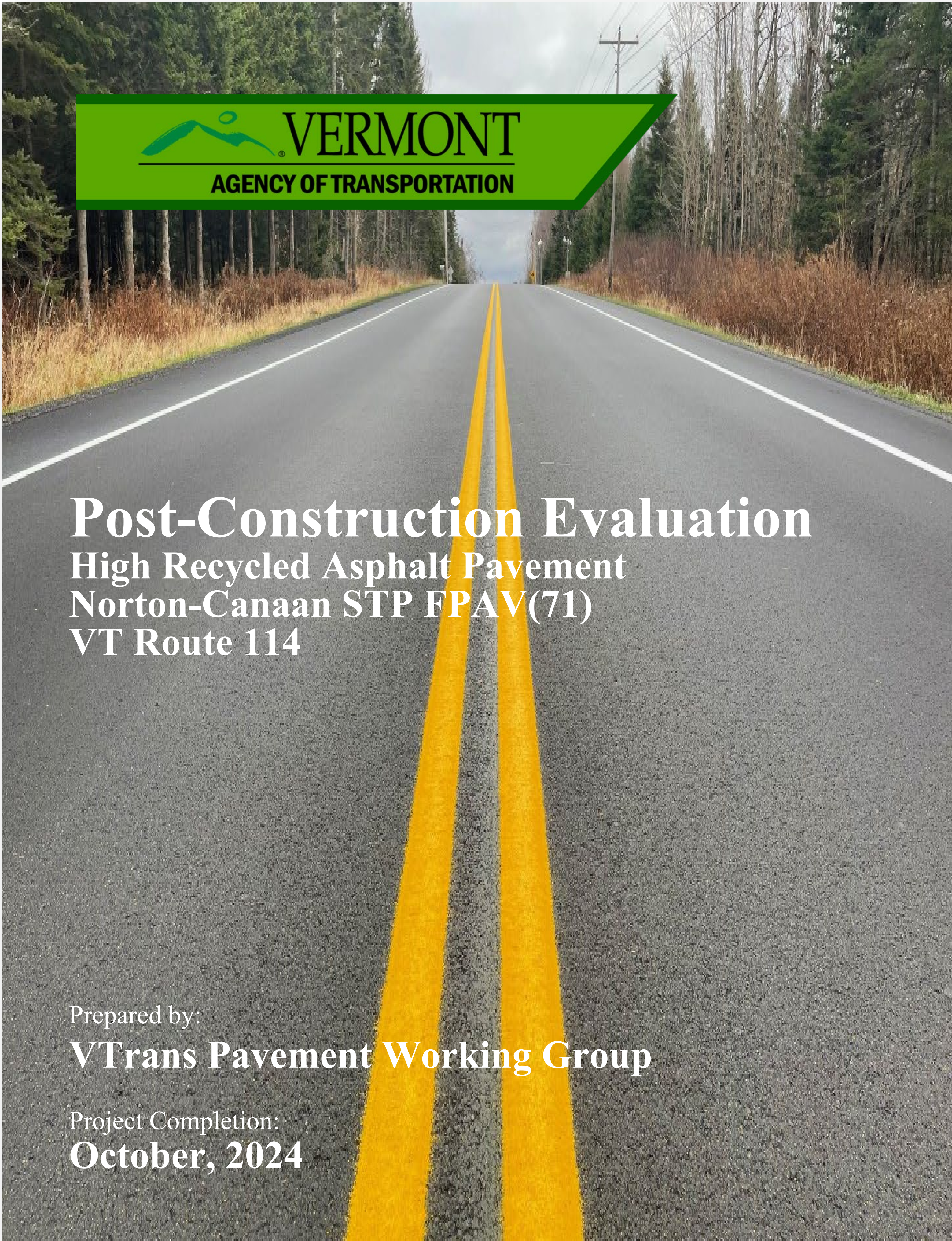

VERMONT
AGENCY OF TRANSPORTATION

Post-Construction Evaluation

High Recycled Asphalt Pavement
Norton-Canaan STP FPAV(71)
VT Route 114

Prepared by:

VTrans Pavement Working Group

Project Completion:

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16. Abstract

This report summarizes the programming, design, and installation of a 9.5mm High RAP Bituminous Concrete Pavement installed on Norton-Canaan STP FPAV(71) in August 2024. The project scope included the application of high RAP mix over approximately 12 lane miles of VT 114 from Norton to Canaan, in direct comparison to the approximate 22 lane miles of conventional Superpave Bituminous Concrete Pavement Type IVS remaining on the project to the East on VT 114. The project was performed on VT 114 from Norton MM 5.53 (ETE MM 37.30) to Canaan MM 8.36 (ETE MM 50.99), with a total project length of 13.68 miles. Other routes included were VT 141, VT 253, and NSH 9480.

The use of recycled asphalt pavement (RAP) in bituminous concrete is widespread and standard practice for most state transportation paving programs. A 20-year study conducted by the Strategic Highway Research Program has shown that RAP mixtures containing 15-25% RAP perform similarly to traditional virgin asphalt mixtures, with a trend of decreasing performance as RAP amounts increase past 50%. However, concerns about the durability of RAP remain, with only 11 states consistently using more than 25% RAP, while 40 states allow for the use of over 30%. VTrans in collaboration and consultation with our paving industry partners elected to pilot a high RAP mix to document the material properties and constructability, while utilizing Balanced Mix Design constraints to target an initial quality equivalent to the statewide averages for rutting and cracking performance.

Comparison between the high RAP and conventional mix shows similar material results and construction outcomes between the two mixes. The high RAP mix was able to be produced to meet the specifications at an existing HMA plant with minimal changes was suitably workable and placed with the same construction effort as a conventional mix. The report includes recommendations regarding the design, material specifications, construction and monitoring of future High RAP pavements. Appendices include the High RAP Special Provisions used for this project, the Approved Mix Design and Backup Documentation, Pre and Post Pavement Condition Photos, High RAP Placement Photos, and Balanced Mix Design Test Results.

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High RAP, Superpave asphalt mixture, construction, materials testing	No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

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SUMMARY

This report summarizes the programming, design, and installation of a 9.5mm High RAP Bituminous Concrete Pavement installed on Norton-Canaan STP FPAV(71) in August 2024. The project scope included the application of high RAP mix over approximately 12 lane miles of VT 114 from Norton to Canaan, in direct comparison to the approximate 22 lane miles of conventional Superpave Bituminous Concrete Pavement Type IVS remaining on the project to the East on VT 114. The project was performed on VT 114 from Norton MM 5.53 (ETE MM 37.30) to Canaan MM 8.36 (ETE MM 50.99), with a total project length of 13.68 miles. Other routes included were VT 141, VT 253, and NSH 9480.

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High RAP as specified in this project was a Superpave mixture containing between 25% and 40% RAP by percent of the total aggregate weight in the mixture, including the RAP. To produce and construct the mixture, a recycling agent was added to the mixture to recondition the RAP via chemical processes for the RAP binder to behave similarly to virgin asphalt binder in the mixing process. The recycling agent improved workability and softened the binder to improve cracking performance. This greatly improved the placement and compaction characteristics of the mixture and enabled the mixture to be installed using traditional paving equipment out in the field. No major changes were made regarding field placement as a result.

Comparison between the high RAP and conventional mix shows similar material results and construction outcomes between the two mixes. The high RAP mix was able to be produced to meet the specifications at an existing HMA plant with minimal changes and was suitably workable and placed with the same construction effort as a conventional mix.

This memo/report was prepared by the members and subject matter experts of the VTrans Pavement Working Group. Appendices include the High RAP Special Provisions used for this project, the Approved Mix Design and Backup Documentation, Pre and Post Pavement Condition Photos, High RAP Placement Photos, and Balanced Mix Design Test Results.

BACKGROUND

There is no documented use of this type of treatment in Vermont, but since 2008 allowance for 50% RAP by total aggregate weight has been mandated for use in asphalt mixtures placed on Vermont roads under the Vermont Statutes Annotated Title 19, Chapter 1, Subsection 10m (19 VSA §10m). VTrans specifications, 406.03B Composition of Mixture – Superpave, allow up to 20% RAP in standard mixes and require grade bumping to 70-34 between 21-25% RAP. RAP between 26-50% requires extraction of the binder from the final mix to prove it meets the requirements for 70-28. Since modifiers are not allowed in the standard specifications, the use of mixes with over 25% RAP is not readily attainable.

A wearing course surface with 25% RAP was previously placed on the Bradford – Ryegate STP 2929(1) on US 5 in 2016, which required the producer to lower the target PG binder grade from 58-28 to 52-34 via "grade bumping" per the *2011 Standard Specifications for Construction* and the noted AASHTO Materials Standards. VTrans has utilized higher RAP percentages through recycling treatments at deeper depths, such as cold central plant recycling (CCPR), cold in-place recycling (CIPR), and full-depth reclamation (FDR), sometimes utilizing up to 100% RAP depending on existing roadway conditions.

Advancements in asphalt paving technologies, in the form of performance testing of asphalt mixtures via balanced mix design (BMD) principles to more appropriately characterize rutting and cracking characteristics, have led to numerous endeavors nationwide in recent years to allow for higher amounts of recycled asphalt materials (RAM) in Superpave asphalt mixtures. Combined with lobbying by local asphalt producers, recent sustainability efforts being promoted by FHWA in the form of using low-carbon transportation materials (LCTM), and VTrans' enrollment in FHWA's Demonstration to Advance New Pavement Technologies Pooled Fund to kick-start the implementation of BMD as a standard business practice, a decision was made to pilot this new treatment.

PROGRAMMING

This project was initially programmed as an overlay project in 2020 due to the very poor pavement condition expected in 2023. The pavement management system's recommendation was a "Do Nothing" strategy for most of this segment given the funding scenario for the entire VTrans roadway network. However, given the "Very Poor" rating on the overall composite assessment, it was determined that an FPAV treatment would be appropriate. This project was selected for a high-RAP trial during the project design phase after the project was programmed by the Asset Management Bureau (AMB).

The leading distress of this segment was structural cracking as the last time a major rehabilitation treatment was performed on this segment was in 2001 with the Norton-Canaan STP 2222 project, with most of the project being full-depth reclaimed and a short section at the Canaan end being a mill and fill type treatment. (Pre and post-treatment condition photos are provided in Appendix C.) Overlay treatments of 1.5" with a combination of milling and paving (such as the 2024 construction with the high RAP segment) typically have an estimated life of 5-8 years depending on the condition of the existing roadway and the quality of production and laydown. However, with this being the first trial of high RAP mixtures, VTrans does not have an estimated life expectancy for the high RAP trial section.

DESIGN

VTrans has traditionally piloted new pavement treatments on state-maintained roadways that aren't subjected to high and/or heavy traffic loads, and this same principle was applied for piloting high RAP. Initially, this treatment was to be piloted on the Rupert – Pawlet STP FPAV(80) project on VT 30, but because that project was delayed due to budget constraints, the planned pilot was shifted to this particular project instead. Coincidentally, this segment of VT 114 also served as a pilot pavement treatment location for the 6.3mm Polymer-Modified Bituminous Concrete

Pavement treatment on the Canaan STP SURF(7) project, and Norton – Canaan STP SURF(13) was a Type VS pavement with latex modifier, constructed in 2008 and 2009. This treatment was used as a pavement preservation treatment on SURF projects (when option bidding with Bonded Wearing Course occurred) up through the 2016 construction season, and the two projects were the last time this segment of VT114 was repaved before the subject project.

Ahead of developing the specification, a high RAP seminar hosted by VTrans in collaboration with Pike Industries and the Paving Association of Vermont was held on April 11, 2023, at VTTC. Using information obtained from this seminar, the Special Provision (found in Appendix A) used for this project was developed collaboratively by the Materials, Construction, and Pavement Design sections. Many of the requirements included in the specification, such as BMD for mix design approval, are used in other states that have piloted high RAP treatments with great success, such as Virginia DOT and Massachusetts DOT. Findings from NCHRP Project 09-65 (of which Bituminous & Unbound Materials Engineer Aaron Schwartz served on the panel and was published as NCHRP Report 1130), also influenced the requirements that were incorporated into the special provision.

The desirable outcome from piloting this high RAP treatment was to have the mixture perform at a level equivalent to traditional Superpave treatments. As such, the decision was made to use the same materials testing criteria for acceptance (mixture air voids) as is traditionally done on FPAV projects. Similarly, the decision was also made to have a design lift thickness of 1 ½" inches for the high RAP treatment and lay it down as the wearing course treatment where specified in the plans.

The special provision for high RAP called for incorporating a minimum of 25% RAP, with up to 40% RAP allowed for use. Binder grade requirements were waived, and recycling agents were allowed. The producer (Pike Industries) elected to utilize up to 30% RAP, likely based on what their drum plant in Waterford, VT is capable of handling in terms of processing and incorporating RAP aggregates. Pike decided to incorporate a vegetable oil-based recycling agent known as Anova® 1815 manufactured and sold by Cargill, with a dosage of 1.1% (of total binder weight) incorporated into the approved mix design. They elected to utilize a 70-28 binder, to achieve required BMD performance requirements. Moreover, the special provision also required that additional binder quality testing of the RAP occur as part of the mix design approval process. The final composite grade of the binder that was extracted from the mixture (rather than the virgin binder) was required to meet a binder grade of 58S-28 and results from 40 hours of Pressurized Aging Vessel (PAV) conditions for the composite binder were to be provided for information purposes only, including 40-hour Delta Tc. The latter requirement enabled VTrans to obtain a better understanding of how the mixture would very likely perform in the long term, with 40-hour delta Tc results reported as -7.2°C. The 2024 specifications require that binder used in a regular Superpave mixture shall have a delta Tc result greater than –5.0°C, but the results from the extracted binder instead capture the full mixture properties. Thus, these results are not equivalent to the 2024 specification requirement of greater than -5.0°C.

In addition to the above requirements in the special provision, performance testing was also required to ensure the mix design wasn't susceptible to rutting, stripping, and/or cracking characteristics after laydown. For the mix design to be approved, it was necessary to demonstrate the mix design can have a maximum average rut depth measured via the Hamburg Wheel Tracker Test (HWTT) of no more than 12.5 mm (1/2 inch), a minimum HWTT Stripping Inflection Point (SIP) of 15,000 passes, and a minimum average Cracking Tolerance Index (CT-Index) value measured via the Indirect Tensile Cracking Test (informally known as the IDEAL-CT) of 115.0. This criterion is largely based on test data compiled from split samples of traditional Superpave mixes collected as part of VTrans' efforts to implement BMD over the last eight years. The submitted mix design (found with vendor-provided performance results in Appendix B) met these requirements, with an average rut depth of 2.8 mm, no SIP measured (meaning no stripping detected in the mixture during the HWTT), and an average CT-Index value of 181.1. In comparison, the control Superpave mix design had an average rut depth of 1.8 mm, a SIP of 11,952 passes, and a Flexibility Index (FI) value of 11.1; no IDEAL-CT test results were submitted with the control mix design, but for context, an FI value of 9.3 is roughly equivalent to a CT-Index value of 150.0 based on prior research conducted under New England Transportation Consortium (NETC) Project 18-2. Performance test results from samples collected during production can be found in the Appendices.

The mix design was formally submitted to VTrans for review and approval on May 24, 2024, by Pike Industries. This design, SP24 P-800, was officially approved by VTrans on June 5, 2024, and the signed copy of the design can be found in the Appendices.

CONSTRUCTION

Pike Industries was awarded the contract for the Norton Canaan STP FPAV (71) project on 2/9/24. They served as both the laydown contractor and supplier of the high RAP mix. The high RAP mix was produced at Pike's Waterford, VT Plant and placed as a 1.5" wearing course on the project from Norton MM 5.70 (ETE MM 37.47) to Canaan MM 0.72 (ETE MM 43.35) covering about 12 lane miles. High RAP mix was also used for driveway aprons and other wearing course areas that could be paved with the paver within the trial limits. Standard Superpave mix was used for surface preparation and spot shimming within the trial limits.

The high RAP mix was bid at $100 per ton, while the Superpave mix was bid at $105 per ton. During the pre-pave meeting on 08/02/2024, Pike confirmed that they didn't have any major concerns about producing and placing the material. Pike confirmed that quality control technicians would work with roller operators to ensure proper compaction. No special equipment was needed for the work. The high RAP mix was remixed through a Material Transfer Vehicle (MTV) and placed with a CAT paver. The same equipment was used for both the high RAP and Superpave mixes. The weather during placement ranged between 50-80 F with the weather varying between sunny to cloudy depending on the day. Photos of construction and equipment are provided in Appendix D.

The project was completed without major issues however some MTV malfunctions temporarily interrupted the work. On 8/23/2024 Pike Industries started paving from N(Norton)8.47 to N8.50 RT placing 42.42 tons of material when they had the MTV break down. Due to the MTV being broken down in the roadway, the crew jumped ahead to N8.84 to resume paving without the MTV. 1.212 miles were paved placing 997.17 tons without the MTV ending at A(Averill) 0.1 RT. On 8/26/2024 Pike Industries continued to have MTV issues. They placed 400.13 tons from N8.50 to

N8.84 to fill in the gap left on 8/23/24 and then stopped paving for the day. No other equipment breakdowns were reported. There were some flood-related damages to the roadway and shoulders outside of the high RAP trial limits, but no flood repairs were needed within the high RAP paving limits.

The paving process started on 8/07/2024 and ended on 8/30/2024. The tack application rate for all mix types was consistent at 0.041 gal/sy. A total of 9,018.56 tons of high RAP mix was used, close to the 9,150 tons planned, and the work met all specifications.

While the high RAP mix placed well, there were some challenges with handwork, especially when working around takeoff joints, side roads, and drainage inlets, likely due to the polymer-modified binders in the mix. Field staff encounter similar complaints with the 70-28 binders currently used for mainline paving. VTrans and contractor staff agreed that the high RAP mix was comparable to the conventional Superpave mix in terms of placement and compaction.

MATERIALS TESTING

The test strip was completed on 8/7/2024. Two loose mixture samples were obtained from the asphalt plant on 8/7/2024 for verification testing of the mixture volumetrics. These tests verified that the volumetrics were within conformance with the air void requirements (3.4% and 3.2%). In addition, six investigative cores were taken on the test strip the following day and were tested at the Central Lab. The average compaction of all six cores was above the 91.0% minimum requirement at 94.74%. This demonstrated that the approved mix design, mixing & compaction equipment, and laydown processes were suitable for use on the project. The results as defined above allowed for full production of the high RAP mixture to occur the following week.

From August 15th through August 30th, the remaining tonnage of the high RAP mix was placed on the project. Loose mixture acceptance test results for each QA Lot and the resulting pay factor under the Air Voids Pay Adjustment are summarized below in Table 1.

Table 1: Summary of Loose Mixture Acceptance Test Results for the High RAP Mixture

Site Manager Sample ID (QA Lot Number)	Number of Test Results	Average Air Voids	Standard Deviation of Air Voids	Percent Within Limits (PWL)	Air Voids Pay Factor
bhunting248F052035 (1)	6	3.4%	0.54	76	-0.037
khagan248F202747 (2)	6	4.2%	0.66	88	-0.004
bhunting248R054557 (3)	4	4.1%	0.44	100	0.03

Conventional Superpave was placed in 5 QA lots, with Air Void test result PWL of 100, 98, 100, 79, and 88. Overall, mix production for both high RAP and conventional Superpave meet the usual level of quality seen on this type of project.

Low PWL scores are the result of both target miss (distance from mean to target) and variability (higher standard deviation).

There were no roadway cores taken for acceptance testing, which is a common practice for a single-lift FPAV treatment. RS-1h emulsified asphalt tack coat material from All States Asphalt in Holliston, met the contract requirements for both penetration and residue testing.

Box samples, taken from the haul unit at the plant, were split sampled concurrently with air voids acceptance samples to conduct performance testing on both the high RAP mixture material and the conventional Superpave. In total, there were 3 box samples collected for the High RAP section and 5 for the control Superpave section. These samples were reheated, mixed, compacted, and tested during the winter of 2024/2025. These samples were tested in the Hamburg Wheel Tracker Test (HWTT) to assess rutting and moisture susceptibility, the Rapid Shear Rutting Test (IDEAL-RT), and the IDEAL-CT cracking test as part of VTrans' internal research on Balanced Mix Design (BMD). A brief analysis and summary of the results are provided herein and the complete set of test results can be found in Appendix E.

In terms of rutting resistance, the average rut depth measured from the HWTT for the high RAP section was 1.83 mm, and the rutting tolerance index (RT-Index) measured from the IDEAL-RT was 146.0. It is worth noting that only two box samples were tested in the IDEAL-RT due to specimen preparation issues resulting from a different maximum specific gravity (G_{mm}) for the third QA Lot. For the Superpave section, the average rut depth measured from 4 out of the five 5 box samples/QA Lots was 2.23 mm and the average RT-Index from the same number of box samples was 144.0. This demonstrates that the high RAP section has adequate and/or superior rutting resistance compared to the Superpave section, which was expected due to the polymer-modified binder used in the Superpave section and more RAP (i.e., stiffer aggregate and binder) being used in the high RAP section.

Short-term cracking resistance for both mixtures yielded lower test results than what was reported in the mix design submittals, as measured from the IDEAL-CT. This testing was accomplished via reheating of the box samples and then compacting without inducing the mixtures to additional aging. For the high RAP section, the average CT-Index reported from the IDEAL-CT test from all 3 box samples was 64.0. For the Superpave section, the average CT-Index from all 5 box samples was 75.7. The root cause of these lower-than-expected values is unknown, but it can be assumed that variabilities often seen in production that are generally beyond the control of the Agency (i.e., silo storage, allowable production tolerances in our specification, etc.) resulted in these values. This phenomenon of differing results between lab-produced specimens and plant–produced specimens has been noted in national research and there are efforts underway under various research projects to help mitigate this issue. Nevertheless, the high RAP section results being slightly lower than the Superpave section results was an expected outcome due to the increased amount of RAP present in that design. These results suggest that the high RAP section will face cracking distresses earlier than the Superpave section.

Long-term cracking resistance as measured from the IDEAL-CT is determined by reheating the box samples and then aging the loose mix for 20 ± 0.5 hours at 110°C in accordance with *AASHTO R 121, Method D*. This testing demonstrated that a marginal decrease in cracking resistance would be expected over the service life of the pavement. For the high RAP section, the average CT-Index measured from 2 out of the 3 box samples was 56.1, and for the Superpave section, the average CT-Index measured from 3 out of the five 5 box samples was 55.0. The average result from the high RAP section samples implies that the effects of the recycling agent would mitigate future long-term cracking distresses resulting from the increased amount of RAP aggregate and oxidized binder within the RAP. In addition, the average result from the Superpave section being slightly lower than the high RAP section was not an expected outcome due to less RAP being incorporated. Research suggests that this aging method is an adequate predictor of fatigue cracking after 8 – 12 years of in-place service. However, given the expected service life of an FPAV treatment being 5 – 8 years as previously noted, it is expected that these predicted cracking distresses will occur much sooner.

The pavement Surface profile was collected with the Agency's high-speed profiler for the portion of the project on Vermont Route 114. The high RAP section had a Mean Roughness Index (MRI) of 65.2 in/mi NB and 61.77 in/mi SB. The Superpave sections had MRI of 67.25in/mi NB and 63.93 in/mi SB. Overall, the high RAP section was found to have a slightly better ride quality, likely due to construction practices in paving rather than any material differences.

Asphalt extracted from box sampled mixture from the production of both high rap and conventional mix was tested for binder grading. The asphalt was extracted and recovered by PRI Asphalt Technologies in Tampa FL and returned to VTrans for testing. Testing was conducted in accordance with VTrans standard practices, graded for both AASHTO M320 and AASHTO M332, including testing for 40hr Delta Tc.

AASHTO M320 results indicate the binder extracted from the high RAP mixture meets a performance grade of 76-28, and the binder extracted from the conventional Superpave mixture is 70-28, indicating the high rap mix is stiffer, and both comply with Vermont's 58-28 climatic temperature requirements. AASHTO M332 testing, also referred to as Multiple Stress Creep Recovery (MSCR), displays the opposite result for stiffness. The MSCR test results indicate that the conventional mixture is more resistant to rutting, with lower values on Jnr3.2 at each testing temperature from 58 to 76. The MSCR test is believed to better represent rutting performance, by comparing stiffness at a given temperature to determine suitability for higher traffic.

For M332 MSCR performance grading, the binder extracted from the high RAP mixture graded as 58E+, 64E, 70H and 76S, and the binder extracted from the conventional Superpave mixture graded as 58E+, 64E, and 70V. Conventional technically failed 76S on the Jnrdiff, but literature suggests the failure can be disregarded since the Jnr3.2 value is not close to the spec limit.

POST CONSTRUCTION REVIEW

During the final inspection of the project, the high RAP pavement had no discernable differences from the conventional Superpave section. There was minimal segregation found at the take-off points at the beginning of each day's production. This can be caused by handwork performed to blend the joint or be caused by a screed that has a slightly lower temperature than the placed pavement. These areas are isolated to the first 25ft of paving at some of the start joints. Similar minimal segregation was found at some of the take-off joints within the high RAP sections as well. Minimal surface segregation was also found in Norton from MM 8.47 to 8.90 in the right lane. This was the area where the contractor experienced an MTV breakdown resulting in some of the loads cooling down. When the contractor continued paving without the MTV, the pavement was not able to be remixed causing some thermal segregation in the mat. The minor surface deficiencies in this area should not be attributed to the high RAP mix and were caused by the equipment breakdown. We see similar results with conventional mixtures when MTVs break down and the days' production is completed without them.

Overall, the project came out great, and driving down the roadway it's not possible to visually tell where the high RAP mixture placement begins and ends. Both VTrans and Pike contractor staff were pleased with how the material was placed, and compacted, and the overall result of the project.

RECOMMENDATIONS

Recommendations regarding the design, material specifications, construction, and monitoring of the high RAP treatment are as follows.

Design Management Recommendations:

- Future experimental treatments should be applied to roads in better structural condition, ideally reclaimed roadways so that roadway base conditions will be known.
- Inform the District that the treatment is experimental and provide feedback during routine maintenance activities.
- Avoid making last-minute changes to treatments for projects with established treatments in order to choose the right roadway candidate for the relevant experimental treatment.
- Include signs/plaques indicating experimental treatments for stakeholder awareness and as a best practice.

Material-Related Recommendations:

- Future revisions to the high RAP specification should include IDEAL-CT cracking test criteria under long-term oven aging (LTOA) conditions for mix design approval purposes to better characterize cracking behaviors. LTOA conditions are meant to simulate the in-place field performance roughly 8-12 years after placement depending on the specific method used per *AASHTO R 121*.
- Consider other tests for mix design approval recommended in NCHRP Report 1130, such as the Cantabro abrasion test to evaluate mixture raveling characteristics.
- Conduct annual site visits to observe the in-place field performance of the high RAP and the control Superpave treatments. One reason to do this is the composite binder test results after 40 hours of PAV aging did give some indication that the high RAP mixture may be prone to premature instances of cracking distresses in the long term. This would manifest in thermal cracking transversely across the roadway mat, largely due to climatic conditions on the project site.
- Use the Agency's High-Speed Profiler to measure pavement roughness and rutting depths after placement for baseline conditions.
- Collect data on cracking distresses every other year using Fugro's Automatic Road Analyzer (ARAN) inertial surface profiler.
- Coordinate between the Materials Section and the Geotechnical Engineering Section to collect investigative cores at least once every two years to evaluate each mixture's in-place performance via BMD testing.

Construction Recommendations:

- Base future high RAP locations on areas with known producers or facilities with RAP surplus.

- Laydown be performed during the mid-summer months and during dry weather conditions to facilitate ideal conditions for any alternative treatment.
- Experimental sections must comply with all specification requirements, including the use of operational equipment. If any equipment malfunctions, operations must be halted until the equipment is functional.

Monitoring Recommendations

- Further evaluation of material properties, including cracking behavior under LTOA conditions and resistance to raveling.
- Regular monitoring of in-place field performance, including pavement roughness, rutting depths, and cracking distresses every 2 years.
- Routine maintenance inspection findings shall be brought to the attention of the Construction Paving Engineer.
- Collection of investigative cores to assess the mixture's performance through BMD testing in 2028 in comparison to baseline test results. A minimum of one sample location for both the high RAP section and the conventional Superpave section to determine binder quality.

CONCLUSION

The first trial of high RAP appeared to be successful overall. A high RAP mix design that meets specifications was used, and the material was placed and compacted successfully during construction. The materials used on the project met specifications and have been found to be suitable for Vermont's climate and traffic. Initial observations, two months after construction, did not indicate any problems. However, long-term performance monitoring is crucial to fully evaluate the efficacy and durability of high RAP pavements.

By monitoring the performance VTrans can gain valuable insights into the long-term performance of high RAP pavements, leading to more informed decisions regarding optimization and implementation in future road construction projects. All future testing performed within the trial and project limits shall be included in this report as addendums.

Appendix A - High RAP Special Provisions

PART II – SECTION 900 SPECIAL PROVISION ITEM

BITUMINOUS CONCRETE PAVEMENT, HIGH RECYCLED ASPHALT PAVEMENT

1. DESCRIPTION. This work shall consist of constructing one or more courses of high Recycled Asphalt Pavement (RAP) bituminous concrete pavement, containing between 25% and 40% RAP, on a prepared foundation in accordance with these specifications and the specific requirements of the type of surface being placed, and in conformity with the lines, grades, thicknesses, and typical cross sections shown on the Plans or established by the Engineer.

   The work under this Section shall be performed in accordance with these provisions, the Plans, and Section 406 of the Standard Specifications, except as modified below.

2. MATERIALS. Materials shall meet the following requirements of the following subsections:

Performance-Graded Asphalt Binder.. 702.02
Emulsified Asphalt.. 702.04
Aggregate for Bituminous Concrete Pavement .... 704.10(a)

   (a) Performance-Graded Asphalt Binder. The performance-graded (PG) asphalt binder shall be the grade and traffic designation listed in the approved mix design, and conform to the requirements of *AASHTO M 332*, except requirements for J_{nrdiff} are waived. If the binder is modified to meet the composite binder grading requirements specified herein, the material shall also meet the requirements of *AASHTO R 92*, and a certificate of analysis (COA) and bill of lading (BOL) shall include the modifier types. The binder shall not contain re-refined engine oil bottoms (REOB), vacuum tower asphalt extenders or other modifiers produced from recycled petroleum products.

   (b) Recycling Agent. If a recycling agent is used to recondition the RAP for the purposes of improving the material properties and placement characteristics, then the product used shall conform to the requirements of *ASTM D4552*. The recycling agent shall not contain re-refined engine oil bottoms (REOB), vacuum tower asphalt extenders or other modifiers produced from recycled petroleum products.

   (c) Recycled Asphalt Pavement (RAP). The bitumen component of RAP shall be asphalt binder and free of significant contents of solvents, tars, and other volatile organic compounds or foreign substances that will make the RAP unacceptable for recycling as determined by the Agency.

RAP shall consist of crushed or milled bituminous concrete pavement. The Contractor may blend, crush, or prepare the RAP into one or more homogenous stockpiles. The gradation of the RAP shall be such that, when combined with a coarse and fine aggregate, the composite aggregate shall meet the specified gradation requirements for Superpave bituminous concrete pavement.

3. COMPOSITION OF MIXTURE. All high RAP mixtures shall meet the requirements of Subsection 406.03B unless otherwise stated herein.

(a) Gradation. The materials shall be combined and graded to meet the limits corresponding to a Type IVS mix type as specified in Table 406.03D.

(b) Design Criteria. The number of Gyrations at N_{design} (for example, 50, 65, or 80 gyrations) is determined by the Agency and shall be as detailed on the Plans. Design criteria for high RAP mixtures shall be as specified in Table 1 below.

TABLE 1 – DESIGN CRITERIA

Mix Type and Nominal Maximum Aggregate Size, mm. (in.)	Type IVS, 9.5 (3/8)
Voids in Mineral Aggregate (%)	16.0 minimum
Dust Proportion Range (filler/asphalt ratio, dry sieve)	0.50 – 1.00
Air Voids (%)	4.0
Final Composite PG Binder Grade	58S-28
RAP Content	25.0% ≤ RAP ≤ 40.0%
Performance Test Criteria	
Hamburg Wheel Tracker Test (HWTT) Average Rut Depth, mm (inches)	12.5 (0.5) maximum
HWTT Stripping Inflection Point (SIP), passes	15,000 minimum
Indirect Tensile Cracking Test (IDEAL-CT) Cracking Tolerance Index (CT-Index)	115 minimum

Additionally, the ΔT_c value for the final composite asphalt binder grade when measured in accordance with *AASHTO PP 113* after 40-hours of aging shall be provided with the mix design.

(c) Mix Design. For high RAP mixtures, *AASHTO R 35* will be the method used to develop a mix that will meet the specified Gradation and Design Criteria in accordance with *AASHTO M 323*, unless otherwise specified. A copy of all design test data used in developing the mix design, including graphs, may be required with the submittal of the mix design or anytime following as directed by the Engineer.

The High RAP mix will be designed using the following methodology to be in accordance with Table 1 herein:

(1) Select materials (aggregate, RAP, PG asphalt binder, and additives).

(2) Conduct an analysis of the RAP material. The aggregate gradation, coarse aggregate specific gravity, fine aggregate specific gravity, asphalt content, and extracted binder performance grade shall be provided in the mix design.

(3) Select design aggregate structure.

(4) Select design asphalt binder content.

(5) Extract the binder from the batched design mix and determine the composite asphalt binder performance grade to ensure the material is in conformance with *AASHTO M 332*.

(6) Evaluate moisture sensitivity and rutting susceptibility using *AASHTO T 324*. Specimen fabrication, conditioning, and procedures for the HWTT shall be in accordance with Appendix A of the *VTrans Bituminous Concrete Mix Design Submittal Policy*.

(7) Determine cracking susceptibility using the Indirect Tensile Cracking Test in accordance with *ASTM D8225*. Specimen fabrication, conditioning, and procedures for determination of the CT-Index shall be in accordance with Appendix C of the *VTrans Bituminous Concrete Mix Design Submittal Policy*.

The job-mix formula (JMF) for each mixture shall establish a single percentage of aggregate passing each sieve, a single percentage of bituminous material and additives to be added to the aggregate, and a single percentage for VMA. No change in the job-mix formula may be made without the written approval of the Engineer.

The JMF must fall within the specification gradation band as shown in Table 406.03D. The JMF shall include values for all of the following sieves: 3/4 inch (19.0 mm), 1/2 inch (12.5 mm), 3/8 inch (9.50 mm), No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (0.600 mm), No. 50 (0.300 mm), No. 100 (0.150 mm), and No. 200 (0.075 mm).

The Contractor's mix design may specify either hot mix asphalt (HMA), or asphalt produced with an accepted warm mix asphalt (WMA) technology if approved by the Agency. The Contractor shall include the design mixture temperature, as well as action and suspension limits, in the JMF. Mixing temperatures for either HMA or WMA shall not exceed 355°F.

Mix designs shall be submitted in accordance with the most current version of the *VTrans Bituminous Concrete Mix Design Submittal Policy*. No work shall be started until the Contractor has submitted and the Engineer has approved a mix design, including cold feed gradations derived by wet sieve analysis, mixing times, the percentage of each ingredient including bitumen, the JMF from such a combination, and the optimum mixing and compaction temperatures.

The Engineer may approve changes in the design's job-mix formula or discontinue use of the design if placement, finishing, or compaction characteristics are determined unsatisfactory by the Engineer.

At the time the above mix design is submitted, the Contractor shall provide batched asphalt mixture to the Agency for determining asphalt ignition oven calibration. The Contractor shall also indicate and make available for sampling and testing the PG asphalt binder and stockpiles of all aggregates proposed for use. If a recycling agent is incorporated into the material, then the certificate of analysis (COA) and Safety Data Sheets (SDS) sheets for the recycling agent shall be furnished to the Agency prior to mix design approval.

A minimum of three weeks shall be allowed for the testing and evaluation of the submitted mix design. Once a mix design is approved, the JMF is valid until a change is made in aggregate source, RAP source, recycling agent, PG asphalt binder grade, or PG asphalt binder source. If any change to aggregate source, RAP source, recycling agent, PG asphalt binder grade, or PG asphalt binder source is made, a new mix design shall be submitted and a minimum three-week evaluation period shall be allowed prior to resuming production.

4. REQUIREMENTS FOR HIGH RAP BITUMINOUS MIXTURES. All requirements of

Subsection 406.03C shall apply except as modified herein.

Composite binder grading for quality control shall not be required.

The Quality Control (QC) Plan shall detail modification to plant operations, additional processes, and testing to ensure quality of high RAP mixtures, including efforts to make stockpiled RAP uniform. Recycling Agents, if utilized shall be introduced into the mixture as recommended by the supplier and detailed in the QC Plan.

5. INITIAL PRODUCTION LOT. The first day of high RAP bituminous concrete placement shall be done via an initial production lot of no more than 1,000 tons. The initial production lot will be used to verify the mix design in production and laydown. It is intended to demonstrate that the equipment and processes described in the approved QC Plan can produce high RAP bituminous concrete in accordance with the approved JMF through plant verification tests and ensure the sequence and manner of rolling necessary to meet the placement procedures, through verification cores.

   The initial production lot location and acceptance shall be determined and discussed in the pre-pave meeting. Full-scale production shall not proceed until the initial production lot is accepted.

   Acceptance of the initial production lot requires:

   (1) Two successive plant acceptance tests, sampled from different loads, showing gradation, air voids and VMA within the production tolerances.
   (2) A minimum of 4 cores, whose average is above 91% compaction.

   Should the initial production lot fail to meet the acceptance requirements, the material shall be rejected and another initial production lot shall be required, unless otherwise directed by the Engineer. The Air Voids Pay Adjustment shall not apply to the initial production lot.

6. WEATHER AND SEASONAL LIMITATIONS. The limitations and conditions outlined in Subsection 406.04 shall apply with the following modifications:

   High RAP mix shall not be placed when the ambient air temperature at the paving site in the shade and away from artificial heat is below 50°F.

   All high RAP bituminous concrete paving operations shall occur from May 15th to September 15th. Extended-Season paving will not be allowed.

7. BITUMINOUS MIXING PLANT AND TESTING. Bituminous mixing plant and testing shall meet the requirements of Subsection 406.05.

8. PREPARATION OF BITUMINOUS MATERIAL. Preparation of bituminous material shall meet the requirements of Subsection 406.06.

9. PREPARATION OF AGGREGATES. Preparation of aggregates shall meet the requirements of Subsection 406.07.

10. MIXING. Mixing shall meet the requirements of Subsection 406.08.

11. HAULING EQUIPMENT. Hauling equipment shall meet the requirements of Subsection 406.09.

12. PLACING EQUIPMENT. Placing equipment shall meet the requirements of Subsection 406.10.

13. ROLLERS. Rollers shall meet the requirements of Subsection 406.11.

14. CONDITIONING OF EXISTING SURFACE. Conditioning of existing surface shall meet the requirements of Subsection 406.12.

15. PLACING AND FINISHING. Placing and finishing shall meet the requirements of Subsection 406.13.

16. COMPACTION. Compaction shall meet the requirements of Subsection 406.14.

17. JOINTS. Joints shall meet the requirements of Subsection 406.15.

18. SURFACE TOLERANCE. Surface tolerance shall meet the requirements of Subsection 406.16.

19. TRAFFIC CONTROL. Traffic control shall meet the requirements of Subsection 406.17 shall apply.

20. METHOD OF MEASUREMENT. The quantity of Special Provision (Bituminous Concrete Pavement, High RAP) of the type specified to be measured for payment will be the number of tons complete in place in the accepted work as determined from the weigh tickets.

    The quantity of all applicable Pay Adjustments will be measured for payment according to the requirements of Subsection 406.19, as applicable.

21. BASIS OF PAYMENT. The accepted quantity of Special Provision (Bituminous Concrete Pavement, High RAP) of the type specified will be paid for at the Contract unit price per ton. Payment will be full compensation for furnishing, mixing, hauling, and placing the material specified and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

    Payment for Air Voids Pay Adjustments shall be debited or credited against the Contract prices (lump units) bid for Pay Item 406.28, included in the contract.

The costs of furnishing testing facilities and supplies at the plant will be considered included in the Contract unit price bid for Special Provision (Bituminous Concrete Pavement, High RAP).

The cost of taking cores for acceptance testing and filling the core holes will be incidental to the Contract item being cored. All other costs associated with obtaining samples for acceptance testing will be incidental to the Contract item being sampled. The cost of traffic control for taking cores for acceptance testing and filling the core holes will be paid under the appropriate Section 630 Contract item.

The costs of obtaining, furnishing, transporting, and providing the straightedges required by Subsection 406.16 will be paid for under the appropriate Section 631 pay item included in the Contract.

Payments for Price Adjustment, Asphalt Cement shall be debited or credited against the Contract price (lump unit) for Price Adjustment, Asphalt Cement, included in the contract.

Payment will be made under:

Pay Item	Pay Unit
900.680 Special Provision (Bituminous Concrete Pavement, High RAP)	Ton

Appendix B - Approved Mix Design and Backup Documentation

VERMONT AGENCY OF TRANSPORTATION SP24 P 800 HMA

HIGHWAY DIVISION - CONSTRUCTION & MATERIALS BUREAU - MATERIALS SECTION

SUPERPAVE BITUMINOUS CONCRETE MIXTURE DESIGN, HIGH RAP

May 16, 2024

Design Type (Project or Master): **Project** Intended Projects (if any): **Norton - Canaan STP FPAV(71)**

Mix Type: **Superpave Type IVS w/ rap** Gyrations, Nini / Ndes / Nmax: **7/65/115**

Produced By: **PIKE IND (733) DRUM - WATERFORD, VT**

PLANT TYPE: DRUM

Stockpile Gradations - % Passing (WET Sieve Analysis)

Size (mm)	% Used	50.0	37.5	25.0	19.0	12.5	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075	RAP % AC
WMS	11	100	100	100	100	100	99	93	83	64	39	19	8	3.5	
WSS	25	100	100	100	100	100	100	99	69	39	23	13	7	4.6	
NA. SA.	5.5	100	100	100	100	100	100	97	93	85	68	41	13	4.1	
9.5	28.5	100	100	100	100	100	98	27	3	2	1	1	1	1.0	
RAP	30	100	100	100	100	100	95	71	52	38	28	20	13	8.8	5.01
Resultant	100.0	**100**	**100**	**100**	**100**	**100**	**98**	**69**	**48**	**33**	**22**	**14**	**8**	**4.7**	4.7

"6.3mm sieve only required for "6.3mm POLYMER MODIFIED/Superpave Type VS" mix type

	ASTM D4791	ASTM D5821	ASTM D5821	AASHTO T 304	AASHTO T 176	AASHTO T 324		ASTM D8225	ASTM D3625
PROPERTY	Thin & Elongated	One Fractured Face	Two Fractured Faces	Fine Aggregate Angularity	Sand Equivalance	Rut Depth @ 20k Passes	Stripping Inflection Point (SIP)	Cracking Tolerance Index (CT-Index)	Percent Coating
SPECIFICATION	10% max	100% min	100% min	45% min	45% min	12.5 mm max	15k passes min	115 min	95% min
VALUES	0.8	100	100	46	88	2.8	N/A	181.1	100

Batch Weight (Kg)	Bin - Sand	Bin No. 2	Bin No. 3	Bin No. 4	Bin No. 5	Bin Mfg. Fine	RAP	Performance Graded Binder: Virgin	RAP	Total	Total	Reclaimed Binder Ratio (RBR)
	3760	2820					3000	420	150	570	10000	0.26

% PG Binder Content	Sieve (mm)	50.0	37.5	25.0	19.0	12.5	9.5	4.75	2.36	1.180	0.600	0.300	0.150	0.075
	Job Mix Formula	**100**	**100**	**100**	**100**	**100**	**98**	**69**	**48**	**33**	**22**	**13**	**7**	**3.6**
Virgin 4.2 / Total 5.7	Job Aim	100 / 100	100 / 100	100 / 100	100 / 100	100 / 100	92 / 100	61 / 75	44 / 52	29 / 37	18 / 26	9 / 17	3 / 11	2.6 / 4.6
	Design Limits	100 / 100	100 / 100	100 / 100	100 / 100	100 / 100	90 / 100	/ 90	32 / 67					2 / 10

NOTE: PROVIDE CERTIFICATE OF ANALYSIS (COA) FOR BOTH THE PG BINDER AND THE RECYCLING AGENT. A SAFETY DATA SHEET (SDS) SHALL ALSO BE FURNISHED FOR THE RECYCLING AGENT

Aggregates			Performance Graded Binder		
	GILEAD SAND	Original PG Grade:	PG 70-28	PG 70-28	PG 70-28
Fine:	PIKE IND PIT - WATERFORD, VT	Final Composite PG Grade:	PG 58E-28	PG 58E-28	PG 58E-28
	PIKE IND PIT - COVENTRY, VT	Recycling Agent (RA) & Dosage:	Anova @1.1%		
		RA Manufacturer:	Cargill		
Coarse:	PIKE IND PIT - WATERFORD, VT	PGB Manufacturer:	ALL STATES ASPHALT, LLC		
		Mixing Temp.:	165 °C ± 11 °C	°C ± °C	°C ± °C
RAP:	PIKE IND (733) DRUM - WATERFORD, VT	Comp. Temp.:	157 °C ± 5 °C	°C ± °C	°C ± °C

Mixing Times: Dry: Wet: Total:

Submitted By: [signature] Title: QC Supervisor

Company: **Pike Industries Inc.** Date: 5/30/24

Job Mix Formula			
VMA	17.2	+/- 1%	

FOR STATE OF VERMONT USE ONLY

Comments: THIS DESIGN HAS BEEN APPROVED BASED ON THE SUBMITTED SUPERPAVE TEST DATA. CONTINUED USE OF THIS DESIGN ON AGENCY PROJECTS IS CONTINGENT ON PRODUCT TEST RESULTS MEETING ALL STATE, FEDERAL, AND CONTRACT SPECIFICATIONS. IF DURING CONSTRUCTION, THE MIX DISPLAYS UNSATISFACTORY LAY DOWN CHARACTERISTICS AND/OR INABILITY TO COMPACT, THE DESIGN MAY BE DISCONTINUED.

Signature: Aaron Schwartz

Title: Bituminous Concrete Engineer or Designee Date: 6/25/2024

Date & Time Received Stamped Below

REVISED
10:22 am, Jun 25, 2024

Design originally approved 6/5/2024. Ignition oven CF added 6/25/2024.

Asphalt Content Ignition Oven Correction Factor Information

Internal Designation: B-31

Value: 0.43

This document is intended for receivers use only. If you received this by mistake please delete.

PIKE INDUSTRIES
A CRH COMPANY

Reviewed
VTrans
By Aaron Schwartz On May 30 2024, 9:48 am

PG Asphalt Binder Test Summary

Lab / Location	Belmont	Sample Source	Pike VT	Tank	
Sample Number	99-0502	PG Grade	PG 58S-28	Lot	
Sample Date	05/01/2024	Test Date	05/02/2024	Sample ID	127 - 1

PROPERTIES		Results	UNIT / TEMPERATURE		TEST METHODS	SPECIFICATIONS
ORIGINAL BINDER						
Specific Gravity		1.0390	60°F (15.6°C)		AASHTO T 228	Report Only
		1.0329	77°F (25°C)			
API Gravity		4.68	API			Report Only
LBS/GAL @ 60°F		8.662	LBS/GAL		ASTM Table 8	Report Only
Viscosity, Pa*s		1.354	135°C		AASHTO T 316	max. 3.000 Pa*S
		0.346	165°C			max. 3.000 Pa*S
Mixing Temperatue, min./max.		181/188	58 °C			Report Only
Compaction Temperature, min./max.		168/174	58 °C			
Dynamic Shear, G* Sin / Delta kPa		7.75	58 °C		AASHTO T 315	min. 1.000 kPa
		4.23	64 °C			
RTFO RESIDUE						
Mass Change		-1.076	% @ 163 °C		AASHTO T 240	max. 1.00 +/- %
Dynamic Shear, G* Sin / Delta kPa		14.60	58°C		AASHTO T 315	min. 2.200 kPa
		7.61	64°C			
MSCR		68.70	% Rec. 0.1 kPa	58°C	AASHTO T 350	6000 kPa per AASHTO M 332.
		60.40	% Rec. 3.2 kPa			
		12.10	R Diff. %			
		0.13	Jnr @ 0.1 kPa			
		0.17	Jnr @ 3.2 kPa			max. 4.500
		29.10	Jnr Diff. %			max. 75.000
PAV RESIDUE						
Dynamic Shear, G* Sin Delta kPa		4220	19°C		AASHTO T 315	max. 5000 kPa
		5950	16°C			
Fail Temperature		17.5	°C			
Creep Stiffness	Stiffness (S)	199	-18°C		AASHTO T 313	max. 300 MPa
	m-Value	0.313				min. 0.300
40 HOUR PAV RESIDUE						
Creep Stiffness	Stiffness (S)	120	-12°C		AASHTO T 313	max. 300 MPa
	m-Value	0.306				min. 0.300
	Stiffness (S)	237	-18°C			max. 300 MPa
	m-Value	0.277				min. 0.300
	Stiffness (S)	427	-24°C			max. 300 MPa
	m-Value	0.243				min. 0.300
Fail Temperature		-23.2°C	°C			
Delta Tc		-7.2				
Fail Temperature		...				
Meets Specification for		...				
Remarks		DHR2 Recovered Lab mixed binder 70-28 base/30% RAP/1.1% Anova				

Anova™ 1815 Rejuvenator
Sample Analysis Report

CONTACT

Cargill, Incorporated – BioIndustrial Business

13400 15th Ave N, STE B
Plymouth, MN 55441

1-800-842-3631

Anova-Asphalt@cargill.com

www.cargill.com/asphalt

Material Tested:
Anova 1815 Rejuvenator, Lot # 16255636.

Test Procedure:
Sample tested in accordance to procedures designated to meet or exceed conformance requirements for the following requirements:

- ASTM D4552-20 for Classification of Asphalt Recycling Agents
- MNDOT 2360 Provisional High-RAM Mix Design Procedure
- OHDOT Item 441. Asphalt Concrete Misc.: Surface Course. Type 1. (448). PG70-22. High RAP
- Rejuvenating emulsion applications and rejuvenating polymer modified emulsion applications.

Test Results:
The following data has been collected from testing done in accordance to the stated ASTM specification for the aforementioned applications.

	Specification	Min	Max	Measured
Appearance	Visual	-	-	Homogenous
Viscosity, 60°C, mm2/s	ASTM D2170	10	49	30
Flash Point (COC), °C	ASTM D93	240	-	323
Specific Gravity at 25°C, g/ml	ASTM D70	0.90	1.10	0.93
Asphaltenes, W%	ASTM D3279	-	1%	0.5%
Saturates, %W	IP-469*	-	30%	0.9%
Mass Loss after TFO, W%	ASTM D2872	-	1.0%	0.134%
Viscosity Ratio (TFO/Orig)	ASTM D2170	-	3.0	1.06
PAV Viscosity Index	ASTM D6521		3.0	1.10

*IP-469 using the Iatroscan and a 60 minute N-Pentane elution performed as alternative to ASTM D2007. Results are deemed comparable within the context of specification requirements and ASTM D4552 Table 1 footnote A.

Conclusions:
Test results indicate that the sample meets requirements for the stated application.

Reviewed and approved by:

Appendix C - Pre & Post Pavement Condition Photos

Norton MM 5.80: Pre-placement Conditions. Minimal rutting & extensive cracking

Norton MM 5.70: Post-construction. Beginning of the high RAP section

Norton MM 6.90: Post-construction. High RAP section

Averill MM 0.20: Post-construction. High RAP section

Canaan MM 0.70: Post-construction. End of high RAP section

Canaan MM 1.30: Post-construction. Conventional Superpave section

Appendix D – High RAP Placement Photos


DYNAPAC
0489
AMBROSE
RENTALS
DYNAPAC

Appendix E – Balanced Mix Design Test Results

Table E-1: Hamburg Wheel Tracker Test (HWTT) Results for the Control & High RAP Sections

Control Section Test Results (Mix Design: SP21 P-800)		High RAP Test Sections (Mix Design: SP24 P-800)	
SiteManager Sample ID	Avg. Rut Depth (mm)	SiteManager Sample ID	Avg. Rut Depth (mm)
bhunting248T052322 (1)	--	bhunting248F052035 (1)	1.7
jlegg2493114633 (2)	3.5	khagan248F202747 (2)	1.9
jlegg2495085904 (3)	1.9	bhunting248R054557 (3)	1.7
jlegg2497083628 (4)	1.8		
jlegg24A122037 (5)	1.7		

Table E-2: Rapid Shear Rutting Test (IDEAL-RT) Results for the Control & High RAP Sections

Control Section Test Results (Mix Design: SP21 P-800)			High RAP Test Sections (Mix Design: SP24 P-800)		
SiteManager Sample ID	Avg. RT-Index	Number of Replicate Specimens	SiteManager Sample ID	Avg. RT-Index	Number of Replicate Specimens
bhunting248T052322 (1)	--	--	bhunting248F052035 (1)	151.1	5
jlegg2493114633 (2)	143.9	3	khagan248F202747 (2)	140.9	5
jlegg2495085904 (3)	131.1	3	bhunting248R054557 (3)	--	--
jlegg2497083628 (4)	143.7	4			
jlegg24A122037 (5)	157.4	4			

Table E-3: Indirect Tensile Cracking Test (IDEAL-CT) Results for the Control & High RAP Sections, Reheated Mix

Control Section Test Results (Mix Design: SP21 P-800)			High RAP Test Sections (Mix Design: SP24 P-800)		
SiteManager Sample ID	Avg. CT-Index	Number of Replicate Specimens	SiteManager Sample ID	Avg. CT-Index	Number of Replicate Specimens
bhunting248T052322 (1)	67.2	5	bhunting248F052035 (1)	51.5	5
jlegg2493114633 (2)	78.6	4	khagan248F202747 (2)	80.2	5
jlegg2495085904 (3)	90.5	4	bhunting248R054557 (3)	60.2	5
jlegg2497083628 (4)	70.5	4			
jlegg24A122037 (5)	71.8	4			

Table E-4: Indirect Tensile Cracking Test (IDEAL-CT) Results for the Control & High RAP Sections, Aged Mix via AASHTO R 121, Method D (20 ± 0.5 hours at 110°C)

Control Section Test Results (Mix Design: SP21 P-800)			High RAP Test Sections (Mix Design: SP24 P-800)		
SiteManager Sample ID	Avg. CT-Index	Number of Replicate Specimens	SiteManager Sample ID	Avg. CT-Index	Number of Replicate Specimens
bhunting248T052322 (1)	63	3	bhunting248F052035 (1)	49.2	4
jlegg2493114633 (2)	--	--	khagan248F202747 (2)	63.2	5
jlegg2495085904 (3)	55.4	3	bhunting248R054557 (3)	--	--
jlegg2497083628 (4)	--	--			
jlegg24A122037 (5)	46.5	4			