CHAPTER 3 – LABORATORY ANALYSIS OF MATERIALS

TESTS FOR MATERIAL CHARACTERISTICS

The material attributes for the aggregate surfacing were determined using the test procedures shown in Table 3 at the end of Chapter 1. Results from untreated material samples taken from the stockpile shown in Figure 8 or from material delivered to one of the six project sections are shown in Table 4. Though most of the initial testing was done by the CFLHD Materials Laboratory, a commercial laboratory also performed tests on the untreated surfacing aggregate. Table 5 reports laboratory test results on the treated material after stabilizer products were applied. All the post-application testing was performed by a commercial laboratory. Observation and discussion of laboratory test results follows.

SOIL CLASSIFICATION

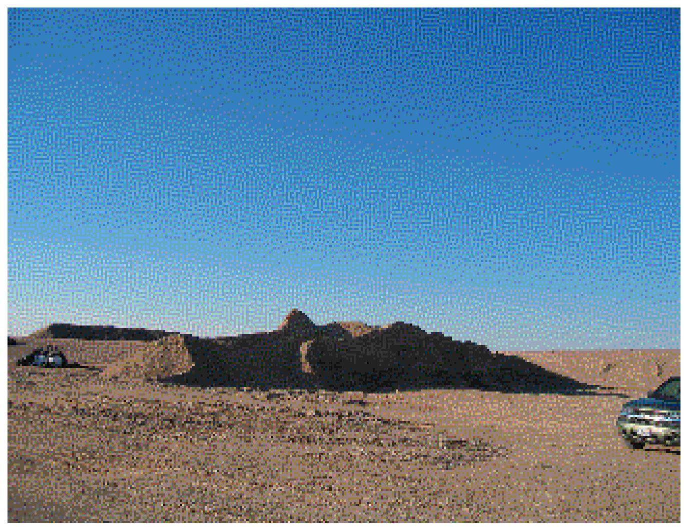

Figure 8. Photo. Materials stockpile at Seedskadee Pit.

The construction contract specified a surface course aggregate for the Seedskadee project. Test results of the sampled material show that the material was within the contract tolerances. Despite differences in plasticity that are discussed in the following subsection the soil classification results show only minor variations across the samples. As shown in Table 4, under the AASHTO M 145 classification system, the aggregate surfacing material was an A-1-b material defined as well-graded finer stone fragments, gravel, and sand with a plasticity index (PI) less than or equal to 6%. Under the ASTM D 2487 classification system, the aggregate surfacing material fell into three different classifications of course-grained soils: SP-SM (poorly graded sand with silt), SP-SC (poorly graded sand with clay), and SC-SM (silty clayey sand.) The monitoring team did not consider these ASTM classification differences to be significant.

In Table 5 that shows test results following application of the stabilizer products, the sieve analysis of Section II materials indicates 5% retained on the 19-mm (3/4-in) sieve. Though not shown in this table, the commercial lab actually reported nearly 4% retained on the 37.5-mm (1½-in) sieve. The presence of this larger sized material indicates that the contractor may have dug into the sub-grade when processing the materials during application in that section. However, this variation did not change that section’s soil classification.

Table 4. Initial test results on aggregate surfacing material.

Laboratory Test	Surfacing Aggregate	Stockpile	Section III Sublot 7	Section IV Sublot 11	Section VI Sublot 1	Section VI Sublot 2	Section VI Sublot 3
Laboratory	Commercial	CFLHD	CFLHD	CFLHD	CFLHD	CFLHD	CFLHD
3/4 in sieve (% passing)	100	100	100	100	100	100	100
1/2 in sieve		90	92	92	90	92	91
3/8 in sieve	82	82	85	85	83	84	85
#4	67	66	69	70	67	67	69
#8		55	58	59	56	57	60
#10	54	53	56	57	54	55	58
#20	44						
#30		38	41	42	39	40	42
#40	32	33	35	35	33	33	36
#50		28	28	28	27	26	29
#60	23						
#100	16						
#200	11.6	11	12.2	12.7	11.7	11.9	12.5
Liquid Limit	NP	21	21	22	21	21	21
Plasticity Index	NP	4	4	4	4	4	4
AASHTO Classification		A-1-b	A-1-b	A-1-b	A-1-b	A-1-b	A-1-b
ASTM Classification	SP-SM	SP-SM	SP-SC	SC-SM	SP-SC	SP-SC	SC-SM
Optimum Moisture Content (%)		6					
Maximum Dry Density (pcf)		138					
CBR @ 0.1 inches	17						
CBR @ 0.2 inches	15						
R-value	62						
Organic Matter Content (%)		0.4					
Moisture Content, Method A (%)		1					

Table 5. Test results following application of the stabilizer products.

Laboratory Test	Section I TerraZyme	Section II Lignosulfonate	Section III PermaZyme	Section IV Soil Sement	Section V Caliber	Section VI Mag/Lig
Laboratory	Commercial	Commercial	Commercial	Commercial	Commercial	Commercial
3/4 in sieve (% passing)	100	95	100	100	100	100
3/8 in sieve	82	82	84	83	85	83
#4	67	66	67	68	70	69
#10	54	54	54	54	57	56
#20	43	43	43	42	46	45
#40	31	32	30	31	32	32
#60	22	24	21	21	22	22
#100	15	17	14	14	15	15
#200	10.3	12.5	9.3	9.6	10.2	10.6
Liquid Limit	NP	20	NP	NP	NP	NP
Plastic Limit	NP	14	NP	NP	NP	NP
Plasticity Index	NP	6	NP	NP	NP	NP
AASHTO Classification	A-1-b	A-1-b	A-1-b	A-1-b	A-1-b	A-1-b
ASTM Classification	SP-SM	SC-SM	SP-SM	SP-SM	SP-SM	SP-SM
Optimum Moisture Content (%)		5.3			5.2	
Maximum Dry Density (pcf)		141			140.7	
CBR @ 0.1 inches	15	16	20	18	16	15
CBR @ 0.2 inches	15	14	17	19	17	13
R-value	76	42	78	81	72	64

PLASTICITY

The material was sampled before and after treatment as shown in Figure 9. The test results in Table 4 above for the untreated material show that a commercial laboratory determined the material was non-plastic (NP), whereas the CFLHD laboratory found it to have a plasticity index (PI) of 4%. Since the contract specified a PI target value of 8% plus or minus 4%, the CFLHD laboratory test results were used to initially determine that the material met the specifications.

Figure 9. Photo. Collecting treated samples for laboratory testing.

The PI of a sample is the difference in test results for liquid limit (LL) and plastic limit (PL). The LL signifies the percent of moisture at which the sample changes, with a decrease in moisture, from a liquid state to a plastic state. The PL is the percentage of moisture at which the sample changes, with a further decrease in moisture, from a plastic to a semisolid state. The PI, in percent water content, is the range of plasticity of the material.

All test procedure results have an inherent variability introduced by material, equipment, and operators, and this precision is identified for the LL in AASHTO T 89 and the PL in AASHTO T 90. For materials having a liquid limit range from 21 to 67, the repeatability of results for a single operator on the same sample, in the same laboratory, using the same equipment, on different days, should not vary by more than 7% of the average. The reproducibility between different laboratories should not vary by more than 13% of the average. Similarly for materials having a plastic limit range from 15 to 32, the single operator repeatability should not exceed 10%, and the different laboratories reproducibility should not exceed 18%. AASHTO however, does not discuss how these precision statements contribute to the calculation of the PI. Conceivably, if one laboratory erred within the allowable precision on the high side of the LL and the low side of the PL, potentially the reported PI could have a variation as much as 17%. Similarly, different laboratory result comparisons could have a variation as much as 31%.

For this project, when the material was noted to be plastic, the LL and the PL varied from 20 to 22, and 14 to 17, respectively. As a result, the PI results for all the test results were low, ranging from NP to 6%. For instance, the Lignosulfonate-treated material in Section II tested by the commercial laboratory reported in Table 5, showed a PI of 6% whereas the other sections' samples tested NP. In hindsight, even though some of the LL and PL values fell outside AASHTO's ranges by just one point, it should have raised concerns that the material test results were indicating that the overall PI may not have been what was wanted. Also, applying an interpretation of the AASHTO precision statements to estimate a higher potential PI still does not resolve concerns over those test results shown as NP.

Therefore, this low or lack of plasticity of the surfacing material at Seedskadee may have been significant in how some classes of stabilizer products performed. Specifically, the enzyme products – that is the TerraZyme and PermaZyme used on Sections I and III – were formulated to react with materials containing clay particles and are dependent on fine clay mineralogy to achieve maximum performance for dust abatement and soil stabilization. For these products, there must be both sufficient fines with material passing the 75-µm (No. 200) sieve and sufficient plasticity; that is, clay rather than silt fines.

MAXIMUM DRY DENSITY

Tests to determine the optimum moisture at which the material could be compacted to its greatest density were performed on initial samples taken from the stockpile of aggregate surfacing material. From this testing, the target values of 6% moisture and 2,220 kg/m^3 (138 lb/ft^3) maximum dry density were determined. Subsequent laboratory test results shown in Table 5 following application of the stabilizer products showed that the maximum dry density that could be achieved was 2270 kg/m^3 (141 lb/ft^3) at 5.3% moisture. In other words, the addition of stabilizer products did not significantly change compaction characteristics.

In-place density readings, using a nuclear device, were taken 3 to 4 weeks after completion of the project and showed that all sections were compacted to at least 95% of the maximum dry density target. No additional nuclear density testing was performed during the two years of monitoring.

CALIFORNIA BEARING RATIO (CBR)

The construction contract did not require the CBR test; rather the test was performed to establish a base line for the monitoring activities. To determine a laboratory CBR, the sample with the maximum dry density, while still in its compacting mold, was soaked in water for four days. Then a cylindrical piston was forced into the confined specimen to 2.5-mm (0.1-in) and 5.0-mm (0.2-in) depths while load-deformation data was collected. By definition, the CBR is the ratio of the load carried by the test specimen to the load carried by an excellent crushed rock base course multiplied by 100. Unfortunately, CBRs depend on a lot of factors like quality of compaction, moisture content, and amount of fines so they can be quite variable.

For the Seedskadee surfacing aggregate, laboratory CBR results ranged from 15 to 20. A comparison of the initial CBR values on untreated material, as shown in Table 4, to those following application of stabilizer products, as shown in Table 5, showed little change. The stabilization products apparently did not have any effect on the CBRs as tested in the laboratory. The monitoring team decided that the laboratory CBR test would not be done again during monitoring because it was not an in-situ test. The Dynamic Cone Penetrometer test was performed instead throughout the two years of monitoring and the results were converted to in situ CBR values.

R-VALUE

The R-value, generally defined as the resistance of the material to deformation, gives a general indication of the quality of a material. There is generally less test variability with the R-values than with CBR values. R-values can range from 0, the resistance of a fluid, to 100 that would be the resistance of an infinitely rigid solid. All R-value tests on the Seedskadee material were done by the commercial laboratory. The R-value test was performed to establish a baseline for monitoring rather than for contract acceptance, and likewise the test was not repeated during the monitoring period because of the desire to use in situ tests.

A high laboratory CBR and high laboratory R-value would be ideal and indicative that rutting would not be a problem. For Seedskadee, the overall values were not ideal - laboratory CBR values were low and R-values were quite high – yet rutting was not noted as a problem. The stockpile material had an R-value of 62, while the samples from treated sections were generally a little higher. The Lignosulfonate section was an exception with a lower R-value of 42. The Soil Sement section appeared to gain the most immediate strength with an R-value of 81. Results of monitoring for rutting in Chapters 5 and 6 show that actual product performance used with the Seedskadee material was more accurately indicated by the R-value.

LOSS ON IGNITION TEST FOR ORGANIC CONTENT

In the past, some enzymes have been produced as organic and others as inorganic enzymes. To work effectively, they were formulated to either react with organic matter inherent in the clay particles, or they could externally supply organics to form a protective layer around the clay particle. The FHWA report, *Dust Control on Low Volume Roads*[8] notes that most of the common enzymes are based on a bacterial culture, and that the bacteria when exposed to air produce large organic molecules that are absorbed by the clay particle lattice.

In an attempt to explain the performance of the enzymes used in this study, the monitoring team performed the ASTM D 2974 Loss on Ignition test to estimate the level of organics in the material, even though it was not conducted on the previous Buenos Aires NWR study. Results of this test showed the material had an organic content of 0.4%, which was considered to be a value of virtually none, and substantially met the contract requirement that the material be free of organic content.

The evaluation team could find no manufacture statements for the two enzyme products to indicate that an initial organic level was necessary to optimize their performance. Therefore they concluded that the lower ranking of the enzymes' performance was due to a lack of PI in the material rather than a lack of available organics.