBR @ 0.1-in Penetration	30.2	6.1	22.9	2.3	17.8	3.9	2.9
Sieve Size	Gradation, % Passing						
3 in	100	100	100	100	100	100	100
$2\text{-}^1/_2$ in	--	--	--	--	--	--	--
$1\text{-}^1/_2$ in	87	100	94	87	81	97	98
1 in	--	--	--	--	--	--	--
$^3/_4$ in	80	91	82	81	71	88	94
$^1/_2$ in	--	--	--	--	--	--	--
$^3/_8$ in	71	81	72	74	64	79	84
No. 4	62	70	63	66	56	69	75
No. 10	51	57	50	57	45	56	62
No. 16	--	--	--	--	--	--	--
No. 40	25	28	21	39	24	24	33
No 100	13	16	11	26	14	12	18
No. 200	9.4	10.9	7.6	19.3	9.6	7.8	11.2

Dry Density

The objective of the moisture-density test is to determine the maximum dry density and optimum moisture content for the soil. Granular soil is compacted with a standard amount of energy over a range of moisture contents to identify the optimum moisture content at which maximum dry density will be achieved.

In practice, highway and building fills must be compacted to attain appropriate strength and minimize settlement. The most common method of specifying compaction is to require a certain percent of the maximum that can be attained in proctor compaction tests, such as "90% of standard proctor" or “95% of modified proctor.”

The original moisture-density test was developed by R.R. Proctor and is commonly referred to as the Standard Proctor Test, Proctor Test, or Standard Moisture-Density Test. The Modified Proctor or Modified Moisture-Density Test is performed the same way but in a larger mold with higher compactive energy. Each of the 8 different variations of standard and modified proctor can produce different results. The project contract documents must specify which procedure is to be used.

A comparison of maximum dry densities of 2066 kg/m^3 (129 pcf) at the borrow source and 2098 kg/m^3 (131 pcf) after initial treatment could be considered minor and more attributed to gradation variations than to any effect of a stabilization product. Tests run at 6 months using samples from three of the test sections show an average maximum dry density of 2211 kg/m^3 (138 pcf). On the one hand, this may be due to a stabilizing effect of the products, but on the other it may just be a reflection of the randomness of the material.

Plasticity

All tests for plasticity on untreated and treated materials showed they were Non Plastic. This undoubtedly affected the rating and performance of the electrochemical enzymes products, that is, the Permazyme and Terrazyme used on Sections IV and V. These electrochemical products are formulated to perform and react with materials containing clay particles and are dependent on fine clay mineralogy to reach and achieve maximum performance for dust abatement and soil stabilization.

R-Value

The test for R-Value measures the resistance of the soil. This is one measure of soil strength where R = 0 would be a fluid and R = 100 an infinitely rigid solid. The untreated borrow material had an R-Value of 66. After initial treatment, R-Values for the 6 treated sections ranged from 55 to 76. After 6 months the range was 78 to 90. These values indicate a strong material that should structurally hold up well. Although not verified during subsequent events, the higher values obtained from samples taken after 6 months in the field suggest a stabilizing effect of the products. In hindsight, R-Values should probably have been measured on every monitoring event, but due to the labor intensive sampling and costs, it was decided not to further collect this information.

Laboratory CBRs

The California Bearing Ratio rates the strength of a material in terms of that of an excellent base course, which has a CBR of 100. Laboratory tests for CBRs were the most erratic of any of the tests on the Buenos Aires select topping material with results ranging from 2.3 to 32.6. These figures would indicate a very poor to a very good subgrade material. Probably the most important thing to note about this test is that it is not a field fest. Field samples are collected and taken back to the lab, broken up, compacted into molds, soaked, then penetrated to 0.1-inch be a piston. Any effects of the stabilization products on the material could likely be lost with the soaking process.

Starting with the second monitoring event at 12-months, an in situ strength test using a DCP was adopted. As will be shown, CBR values computed from this test show little resemblance to the laboratory CBRs.

Gradations

A comparison of the gradations between Tables 12, 13 and 14 indicate some differences, however these gradation differences are deemed minor and are probably more attributed to slight variations in the material's uniformity, sampling location, processing and sample time rather than any affect attributed to the stabilization product.

ON-SITE TESTING AND EVALUATION

In addition to the subjective visual inspection, nuclear density testing, dynamic cone penetrometer testing, soil stiffness and modulus testing, and silt load testing were performed during the monitoring events.

Nuclear Density Testing

Nuclear Density readings were taken only during the 6-month monitoring event to determine relative in-place material densities. Since the roadway did not display any visible evidence of soft or questionable subgrade, densities were not taken during subsequent visits. For each test section, a measurement for percent compaction was taken at a randomly selected location in both the 100 mm (4 in) depth and backscatter modes. These values are shown in Table 15.

AASHTO T 310 allows the in-place density and moisture content of soil to be performed using two methods. The backscatter or backscatter/air-gap method measure is more sensitive to the material at the surface because the source rod is never embedded into the material. The direct transmission method, however, requires the source rod to be lowered into a pre-driven hole in the materials to be tested. Density measurements with direct transmission are the preferred method.

The values for the backscatter mode for each measurement taken at the surface of the roadway were lower than the direct transmission. This was not unexpected as the thin layer of loose material on the surface in each section should naturally be less dense than the material underneath. This phenomenon is routinely observed on soil and aggregate surfaces, so the evaluation team felt no concern that the data from direct transmission mode was higher than from the backscatter mode.

Table 15. In-place density by nuclear method at 6-month evaluation.

Test Section	Product	Milepost (within test section)	Nuclear In-place Density/Compaction (%)	
			@ 4" depth	Back Scatter
I	**Mag/Lig**	0.60	104	96
II	**Caliber**	0.60	101	93
III	**Soil Sement**	0.42	99	89
IV	**Permazyme**	0.08	94	69
V	**Terrazyme**	0.91	95	87
VI	**Lignosulfonate**	0.43	94	69
VII	**Mag/Cl**	1.00	96	74

Note that on Sections I and II values for in-place densities greater than 100% were achieved. A value for in-place density of a material should not be greater than 100% of its maximum dry density. An explanation for these high compaction values is that nuclear test results can be affected by natural variation in material uniformity, such as the presence of large rock, or the chemical composition of the soil.

Using a calculated maximum dry density of 2098 kg/m3 (131 pcf) from the original borrow source material, the sections varied in nuclear density from 94% to 104% in the direct transmission mode. This was consistent with the original construction quality control that ensured the material was compacted to at least 90% of the maximum dry density.

There may be merit in the argument that nuclear density tests should have been taken for all remaining monitoring events to measure the stabilizing effect of each product over time. The evaluation team felt however, that if there were any loss of stability evident as a decrease in density, it would also be exhibited in the attributes of raveling, washboarding, potholing, and dust. Other than confirming that each section was properly constructed, no other conclusions are drawn from these test results.

Dynamic Cone Penetrometer (DCP) Testing

A Dynamic Cone Penetrometer (DCP) as shown in Figure 18 was used to evaluate the in situ strength of the treated soils. The evaluation team added this test procedure after the 6-month monitoring event. The DCP strength values were then used to estimate the California Bearing Ratio (CBR) or shear strength of the treated roadway material throughout its depth.

Calculations of CBR measurements at two or three locations in each of the sections are shown in the Appendix A, Tables 21, 22, and 23. Each table represents a different monitoring event. The

Figure 18. Photo. Dynamic cone penetrometer testing.

values from each event are summarized as one averaged CBR number in Table 16, and are plotted in Figure 19. No DCP measurements were taken in the Mag/Cl Section VII.

While the ASTM D 6951 procedure for the DCP recommends recording the depths of penetration every 10 hammer blows, the evaluation team used a modified method. Since the roadway was consistently treated to a depth of 150 mm (6 in), the total blows to penetrate to this depth were recorded. The overall average blows per inch were used to calculate the average CBR for the treated depth.

The CBR values showed some variation over time for each product. Some product's values consistently increased, some consistently decreased, and some went both up and down. These variations can be partly explained as a result of different sampling locations with slightly varying material compositions and compactions.

Interestingly enough, the two products with the highest CBR values also had the highest nuclear density readings. But while the Soil Sement had lower CBR values, it too had a higher nuclear density. So while it is tempting to correlate the two measures, in reality with an $R^2 = 0.31$, it is really quite weak.

Table 16. Dynamic cone penetrometer derived CBR values summary

Test Section	Product	12-Month CBR Mean	18-Month CBR Mean	24-Month CBR Mean	Mean of CBR Means	Normalized Rank[1]
I	**Mag/Lig**	79	93	87	86	86
II	**Caliber**	95	78	89	87	87
III	**Soil Sement**	49	50	61	53	53
IV	**Permazyme**	77	69	60	69	69
V	**Terrazyme**	59	53	58	57	57
VI	**Lignosulfonate**	62	70	84	72	72

1-Normalized Rank is the same as CBR value since its scale is already from 0 to 100.

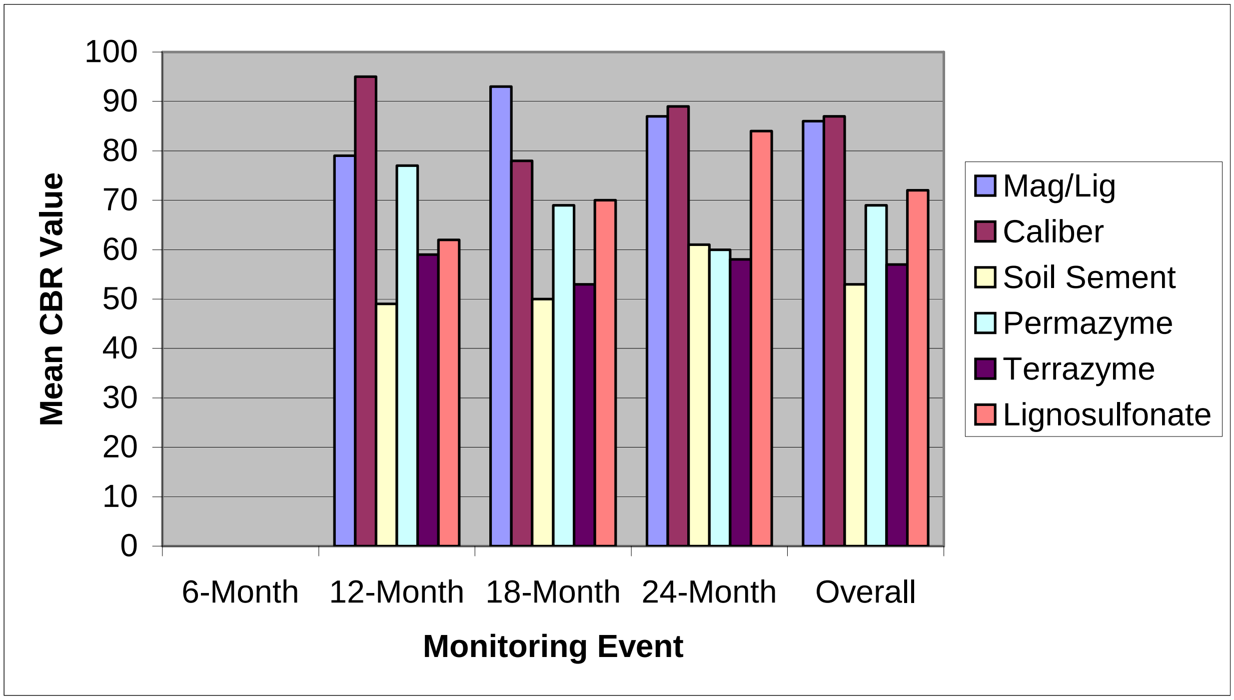

Figure 19. Plot. Dynamic cone penetrometer testing.

The evaluation team had hoped to see clear trends in the DCP data that showed how each product either maintained its stability over time, or more likely indicated a lessening of effectiveness. Unfortunately, the lack of a consistent trend in the overall data makes it difficult to draw conclusions about each specific product's performance over time. However, one observation that can be made is that the Caliber and Mag/Lig products consistently produced higher CBR values, while the Soil Sement and Terrazyme had the lowest. Even so, all CBR values were within a good to excellent range.

Soil Stiffness and Soil Modulus Testing

Soil stiffness and soil modulus testing were performed during the 12-month monitoring event using a Humboldt H-4140 GeoGage. This method was not originally part of the overall monitoring plan, but was included because one of the product suppliers offered their Samitron (GeoGage) Acoustic Soil Modulus Tester for a one-time evaluation. This test procedure is formalized under ASTM D 6758.

The GeoGage as shown in Figure 20 is a non-nuclear non-destructive acoustic device that measures stiffness and modulus throughout the depth of a section rather than at discrete depths. The gauge generates a series of varying frequency impedance, or mechanical vibrations, which produce small changes in force that induce small deflections of the surface. The response measurements are then recorded as stiffness and modulus. Both stiffness and modulus values are produced for each single test and are related to each other mathematically. The GeoGage's stiffness and soil modulus can be related to soil density, thus providing a quality control method for construction. Because the GeoGage data can be related to density, it is tempting to compare

Figure 20. Photo. Soil modulus testing device.

the relative standings of the products using GeoGage and Nuclear Gage results. Though little correlation exists, it must be acknowledged that far too little data from this project is available to study any correlation of these instruments.

The soil stiffness is a material's resistance to deflection. More specifically, stiffness is a structural property defined as the ratio of a change of force to a corresponding change in translational deflection of an elastic element, that is, a layer's resistance to deflection. The modulus (Young/Resilient modulus) is a material's resistance to change in shape in the direction of stress. It is the ratio of the increase in stress on a test specimen to the resulting increase in strain under constant traverse stress limited to materials having a linear stress-strain relationship over a range of loading. It is also called the elastic modulus.

Two GeoGage Soil Stiffness measurements were taken in each of the test sections and averaged as shown in Table 17. Only the soil modulus numbers results are included in this report. The higher the value the stiffer is the material.

Table 17. Modulus of soils by GeoGage method at 12-month evaluation.

Test Section	Product	GeoGage Reading – Soil Modulus			Normalized Rank[1]
		0.20 mi.	0.80 mi.	Mean	
I	Mag/Lig	10.41	15.85	13.13	92.4
II	Caliber	24.89	17.17	21.03	95.2
III	Soil Sement	11.80	10.96	11.38	91.2
IV	Permazyme	17.88	11.60	14.74	93.2
V	Terrazyme	10.53	10.92	10.73	90.7
VI	Lignosulfonate	18.19	16.06	17.13	94.2
VII	Mag/Cl	11.57	11.58	11.58	91.4

1-Normalized Rank = 100 - [(1 / Modulus Mean) x 100]

The products with the highest values and therefore the stiffest material were the Caliber, followed by the Lignosulfonate. The Permazyme and the Mag/Lig were next with similar but lesser stiffness values. The remaining three products with the lowest values were in the third group. While the Caliber had the highest values under this test method, just as it did for the nuclear density, DCP, and silt loading, the order of the remaining products' was different. The Lignosulfonate, for instance, showed the second highest GeoGage values, whereas it was in the middle to lower ranges for the other parameters. Please note that since under this one-time use of the GeoGage, no ASTM D 698 *Laboratory Compaction Characteristics of Soil Using*

Standard Effort correlations were established, the values are reported as measured relative to each other, and not referenced to an absolute value.

Figure 21. Photo. Silt load sampling.

Silt Load Testing

The evaluation team had initially identified only a visual monitoring system. However once monitoring began, several additional physical tests were proposed to be part of the monitoring process. The Silt Load Test was added to the system at the 12-month monitoring event. This test method from Title 40 of the Code of Federal Regulations [(16)] can be found in Appendix B. Under this method, silt is defined as material that passes the 75 µm (No. 200) sieve. The Silt Load test method is used to determine the amount of minus 75 µm (No. 200) on the surface of the road, which then can be correlated to the generation of airborne dust particles. Loose roadway materials are swept from the surface as shown in Figure 21 creating a 0.3 m (1ft) wide swath across each wheel path. The percentage of minus 75 µm (No. 200) is then computed from the total material volume collected from this area.

Under this method, for an aggregate surfaced road to be considered stabilized, the silt loading, that is the weight of silt per unit area, must be less than 0.1 kg/m^2 (0.33 oz/ft^2), or where the silt loading is greater than or equal to this limit, the silt content should not exceed six percent for unpaved road surfaces or eight percent for unpaved parking lot surfaces. Calculations of the Silt Load measurements at two locations in each of the sections are shown in the Appendix C, Tables 24, 25, and 26. These values are summarized as one average Silt Load value in Table 18, and are plotted in Figure 22.

Table 18. Silt load value summary.

		Ounces of -No. 200 / ft^2				Normalized Rank[1]
Test Section	**Product**	**12-Month Mean**	**18-Month Mean**	**24-Month Mean**	**Mean of Means**	
I	**Mag/Lig**	1.19	0.30	0.32	0.60	91.3
II	**Caliber**	0.44	0.14	0.44	0.34	95.1
III	**Soil Sement**	0.76	0.94	1.81	1.17	83.1
IV	**Permazyme**	1.77	1.14	2.81	1.91	72.4
V	**Terrazyme**	0.59	0.99	1.40	0.99	85.7
VI	**Lignosulfonate**	0.98	0.68	1.32	0.99	85.7
VII	**Mag/Cl**	1.00	0.86	Not Sampled	0.93	86.6

1-Normalized Rank = 100 - [(Mean of Monthly Means / Σ of Mean Values) x 100]

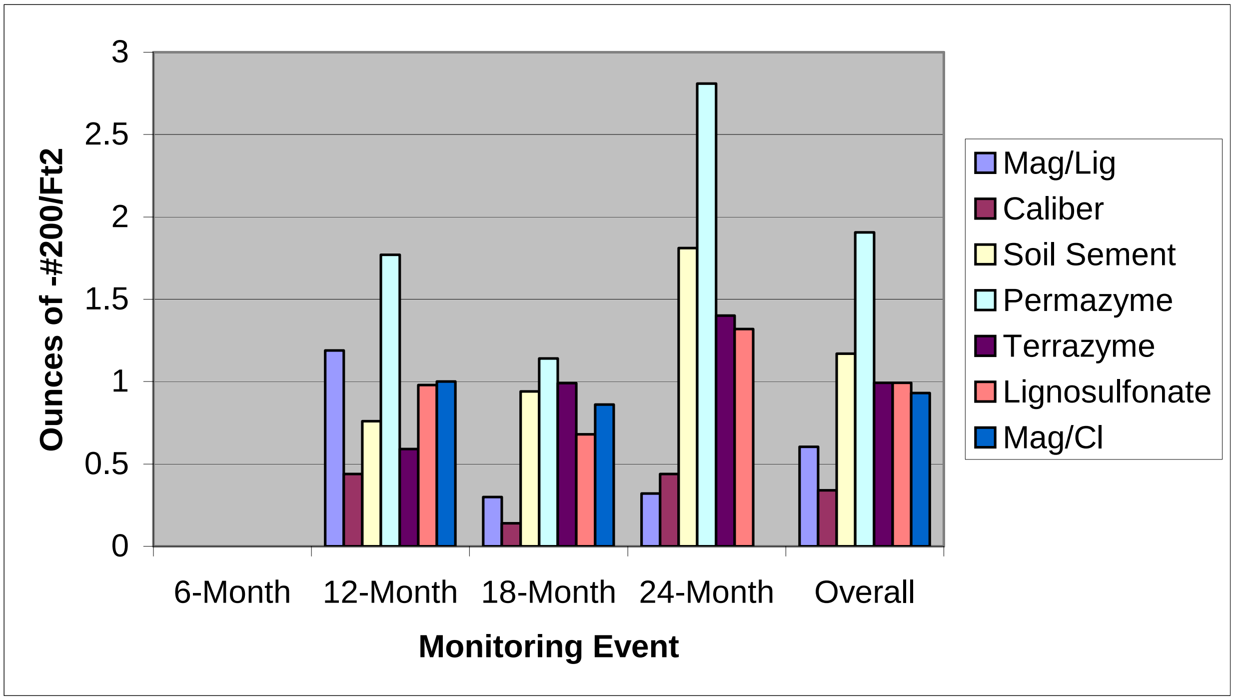

Figure 22. Plot. Silt Loading tests.

Once again three groups are evident based on the mean of the means. In the first group the products with the lowest silt loading value and therefore the least amount of material available for dust generation were the Caliber and the Mag/Lig. In the second group with somewhat higher silt loading values were the Soil Sement, Terrazyme, Lignosulfonate, and Mag/Cl. Only one product, Permazyme, was in the third group with the highest silt loading value. Unfortunately as indicated in Table 18, all of the products' mean of the means silt load values exceeded the maximum limit of 0.1 kg/m^2 (0.33 oz/ft^2) set for stabilized material according to the 40 CFR method.

It is interesting to note that the silt loading evaluations correspond to the subjective dust abatement observations noted in the previous chapter in Table 6 and Figure 9. There, the Caliber and the Mag/Lig were noted as producing the least dust, just as was measured with the silt loading test. And while all of the other products were included in the second subjective dust abatement group, a look at the actual overall average values shows that the Permazyme was the lowest of all, similar to the actual silt loading observations.

PHYSICAL ANALYSIS SUMMARY

The normalized rankings for DCP/CBR, Soil Stiffness, and Silt Loading are shown in Table 19 for each product. To arrive at an overall ranking of the products based on physical in situ tests, the three normalized rankings were averaged to show a single value.

From this average normalized rank for all physical parameters, three groups of product performance are evident. The first group's sole product, the Caliber, performed the best overall. Second to this were the Mag/Lig and Lignosulfonate products. The other products showed a fairly comparable relative performance in the third group. The order and rank of these objective physical evaluations correspond to the subjective visual evaluations noted in the previous chapter.

Table 19. Physical analysis normalized rank summary.

Test Section	Product	DCP/CBR	GeoGage Soil Stiffnes	Silt Loading	Physical Overall Normalized Rank
I	**Mag/Lig**	86	92.4	91.3	90
II	**Caliber**	87	95.2	95.1	92
III	**Soil Sement**	53	91.2	83.1	76
IV	**Permazyme**	69	93.2	72.4	78
V	**Terrazyme**	57	90.7	85.7	78
VI	**Lignosulfonate**	72	94.2	85.7	84
VII	**Mag/Cl**	N/A	91.4	86.6	89

As stated earlier, all products performed acceptably throughout this study. Therefore the conclusion to be drawn here is not that some products performed well and the others poorly, but that some products exhibited better performance than others.