Reclaimed Stabilized Base
Determination of Cement Content
Testing Summary & Future Recommendations
Project: Randolph-Roxbury ER STP 0187(11)
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State of Vermont
Agency of Transportation
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Introduction

Reclaimed stabilized base (RSB) consists of pulverizing the existing pavement together with underlying base course material to the depth and width specified in the Contract Plans. It consists of adding aggregate materials as required or as ordered by the Engineer. RSB with cement involves adding a stabilizing agent as indicated on the Plans, in this case cement, mixing the components thoroughly, shaping and compacting the stabilized material to the desired grade and density. For the Randolph-Roxbury ER STP 0187(11) project, the work consisted of removing a volume of material by first cold planning the asphalt surface and then pulverizing a combination of supplemental aggregate, reclaimed asphalt pavement, and subgrade material. Once pulverized, a specified amount of cement was then placed on the roadway surface and reclaimed again to create a homogeneous cement stabilized base. The amount of cement to be added was determined at the VTrans Construction and Materials Bureau Central Laboratory. The process which was developed and was carried out for the Randolph-Roxbury project is documented herein.

At the request of the Resident Engineer, several laboratory tests were performed to determine the target percentage of cement to add to the reclaimed stabilized base (RSB) for the project. Samples of subbase (SB) material from the project site, supplemental aggregate (SA), reclaimed asphalt pavement (RAP) and portland cement were provided in order to develop blends with various percentages of each. Multiple blends were evaluated with various percentages of cement to account for the various amounts of material used on site to meet specified lines and grades throughout the length of the project, as well as to determine the target cement percentage that correlates to the desired compressive strength of material. According to the project specifications, the target 7 day compressive strength of the cement treated reclaimed stabilized base was specified as 275 psi, with a minimum compressive strength of 175 psi and a maximum compressive strength of 350 psi.

The field sampling involved taking four representative samples from test pit excavations throughout the section of roadway being reclaimed. The four samples were taken at random, representing the four-quarter segments of the project length. There were a total of 21 five gallon buckets used for testing which included eight buckets of subbase material, eight buckets of supplemental aggregate, four buckets of RAP, and one bucket of Portland cement.

Laboratory Testing

Before making the blends, coarser material retained on the ¾ inch sieve was removed from the subbase material in order to perform tests on the material meeting AASHTO specifications. In order to adjust for the loss of coarser material, a stone correction was applied by adding additional subbase material that was retained on the No. 4 sieve and passing the ¾ sieve into the sample. This correction allowed the sample to maintain an accurate proportion between coarse material and fine material. This same process was performed for the supplemental aggregate material and the RAP material. After the stone correction was applied to each material, the various blends could be created. About 25 pounds of material for each blend was mixed to allow for enough material to determine moisture density relationships as well as to make cylinders. Eight design mix formulas, or blends (labeled A-H), were developed for evaluation as shown in Table 2.1.

Table 2.1: Different Blends and the Percent Content of Each Material

	% of Material in Blend		
Blend ID	**RAP**	**Existing Subbase (SB)**	**Supplemental Aggregate (SA)**
A	0	100	0
B	10	90	0
C	30	70	0
D	10	80	10
E	20	60	20
F	30	40	30
G	100	0	0
H	0	0	100

A gradation plot following testing in accordance to AASHTO T27 *Sieve Analysis of Fine and Coarse Aggregates* of the in-situ subbase and the supplemental aggregate is shown in Figure 2.1, to compare the two materials. The sieve sizes that were used for gradation were those as contained in table 704.05A designated for crushed gravel for subbase-fine grading of the VTrans Standard Specifications. The calculated grain size distribution curve parameters and the coefficient of uniformity, C_u, and coefficient of curvature, C_c, for the in-situ subbase and the supplemental aggregate are shown in Table 2.2. The project special provisions specify that supplemental aggregate material should be similar in gradation to the reclaimed material sampled from the first reclamation pass.

Table 2.2: Calculated Grain Size Distribution Curve Parameters and Coefficient of Uniformity and Curvature for In-situ Subbase and Supplemental Aggregate

	In-situ Subbase	**Supplemental Aggregate**
D_{10} (mm)	0.45	0.25
D_{50} (mm)	8.0	6.8
D_{90} (mm)	42.5	20.5
C_u	29.78	39.20
C_c	1.49	2.35

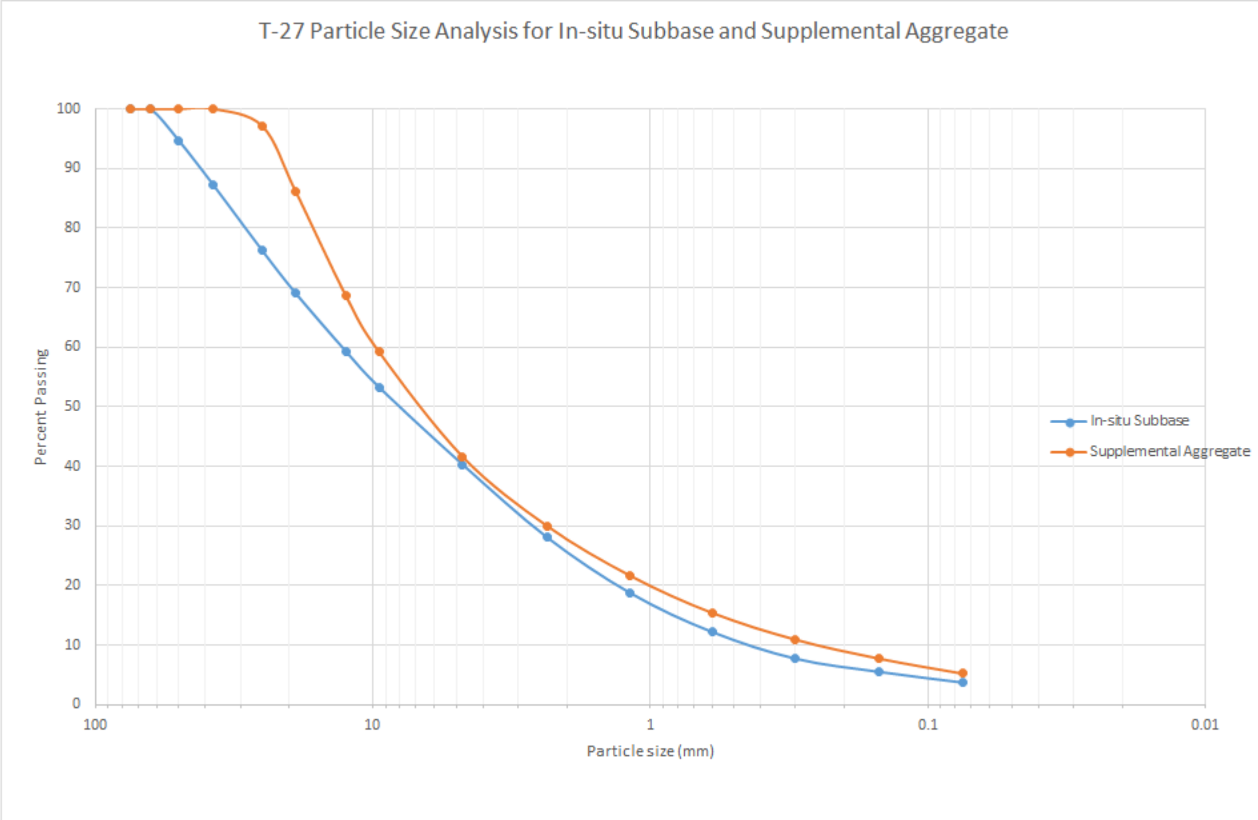


Figure 2.1: Gradation Plot of the In-Situ Subbase and the Supplemental Aggregate

A moisture-density curve was then developed for each blend in accordance with AASHTO T99 *Standard Method of Test for Moisture-Density Relations of Soils*. The optimum moisture content was determined at the maximum density for each blend. All curves were plotted on a single graph, as shown in Figure 2.2 as well in Attachment A, for a visual comparison of the blends and to easily identify the optimum moisture content for use in fabricating test cylinders.

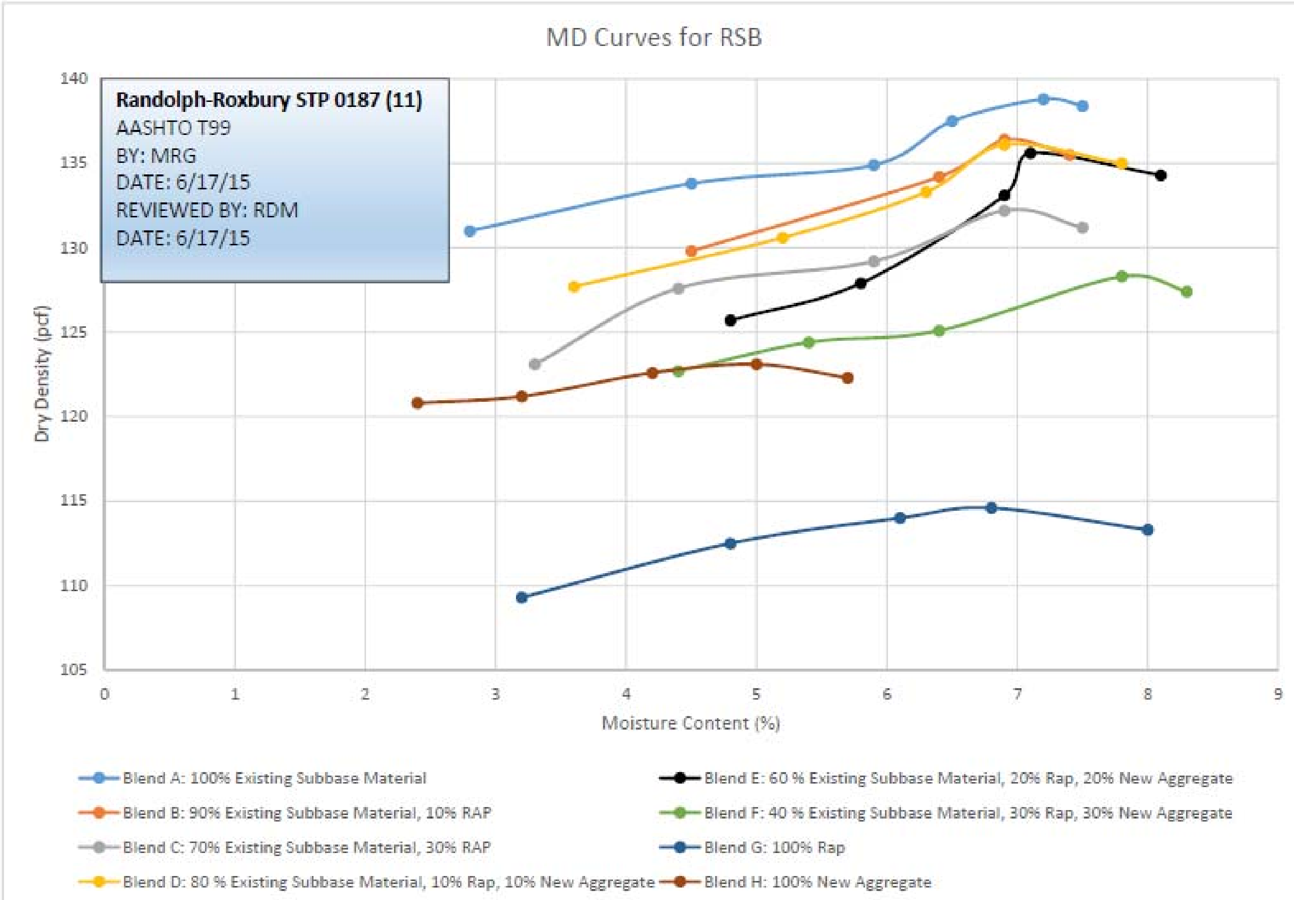


Figure 2.2: Moisture Content vs. Dry Density for Blends A-H

The optimum moisture content for each blend was then used to create soil-cement cylinders, each with varying percentages of cement, to then test for compressive strength. The material was thoroughly blended with the cement to create a homogeneous mixture. Three 4-inch cylinders were made with each percentage being evaluated. Cement percentages evaluated were either 1% or 1.5%, and 3% and 5%. This equates to a total of nine cylinders created for each blend. Cement content of 1.5% instead of 1% was chosen for the blends because the results were closer to the target compressive strength required for the reclaimed material. The cement contents added to each blend are shown in Table 2.3.

Table 2.3: Cement Content Added for Each Blend

	Blend, %			Cement Content by Weight			
Blend	RAP	SB	SA	1%	1.5%	3%	5%
A		100			X	X	X
B	10	90		X		X	X
C	30	70		X		X	X
D	10	80	10	X		X	X
E	20	60	20		X	X	X
F	30	40	30	X		X	X
G	100				X	X	X
H			100		X	X	X

The nine molds were compacted in general accordance with ASTM D1633 *Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders*. After compaction was completed, a procedure for curing the samples was followed that was used on similar projects in the past and slightly adjusted based on experience with the specific RSB material properties and results. According to the procedure, the molded samples would set in the lab for 24 hours before extracting them. This was deemed necessary because in the past the material was too fragile to be extracted on the same day. This differed from the ASTM D1632 procedure which calls for the samples to be extracted after 12 hours of curing in the lab. After the samples had been extracted as shown in Figure 2.3, they were placed in the fog room for 6 days with a plastic bag placed over them. After 6 days, the cylinders were then submerged in water, as shown in Figure 2.4, for four hours prior to performing compressive strength testing according to ASTM D1633.

Figure 2.3 (Left): Picture of a cylinder getting removed from the mold
Figure 2.4 (Right): Picture of cylinders submerged in water prior to compressive strength testing

The cylinders were tested for compressive strength in according to ASTM D1633, and the maximum compressive strength was recorded for each cylinder. Figure 2.5 is a picture of a cylinder prior to performing the compressive strength test and Figure 2.6 is a picture of a cylinder after performing the compressive strength test. The average compressive strength for the three cylinders at each cement content was determined and plotted in Figure 2.7, as well in Attachment B. The target value of 275 psi was also plotted on that same graph for a visual comparison.

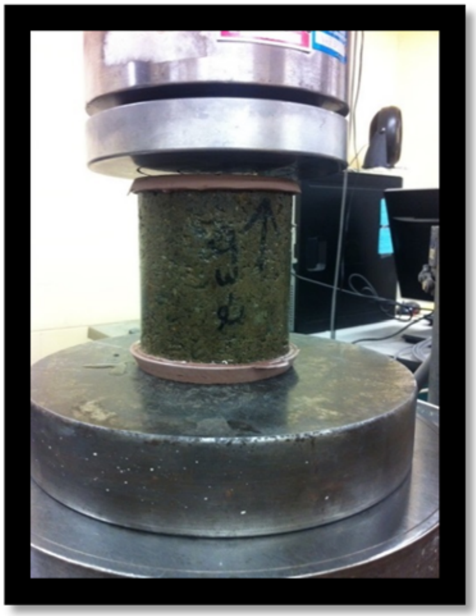


Figure 2.5 (Left): Picture of a cylinder prior to the compressive strength test.
Figure 2.6 (Right): Picture of cylinder after the compressive strength test.

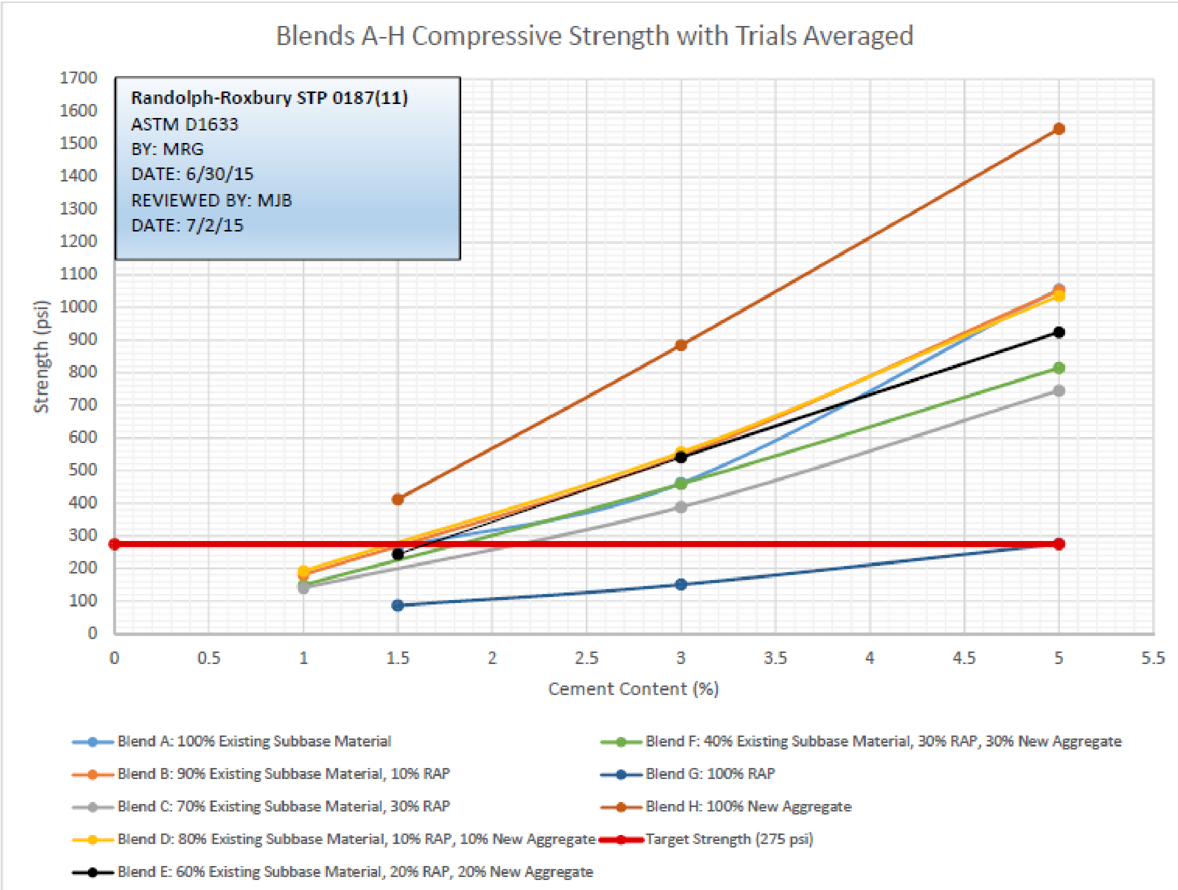


Figure 2.7: Cement Content vs. Strength for Blends A-H

An asphalt content determination was completed on the RAP material in accordance with AASHTO T308 *Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the ignition method* and results are provided in Attachment C. This test is performed per the project specification because moisture measurements taken with the nuclear density gauge should be adjusted for asphalt content. The RAP material that was tested had an asphalt content of 6.2%.

Results

As stated above, the target 7 day compressive strength of the cement treated reclaimed stabilized base was specified as 275 psi, with a minimum compressive strength of 175 psi and a maximum of 350 psi. The cement content for each blend at a compressive strength of 275 psi is shown in Table 3.1. Blends A through F fall into the optimum strength range in cement contents between approximately 1.50% and 2.15%. Blends G and H are made up of 100% RAP and 100% virgin aggregate, respectively. As such, blends G and H were considered on average less likely scenarios in the field and were given less weight in the decision on what cement content to use in construction.

Table 3.1: Cement Content for Each Blend at Target Compressive Strength of 275 psi

Blend	Cement Content (%)
Blend A: 100% Existing Subbase Material	1.60
Blend B: 90% Existing Subbase Material, 10% RAP	1.55
Blend C: 70% Existing Subbase Material, 30 RAP	2.15
Blend D: 80% Existing Subbase Material, 10% RAP, 10% New Aggregate	1.50
Blend E: 60% Existing Subbase Material, 20% RAP, 20% New Aggregate	1.65
Blend F: 40% Existing Subbase Material, 30% RAP, 30% New Aggregate	1.85
Blend G: 100% RAP	4.95
Blend H: 100% New Aggregate	< 1.5

Based on these results, a cement content of 1.5% for the reclaimed stabilized base was recommended to the Resident Engineer for this project. The curves in Figure 2.5 were provided to use if a slight adjustment of the cement content was warranted based on the variation of material reclaimed throughout the project; however we recommended that a 2% cement content not be exceeded.

Recommendations

It is recommended that future reclaimed stabilized base projects should be performed with three to five blends, however this number should be determined based on in-situ subbase conditions as well as the volume of supplemental aggregate that is planned for the project. Blends and percentages of cement content that we recommend as a starting point for these projects moving forward are shown in Table 4.1.

Table 4.1: Recommended Blends and Percentages of Cement Content

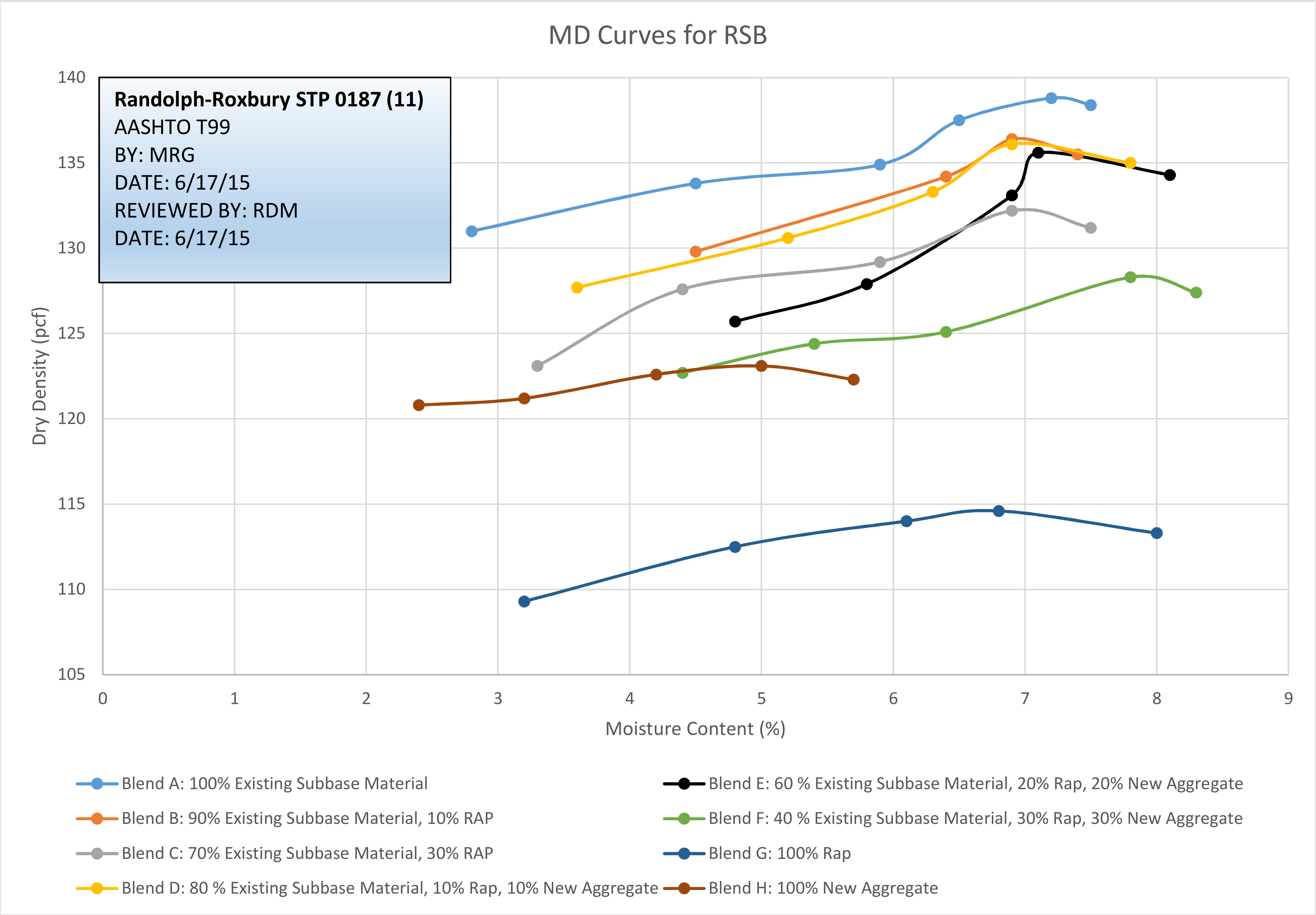
	Blend, %			Cement Content by Weight		
Blend	RAP	SB	SA	1.5%	3%	5%
A		100		X	X	X
B			100	X	X	X
C	20	40	40	X	X	X

For the three blends recommended in Table 4.1, the lab will require four buckets of subbase material, four buckets of supplemental aggregate, two buckets of RAP, and one bucket of Portland cement to have sufficient material for testing. This totals to 11 buckets of material provided by the Contractor. The current specification for RSB with cement allows for 14 days to perform this testing and provide results. Based on the reduction in blends for future projects, the 14 days specified appear to be reasonable, assuming the time frame begins when all materials are provided to the Central Laboratory.

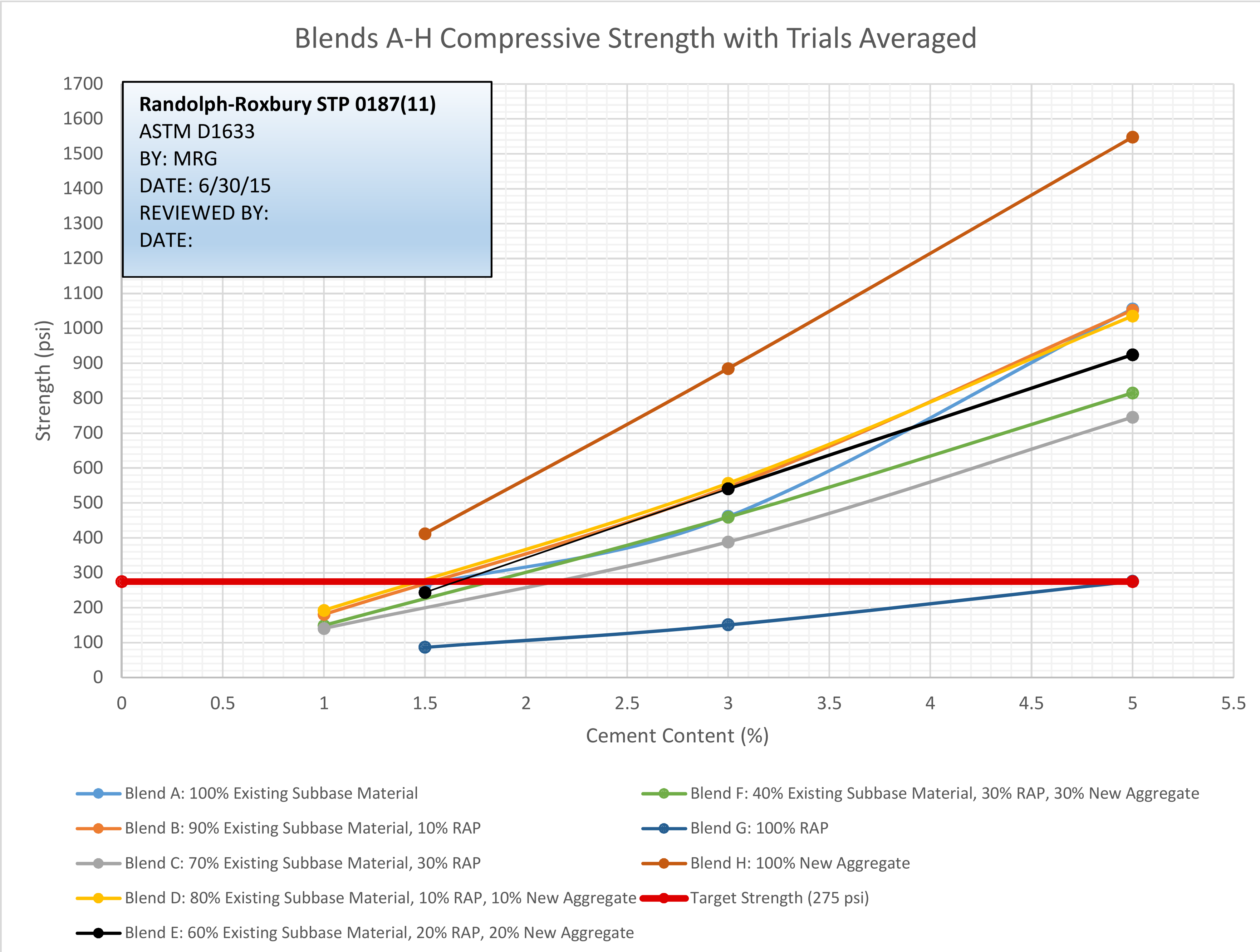
Attachments

A. Moisture Content vs. Dry Density Graph
B. Cement Content vs. Compressive Strength Graph
C. Results of Asphalt Content Determination on the RAP Material

Attachment A



Attachment B



Attachment C

Corrected Copy No.:
Date:
DISTRIBUTION

VERMONT AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH SECTION
BITUMINOUS CONCRETE UNIT

REPORT ON SAMPLE OF BITUMINOUS CONCRETE (SUPERPAVE)

LAB NO.:		REPORT DATE:	
PROJECT:	J1500013		
PAY ITEM:	S.P. Bituminous Concrete Pavement 490.30	SAMPLED BY:	
MATERIAL NAME/TYPE:	RAP	DATE SAMPLED:	6/1/2015
MATERIAL SPEC NO.:	490.03	SAMPLED FROM:	
QUANT. REPRESENTED:		DATE RECEIVED:	
SAMPLE TYPE:		TESTED BY:	D Breivogel-Williams
SAMPLE SOURCE:		DATE COMPLETE:	6/4/2015
AGGREGATE SOURCE:		IDENT.NO.:	
BINDER SOURCE:		COMPARISON SAMPLE:	

COMMENTS: Initial individual masses 2485.2g, 1814.6g, 1963.6g, 1869.4g, 1500.7g, 782.7g

Design No.: ______ N initial: ______ Time: ______

Binder Type: ______ N design: ______ Slip #: ______

Binder Sp. Gr.: ______

AASHTO T-209
Maximum Sp. Gr.

Flask ID	
Wt. of Flask & Sample (g)	
Wt. of Flask (g)	
Wt. of Sample (g)	
Wt. of Flask & Water (g)	
Wt. of Flask, Water, & Sample (g)	
Maximum Specific Gravity	

AASHTO T-166A
Bulk Specific Gravity of Compacted Specimen

H initial (mm)	
H design (mm)	
Wt. in Air (g)	
Wt. in Water (g)	
Wt. SSD (g)	
Bulk Sp.Gr. @H(Nini)	
Air Voids @H(Nini)	
Bulk Sp.Gr.@ H(Ndesign)	

Bulk Specific Gravity of Aggregate

Material			
		=	
		=	
		=	
		=	
		=	
		=	
		=	
	Total	=	
	BSG	=	

Additional AASHTO PP-19 Volumetrics

Effective Sp. Gr.	
% Absorption	
% Effective AC	
% AC by Vol	
Unit Weight (kg/m³)	

AASHTO PP-19 Volumetric Analysis

Mixture Properties	Job Aim min	Job Aim max	Report	Out of Tol. low	Out of Tol. high
Compaction Temp.					
% Slip Binder					
% VMA					
% VFA					
Dust Proportion	0.50	1.20			
Air Voids @ Ndesign	3.0	5.0			

AASHTO T-308 Ignition Oven, AASHTO T-30 Gradation

Mix Wt. (g)	Agg. Wt. (g)	Min. in Filter (g)	Total Agg. (g)	% AC
10416.2	9758.1		9758.1	6.32

Sieve (mm)	Mass Ret. (g)	Job Aim min	Job Aim max	Report %Pass.	Out of Tol. low	Out of Tol. high
50 mm						
37.5 mm						
25 mm						
19 mm						
12.5 mm						
9.5 mm						
4.75 mm						
2.36 mm						
1.18 mm						
600um						
300um						
150um						
75um						
Pan						
Total						

Comments:

Inspector: ______

No gradation performed. Gradation information provided in preceding and/or subsequent sublot samples.

Reviewed By: A. Willette, Bituminous Concrete Supervisor ______

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