Large-Scale Laboratory Testing of Geosynthetics in Roadway Applications

Second Task Report: Testing Setup and Planning

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1 Introduction

This task report describes activities related to Task 2 of the project proposal. Task 2 involves the acquisition of and material tests on the subgrade soil, the base course aggregate, the hot-mix asphalt (HMA) and the two geotextiles. At the time this report was submitted, certain tests on HMA materials were on-going or scheduled to be completed. As such, this report has been submitted in draft form. The final draft will be submitted once the HMA test data is available.

2 Pavement Materials

2.1 Hot-Mix Asphalt

In this project, test sections constructed in South Carolina (SC) will be paved with HMA locally produced. MDT is interested in test sections using materials that are either identical to or have similar performance characteristics of typical materials used in Montana. To have confidence that the SC HMA performs similarly to typical Montana mixes and to account for any differences that may exist, testing of both MT and SC mixes was performed.

Three MT HMA mixes from different state DOT districts were selected. Three projects from Ashland, Bozeman and Great Falls were selected. Volumetric data was obtained from MDT from gyratory compaction tests for these mixes and is summarized in Table 2-1.

Table 2-1: Volumetric data for 3 MT HMA mixes

Mix Name	Ashland	Bridger Canyon	Great Falls
Binder PG grade	64-28	64-28	64-28
Asphalt Content (%)	5.09	5.30	5.36
Rice Specific Gravity (G_{mm})	2.46	2.44	2.42
Bulk Specific Gravity (G_{mb})	2.36	2.39	2.35
Air Voids (%)	3.99	2.46	3.00
VMA	13.7	13.8	13.8
VFA	71	82	79

Bulk material was sent to NCAT where dynamic modulus testing was performed. Bulk material was re-heated and compacted to a target air voids content of 7 +/- 0.5 %. Three samples for each mix were prepared and tested. Table 2-2 provides volumetric data for the specimens compacted at NCAT for dynamic modulus testing. Dynamic modulus testing uses 3 to 4 frequencies of loading and three test temperatures. The complex modulus (E*) is determined for each combination of load frequency and temperature. Figure 2-1, Figure 2-2 and Figure 2-3 show values of E* from these tests.

Table 2-2: Volumetric data MT HMA mixes compacted at NCAT

Mix ID	Sample	Air Voids, %	P_b	G_{mm}	G_{mb}	VMA	VFA
Ashland	1	7.3	5.1	2.455	2.276	16.7	56.2
Ashland	2	7.4	5.1	2.455	2.273	16.8	55.8
Ashland	3	7.1	5.1	2.455	2.281	16.5	56.9
Bridger Canyon	1	7.2	5.3	2.440	2.264	17.7	59.4
Bridger Canyon	2	7.4	5.3	2.440	2.259	17.9	58.7
Bridger Canyon	3	7.5	5.3	2.440	2.257	18.0	58.4
Great Falls	1	6.7	5.4	2.420	2.258	17.1	60.8
Great Falls	2	6.5	5.4	2.420	2.263	16.9	61.5
Great Falls	3	7.4	5.4	2.420	2.241	17.7	58.2

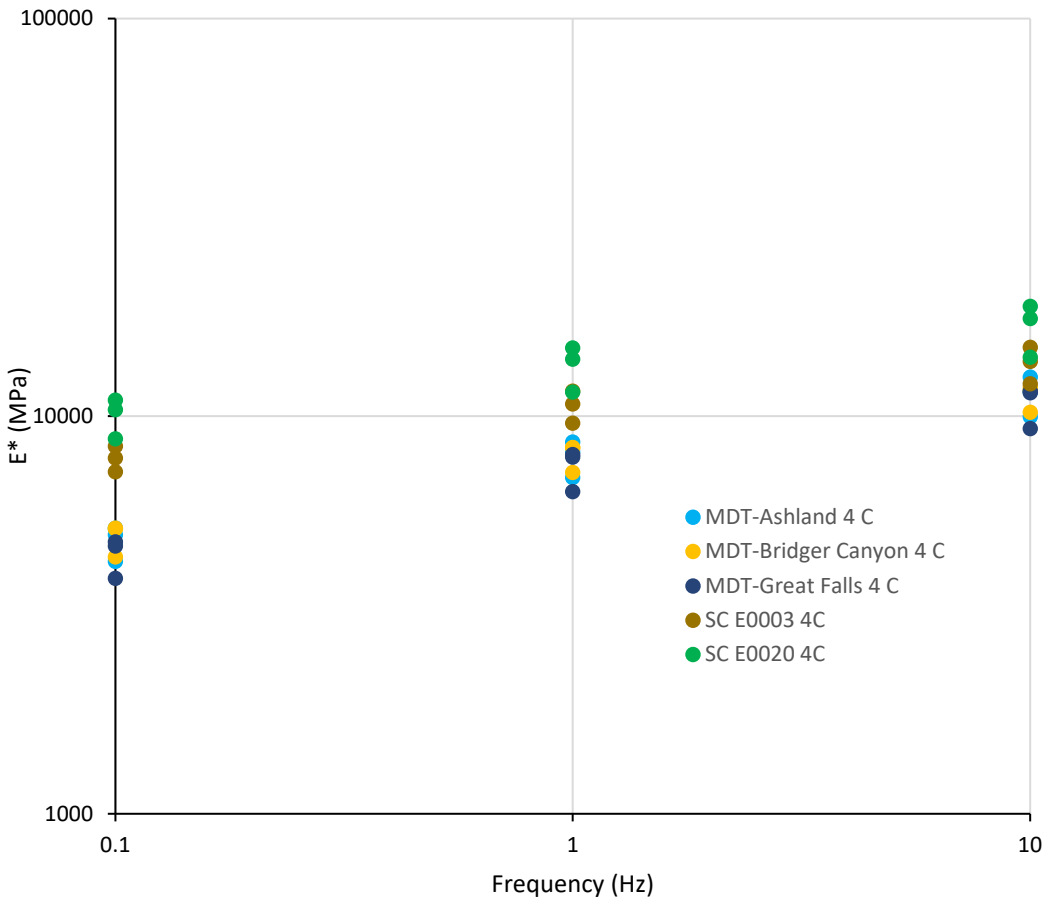

Figure 2-1: Dynamic complex modulus versus load frequency at a test temperature of 4°C for 3 MT mixes and 2 SC mixes.

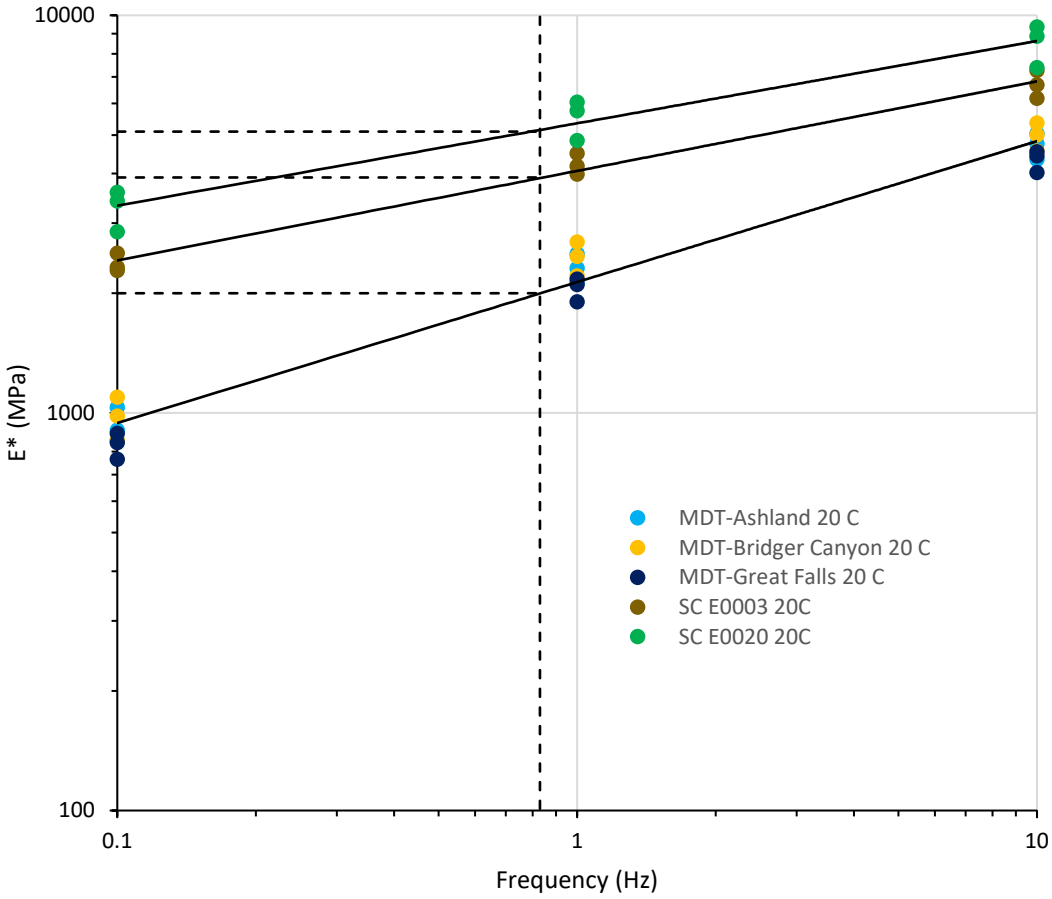

Figure 2-2: Dynamic complex modulus versus load frequency at a test temperature of 20°C for 3 MT mixes and 2 SC mixes.

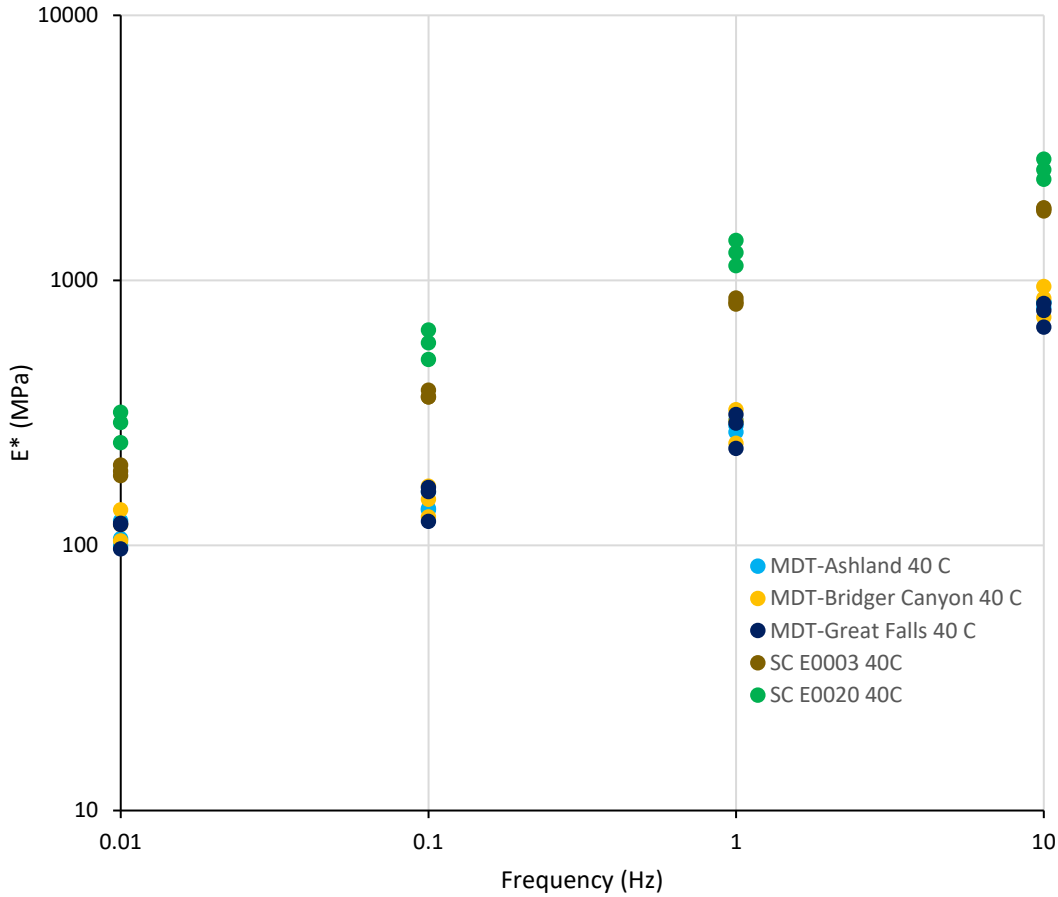

Figure 2-3: Dynamic complex modulus versus load frequency at a test temperature of 40°C for 3 MT mixes and 2 SC mixes.

Three HMA mixes were identified as potential sources in SC. All mixes used an asphalt binder with a PG 64-22 grade. Bulk material for two mixes were sent to NCAT for dynamic modulus testing. Volumetric data for gyratory compaction samples for these two mixes is given in Table 2-3. Values of E* are shown on Figure 2-1, Figure 2-2 and Figure 2-3.

Table 2-3: Volumetric data SC HMA mixes compacted at NCAT

Mix ID	Sample	Air Voids, %	P_b	G_{mm}	G_{mb}	VMA	VFA
E0003	1	7.0	6.1	2.462	2.290	19.2	63.5
E0003	2	7.0	6.1	2.462	2.290	19.2	63.5
E0003	3	7.3	6.1	2.462	2.282	19.4	62.4
E0020	1	6.8	5.1	2.474	2.306	17.8	61.7
E0020	2	6.8	5.1	2.474	2.306	17.8	61.7
E0020	3	6.5	5.1	2.474	2.313	17.5	62.9

Six gyratory compaction pucks for each SC mix were prepared and sent to MDT for Hamburg testing. MDT has performed Hamburg tests on mix E0020 and it passed with little rutting. MDT plans to test the other two SC mixes once the Hamburg testing equipment is functional.

The data in Figure 2-1, Figure 2-2 and Figure 2-3 shows the two SC mixes to be more stiff than the MT mixes. Of interest is a comparison of E* values close to the test conditions in the accelerated test facility. This facility should operate close to room temperature, hence the data in Figure 2-2 is pertinent. It is generally agreed that a vehicle speed of 60 mph corresponds to a load frequency of 10 Hz. The accelerated test facility operates at a wheel speed of approximately 5 mph, corresponding to a load frequency of 0.83 Hz. A best fit line of E* values for all MT mixes and tests is shown in Figure 2-2. A best fit line through the test data for each SC mix is also shown in Figure 2-2. At a load frequency of 0.83 Hz, the best fit values of E* are 2000, 3910 and 5100 MPa for all MT mixes, SC E0003 and SC E0020, respectively.

Use of one of the two SC mixes requires the originally proposed test section thickness of 3.6 inch of HMA and 14.3 inch of base aggregate to be reduced to account for the greater HMA stiffness. The 1992 AASHTO Pavement Design Guide and structural thickness design equations together with input from the MDT Pavement Design Manual were used to analyze new pavement thickness using the two SC HMA mixes. The originally proposed cross section was analyzed using the AASHTO pavement design equation to calculate the number of ESAL's carried by the pavement. The following inputs were used in the equation: Reliability = 85 %, Standard Deviation = 0.45, Initial Serviceability = 4.2, Terminal Serviceability = 2.5, Subgrade Resilient Modulus = 4590 psi (corresponding to a CBR of 2.5), HMA Layer Coefficient = 0.41, and Base Aggregate Layer Coefficient = 0.14. The correlation chart for estimating resilient modulus of HMA surface course by Van Til et al. (1972) was used to estimate resilient modulus for a layer coefficient of 0.41. This value was multiplied by the ratio of the E* values reported above for the two SC mixes as compared to the MT mix to estimate resilient modulus values for the two SC mixes. These values were then used in the correlation chart to estimate layer coefficient. Values of 0.54 and 0.57 were estimated for SC E0003 and SC E0020 mixes, respectively. These values were then used in the AASHTO pavement design equation with the HMA thickness set at 3 inch to estimate the base layer thickness to yield the same number of ESAL's as the original cross section. Values of base thickness of 13.3 and 12.6 were obtained for SC E0003 and SC E0020 mixes, respectively.

MDT would prefer to use the less stiff SC HMA mix (E0003), however Hamburg tests are currently available only for the E0020 mix. The top of the subgrade in the test sections will be completed soon (by February 1, 2019). The elevation for the top of the subgrade has been chosen to produce a top of base course level with the top of the test pit walls when the SC E0020 mix is used (i.e. a base thickness of 12.6 inch). Should Hamburg tests on E0003 become available before the top of the base is reached, and the results pass, an additional 0.7 inch of base aggregate will be added to the test section and the SC E0003 mix will be used.

2.2 Base Course Aggregate

A base course aggregate meeting MDT specifications for a Type 7A was selected from the Brewer Pit near Forsyth, MT. Previous tests by MDT resulted in a specific gravity of coarse aggregate of 2.631 and a specific gravity of fine aggregate of 2.653. MDT performed the following tests on the source aggregate and reported the following:

LA Abrasion: 18 % loss

Micro-Deval: 5.5 % loss

R-Value: 73

TRI performed the following tests on the base aggregate material and reported the following:

Fines: Non-Plastic

USCS Soil Classification: SP

AASHTO Soil Classification: A-1-a

California Bearing Ratio (CBR): 100 at 95 % Modified Proctor Maximum Dry Density

Modified Proctor Maximum Dry Density: 21.5 kN/m^3

Modified Proctor Optimum Moisture Content: 7.7 %

Fractured Face (one or more) Percentage: 65 %

Data sheets for the above tests and a grain size distribution curve are given in Appendix A.

2.3 Subgrade Soil

MDT performed an R-value test and reported a value of 23.5 at an exudation pressure of 2.07 MPa (300 psi).

TRI performed the following tests on the subgrade material and reported the following:

Liquid Limit: 40 %

Plastic Limit: 25 %

Plasticity Index: 15 %

Percent Passing # 200 Sieve: 75.5 %

USCS Soil Classification: CL

AASHTO Soil Classification: A-6

Standard Proctor Maximum Dry Density: 15.9 kN/m^3

Standard Proctor Optimum Moisture Content: 18.6 %

Modified Proctor Maximum Dry Density: 17.4 kN/m^3

Modified Proctor Optimum Moisture Content: 17.0 %

Data sheets for the above tests and a grain size distribution curve are given in Appendix A.

TRI performed a series of tests to establish a relationship between subgrade water content, subgrade CBR and undrained shear strength as measured with a hand-held vane shear device. Standard laboratory CBR tests were performed on the subgrade prepared to various water contents. These tests were performed as unsoaked tests. Vane shear tests were performed for each sample prepared. Figure 2-4 shows the variation of CBR and undrained shear strength with water content of the samples prepared. This data shows that the subgrade should be prepared to a water content of 25.4 % to reach the target subgrade CBR of 2.5. An undrained shear strength from the hand-held vane would be expected to yield a value of 94 kPa at this water content.

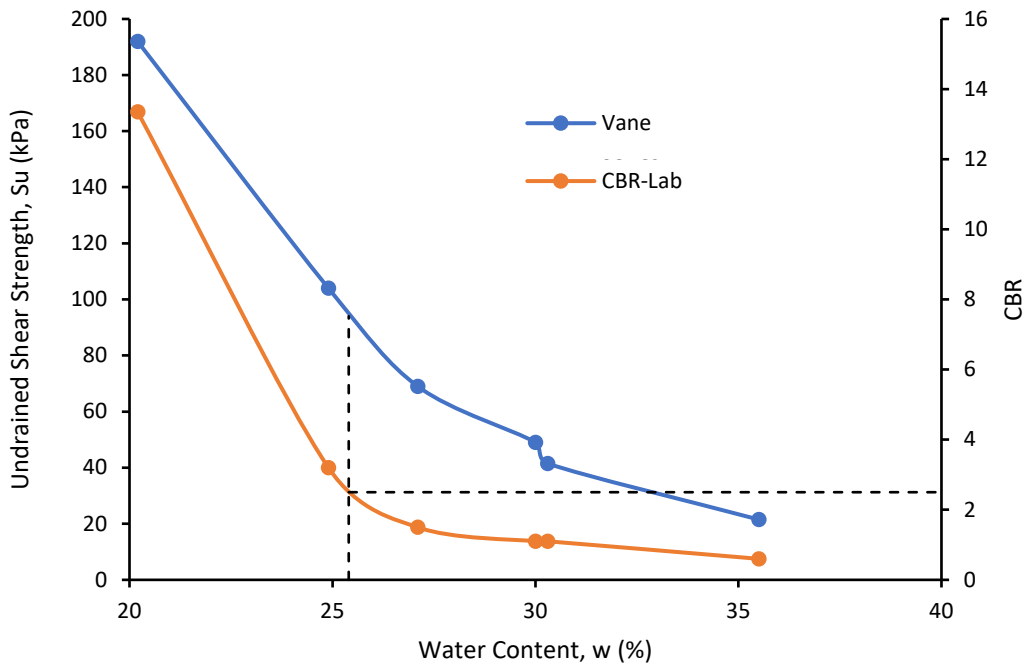

Figure 2-4: Subgrade soil water content versus CBR and undrained shear strength from laboratory CBR tests.

Additional tests were performed by TRI to verify the subgrade water content, subgrade CBR and undrained shear strength relationships shown in Figure 2-4 for compaction conditions more similar to those that will occur in the test pit facility. These tests consisted of preparing four batches of subgrade soil mixed to four different values of water content. Each batch was placed in a plastic-lined wooden frame measuring 99 cm x 99 cm x 14 cm and compacted with a jumping jack compactor. A plastic-lined wooden lid was then placed over the frame. The frame was then flipped over and the wooden bottom removed to expose the smooth side of the clay sample. Field CBR tests were performed on the specimens at times from compaction of 6 hours, 6 days and 41 days. At each time, three CBR tests were performed on each of the four soil

batches. Six vane shear tests were performed around each CBR location. A large water content sample was taken within each CBR and vane shear test area.

Figure 2-5 shows water content versus CBR and undrained shear strength for the tests performed. Trend lines are plotted through the data for the 6 day and 41 day tests. For a given water content, the CBR results show more variability than the vane shear tests. CBR and undrained shear strength increase with time from compaction. This data suggests that if a subgrade CBR of 2.5 is desired at the time of initiation of traffic loading and if this time is 41 days, then the subgrade should be prepared at a water content of 27.2 % and where an undrained shear strength of 60 kPa would be expected at the time of compaction.

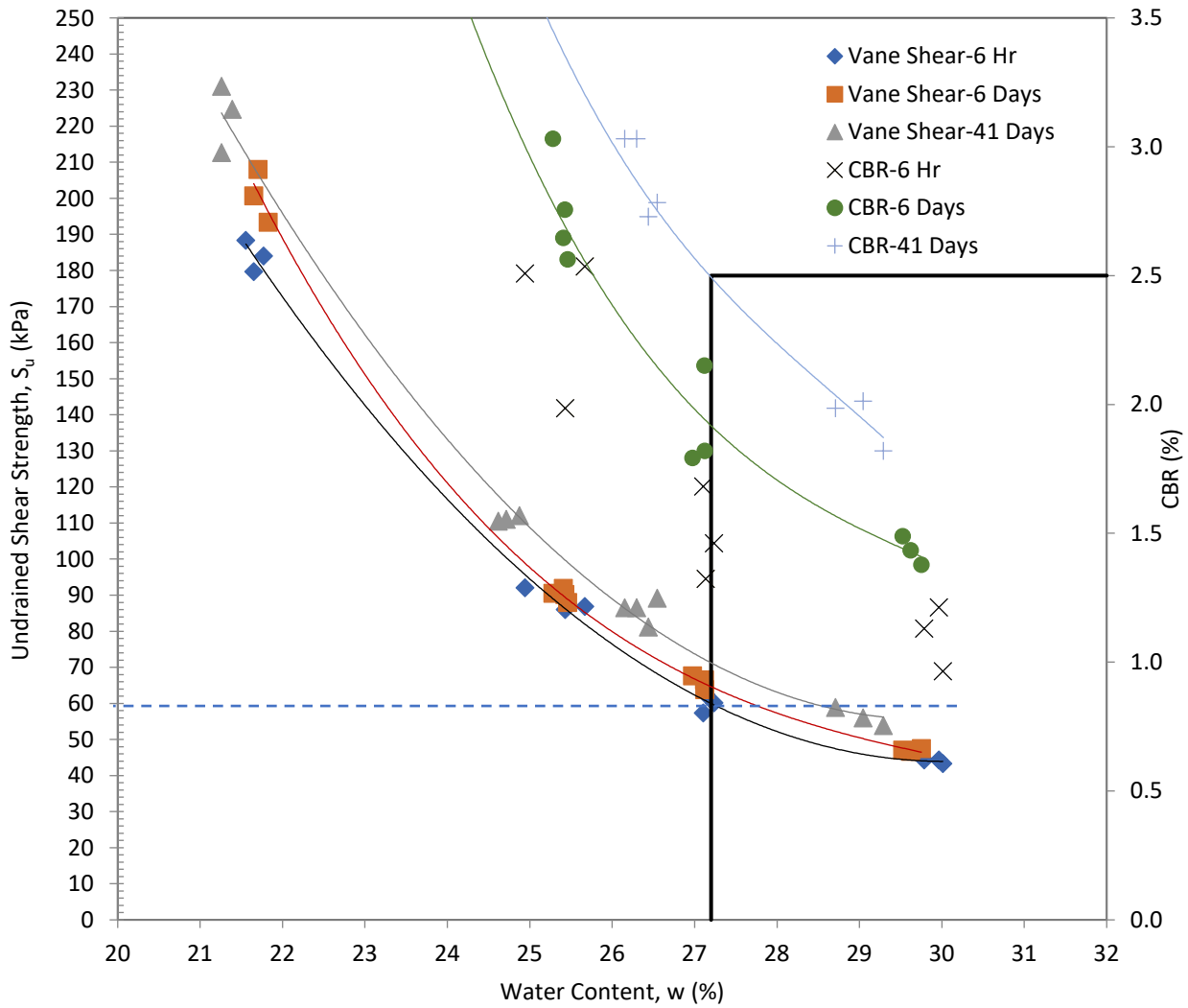

Figure 2-5: Subgrade soil water content versus CBR and undrained shear strength from box frame tests.

TRI recently completed stationary plate load tests using a rectangular test tank containing the same subgrade discussed above and prepared to a water content ranging from 26.8 to 28.1 %.

Hand-held vane tests were performed as the subgrade was placed. The subgrade was covered with 300 mm of compacted gravel and 50 mm of HMA. Approximately 50 days after completion of subgrade placement, the test section was exhumed and additional vane shear and water content tests were made in the top of the subgrade. In contrast to the results shown in Figure 2-5, undrained shear strength did not increase over this elapsed time and in fact decreased by approximately 5 kPa. Figure 2-6 shows data presented in both Figure 2-4 and Figure 2-5 along with the additional data points from the test tank measurements described above. The post test measurement produces the lowest value of undrained shear strength for the "test tank" values plotted.

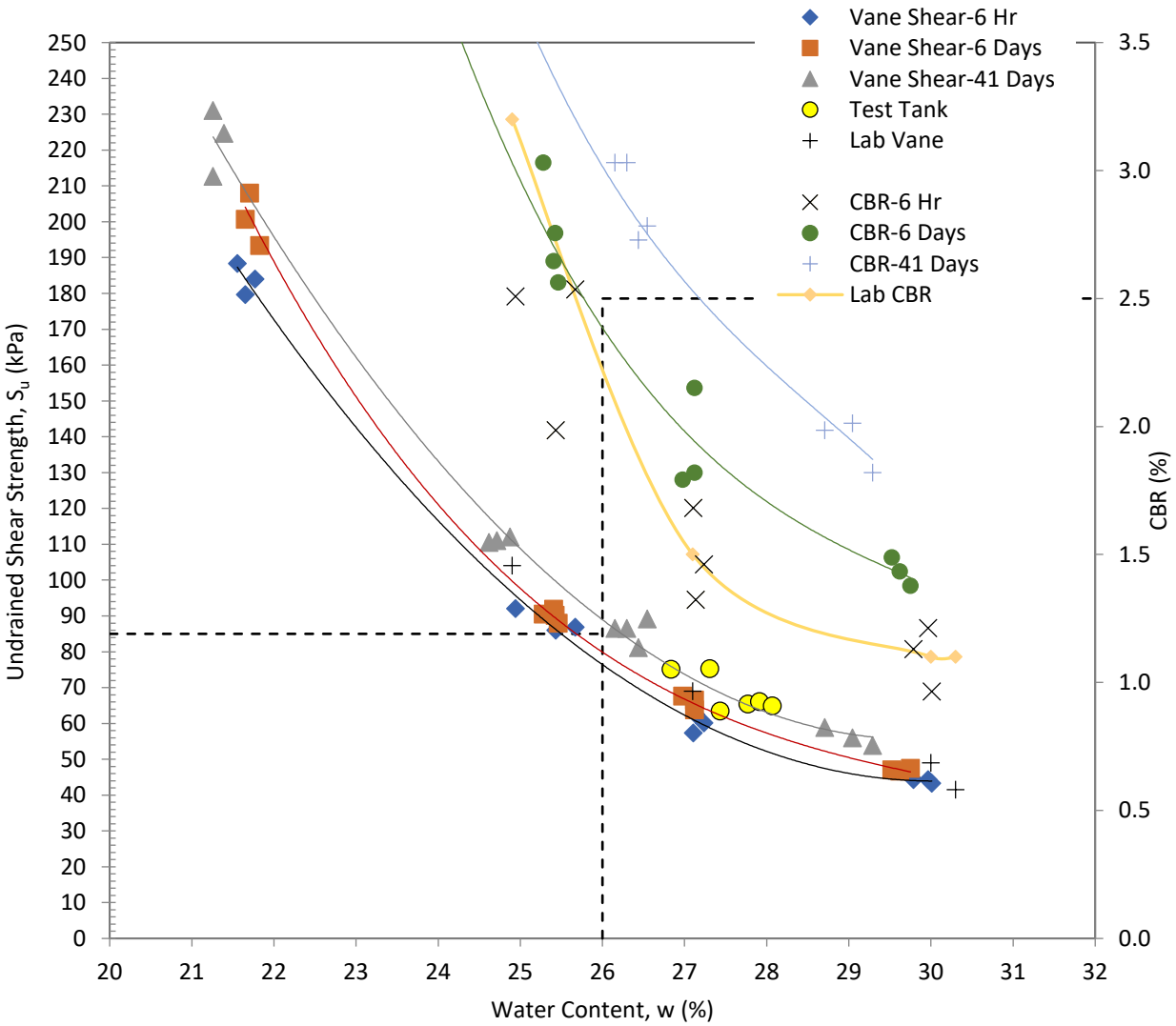

Figure 2-6: Subgrade soil water content versus CBR and undrained shear strength for all tests performed.

Several observations are made from Figure 2-6. While the box frame tests tend to show a trend of increasing undrained shear strength with time following compaction, the lab CBR tests and

the measurements made in the test tank do not appear to support this finding. The three sets of data appear to represent a data scatter band representing variability of the measurements made. The box frame tests show a significant increase in CBR with time following compaction. There is some doubt regarding whether this is due to clay thixotropy or is more due to drying of the clay surface where the CBR tests were performed.

Conflicting data from the tests described above led to a pragmatic approach to selecting a subgrade water content target value for compaction in the test facility in order to minimize the risk of having a subgrade that is too weak to represent typical conditions experienced by MDT and having a subgrade that is too strong such that sufficient rutting is not achieved and a clear distinction between test sections becomes difficult to make. The approach best suited to minimize these risks is believed to choose a subgrade water content target of 26 %. As shown on Figure 2-6, this is expected to produce an undrained shear strength from hand-held vane tests of 85 kPa and a subgrade CBR of as low as 2.0 immediately following compaction. Should clay thixotropy occur, the subgrade CBR may increase to a value of 3.0 over the interval of time needed to complete the test sections and begin trafficking. This approach is supported by data shown in Figure 2-7 where undrained shear strength from hand-held vane tests is plotted against subgrade CBR for the box frame tests and the lab CBR tests. A target water content of 26 % yielding a clay with an undrained shear strength of 85 kPa appears to strike a balance between the competing risks of having a subgrade that is too weak versus one that is too strong.

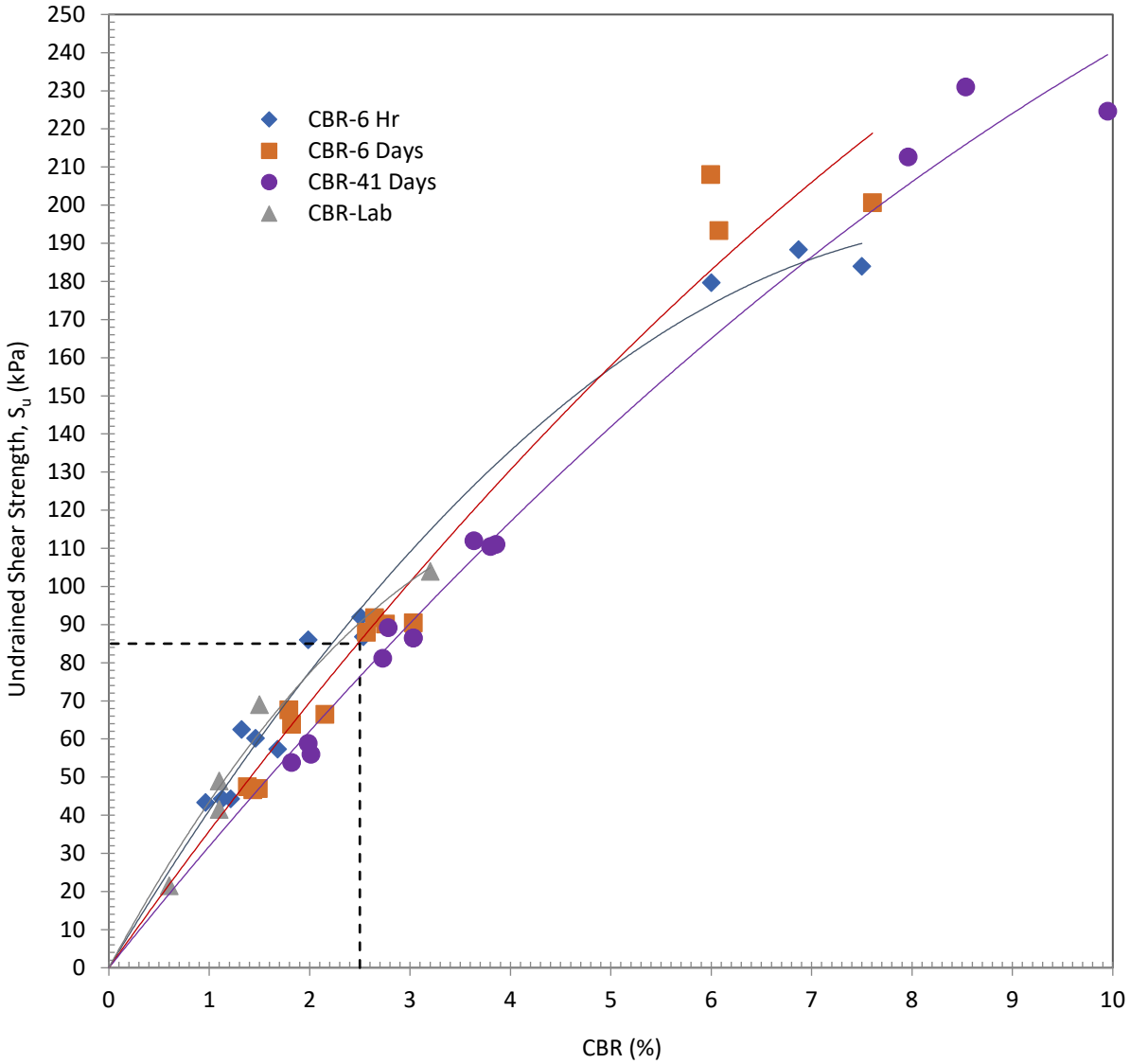

Figure 2-7: Subgrade undrained shear strength versus CBR from box frame and lab CBR tests.

Data collected during compaction of the subgrade in the test facility will be processed real-time to reevaluate the approach described above and changes will be made accordingly.

2.4 Geotextiles

Propex Geotex 801 and Mirafi RS280i are the two geotextiles being used in this project. Geotex 801 is a nonwoven geotextile while RS280i is a woven product. Wide width tension tests (ASTM D4595) were performed on both materials. Grab strength tests (ASTM D4632) were performed on the Geotex 801 product. Results from these tests are summarized in Table 2-4. Test data sheets for these tests are contained in Appendix A.

Table 2-4: Wide-width tension and grab tension properties for Geotex 801 and RS280i Geotextiles

Test	Property	Geotex 801	RS280i
Grab Tensile	Tensile strength, MD (kN)	0.97	NP
	Tensile strength, XMD (kN)	0.99	NP
Wide-Width Tension	Ultimate strength, MD (kN/m)	14.8	65.8
	Ultimate strength, XMD (kN/m)	18.1	50.5
	Strength at 2 % strain, MD (kN/m)	0.52	13.9
	Strength at 2 % strain, XMD (kN/m)	0.43	15.5
	Strength at 5 % strain, MD (kN/m)	1.25	31.0
	Strength at 5 % strain, XMD (kN/m)	1.00	32.0
	Strength at 10 % strain, MD (kN/m)	2.35	58.8
	Strength at 10 % strain, XMD (kN/m)	2.01	49.2

NP: Test Not Performed

3 References

AASHTO (1993). *AASHTO Guide for Design of Pavement Structures*. American Association of State Highway and Transportation Officials, Washington, DC.

ASTM D4595. *Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method*, American Society of Testing and Materials, West Conshohocken, PA, USA.

ASTM D4632. *Standard Test Method for Grab Breaking Load and Elongation of Geotextiles*, American Society of Testing and Materials, West Conshohocken, PA, USA

Montana Department of Transportation (2016). *Pavement Design Manual*, Helena, Montana.

Van Til, C.J., McCullough, B.F., Vallerga, B.A., and Hicks, R.G. (1972). *Evaluation of AASHO Interim Guides for Design of Pavement Structures*, NCHRP 128, Highway Research Board, Washington, D.C.

4 Appendix A: Material Testing Data Sheets

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Project: TRI Environmental, Inc
Date: 11/19/2018
Sample ID: Dynamic Modulus

Project Notes

Specimens for testing were compacted at NCAT from re-heated plant-produced mix provided by the client
Three specimens for each mix were prepared and tested in accordance with AASHTO R83-17 to a target of 7.0 +/- 0.5 percent air voids
Volumetric properties (Gmm, AC%, Gsb) required to calculate the specimen VMA and VFA were provided by the client
Testing was performed in accordance with AASHTO T378-17 with the testing conditions recommended in AASHTO R84-17
Dynamic Modulus Testing Temperatures were 4, 20, and 40°C
Specimens were tested at 10, 1, and 0.1 Hz loading frequencies at all temperatures
The 0.01 Hz loading frequency was only used at the high temperature
Analysis was performed using the Mastersolver.exe program
Dynamic Modulus testing provides a characterization of the stiffness and visco-elastic properties of the mixture across a wide range of temperatures and loading conditions

Results Summary

A summary of the specimens volumetrics is provided in Table 1
The individual specimen results for the individual mixes are provided in Tables 2, 3, and 4
The mastercurve coefficients are provided in Table 4 while the mastercurve plots are shown in Figure 1
Visual inspection of the mastercurves showed the three test mixtures to have very similar Dynamic Modulus results

Table 1: Individual Specimen Volumetrics

Mix ID	*Sample ID*	*Sample Air Voids, %*	*QC Gsb*	*QC Pb*	*Gmm*	*Gmb*	*VMA*	*VFA*
Test 20 (Ashland)	5	7.3	2.592	5.1	2.455	2.276	16.7	56.2
Test 20 (Ashland)	6	7.4	2.592	5.1	2.455	2.273	16.8	55.8
Test 20 (Ashland)	7	7.1	2.592	5.1	2.455	2.281	16.5	56.9
Bridger Canyon	4	7.2	2.607	5.3	2.440	2.264	17.7	59.4
Bridger Canyon	5	7.4	2.607	5.3	2.440	2.259	17.9	58.7
Bridger Canyon	6	7.5	2.607	5.3	2.440	2.257	18.0	58.4
Great Falls	9	6.7	2.577	5.4	2.420	2.258	17.1	60.8
Great Falls	10	6.5	2.577	5.4	2.420	2.263	16.9	61.5
Great Falls	11	7.4	2.577	5.4	2.420	2.241	17.7	58.2

Table 2: Individual Specimen Data - Test 20 (Ashland)

Conditions		*Specimen 1*		*Specimen 2*		*Specimen 3*	
Temperature	*Frequency*	*E**	*Phase Angle*	*E**	*Phase Angle*	*E**	*Phase Angle*
°C	*Hz*	*Ksi*	*deg*	*Ksi*	*deg*	*Ksi*	*deg*
4	0.1	729.7	23.4	625.8	24.7	758.8	24.2
4	1	1,180.5	17.0	1,016.3	18.2	1,248.8	17.8
4	10	1,670.7	12.1	1,447.3	13.1	1,821.7	12.7
20	0.1	131.4	34.9	123.9	34.2	149.7	33.7
20	1	335.5	32.3	308.5	32.0	364.8	31.6
20	10	689.7	25.9	629.6	26.2	732.2	25.7
40	0.01	14.5	12.7	15.4	9.1	18.0	10.3
40	0.1	20.0	21.9	19.8	19.3	23.2	19.7
40	1	41.1	32.2	38.9	29.8	43.2	29.9
40	10	120.3	36.7	114.7	34.9	120.1	35.0

Table 3: Individual Specimen Data - Bridger Canyon

Conditions		*Specimen 1*		*Specimen 2*		*Specimen 3*	
Temperature	*Frequency*	*E**	*Phase Angle*	*E**	*Phase Angle*	*E**	*Phase Angle*
°C	*Hz*	*Ksi*	*deg*	*Ksi*	*deg*	*Ksi*	*deg*
4	0.1	759.3	24.0	755.6	23.2	642.7	24.4
4	1	1,211.2	17.2	1,207.9	16.8	1,047.9	17.8
4	10	1,684.2	12.0	1,711.6	12.0	1,485.9	12.8
20	0.1	159.0	33.4	142.4	33.7	123.8	34.2
20	1	390.6	30.8	359.3	31.1	320.7	31.9
20	10	777.8	24.9	726.1	25.1	661.1	25.9
40	0.01	19.8	10.7	17.4	10.8	15.1	10.1
40	0.1	24.3	20.5	21.7	20.8	18.6	20.1
40	1	47.2	31.2	42.8	30.9	35.3	31.8
40	10	137.5	35.5	124.2	35.5	105.5	36.7

Table 4: Individual Specimen Data - Great Falls

Conditions		*Specimen 1*		*Specimen 2*		*Specimen 3*	
Temperature	*Frequency*	*E**	*Phase Angle*	*E**	*Phase Angle*	*E**	*Phase Angle*
°C	*Hz*	*Ksi*	*deg*	*Ksi*	*deg*	*Ksi*	*deg*
4	0.1	701.0	24.2	684.1	24.1	567.2	26.2
4	1	1,163.1	18.0	1,144.9	18.2	937.7	19.6
4	10	1,676.5	13.0	1,661.1	13.3	1,351.5	14.0
20	0.1	122.2	32.0	129.0	32.8	110.9	33.2
20	1	305.0	31.3	315.0	31.7	276.2	32.6
20	10	642.8	26.5	658.3	26.5	583.5	27.3
40	0.01	17.6	14.1	17.4	15.9	14.1	15.3
40	0.1	23.2	20.6	24.0	23.1	17.9	23.6
40	1	42.0	29.0	45.3	30.8	33.7	32.5
40	10	111.7	34.1	118.9	35.3	96.8	36.7

Table 5: Mastercurve Coefficients

Mix ID	*Max E* (Ksi)*	*Min E* (Ksi)*	*Beta*	*Gamma*	*EA*	*R^2*	*Se/Sy*
Test 20 (Ashland)	3,187.9	6.51	-0.524	-0.579	195,848	0.993	0.06
Bridger Canyon	3,141.9	7.22	-0.528	-0.590	196,118	0.989	0.07
Great Falls	3,181.4	7.28	-0.426	-0.578	194,600	0.994	0.05

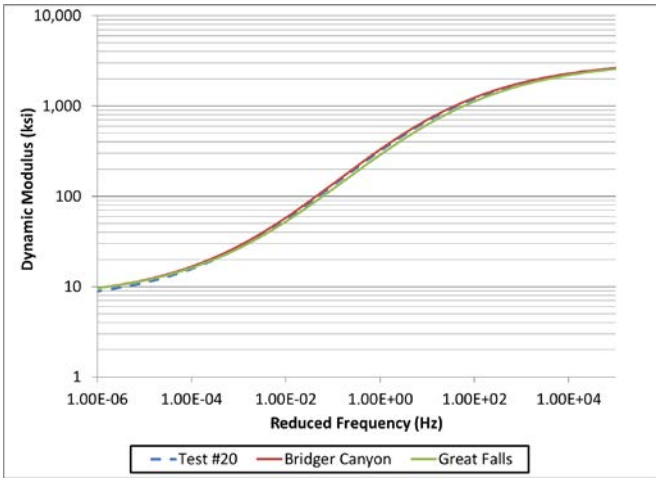

Figure 1: E* Mastercurve Comparison

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

Project: TRI Environmetal, Inc
Date: 12/14/2018
Sample ID: Dynamic Modulus

Project Notes

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Three specimens for each mix were prepared and tested in accordance with AASHTO R83-17 to a target of 7.0 +/- 0.5 percent air voids
Volumetric properties (Gmm, AC%, Gsb) required to calculate the specimen VMA and VFA were provided by the client
Testing was performed in accordance with AASHTO T378-17 with the testing conditions recommended in AASHTO R84-17
Dynamic Modulus Testing Temperatures were 4, 20, and 40°C
Specimens were tested at 10, 1, and 0.1 Hz loading frequencies at all temperatures
The 0.01 Hz loading frequency was only used at the high temperature
Analysis was performed using the Mastersolver.exe program
Dynamic Modulus testing provides a characterization of the stiffness and visco-elastic properties of the mixture across a wide range of temperatures and loading conditions

Results Summary

A summary of the specimens volumetrics is provided in Table 1
The individual specimen results for the individual mixes are provided in Tables 2 and 3
The mastercurve coefficients are provided in Table 3 while the mastercurve plots are shown in Figure 1
Visual inspection of the mastercurves showed the E0020 mixture to be stiffer than the E0003 mixture across the full range of temperatures and frequencies

Table 1: Individual Specimen Volumetrics

Mix ID	*Sample ID*	*Sample Air Voids, %*	*QC Gsb*	*QC Pb*	*Gmm*	*Gmb*	*VMA*	*VFA*
E0003	2	7.0	2.660	6.1	2.462	2.290	19.2	63.5
E0003	3	7.0	2.660	6.1	2.462	2.290	19.2	63.5
E0003	4	7.3	2.660	6.1	2.462	2.282	19.4	62.4
E0020	3	6.8	2.660	5.1	2.474	2.306	17.8	61.7
E0020	4	6.8	2.660	5.1	2.474	2.306	17.8	61.7
E0020	5	6.5	2.660	5.1	2.474	2.313	17.5	62.9

Table 2: Individual Specimen Data - Mix E0003

Conditions		*Specimen 1*		*Specimen 2*		*Specimen 3*	
Temperature	*Frequency*	*E**	*Phase Angle*	*E**	*Phase Angle*	*E**	*Phase Angle*
°C	*Hz*	*Ksi*	*deg*	*Ksi*	*deg*	*Ksi*	*deg*
[redacted]							
4	0.1	1,139.4	15.1	1,052.0	14.5	1,219.2	15.0
4	1	1,556.8	11.7	1,394.8	11.3	1,676.3	11.7
4	10	1,991.7	9.2	1,752.3	9.2	2,163.7	9.2
20	0.1	337.5	28.2	331.0	27.7	365.8	27.7
20	1	606.4	23.2	579.0	22.8	652.5	22.8
20	10	969.4	18.2	897.9	17.8	1,054.9	17.9
40	0.01	26.6	22.6	27.7	22.6	29.2	22.4
40	0.1	52.7	29.2	52.8	28.3	55.9	28.6
40	1	120.4	31.8	118.3	30.9	124.4	31.4
40	10	269.9	30.8	265.3	30.4	273.1	30.5

Table 3: Individual Specimen Data - Mix E0020

Conditions		*Specimen 1*		*Specimen 2*		*Specimen 3*	
Temperature	*Frequency*	*E**	*Phase Angle*	*E**	*Phase Angle*	*E**	*Phase Angle*
°C	*Hz*	*Ksi*	*deg*	*Ksi*	*deg*	*Ksi*	*deg*
[redacted]							
4	0.1	1,272.1	13.3	1,592.1	14.2	1,505.5	13.6
4	1	1,667.2	10.3	2,155.0	11.0	2,020.7	10.6
4	10	2,043.4	8.3	2,741.1	8.6	2,555.1	8.4
20	0.1	414.4	26.5	520.3	26.1	495.4	25.7
20	1	703.1	21.4	877.6	21.3	834.5	20.8
20	10	1,071.5	16.7	1,356.0	17.0	1,285.2	16.4
40	0.01	35.5	23.8	46.2	23.7	42.2	24.8
40	0.1	73.1	29.1	94.4	28.6	84.4	29.4
40	1	164.9	30.6	205.2	29.8	184.8	30.5
40	10	349.8	28.8	416.0	28.0	380.1	28.6

Table 3: Mastercurve Coefficients

Mix ID	*Max E* (Ksi)*	*Min E* (Ksi)*	*Beta*	*Gamma*	*EA*	R^2	*Se/Sy*
E0003	3,097.1	3.07	-1.208	-0.449	211,662	0.999	0.03
E0020	3,168.6	6.68	-1.313	-0.498	207,849	0.997	0.04

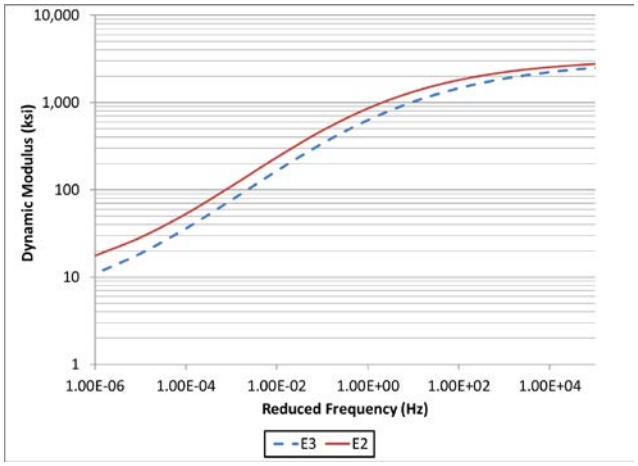


Figure 1: E* Mastercurve Comparison

Form No: TR-C136-1
Revision No. 2
Revision Date: 7/27/17

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

ASTM C 136, C 117

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	1426-16-063 Phase 900	Report Date:	8/07/18
Project Name:	TRI/Environmental - General Laboratory Testing	Test Date(s):	8/03 - 8/07/18
Client Name:	TRI/Environmental		
Client Address:	P.O. Box 9192 Greenville, SC 29604		
Location: Montana 7A	Log #: 77g	Sample Date:	July 2018

Sample Description: Montana 7A Stone [A-1-a]

Tare No.	**145**	Tare Wt.	**0.000**	Mass of Sample after Wash + Tare Wt.	**11.339**
Total Sample Dry Wt. + Tare Wt.			**11.763**	Mass of Sample after Wash	**11.339**
Total Sample Dry Weight			**11.763**	Mass passing #200	**0.424**
Check for 0.3% Mass correspondence			**0.02%**	% Passing #200 **(C117)**	**3.6%**

Sieve Size		Retained Weight	Increment Mass	% Retained Between Sieves	Cumulative Total Sample		SPECS
	mm.	*Cumulative*	*individual*		% Retained	% Passing	
2.0"	50.00	0.000	0.0	0.0%	0.0%	**100.0%**	
1.5"	37.50	0.000	0.0	0.0%	0.0%	**100.0%**	
1.0"	25.00	0.000	0.0	0.0%	0.0%	**100.0%**	
3/4"	19.00	0.000	0.0	0.0%	0.0%	**100.0%**	
3/8"	9.50	2.902	2.9	24.7%	24.7%	**75.3%**	
#4	4.75	5.598	2.7	22.9%	47.6%	**52.4%**	
#10	2.00	7.066	1.5	12.5%	60.1%	**39.9%**	
#40	0.425	8.299	1.2	10.5%	70.6%	**29.4%**	
#200	0.075	11.226	2.9	24.9%	95.4%	**4.6%**	
Pan	<0.075	11.337	*Sum =*	*95.4%*	% Passing #200 **(C136)** =		4.6%

	Maximum Particle Size	**19.00 mm**			

Notes / Deviations / References: ASTM C 117, C 136, C 702

Sieves selected from Tables 701-8 & 701-9 - Montana DOT Section 701 - Crushed Base Course Type "A" & Type "B".

Brian Vaughan, P.E.	Brian Vaughan	Group Leader	8/07/18
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D4318-T89-90
Revision No. 1
Revision Date: 7/26/17

LIQUID LIMIT, PLASTIC LIMIT, & PLASTIC INDEX

ASTM D 4318 ☐ AASHTO T 89 ☒ AASHTO T 90 ☒

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

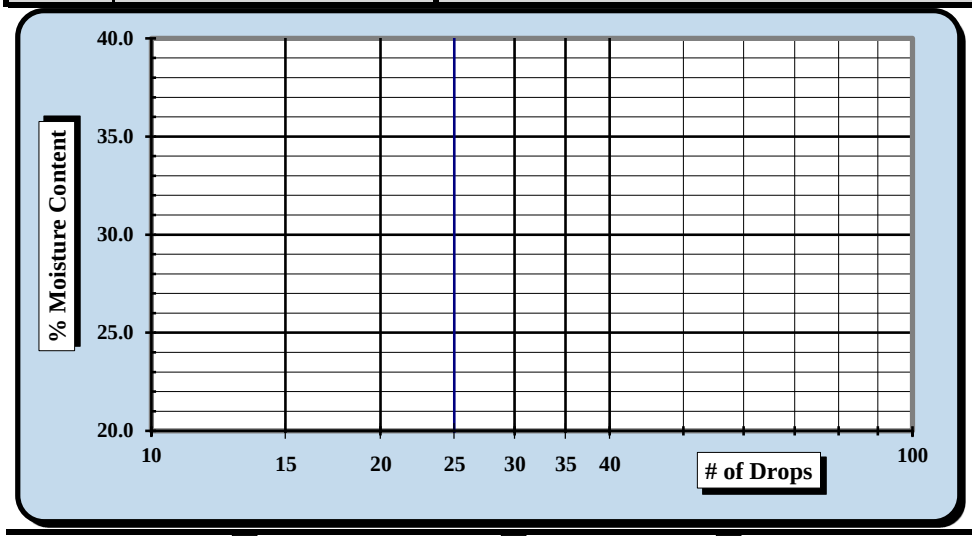
Project #:	1426-16-063 Phase 900	Report Date:	8/07/18
Project Name:	TRI/Environmental - General Laboratory Testing	Test Date(s)	8/07/18
Client Name:	TRI/Environmental, Inc.		
Client Address:	P.O. Box 9192 Greenville, SC 29604		

Location: Montana 7A Log #: 77g Sample Date: July 2018

Sample Description: Montana 7A Stone [A-1-a]

Type and Specification	*S&ME ID #*	*Cal Date:*	*Type and Specification*	*S&ME ID #*	*Cal Date:*
Balance (0.01 g)	13942	8/18/2017	Grooving tool	23119	10/15/2017
LL Apparatus	23158	2/1/2018			
Oven	13978	10/7/2017			

Pan #		Liquid Limit						Plastic Limit		
	Tare #:									
A	Tare Weight									
B	Wet Soil Weight + A									
C	Dry Soil Weight + A									
D	Water Weight (B-C)									
E	Dry Soil Weight (C-A)									
F	% Moisture (D/E)*100									
N	# OF DROPS							*Moisture Contents determined by AASHTO T 265*		
LL	LL = **F** * FACTOR									
Ave.	*Average*									



One Point Liquid Limit

N	Factor	N	Factor
20	0.974	26	1.005
21	0.979	27	1.009
22	0.985	28	1.014
23	0.99	29	1.018
24	0.995	30	1.022
25	1.000		

NP, Non-Plastic ☒

Liquid Limit	---
Plastic Limit	**NP**
Plastic Index	**NP**
Group Symbol	**A-1-a**

Multipoint Method ☑
One-point Method ☐

Wet Preparation ☐ Dry Preparation ☑ Air Dried ☑ % Passing the #200 Sieve: 4.6%

Notes / Deviations / References:

AASHTO T90: Determining the Plastic Limit & Plastic Index of Soils *AASHTO T89: Determining the Liquid Limit of Soils*

Benjamin J. Kovaleski	8/07/18	Brian Vaughn	8/07/18
Technician Name	*Date*	*Technical Responsibility*	*Date*

Form No. TR-D1883-T193-3
Revision No. 2
Revision Date: 08/11/17

CBR (CALIFORNIA BEARING RATIO) OF LABORATORY COMPACTED SOIL

AASHTO T 193

S&ME, Inc. - Greenville 48 Brookfield Oaks Dr., Suite F Greenville, SC 29607

Project #:	1426-16-063 Phase 900	Report Date:	8/10/18
Project Name:	TRI/Environmental - General Laboratory Testing	Test Date(s)	8/06 - 8/10/18
Client Name:	TRI/Environmental		
Client Address:	P.O. Box 9192 Greenville, SC 29604		

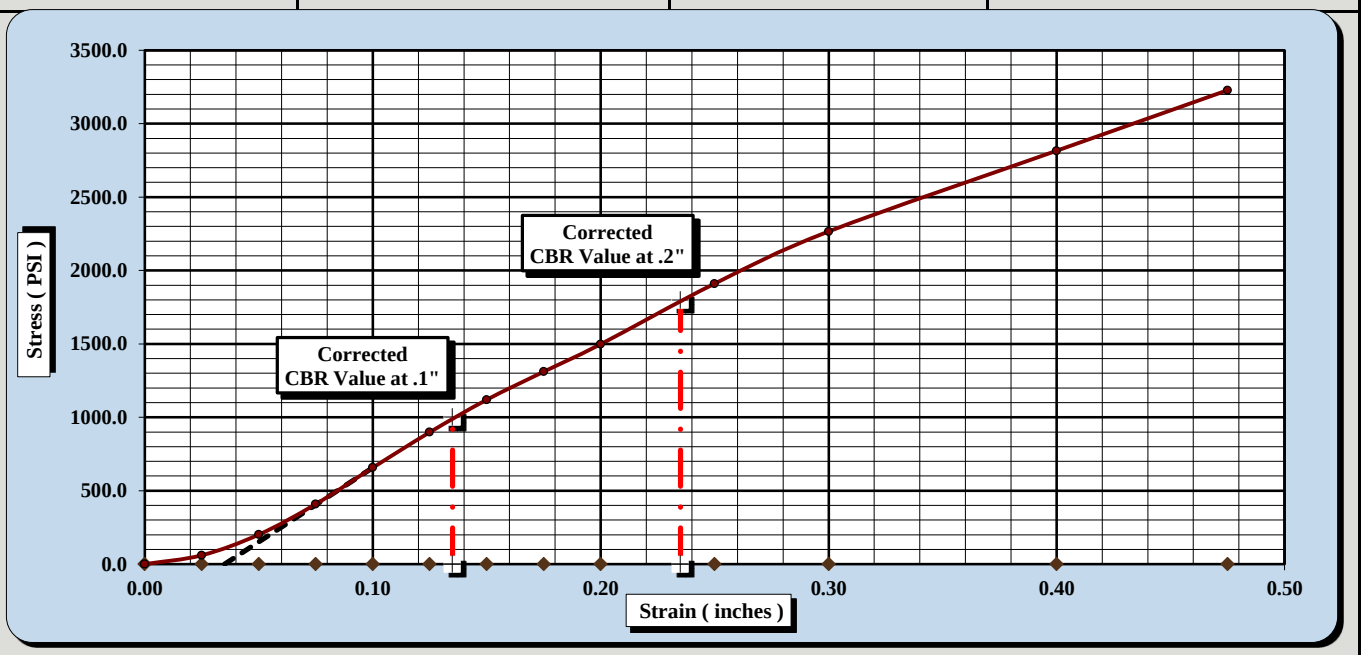
Boring #:	N/A	Log #:	77g	Sample Date:	July 2018
Location:	Montana 7A	Type:	Bulk	Depth:	N/A

Sample Description: Montana 7A Stone [A-1-a]

AASHTO T180 *Method D* Maximum Dry Density: 136.7 PCF Optimum Moisture Content: 7.7%

Compaction Test performed on grading complying with CBR spec. % Retained on the 3/4" sieve: 0.0%

Uncorrected CBR Values				Corrected CBR Values			
CBR at 0.1 in.	65.7	CBR at 0.2 in.	99.9	CBR at 0.1 in.	100.0	CBR at 0.2 in.	120.0



CBR Sample Preparation:

The entire gradation was used and compacted in a 6" CBR mold in accordance with AASHTO T 193, Section 5.1.1

Before Soaking		*After Soaking*	
Compactive Effort (Blows per Layer)	35		
Initial Dry Density (PCF)	129.9	Final Dry Density (PCF)	129.9
Moisture Content of the Compacted Specimen	7.7%	Moisture Content (top 1" after soaking)	8.4%
Percent Compaction	95.0%	Percent Swell	0.0%

Soak Time:	96 hrs.	Surcharge Weight	10.0	Surcharge Wt. per sq. Ft.	50.9
Liquid Limit	---	Plastic Index	NP	Apparent Relative Density	2.700

Notes/Deviations/References:

Brian Vaughan, P.E.	Brian Vaughan	Group Leader	8/10/18
Technical Responsibility	*Signature*	*Position*	*Date*

Form No. TR-D698-2
Revision No. : 1
Revision Date: 07/25/17

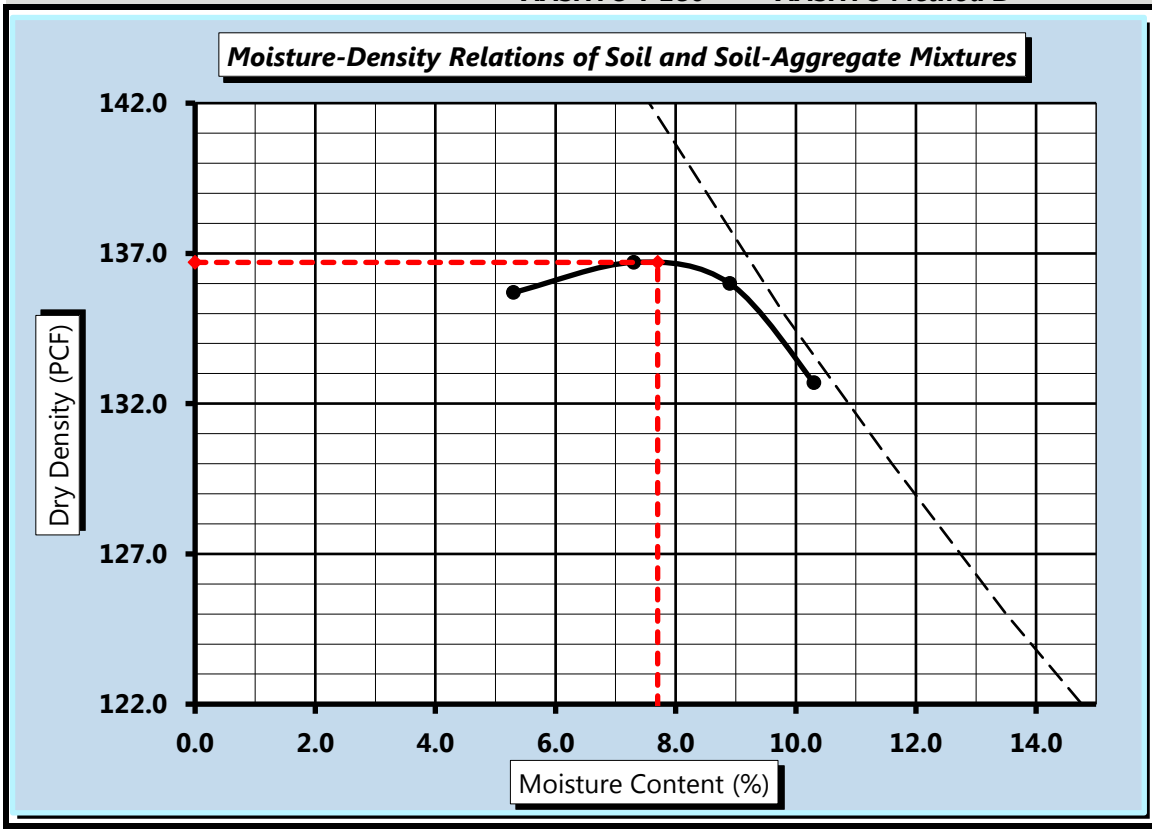
MOISTURE - DENSITY REPORT

	S&ME, Inc. - Spartanburg: 301 Zima Park Drive, Spartanburg, SC 29301		
Project #:	1426-16-063 Phase 900	Report Date:	8/07/18
Project Name:	TRI/Environmental - General Laboratory Testing	Test Date:	7/25/18
Client Name:	TRI/Environmental, Inc.		
Client Address:	P.O. Box 9192 Greenville, SC 29604		
Location:	Montana 7A	Log #: 77g	Sample Date: July 2018

Sample Description: Montana 7A Stone [A-1-a]

Maximum Dry Density **136.7** PCF. Optimum Moisture Content **7.7%**

AASHTO T 180 - - AASHTO Method D



Soil Properties	
Natural Moisture Content	-
Specific Gravity of Soil	2.700
Liquid Limit	---
Plastic Limit	NP
Plastic Index	NP
% Passing	
1.5"	100.0%
1.0"	100.0%
3/4"	100.0%
3/8"	75.3%
#4	52.4%
#10	39.9%
#40	29.4%
#200	4.6%
Oversize Fraction	
Bulk Gravity	
% Moisture	
% Oversize	
MDD	
Opt. MC	

Moisture-Density Curve Displayed: Fine Fraction ☒ Corrected for Oversize Fraction (ASTM D 4718) ☐

Sieve Size used to separate the Oversize Fraction: #4 Sieve ☐ 3/8 inch Sieve ☐ 3/4 inch Sieve ☒

Mechanical Rammer ☐ Manual Rammer ☒ Moist Preparation ☐ Dry Preparation ☒

References / Comments / Deviations:

AASHTO T 265: Laboratory Determination of Moisture Content of Soils

AASHTO T 180: Moisture-Density Relations of Soil Using a 10 Lb. Rammer and a 18" Drop

Brian Vaughan, P.E.	Brian Vaughan	Group Leader	8/07/18
Technical Responsibility	*Signature*	*Position*	*Date*

48 Brookfield Oaks Dr., Suite F
Greenville, SC 29607

Percentage of Fractured Particles in Coarse Aggregate

ASTM D5821

TRI/Environmental - General Laboratory Testing

S&ME Project No. 1426-16-063 Phase 900

Sample ID	Total Sample Mass (grams)	Mass of Aggregate Particles with One or More Fractured Faces (grams)	Mass of Aggregate Particles with No Fractured Faces (grams)	Fractured Face %
Montana 7A Stone	1576.21	1029.90	546.31	65%

P = [F/(F+N)] X 100

P = Percentage of particles with the specified number of fractured faces (≥1 for this project)

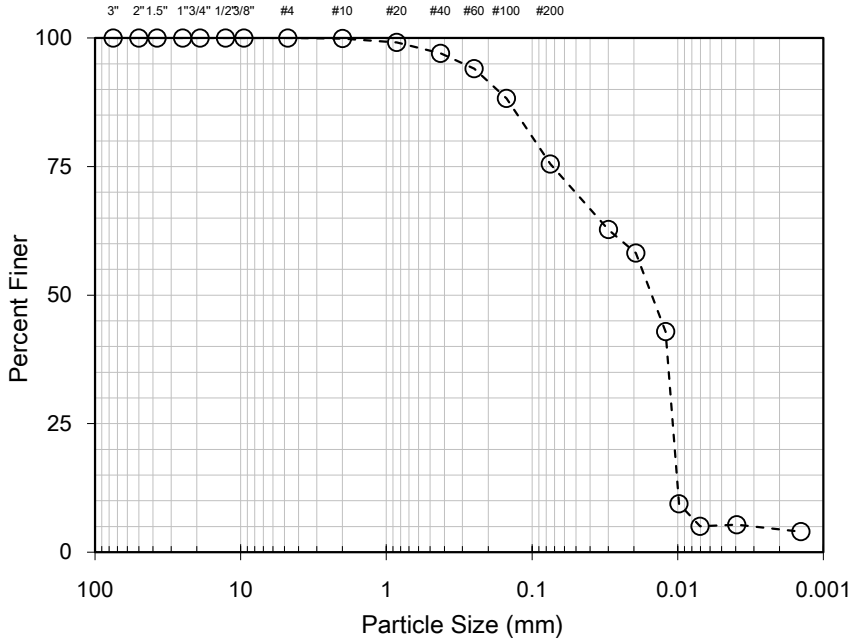
F = Mass of fractured particles with at least the specified number of fractured faces (≥1 for this project)

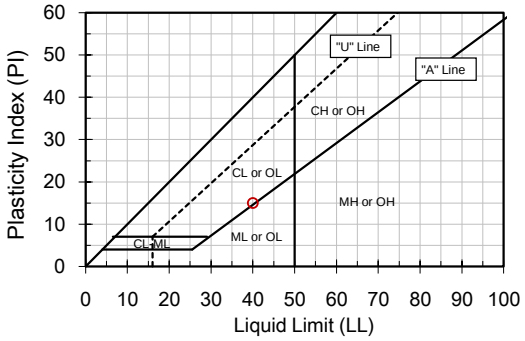
N = Mass of particles in the non-fractured category not meeting the fractured particle criteria

Particle Size, Atterberg Limit, and USCS Analyses for Soils

Client: DDRF
Project: CBR Testing Program
Sample ID: Soil

TRI Log #: 36943.2





Atterberg Limits	
(ASTM D4318, Method A : Multipoint, Air Dried)	
Liquid Limit	40
Plastic Limit	25
Plastic Index	15
(NL = No Liquid Limit, NP = No Plastic Limit)	

Mechanical Sieve (ASTM D422)		
Sieve Designation		Percent Passing
-	mm	
3 in.	76.2	100.0
2 in.	50.8	100.0
1.5 in.	38.1	100.0
1 in.	25.4	100.0
3/4 in.	19.0	100.0
1/2 in.	12.7	100.0
3/8 in.	9.51	100.0
No. 4	4.76	100.0
No. 10	2.00	99.9
No. 20	0.841	99.2
No. 40	0.420	97.0
No. 60	0.250	94.0
No. 100	0.149	88.3
No. 200	0.074	75.5

Hydrometer Analysis (ASTM D422)	
Particle Size	Percent Passing
mm	
0.0299	62.77
0.0194	58.18
0.0121	42.91
0.0098	9.42
0.0070	5.04
0.0039	5.35
0.0014	4.01

Log-Linear Interpolation	
Particle Size	Percent Passing
mm	
0.005	5.2
0.002	4.5

D_X (mm), Log-Linear Interpolation			
10	30	50	60
0.01	0.01	0.02	0.02
Cu	**Cc**		
2.34	0.55		

USCS Classification (ASTM D2487)
Lean clay with sand (CL)
Moisture Content (%) (ASTM D2216)
14.2
Organic Content (%) (ASTM D2974)
0.9
Carbonate Content (%) (ASTM D4373)
<1 (Below Method Detection Limit)

pH ASTM D4972 (method A)	
(H_2O)	($CaCl_2$)
4.90	4.10

Jeffrey A. Kuhn, Ph.D., P.E., 6/7/2018
Analysis & Quality Review/Date

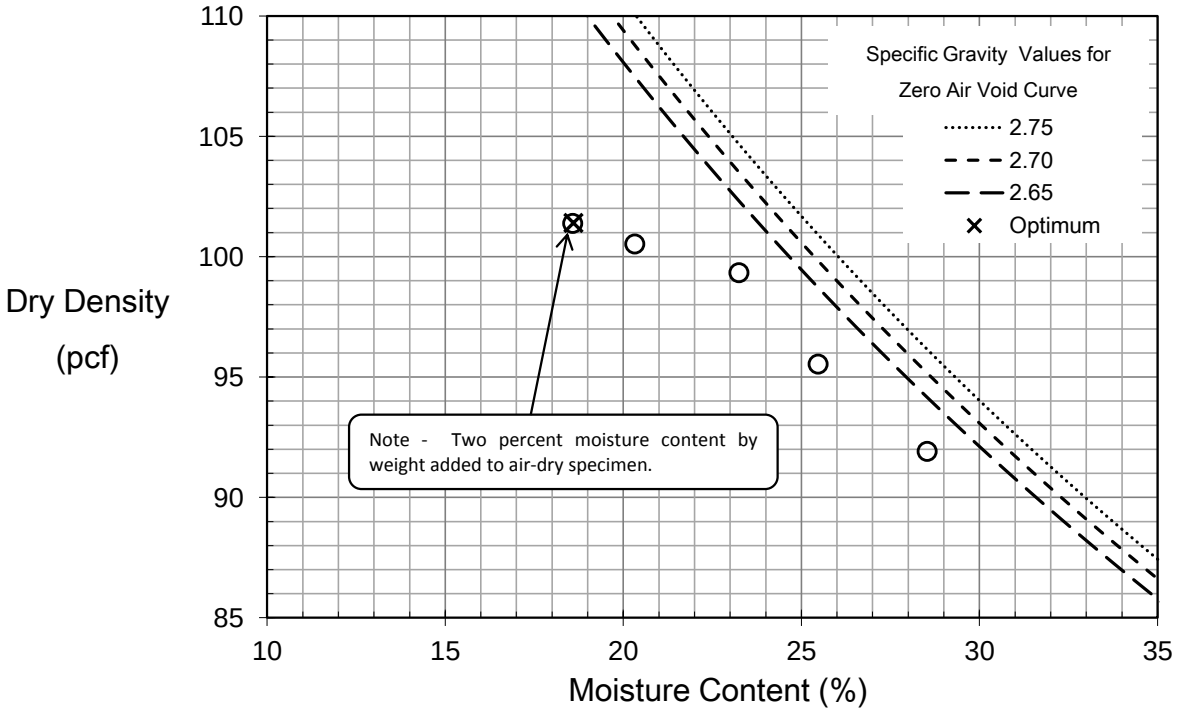
Laboratory Compaction Characteristics of Soil Using Standard Effort (ASTM D698)

Client: DDRF
Project: CBR Testing Program
Sample ID: Soil

TRI Log #: 36943.2

Compaction Effort	-	Standard
Method	-	A
Rammer Type	-	Automatic
Maximum Dry Density	pcf	101.4
Optimum Water Content	%	18.6

Oversize Particle / "Rock" Correction (ASTM D4718)		
Oversized Particles	%	- -
Maximum Dry Density	pcf	- -
Optimum Water Content	%	- -



Jeffrey A. Kuhn, Ph.D, P.E., 6/7/2018
Quality Review / Date

TRI ENVIRONMENTAL, INC.
9063 BEE CAVES RD. – AUSTIN, TX 78733 – USA | PH: 800.880.TEST OR 512.263.2101

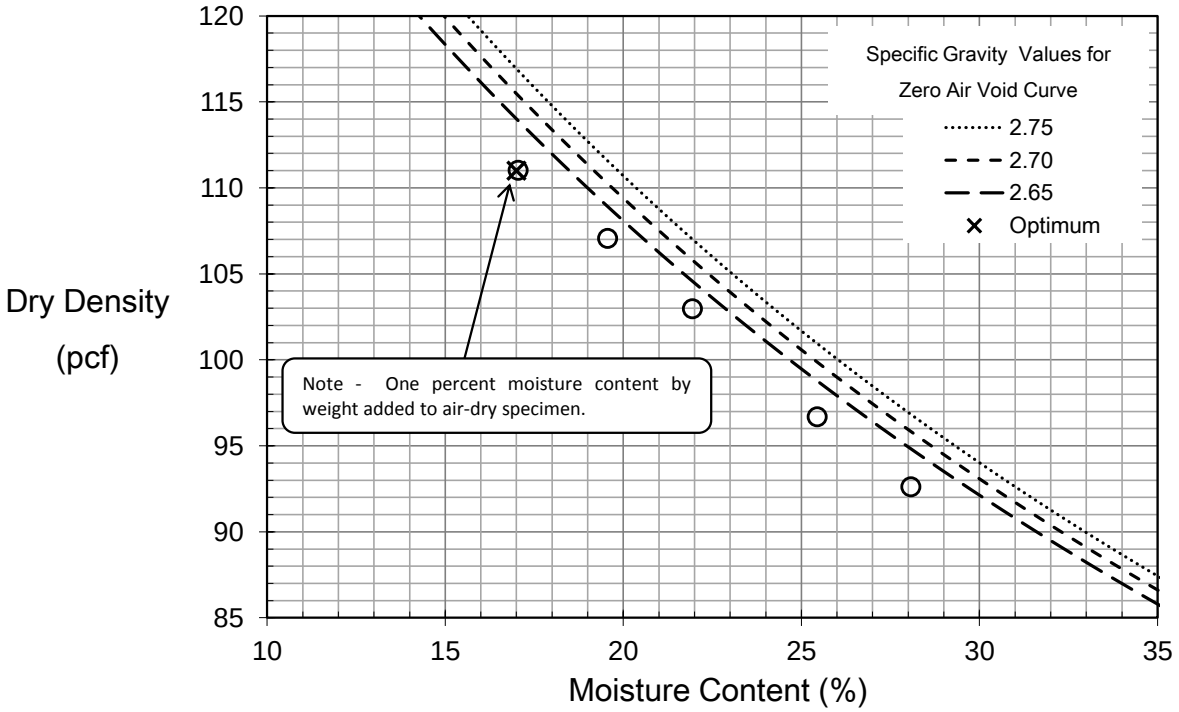
Laboratory Compaction Characteristics of Soil Using Modified Effort (ASTM D1557)

Client: DDRF
Project: CBR Testing Program
Sample ID: Soil

TRI Log #: 36943.2

Compaction Effort	-	Modified
Method	-	A
Rammer Type	-	Automatic
Maximum Dry Density	pcf	111.0
Optimum Water Content	%	17.0

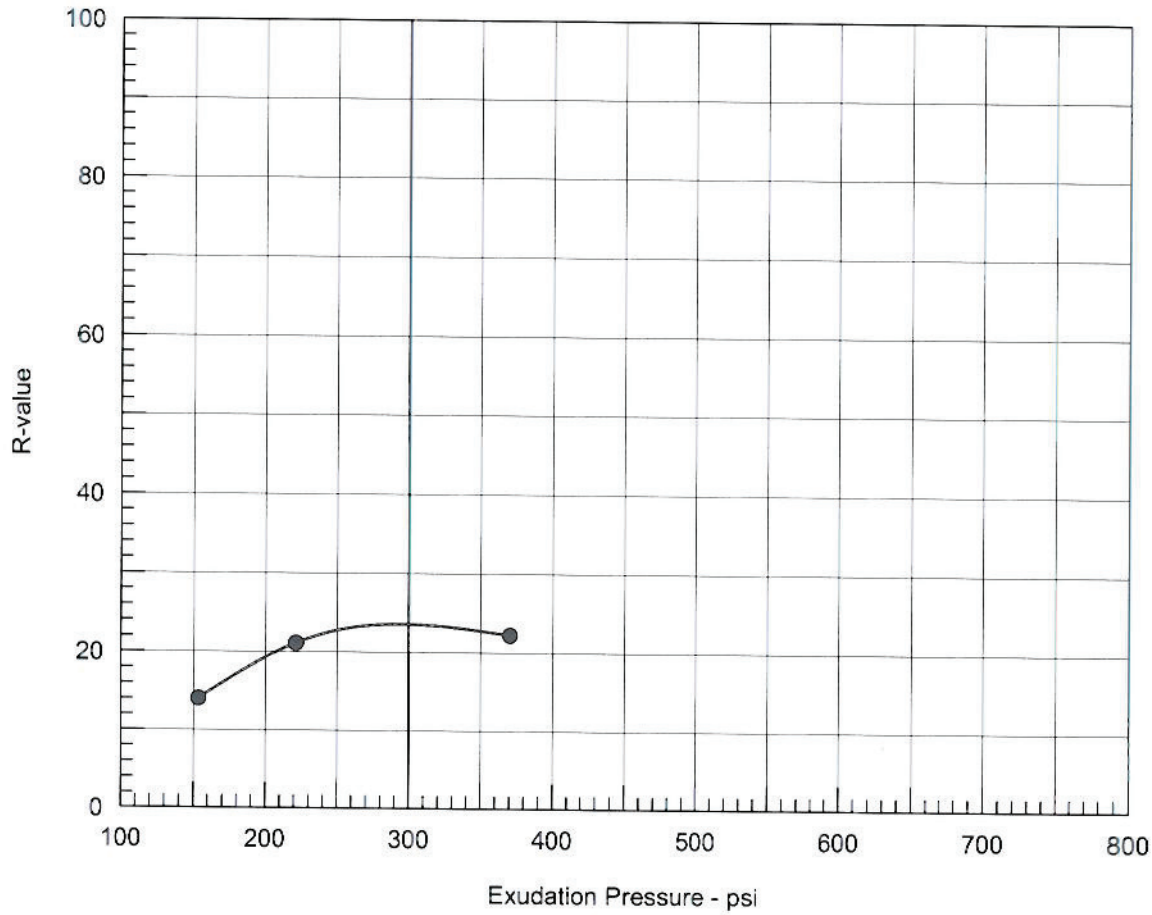
Oversize Particle / "Rock" Correction (ASTM D4718)		
Oversized Particles	%	- -
Maximum Dry Density	pcf	- -
Optimum Water Content	%	- -



Jeffrey A. Kuhn, Ph.D, P.E., 6/7/2018
Quality Review / Date

TRI ENVIRONMENTAL, INC.
9063 BEE CAVES RD. – AUSTIN, TX 78733 – USA | PH: 800.880.TEST OR 512.263.2101

R-VALUE TEST REPORT



Resistance R-Value and Expansion Pressure - ASTM D 2844

No.	Compact. Pressure psi	Density pcf	Moist. %	Expansion Pressure psi	Horizontal Press. psi @ 160 psi	Sample Height in.	Exud. Pressure psi	R Value	R Value Corr.
1	350	0.0	0.0	0.00	132	2.60	153	13.2	14.0
2	350	0.0	0.0	0.00	120	2.60	221	19.8	21.1
3	350	0.0	0.0	0.00	116	2.50	370	22.2	22.2

Test Results	Material Description
R-value at 300 psi exudation pressure = 23.5	Subgrade for the South Carolina Geosynthetics Trafficking Study

Project No.:

Project: MDT Research

Location: SubGrade Material

Sample Number: 1

Date: 6/19/2018

Tested by: TSH

Checked by:

Remarks:

R-VALUE TEST REPORT

MONTANA DEPARTMENT OF TRANSPORTATION

Figure _____

GEOTEXTILE TEST RESULTS
TRI Client: TRI
Project: MDT Study

Material: Nonwoven Geotextile
Sample Identification: Geotex 801
TRI Log #: 42772

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	6	7	8	9	10	MEAN	STD. DEV.
Grab Tensile Properties (ASTM D 4632)												
MD - Tensile Strength (lbs)	233	192	208	356	155	330	260	180	147	130	**219**	76
TD - Tensile Strength (lbs)	232	243	238	219	125	212	239	251	217	248	**222**	37
MD - Elong. @ Max. Load (%)	79	82	95	64	85	75	98	72	71	90	**81**	11
TD - Elong. @ Max. Load (%)	113	114	101	115	84	93	101	101	88	80	**99**	13
Wide Width Tensile Properties (ASTM D 4595)												
MD Specimen Width (inches)	8											
MD Specimen Width (mm)	203											
MD Ultimate Strength (lbs)	452	510	1001	600	688	791					**674**	201
MD Ultimate Strength (N)	2013	2270	4456	2668	3062	3521					**2998**	896
MD Ultimate Strength (ppi)	56.6	63.8	125.2	74.9	86.0	98.9					**84.2**	25.2
MD Ultimate Strength (kN/m)	9.9	11.2	21.9	13.1	15.1	17.3					**14.8**	4.4
MD Strength @ 2% Strain (lbs)	18.5	17.6	34.6	22.1	22.9	27.9					**23.9**	6.4
MD Strength @ 2% Strain (N)	82.2	78.2	154	98.4	102	124					**106**	28
MD Strength @ 2% Strain (ppi)	2.31	2.20	4.32	2.76	2.86	3.48					**2.99**	0.80
MD Strength at 2% Strain (kN/m)	0.40	0.38	0.76	0.48	0.50	0.61					**0.52**	0.14
MD Strength @ 5% Strain (lbs)	40.0	37.5	91.0	50.3	54.7	69.6					**57.2**	20.2
MD Strength @ 5% Strain (N)	178	167	405	224	244	310					**255**	90
MD Strength @ 5% Strain (ppi)	5.00	4.69	11.4	6.29	6.84	8.70					**7.15**	2.52
MD Strength at 5% Strain (kN/m)	0.88	0.82	1.99	1.10	1.20	1.52					**1.25**	0.44
MD Strength @ 10% Strain (lbs)	74.1	69.7	175	92.4	103.5	131					**108**	40
MD Strength @ 10% Strain (N)	330	310	778	411	460	581					**478**	176
MD Strength @ 10% Strain (ppi)	9.26	8.72	21.9	11.6	12.9	16.3					**13.4**	5.0
MD Strength at 10% Strain (kN/m)	1.62	1.53	3.83	2.02	2.27	2.86					**2.35**	0.87
MD Break Elongation (%)	64.0	77.1	76.8	76.6	70.6	79.2					**74.0**	5.7
TD Specimen Width (in)	8											
TD Specimen Width (mm)	203											
TD Ultimate Strength (lbs)	798	751	766	879	1006	768					**828**	98
TD Ultimate Strength (N)	3552	3341	3407	3910	4476	3419					**3684**	438
TD Ultimate Strength (ppi)	100	93.9	95.7	110	126	96.0					**103**	12
TD Ultimate Strength (kN/m)	17.5	16.4	16.8	19.2	22.0	16.8					**18.1**	2.2
TD Strength @ 2% Strain (lbs)	18.2	17.7	18.1	22.1	23.6	18.8					**19.7**	2.5
TD Strength @ 2% Strain (N)	81.0	78.7	80.5	98.5	105	83.5					**87.9**	11.0
TD Strength @ 2% Strain (ppi)	2.28	2.21	2.26	2.77	2.95	2.35					**2.47**	0.31
TD Strength at 2% Strain (kN/m)	0.40	0.39	0.40	0.48	0.52	0.41					**0.43**	0.05
TD Strength @ 5% Strain (lbs)	40.0	36.7	37.4	53.4	62.1	43.5					**45.5**	10.1
TD Strength @ 5% Strain (N)	178	163	166	237	276	193					**202**	45
TD Strength @ 5% Strain (ppi)	5.01	4.59	4.67	6.67	7.76	5.44					**5.69**	1.27
TD Strength at 5% Strain (kN/m)	0.88	0.80	0.82	1.17	1.36	0.95					**1.00**	0.22
TD Strength @ 10% Strain (lbs)	80.9	68.7	71.6	109	131	90.6					**91.9**	24.0
TD Strength @ 10% Strain (N)	360	306	319	486	581	403					**409**	107
TD Strength @ 10% Strain (ppi)	10.1	8.59	8.95	13.7	16.3	11.3					**11.5**	3.0
TD Strength at 10% Strain (kN/m)	1.77	1.50	1.57	2.39	2.86	1.98					**2.01**	0.52
TD Break Elongation (%)	111	106	107	100	89.7	85.5					**100**	10

MD Machine Direction TD Transverse Direction

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GEOTEXTILE TEST RESULTS
TRI Client: TRI Environmental
Project: Geotextile Testing

Material: Tencate RS280I Woven Geotextile
Sample Identification: Lot: 023161328, Unit: 956716035
TRI Log #: 43853

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	6	7	8	9	10	MEAN	STD. DEV.
Wide Width Tensile Properties (ASTM D 4595)												
MD Specimen Width (inches)	8											
MD Specimen Width (mm)	203											
MD Ultimate Strength (lbs)	3008	3001	3012	3108	2979	2911					**3003**	63
MD Ultimate Strength (N)	13384	13353	13405	13830	13256	12955					**13364**	282
MD Ultimate Strength (ppi)	376	375	377	388	372	364					**375**	8
MD Ultimate Strength (kN/m)	65.9	65.7	66.0	68.1	65.2	63.8					**65.8**	1.4
MD Strength @ 2% Strain (lbs)	646	640	640	642	618	619					**634**	12
MD Strength @ 2% Strain (N)	2874	2847	2848	2857	2750	2757					**2822**	54
MD Strength @ 2% Strain (ppi)	80.7	80.0	80.0	80.3	77.2	77.4					**79.3**	1.5
MD Strength at 2% Strain (kN/m)	14.1	14.0	14.0	14.1	13.5	13.6					**13.9**	0.3
MD Strength @ 5% Strain (lbs)	1434	1412	1427	1430	1402	1389					**1416**	18
MD Strength @ 5% Strain (N)	6382	6283	6349	6364	6239	6182					**6300**	79
MD Strength @ 5% Strain (ppi)	179	176	178	179	175	174					**177**	2
MD Strength at 5% Strain (kN/m)	31.4	30.9	31.2	31.3	30.7	30.4					**31.0**	0.4
MD Strength @ 10% Strain (lbs)	2714	2649	2712	2727	2656	2650					**2685**	37
MD Strength @ 10% Strain (N)	12079	11788	12067	12135	11819	11791					**11947**	163
MD Strength @ 10% Strain (ppi)	339	331	339	341	332	331					**336**	5
MD Strength at 10% Strain (kN/m)	59.4	58.0	59.4	59.7	58.2	58.0					**58.8**	0.8
MD Break Elongation (%)	11.7	12.2	11.8	11.8	11.6	11.5					**11.8**	0.2
TD Specimen Width (in)	8											
TD Specimen Width (mm)	203											
TD Ultimate Strength (lbs)	2483	2237	2259	2245	2322	2277					**2304**	93
TD Ultimate Strength (N)	11048	9954	10051	9990	10335	10133					**10252**	413
TD Ultimate Strength (ppi)	310	280	282	281	290	285					**288**	12
TD Ultimate Strength (kN/m)	54.4	49.0	49.5	49.2	50.9	49.9					**50.5**	2.0
TD Strength @ 2% Strain (lbs)	699	684	686	762	706	697					**706**	29
TD Strength @ 2% Strain (N)	3111	3045	3054	3393	3141	3101					**3141**	129
TD Strength @ 2% Strain (ppi)	87.4	85.5	85.8	95.3	88.2	87.1					**88.2**	3.6
TD Strength at 2% Strain (kN/m)	15.3	15.0	15.0	16.7	15.5	15.3					**15.5**	0.6
TD Strength @ 5% Strain (lbs)	1458	1423	1434	1523	1466	1465					**1461**	35
TD Strength @ 5% Strain (N)	6487	6331	6380	6778	6526	6519					**6503**	156
TD Strength @ 5% Strain (ppi)	182	178	179	190	183	183					**183**	4
TD Strength at 5% Strain (kN/m)	31.9	31.2	31.4	33.4	32.1	32.1					**32.0**	0.8
TD Strength @ 10% Strain (lbs)	2398	2209	2226	2148	2271	2223					**2246**	85
TD Strength @ 10% Strain (N)	10672	9832	9905	9556	10106	9890					**9994**	377
TD Strength @ 10% Strain (ppi)	300	276	278	268	284	278					**281**	11
TD Strength at 10% Strain (kN/m)	52.5	48.4	48.7	47.0	49.7	48.7					**49.2**	1.9
TD Break Elongation (%)	11.4	9.5	9.5	9.2	9.5	9.4					**9.75**	0.82

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