VERMONT

AGENCY OF TRANSPORTATION

INVESTIGATION OF FULL DEPTH RECLAMATION (FDR) ON CAVENDISH-WEATHERSFIELD ROAD

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October 2021

Research Project

Reporting on Project STP 0146(14)

Final Report 2021-04

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This material is based upon work supported by the Federal Highway Administration under ER STP 0146(14), project ID 12c226, Any opinions, findings and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the Federal Highway Administration.

TECHNICAL DOCUMENTATION PAGE

<table>
<tr><td colspan="2">1. Report No.
2021-04</td><td colspan="2">2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="4" rowspan="2">4. Title and Subtitle
Investigation of Full Depth Reclamation (FDR) on Cavendish-Weathersfield Road</td><td colspan="2">5. Report Date
November 11, 2021</td></tr>
<tr><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="4">7. Author(s)
Gallivan, Victor L., P.E.
Cross, Stephen A., Ph.D., P.E.</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="4" rowspan="2">9. Performing Organization Name and Address
Gallivan Consulting Inc.
14193 Klingensmith Blvd.
Carmel, Indiana 46033</td><td colspan="2">10. Work Unit No.</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
Contract PS0855</td></tr>
<tr><td colspan="4" rowspan="2">12. Sponsoring Agency Name and Address
Vermont Agency of Transportation
Research Section
One National Life Drive
Montpelier, VT 05633</td><td colspan="2">13. Type of Report and Period Covered
Final Report 2020-2021</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="6">15. Supplementary Notes
https://vtrans.vermont.gov/sites/aot/files/Research/GCI%20-%20VTrans%202021%20Cavendish-Weathersfield%20Final%20Report..pdf</td></tr>
<tr><td colspan="6">16. Abstract
The objective of this project was to independently document the activities of VTrans and the Contractor in the execution of the Full Depth Reclamation operations with Cement on Cavendish-Weathersfield Road, Windsor County, Vermont. Findings from the shadowing efforts resulted in development of recommended improvements to Quality Control Plans, Mix Design Procedures, Project Scoping and stabilizing agent selection procedures and revisions to the current FDR with cement specification.</td></tr>
<tr><td colspan="3">17. Key Words
Full Depth Reclamation, Cement, Quality Control Plans, Mix Designs, Dynamic Cone Penetrometer, Compressive Strength</td><td colspan="3">18. Distribution Statement
No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td colspan="2">20. Security Classif. (of this page)
Unclassified</td><td colspan="2">21. No. of Pages
51</td><td>22. Price</td></tr>
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1. EXECUTIVE SUMMARY

The objective of this project was to independently document the activities of VTrans and the Contractor in the execution of the Full Depth Reclamation (FDR) operations on Cavendish-Weathersfield VT Route 131, Windsor County, Vermont. Findings from the shadowing efforts resulted in development of recommended improvements to Quality Control Plans, Mix Design Procedures, Project Scoping and Stabilizing Agent Selection Procedures in addition to revisions to the current FDR with cement specifications. The findings from the shadowing effort, should lead to improved processes by VTrans, including but not limited to, improved performance of the roadways. The updated VTrans specifications targeted improvement of the overall FDR specifications with emphasis on improved controls of the cement.

Mix designs were not representative of the materials being reclaimed due to the significant grade corrections that occurred subsequent to sampling. Samples should have been required after grade corrections.

Compressive strength results were highly variable due to difficulties on dialing in the cement application rate and the variabilities of underlying materials. In addition, the high standard deviations of the compressive strength results make it impractical to consider using alternative statistical evaluation processes i.e., Average Absolute Deviation or Percent-Within-Limits, in the acceptance process.

The specified compressive strengths tolerances were too restrictive and contributed to unbalanced bidding on the FDR pay items. In addition, the Contractor appeared to be less concerned with VTrans efforts to introduce a culture of quality, and exhibited a willingness to incur the nominal penalties rather than to adjust their operations.

New procedures have been developed to better control the application of bulk cement that includes off-site and daily on-site calibration of the cement spreader to be completed prior to unrestricted spreading of cement.

Analysis of the Dynamic Cone Penetrometer (DCP) data was limited but sufficient to determine that due to its variability, replacing the nuclear gauge testing for density determination with a DCP is not recommended at this time. VTrans will combine this project data with DCP data from other projects for detailed analysis.

Micro cracking should be initiated as soon as practical after 3-day compressive strength results indicate excessive strengths.

2. INTRODUCTION

The Vermont Agency of Transportation (VTrans) has utilized Full Depth Reclamation (FDR) projects for years with either emulsified asphalt or cement as the stabilizing agent. VTrans FDR with cement projects typically include multiple layers of asphalt materials placed over the reclaimed materials as the final riding surface of the pavement. In 2015, a VTrans moratorium was issued on the use of FDR with cement due to significant pavement heaving (tenting) which was adversely affecting the ride ability and performance of the roadways. This "pavement heaving" was notably observed after the completion of the projects, following the first couple winter cycles.

The term pavement heaving (tenting) has been known by multiple states particularly along the northern tier of States. The Minnesota Department of Transportation (MnDOT) for example, stated "tenting is when heaving lifts up the pavement on one or both sides of a joint and crack, creating a ridge or peak along the joint". Tenting of the underlying materials is typically found in transverse cracks in asphalt pavements. A 2008 Investigation of Winter Pavement Tenting [Report MN/RC 2008-03], reported on the problems with tenting and suggests that base materials that contain high moisture and salt content in the base materials are more susceptible to tenting. VTrans observations on the previous projects has identified that tenting typically occurs on projects with high percentages of cement being used. High percentages of cement being used has resulted in higher frequency of cracking and therefore, more opportunities for moisture to enter the base materials, resulting in subsequent pavement heaving (tenting).

In 2015, VTrans joined the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) efforts to advance performance specifications into highway projects. The joint effort in Vermont starting with a review of the existing method type FDR specifications and targeted improvement on the overall FDR specifications. The joint effort also emphasized better controls of the cement as well as, investigation of alternative methods of acceptance for operations and materials. VTrans specifically targeted the lowering of strengths in treated bases to address tenting.

Updated VTrans FDR specifications were intended not only to provided elements to better address improved overall materials and construction quality but also included elements that provided greater emphasis on improved Quality Assurance Specifications that could be measured at the time of construction. Ultimately, the basis of this initiative was to migrate towards future Performance Related Specification (PRS).

Factors in the improved FDR specification include, but are not limited to, expansion of quality control plans, mix designs and procedures, moisture controls, cement application, statistical acceptance of lots and sublots, updated construction equipment requirements, and testing with DCP equipment for possible use in the acceptance process. Development of the FDR specification utilized input from multiple representatives from VTrans and industry.

The current project, identified as Cavendish-Weathersfield ER STP 0146(14), project ID 12c226, Cavendish-Weathersfield, is on VT Route 131, from VT Route 103 to VT Route 106 for approximately 9 miles. The project was selected and authorized in 2019 and the notice to proceed was issued in 2020. Most of the contiguous roadway work on the project was completed during 2020. The FDR portion of the project was initiated and completed in June 2021. Cold Central Plant materials were then placed over the treated FDR base and then topped off with new Hot Mix Asphalt, beginning in July 2021.

In 2013 VTrans completed an FDR project with cement on the same route adjoining the current project from VT Route 106 to US Route 5 for approximately 6 miles. This project was observed to be showing early cracking similar to the issues VTrans is trying to address with the revised FDR specifications. VTrans should monitor the performance of both projects and perform sealing operations in the cracks to reduce water infiltration into the base materials.

2.1 Objective

The objective of this project was to independently document the activities of VTrans and the Contractor in the execution of the Full Depth Reclamation operations on Cavendish-Weathersfield VT Route 131, Windsor County, Vermont. Findings from the shadowing activities are intended to lead to improved processes by VTrans, and improved specifications for future projects.

2.2 Scope

To meet the above objective, VTrans Research Unit initiated a coordinated effort with multiple Bureaus to monitor the project and to report on the effects of the overall specifications. In addition, an independent evaluation of the operations was established to shadow VTrans and the Contractor. Gallivan Consulting Inc., was selected to perform shadowing activities and report on the FDR operations of VTrans and the Contractor on the project, Pike Industries, Inc.

Shadowing operations began with the review of the Contractor's Quality Control Plan (QCP) and the Contractor's Mix Design in concert with VTrans Construction and Materials Bureau personnel. Shadowing operations of FDR Reclaiming operations concentrated on roadway operations and testing activities of both VTrans and the Contractor from June 7 through June 25, 2021.

3. OBSERVATIONS

3.1 Project Documents

After the project was issued the notice to proceed, the prime contractor, Pike Industries, Inc., began work activities on the project (once weather conditions permitted). VTrans Construction and Materials Bureau took over and provided staffing that reflected the operations on the project. VTrans Construction and Materials Bureau staff were also involved in the review of the Contractor's Quality Control Plan (QCP) and Mix Design submissions to determine compliance with the contract specifications and acceptability of the submissions.

The QCP requirements for the FDR operations were identified in the contract specifications with the intent of establishing a culture of quality on the project. The Contractor submitted their QCP which was summarily rejected by VTrans due to non-compliance with the specifications. After two additional submissions and revisions, the Contractor received notification that the plan was minimally satisfactory and the FDR operations could proceed once the Mix Design was approved.

The project's QCP is an essential part of a quality control system. QCP is a written document which identifies all the Contractor's intended activities to better ensure daily operations are in conformance with the contract requirements. VTrans defined various parameters within specification, such as minimum quality capabilities, operational and technical requirements. It was intended that the Contractor would expand upon these parameters within the QCP. Also, the specifications allowed the Contractor to include other information on their processes to address their quality of the product. Furthermore, the QCP was to include their intended actions to address their operations if problems arose. Very little discussion was included by the Contractor regarding testing and necessary steps to monitor the quality of the operations when failures occurred. The process was further complicated because VTrans did not have statewide QCP submittal procedures for the Contractor to follow except what was listed in the contract specifications.

The project's Mix Design is also an essential part of the quality control system. The Mix Design is the process that analyzes the sampled materials from the roadway to develop a mixture that will meet the project requirements. The Mix Design is intended to evaluate varying amounts of in-place asphalt materials, aggregate base, supplemental aggregate, subgrade, and cement to develop a corresponding design that will meet the contract 7-day compressive strength target value. This project included requirements for the Contractor to develop the FDR Mix Design for this project, based on their processes and methodology, and to be submitted along with the testing data and graphs as applicable, to VTrans for acceptance.

The Contractor submitted their Mix Design which was summarily rejected by VTrans due to non-compliance with the specifications and incomplete submission. After two additional submissions and further revisions, the Contractor finally received notification that the Mix Design was minimally satisfactory and the FDR operations could proceed.

A critical element in the mix design was the in-place sampling of the project materials. Sampling was completed in the fall of 2020, prior to the initial pulverization pass and grade corrections being completed throughout the project. The sampling was conducted at the quarter points of the project in accordance with the specifications. According to the Resident Engineer, two additional samples were obtained. It appears that the sampled materials utilized in the Contractor's mix design process may not have represented the final base materials being treated as part of the FDR operations.

The project provided for an estimated quantity of supplemental aggregates to be included in the project. The Contractor assumed the total quantity was intended to be used and calculated that this represented an average of 2 inches of new materials over the entire length of the project. The project required 8 inches of FDR and thus, the Contractor performed the Mix Designs assuming 25% supplemental aggregate. Observed placement of aggregates were as little as zero up to 24 inches or more, as shown in Figure 1.

FIGURE 1. SIGNIFICANT GRADE ADJUSTMENTS - PHOTO BY GCI

VTrans historically had samples taken from the projects and then delivered to VTrans Materials Laboratory to develop the project's FDR Mix Design. VTrans would then provide the target moisture content and cement percentage to the Contractor. The Advanced Quality Assurance Specifications included with this project differs from what was performed on previous projects because it permits the delegation of the preparation of the Mix Design to the Contractor and then VTrans verifies the Contractor's results. Verification of the Mix Design by VTrans was not completed until after the FDR operations were underway, and showed a lower cement content.

3.2 Pulverization and Reclamation

Pulverization of the roadway is the initial step of a reclamation project that consists of breaking up the existing asphalt pavement and blending with the underlying subbase material, as shown in Figure 2. The specified depth of the pulverization was 8 inches. Following pulverization, the Contractor began placement of the supplemental aggregates to improve the grade of the roadway and improve transverse grades along the roadway. After placement of the supplemental aggregates, the roadway was graded and shaped for maintaining traffic.

FIGURE 2. PULVERIZATION OPERATIONS - PHOTO BY GCI

One issue that came up subsequent to the initial pulverization operations of the roadway was from the Town of Cavendish, as shown in Figure 3. Residents' noted that the roller vibrations during pulverization were causing problems with their adjoining buildings and Historic Structures that were located along the roadway. Many of the buildings which were built in the 1800's with old dry laid stone foundations, had potential to be damaged, and asked for a change in the construction process. The Contractor requested and was approved not to utilize roller vibration in a "No-Vibration Zone" that encompasses the limits of the town, from Sta. ~94+00 to ~125+00 during the subsequent reclamation operations. The No-Vibration Zone determination also carried over to the compaction of the cold central plant mix and hot mix asphalt overlays.

FIGURE 3. LOCAL NEWS ARTICLE - PHOTO BY GCI

The Contractor's cement spreading operations which began on June 7th, appeared to be out of sync from the beginning, and it took several days to normalize. The Contractor was using a Wirtgen reclaimer that was followed by a Wacker Pad-Foot roller and then a Wacker smooth single drum vibratory roller to apply the initial compaction passes of the mixture. Due to the width of the reclaimer to the roadway, the Contractor had to make two reclaiming passes in each direction of the roadway with an overlap of 6-12 inches in the middle of each lane, as shown in Figure 4.

FIGURE 4. OVERLAPPING OF RECLAMATION PASSES - PHOTO BY GCI

The QCP Plan did not distinctly describe the sequencing of the reclaiming equipment; however, the Contractor's reclamation train was considered typical in comparison to common FDR operations in other parts of the country. The operation started off with the leveling out of the roadway and then creating a windrow with a motor grader to contain the cement, followed by the spreading of the dry cement for a distance ahead of the reclaimer, reclaiming operations, and then compaction followed by re-grading operations again. Occasionally, the late delivery of the cement from Canada prevented the FDR operations from starting on time and weather conditions were excellent for most of the operations, albeit for a couple days of rain. Due to the extreme heat and mostly dry conditions, the Contractor consistently had delays in keeping water trucks available to feed the FDR operations. Reclaiming production varied each day but typically achieved 6,000 to 7,000 feet in a single lane per day.

The Contractor estimated an application rate of 27 lbs. per square yard of cement, which was based on their optimum Mix Design. The Cement was being applied by a distributer which was computer controlled with a ground radar system and calibrated the speed of the auger system with the speed of the truck, as shown in Figure 5. The Contractor used their reclamation passes for multiple days, as their control strip attempting to "dial" in the cement spread rate. The first canvas patch test, as shown in Figure 6, weighed 33 lbs. which significantly exceeded the target cement application rate. Canvas patch tests were also being taken at the beginning of each spreader load during production.

FIGURE 5. AUTOMATED CEMENT SPREADER - PHOTO BY GCI

FIGURE 6. CEMENT CANVAS PATCH TEST - PHOTO BY GCI

Following cement mixing operations, the loose mixture behind the reclaimer was tested for moisture content, pH, and samples were obtained for compressive strength determination.

Following the reclamation pass, compaction of the reclaimed material was initiated using a pad-footed vibratory roller and a single drum vibratory roller. A motor grader then followed re-shaping the stabilized base material for the full directional width of the roadway. The Contractor then re-rolled the roadway again with the single drum vibratory roller and choose not to use the 20-ton pneumatic-tired roller which was available for compaction operations but did used it for final closing up of the surface. Occasionally, VTrans density readings did not reach the specified 94.0% of the Target Maximum Density, which then required the Contractor to apply additional passes for retesting the same location before moving forward. It was noted that the additional roller passes were applied but only in the area of the failed test instead of the entire sublot as required by the specifications.

After a successful density reading, the Contractor initiated Dynamic Cone Penetrometer (DCP) testing. The end of day's operations included the rolling of the roadway with the pneumatic-tired roller after which, the full lane was opened to traffic.

The specifications identified a moisture content range of minus 2% to optimum moisture which was determined from a standard Proctor test. The Asphalt Recycling and Reclaiming Association (ARRA) recommends a moisture content range of minus 1% to plus 2% of optimum and the Portland Cement Association (PCA) recommends ± 2% of optimum, both based on a standard Proctor test. The Contractor was using a moisture content derived from the original Proctor keeping the reclaimed materials workable for the compaction process and testing. The issue with this sequence is that since the original Proctor was performed on materials sampled prior to final grade adjustments and final reclamation, the optimum moisture content may not be represented of the materials being reclaimed. When taking the density tests, the field technicians questioned which Proctor test to use and finally settled on a density value that was near 94.0 % of the TMD. Increasing of the moisture content in the specification to plus 2% of the optimum would assist in the hydration of the materials and for compaction. Hitting the moisture target value with materials that are more granular can be difficult, particularly when the specified range is below the optimum value. The target moisture content was an average optimum content determined from the proctors during the development of the mix designs. This target was used throughout and not verified during production.

3.3 Acceptance of Materials

VTrans included in the contract a requirement for the Contractor to conduct Dynamic Cone Penetrometer (DCP) testing to gather data in the evaluation of compaction during construction as a possible alternative to using nuclear testing devices. The DCP test method determines a penetration rate of the hammer through the compacted materials. The penetration rate may be related to the situ strength, California Bearing Ratio (CBR) and soil densities when the soil type and moisture content are known.

The Contractor was using a Humboldt Duel-Mass Penetrometer that included a drive hammer and electronically recorded ten (10) drops at each location. The Contractor was initially having minor difficulties with the DCP software which resulted in delayed submission of the test results. In addition, the DCP system specified number of drops of the hammer did not fully penetrate the FDR layer in many locations. From the penetration per blow data, the CBR was calculated for each hammer drop. The DCP testing was conducted in accordance with ASTM D6951 and the results were submitted to the Resident Engineer. The DCP operational manual as shown in Figure 7 and the roadway testing operations are shown in Figure 8. The DCP tests were not part of the acceptance process for the project.

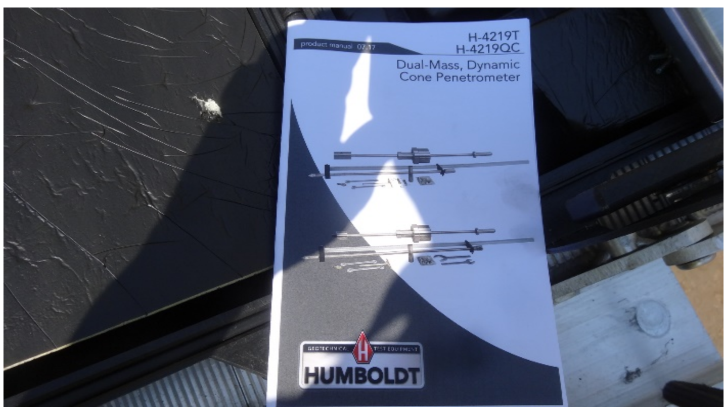

FIGURE 7. DCP MANUAL - PHOTO BY GCI

FIGURE 8. DCP TESTING - PHOTO BY GCI

Initial Contractor's 3-day compressive strength results came back high and were extremely variable. Cement mixing operations, sampling procedures, sample fabrication and testing procedures were closely evaluated to determine if there were any issues with these procedures that could be causing the high strengths and high variability. Observations of pH testing and pH test results indicated proper field mixing of cement. A VTrans 7-day compressive strength test on samples fabricated from the top and bottom portions of the FDR layer had similar strengths, confirming proper mixing. There were no issues found with sampling procedures, sample fabrication, curing or testing procedures as sampling, fabrication and testing of cement stabilized specimens appeared to be in accordance with standard procedures. Although no issues were noted, VTrans personnel were reminded to ensure that future sampling include the entire depth (8 inches) of the FDR layer in equal proportions.

Compressive strengths continued to be high throughout the first week, and beginning on June 14th, discussions between VTrans and the Contractor regarding lowering of the cement content was initiated. Reclamation operations were halted due to weather conditions on the morning of the June 15th and the Contractor formally requested permission to lower the cement content to 2.6% or to 20 lbs. per square yard, which was more in line with the VTrans verification testing. The request was approved and compressive strengths did come down but the variability remained high. Sampling, fabrication and testing for compressive strength was continually monitored and no further issues of non-compliance were noted.

3.4 Micro Cracking

Micro cracking is a technique that is available to states to help prevent shrinkage cracking, and therefore, reduction of reflective cracking in the final surface. According to the Basic Asphalt Recycling Manual (BARM), [FHWA-HIF-14-001], "if cement stabilizing, and the surface course is thin, and the compressive strength is not limited, micro cracking can help prevent shrinkage and reflective cracking". For the Cavendish-Weathersfield VT Route 131 project, the compressive strengths are limited, and there is 1.5 inches of Hot Mix Asphalt surface mix being placed over 2.5 inches of Hot Mix Asphalt intermediate mix and 2.5 inches of Cold-Central Plant recycled mix, over the reclaimed base. None of the project conditions meet the national guidance for micro cracking. Furthermore, micro cracking is typically initiated after the treated base has gained some strength, typically with 24 to 48 hours of curing (ARRA).

Contract specifications required when 7-day Compressive Strength test results were equal to or exceeding 400 psi, the Contractor was required to conduct micro cracking in the identified sublots and adjacent sublots. The micro cracking operations were initiated after the 7-day strength test results were reported.

Lastly, micro cracking is defined as a process to help alleviate the severity of transverse cracking from treated bases to form a network of small "minute" cracks to minimize moisture entering the treated bases and to prevent more severe cracks from forming. (Micro Cracking of Stabilized Bases, TxDOT No. O-4502-P4, May 2005). Micro cracking of the Cavendish-Weathersfield VT Route 131 project was limited where most of the excess application cement issues occurred and Compressive Strength Test results far exceeded 400 psi. It was observed that two vibratory steel single drum rollers in the vibratory mode applied the force to crack the treated base. The resulting significant cracks in the treated base were spaced 6 to 10 inches apart, as shown in Figure 9.

FIGURE 9. MICRO CRACKED FDR SURFACE - PHOTO BY VTRANS

3.5 Curing and Dust Control

The Contractor was required to continuously keep the FDR surface moist cured until an emulsion seal coat could be applied. The Contractor opted to apply a moist cure by using water trucks until the seal coat could be applied. On multiple occasions the Contractor fell behind on keeping the roadway moist not only for the curing of the stabilized base, but for fugitive dust control, which then became a serious safety issue for traffic, as shown in Figure 10. The Cold-Central Plant Mix surfacing materials were later placed over the seal coat.

FIGURE 10. DUST PROBLEMS ON THE ROADWAY - PHOTO BY GCI

The application of the emulsion seal coat was noted to be very satisfactory. There were no noticeable “streaking” lines and a good overlap demonstrating the full coverage of the spray nozzles, to achieve full coverage of the roadway, as shown in Figure 11. The purpose of the emulsion is to assist in the curing operation and as a dust control for traffic along the route.

FIGURE 11 EMULSION SEAL COAT BEING APPLIED - PHOTO BY GCI

The delay in continuous application of water was reported by the Contractor to be caused by a breakdown of one of the water trucks and the diversion of a water truck to the aggregate application. An additional water truck was finally delivered to the project which temporally addressed the safety hazard. The principle reason for the problems was a lack of sufficient numbers of water trucks for the multiple operations going on throughout the limits of the project. The QCP plan only included information about the Contractor will using water trucks for the “initial reclaim and RSB install” and there was nothing specified for the curing of the treated base and dust mitigation. The FDR base needs to stay moist during the cure period up to when a satisfactory 7-day compressive strength test result was determined, after which the emulsion seal coat could be placed. If the compressive strength result exceeds the specification limits, the Contractor was to then micro crack the treated base before applying the seal coat. The specifications stated that a second coat of emulsion was to be placed if micro cracking operations were required. VTrans delayed the seal coat operations until after the micro cracking was completed to reduce the double payment for the application.

4. FINDINGS

4.1 Project Documents

The contract specifications defined minimum process requirements and the minimum technical requirements to be included in the QCP. The Contractor did not sufficiently address the requirements resulting in multiple submissions and lacked critical information. Using a template for the presentation of a QCP does provide for the standardization of the development and presentation of the plans, but it may also stymie innovation. VTrans representatives indicated that they historically have had numerous problems with Contractor’s QCPs for various reasons for years, causing multiple submissions and delays in the operations. Due to the significant issues observed on this project, a standardized QCP template is recommend to be developed and utilized in the future.

It was subsequently determined that VTrans did not have standardized Mix Design Procedures for Contractors to follow. The contract specifications did provide the ASTM reference for compressive strength testing, but lacked any additional specific Mix Design requirements. To improve the quality of the operations, and due to the significant issues witnessed on this project, it is recommended that a standardized Mix Design Procedure be developed and be utilized by both VTrans and contractors in the future.

In addition, it was also discovered that VTrans did not have standardized procedures for selecting the appropriate stabilizing agent based on in-place materials for FDR applications. It is recommended that a standardized selection procedure for stabilizing agents, based on types of materials being encountered, be developed and recommended for VTrans future applications.

4.2 Density Testing

There were no issues observed with density testing. The specification called for determining percent compaction by relating the in-place unit weight to a Target Maximum Density (TMD) established from control strip which determined the rolling pattern. Whenever there was an apparent change in materials, an alternative TMD was selected. Many FDR specifications use field compacted proctors to control density rather than a target density from a rolling pattern. A target density from a rolling pattern is a common and convenient method to evaluate percent compaction for various recycled mixtures.

Occasionally, VTrans density readings did not reach the minimum 94.0% of the TMD which then required the Contractor to apply additional roller passes and retesting before moving forward. It was noted that the additional passes were applied only in the area of the test instead of the entire sublot as required by the specifications. When using statistical specifications, the results of the tests in a specific location applies to the entire sublot whether or not it passes or fails the requirements, hence re-rolling the entire sublot is necessary.

After a successful density test, the Contractor completed the Dynamic Cone Penetrometer (DCP) testing. The end of operations included with rolling of the roadway with a pneumatic-tired roller after which, the lane was opened to traffic. Table 1 lists the average percent compaction of the 14 lots which ranged from a low of 95.2% to a high of 99.6% with 12 of the 14 lots exceeding 97% compaction.

Table 1. Percent Compaction, Compressive Strength Results, Standard Deviations, Average Absolute Deviations and Pay Adjustments.

Lot	Average Compaction	Compaction Standard Deviation	Average Compressive Strength	Compressive Strength Standard Deviation	Compressive Strength Coefficient of Variation	Average Absolute Deviation	Pay Adjustment
1	98.29%	3.2%	119.80 psi	68.2 psi	56.9%	150 psi	-0.04
2	95.20%	1.06%	121.20 psi	53.5 psi	44.2%	149 psi	-0.04
3	99.60%	3.24%	145.50 psi	118.8 psi	81.6%	228 psi	-0.10
4	98.05%	2.70%	109.50 psi	57.7 psi	52.7%	228 psi	-0.10
5	97.77%	1.63%	225.83 psi	164.7 psi	72.9%	108 psi	-0.04
6	97.73%	1.64%	202.80 psi	141.7 psi	69.9%	138 psi	-0.04
7	97.20%	3.30%	197.50 psi	108.2 psi	54.8%	92 psi	-0.02
8	96.88%	1.49%	188.33 psi	54.3 psi	28.8%	53 psi	-0.02
9	97.16%	2.56%	365.50 psi	218.4 psi	59.8%	194 psi	-0.10
10	98.26%	2.55%	197.33 psi	102.6 psi	52.0%	81 psi	-0.02
11	97.84%	3.28%	279.60 psi	157.4 psi	56.3%	125 psi	-0.04

12	98.38%	1.74%	339.83 psi	251.2 psi	73.9%	141 psi	-0.04
13	97.15%	3.48%	457.19 psi	242.7 psi	53.1%	246 psi	-0.10
14	97.93%	2.44%	422.33 psi	203.4 psi	48.2%	216 psi	-0.10

There were six different TMD's determined for the entire project ranging from a low of 124.5 pcf to a high of 149.2 pcf. This is not a large number of TMD's for a project of this length; however, the TMD changed often within a short distance and across the lanes, as shown in Figures 12 and 13. Figure 12 shows the change in TMD by station along the east end of the project, up to the station break. Figure 13 shows the change in TMD by station for the west end of the project. The figures give an indication of the variability of the makeup of the FDR layer throughout the project. This high variability seems to have contributed to the variability of many of the test results.

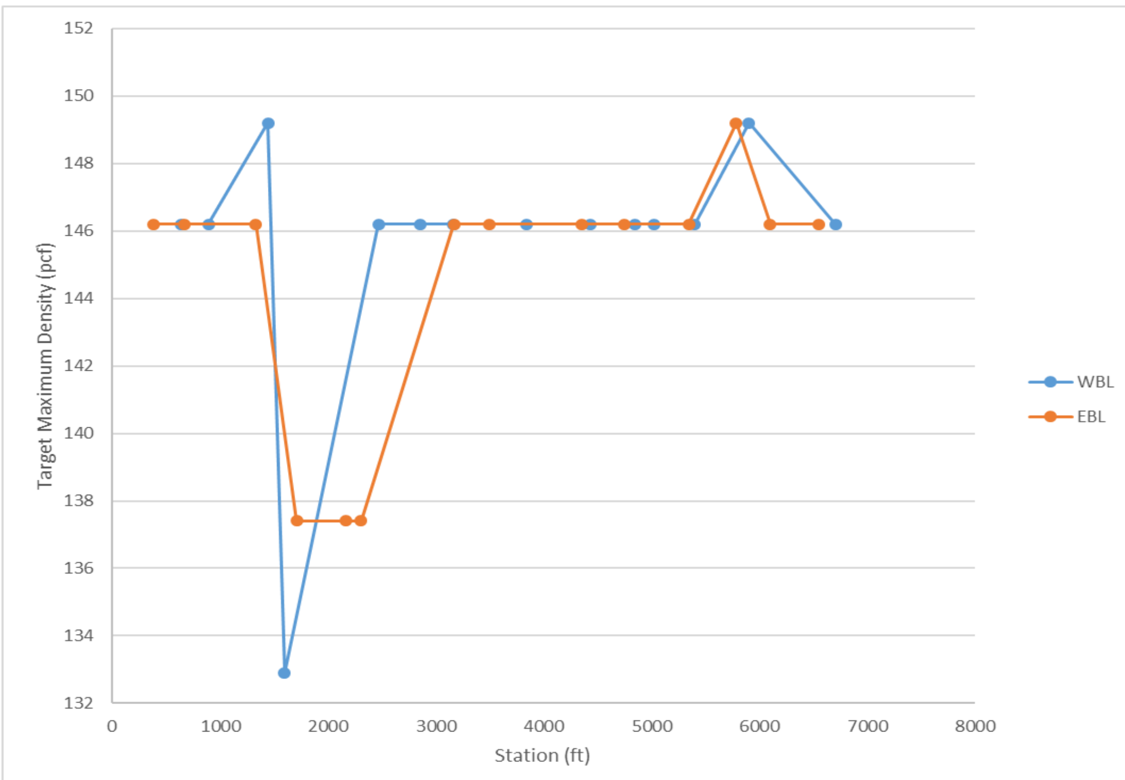

FIGURE 12. TMD DATA POINTS AND DIFFERENCES BETWEEN THE TWO LANES ALONG THE EAST END OF THE PROJECT

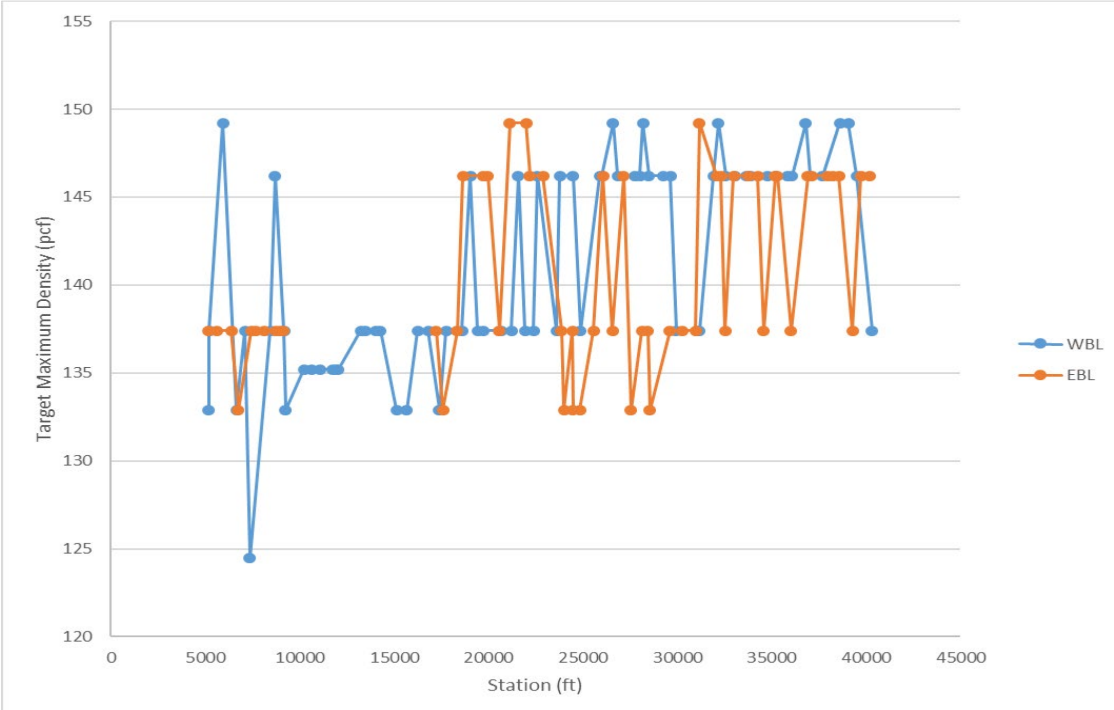

FIGURE 13. TMD DATA POINTS AND DIFFERENCES BETWEEN THE TWO LANES ALONG THE WEST END OF THE PROJECT

4.3 Compressive Strength

Acceptance was based on VTrans 7-day compressive strength results using Average Absolute Deviation (AAD) procedures to determine the Contractor's pay factors per lot. The Contractor had difficulty dialing in the correct cement content on the initial lots, which resulted in a high application of cement and excessively high compressive strengths. Once the cement application rate was adjusted, the strengths were still greater than the specification target value for the next two Lots. The target cement content from the mix design was later lowered which improved the remaining compressive strength results.

Table 1 also shows the average compressive strength, standard deviation, coefficient of variation (CV), Average Absolute Deviations (AAD) and pay adjustment factor for each lot. The Contractor started at the eastern limit of the project with Lot 13, then lot 14 and proceeded up the table alternating lanes as they proceeded west. The table shows the initial difficulty the Contractor had with cement contents and corresponding compressive strengths. The cement content was reduced on July 15th and the compressive strengths became more in line with specification requirements. However, there was still considerable variability with compressive strengths within each lot as indicated by the large standard deviations, large coefficient of variation, and large average absolute deviation results.

As shown in Table 1, no Lot received full pay for compressive strength. Five lots incurred the maximum pay adjustment of 10%, six lots at 4% and three lots at 2%. Testing and sampling procedures were carefully reviewed to determine a possible cause of the high variability within lots. No deviations from standard sampling, fabrication or testing procedures were observed and the high variability was attributed to the variability of the materials in the FDR layer and inherent variability of the test procedure itself. VTrans indicated that there was some thought of using Percent-Within-Limits (PWL) to evaluate compressive strengths for acceptance, however, that the extremely high standard deviations made this analysis impractical.

Compressive strength should be correlated to unit weight or density, as long as the cement content is constant. Figures 14 and 15 show the relationships between compressive strength and percent compaction and unit weight for the density test locations that matched VTrans compressive strength samples. The relationships are very poor, with regression coefficients less than 0.30. The relationships are trending in the correct direction with an increase in compressive strength with an increase in place compaction and unit weight.

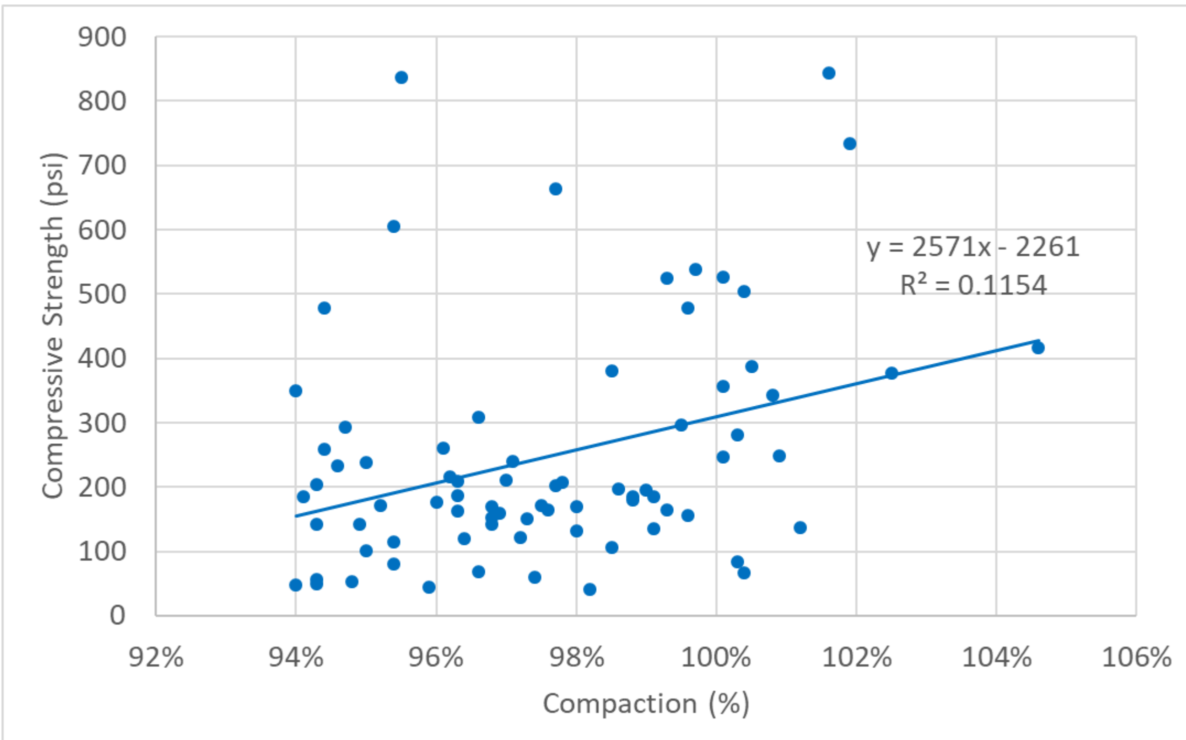

FIGURE 14. COMPACTION DATA POINTS RELATIONSHIP TO COMPRESSIVE STRENGTH

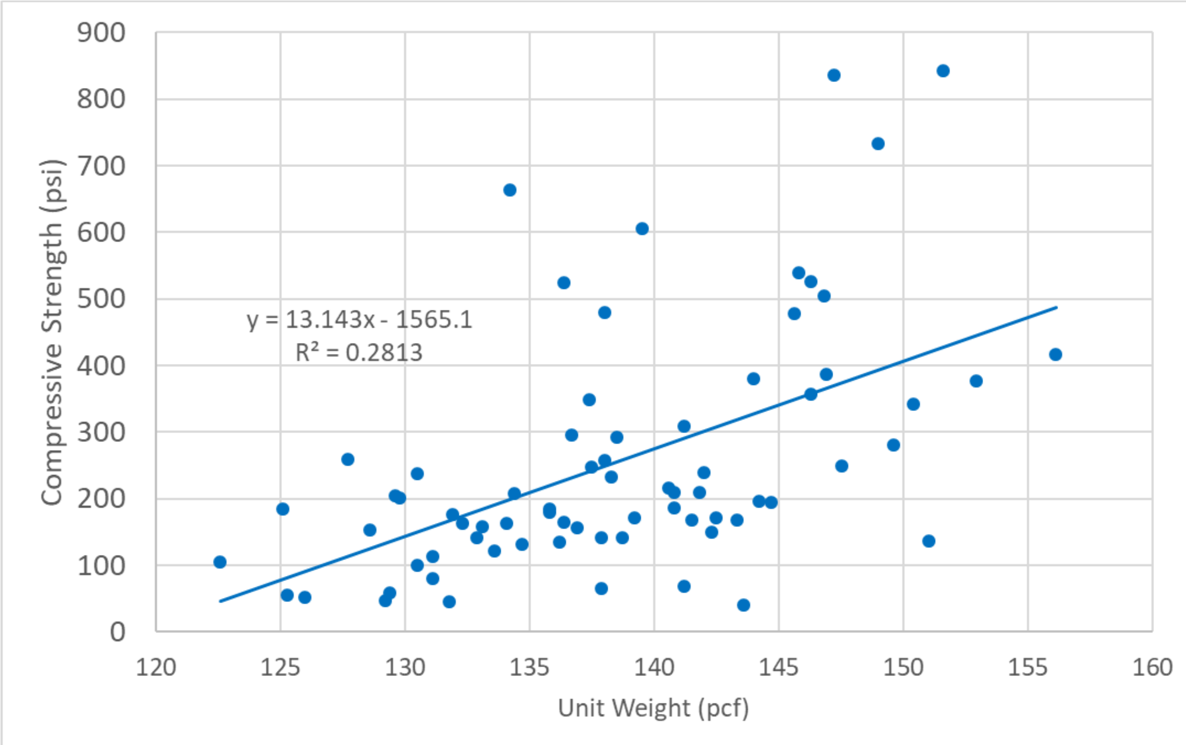

FIGURE 15. UNIT WEIGHT DATA POINTS RELATIONSHIP TO COMPRESSIVE STRENGTH

4.4 Micro Cracking

Micro cracking is a construction process that agencies may need depending upon the anticipated conditions of the in-place materials and the design of the project. For the Cavendish-Weathersfield project, the design of the project included the placement of cold central plant mix and hot mix asphalt over the reclaimed base which many believe negates the necessity for micro cracking of the treated base. In addition, the timing of the micro cracking was initiated after 7-days, after the treated base was well passed the initial cure which then contributed to the "breaking" of the treated base instead of introducing micro cracking on the surface.

4.5 DCP Data

The DCP data for one of the production days, June 22, is presented in Table 2. The CBR results are typical for the other locations. Figure 16 shows CBR with depth at location 132+40 9 Lt. After a couple of hammer drops the CBR values begin to stabilize. The variability after the initial drops could be related to the coarseness of the materials and the effect of larger aggregate/RAP particles on penetration. ASTM D6951 states that DCP is not applicable to stabilized layers or with materials greater than 2-inch maximum size. Indiana DOT uses DCP to measure compaction on embankments and subgrades and excludes DCP testing on materials with a maximum size of greater than 0.75 inch. VTrans required supplemental aggregates, to include 8% retrained the 1.5-inch sieve.

Table 2. CBR Results per Hammer Drop from DCP Testing for June 22, 2021.

Station	Drop 1	Drop 2	Drop 3	Drop 4	Drop 5	Drop 6	Drop 7	Drop 8	Drop 9	Drop 10
132+40	11.3	17.0	38.5	25.6	40.8	39.3	29.3	37.8	32.5	42.4
134+69	7.4	13.2	19.3	31.0	22.7	21.9	25.9	21.4	20.1	27.7
140+27	10.8	15.0	29.3	25.9	40.0	34.1	30.6	34.7	31.0	40.0
142+77	10.5	18.1	34.7	26.6	29.3	39.3	55.6	28.4	36.5	47.1
172+13	12.9	60.1	40.8	28.1	23.2	22.9	60.1	26.9	22.4	32.5
175+95	9.6	15.6	20.8	26.2	25.2	35.3	32.0	32.0	42.4	39.3
183+53	11.3	14.8	26.9	22.4	23.7	31.0	30.1	26.9	30.6	32.0
186+38	7.9	14.8	18.6	25.2	20.1	39.3	30.1	30.6	25.9	44.2
196+93	12.8	26.6	33.6	36.5	30.1	25.9	30.1	39.3	32.5	37.8
199+47	11.7	20.1	24.9	28.1	27.3	32.5	25.6	28.8	32.0	31.5
205+74	7.8	11.4	13.6	18.8	21.4	22.7	24.3	18.8	13.5	16.2
211+15	13.5	38.5	43.3	34.1	21.2	0.52	7.3	9.3	6.9	11.3
219+82	51.6	9.8	32.5	37.2	38.5	39.3	55.6	21.2	54.2	45.1

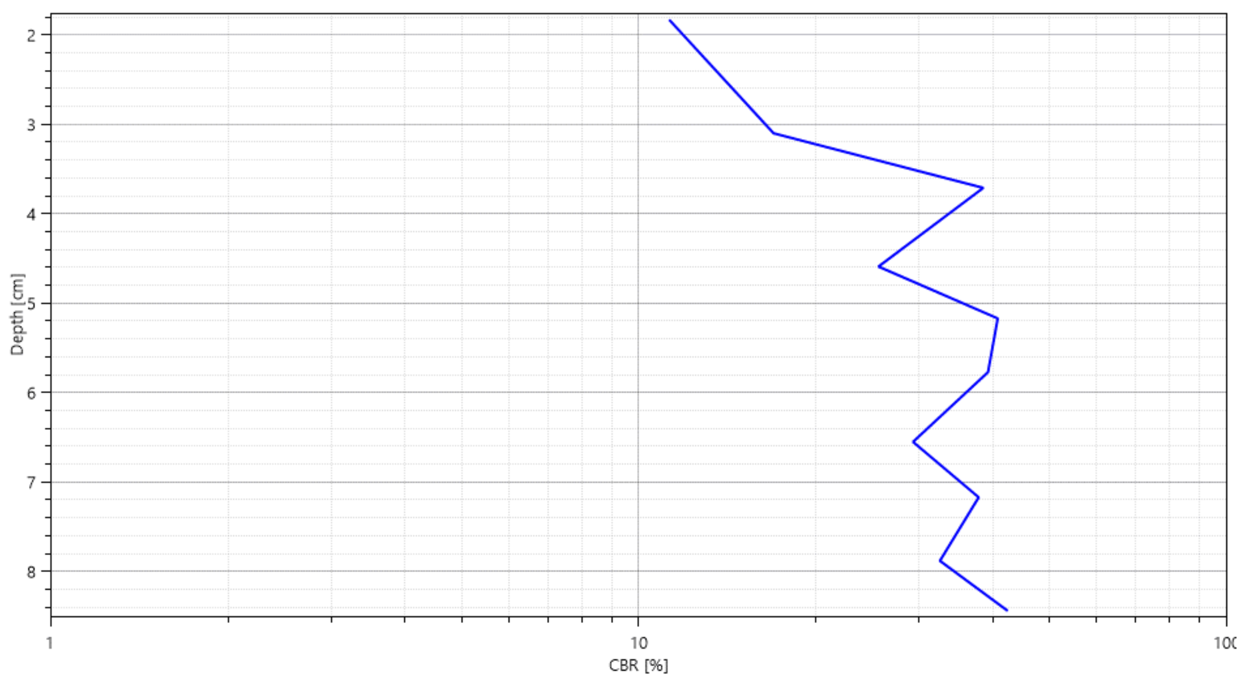

FIGURE 16. DISPLAYS THE PROGRESSION OF THE DCP HAMMER DROPS AT LOCATION 132+40 LT. INTO THE BASE VS. THE CBR VALUES FROM THE DATA IN TABLE 2.

The initial proposal called for analysis of the DCP data. However, VTrans indicated that the DCP data collected from this project will be combined with DCP data from other projects across the State to look for statistical relationships and statewide recommendation outside of the scope of this shadowing effort. Therefore, only a brief analysis of DCP data was undertaken to determine if DCP results could be correlated to compressive strength or compaction. The average CBR for the last 9 hammer drops, plotted by the DCP program at the sample location, was compared to the corresponding unit weight, percent compaction and compressive strength. The results are as shown in Figures 17-19. There was no relationship between unit weight or percent compaction with CBR, with regression coefficients of less than 0.05. There was a slight correlation between compressive strength and average CBR, as shown in Figure 19. However, there were only five locations where CBR could be matched to a corresponding compressive strength.

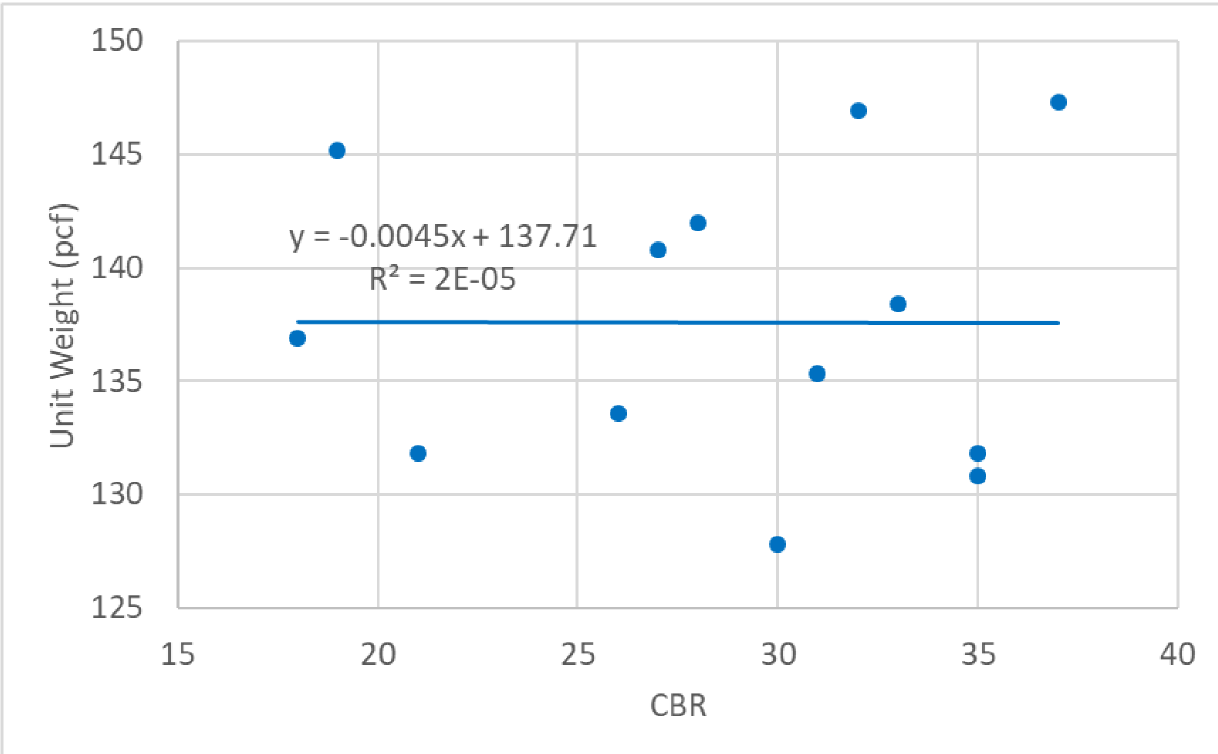

FIGURE 17. CBR DATA POINTS RELATIONSHIP TO UNIT WEIGHT

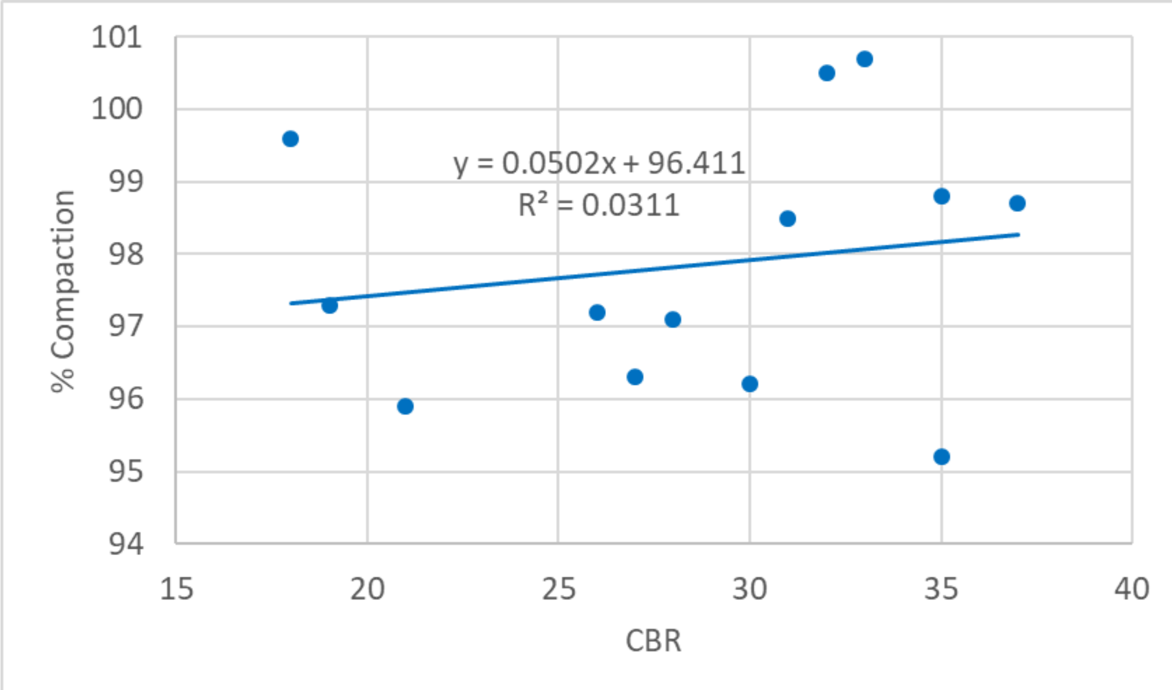

FIGURE 18. CBR DATA POINTS RELATIONSHIP TO % COMPACTION

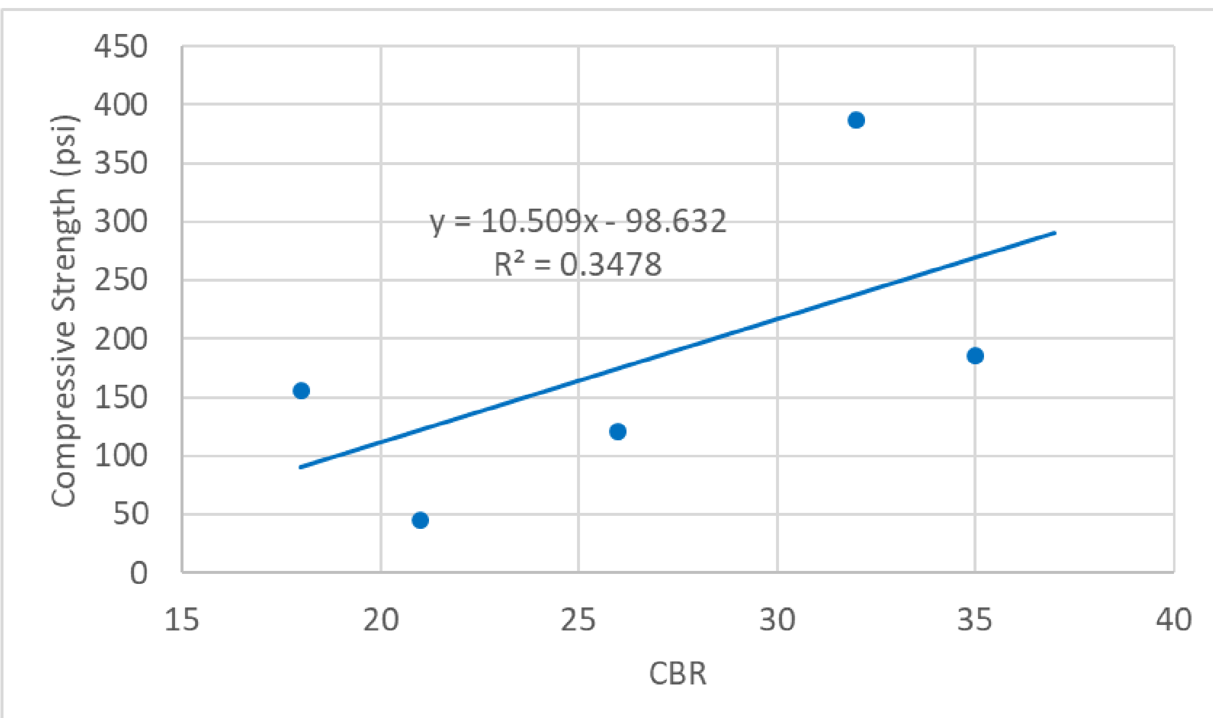

FIGURE 19. CBR DATA POINTS RELATIONSHIP TO COMPRESSIVE STRENGTH

5. SUMMARY AND CONCLUSIONS

The summary and conclusions are based on the observations made during pulverization and reclamation of the roadway, observations of the sampling and testing in the field and laboratory, and discussions with VTrans personnel. This section also introduces best practices into the discussions as well as lessons to be learned for future projects.

5.1 Project Documents

- FDR Stabilizing Agents: To assist VTrans in the selection of appropriate stabilizing agents for future projects, preliminary procedures have been developed for future consideration and are included in the Appendix.
- Quality Control Plans: Due to the significant issues observed on this project, and comments by VTrans representatives of numerous problems with Contractor's QCP's, standardized QCP procedures has been developed for future consideration and is included in the Appendix.
- Mix Designs: VTrans materials representatives indicated there were not standardized procedures for FDR Mix Designs available for VTrans and Contractor's to follow. Mix design procedures have now been developed for future consideration and are included in the Appendix.
- FDR with Cement Specifications: The contract specifications for the most part were operated without issues, but there were some issues noted that needed to be fine-tuned. Proposed revisions to the specifications have been developed for future consideration and are included in the Appendix.

5.2 Operations

- VTrans Construction personnel were actively engaged with the Contractor in the construction operations.
- Field Sampling for the mix design were not representative of the materials being reclaimed due to the significant grade corrections that occurred subsequent to sampling.
- FDR Operations: Overall the Contractor's FDR operations were generally acceptable abet for the rolling operations. Improvements in the rolling operations have been addressed in the updated specifications.
- Bulk Cement Application: Proposed specification revisions have been included in the updated specifications requiring off-site calibration of the cement spreader prior to initiating on-site reclaiming operations. In-addition, daily calibration checks of the cement spreader as well as following the recharging of the spreader also is required prior to unrestricted spreading of cement.
- Quality: The Contractor appeared to be less concerned with VTrans efforts to introduce a culture of quality, and exhibited a willingness to incur the nominal penalties, rather than adjust their operations. Improvements related quality have been included in the updated specifications.
- Field Sampling and Testing: Both the VTrans and Contractor's technicians performing the field sampling and testing for in-place densities, compressive strength, moisture, and DCP tests were

in accordance with standard procedures. The testing operations of the field laboratory were noted to be exceptional.

- Mixture Moisture: Revising the specified moisture content to minus 1% to plus 2% of the optimum would assist in the hydration of cement and for compaction of the treated base materials and has been included in the updated specifications.
- Density Testing: When a failed density test occurred, VTrans personnel allowed the Contractor to only re-roll the area of the failed test, instead of the entire sublot as required by the specifications. When using statistical specifications, the results of the tests applies to the entire sublot whether or not it passes or fails the requirements.
- Curing and Dust Control. Proposed revisions have been included in the updated specifications reinforcing cure periods of the treated base and fugitive dust control.
- Compressive Strength: Due to extremely high standard deviation of the results makes it impractical to consider using statistical evaluations, i.e., Average Absolute Deviation or Percent-Within-Limits, in the acceptance process.
- DCP Testing vs. Nuclear Testing: Limited analysis of the DCP data indicates that replacing the nuclear gauge testing for density determination with a DCP is not recommended at this time. All DCP data will be combined with the data from other projects for VTrans detailed analysis.
- Lots and Sublots: The size of the lots and sublots appeared to be consistent with the actual daily production. No issues were raised with VTrans implementation, but the Contractor did not convey an understanding of the requirements. No changes in the specifications are recommended.
- Compressive strengths: Compressive strengths acceptance tolerances were too restrictive and lead to unbalanced bidding on the FDR items. Average standard deviation for the 14 lots was 138 psi.
- Micro Cracking: Micro cracking was completed after the treated base had already passed the initial cure, which then contributed to the “breaking” of the treated base instead of introducing micro cracking on the surface. Micro cracking if used, should be initiated as soon as practical after 3-day compressive strength results indicate excessive strengths.

6. RECOMMENDATIONS

Full Depth Reclamation (FDR) is one of the principle categories for recycling and reclaiming of roadways across the country. FDR projects typically are used when the full thickness (8 to 10 inches) of asphalt pavement is to be replaced as a new base, and includes the use of either bituminous or cement as the stabilizing agent. VTrans FDR projects with cement are a viable and cost effective alternative to address their pavement needs. It is therefore recommended, that VTrans continue using FDR with cement in the future with the recommend changes as noted below.

- It is recommended that VTrans consider implementing the procedures for the selection of the appropriate stabilizing agents for future proposed projects.
- It is recommended that VTrans consider implementing standardized Quality Control Plan Procedures. Minimal revisions in the procedures would make it applicable to hot mix asphalt and other VTrans construction operations.
- It is recommended that VTrans consider implementing the proposed new FDR Mix Design procedure. Mix designs must be performed on materials that will be reclaimed. This will

require sampling after pulverization and grade corrections. Roadway samples for VTrans verification testing will be collected at the same time.

- It is recommended that VTrans consider the revisions to the Full Depth Reclamation with Cement specifications. Briefly, the revisions include revised text related to quality control, mix design, construction equipment, bulk cement application calibrations, compaction equipment as well as mixture moisture limits, compressive strengths tolerances, micro cracking, seal coats, curing and dust control requirements.
- It is recommended that VTrans reconsider the use of micro cracking as to what the desired outcome is anticipated on future projects. In the meantime, it is recommended initiating micro cracking after the 3-day compressive strength test exceeds 400 psi. VTrans then needs to consider additional research regarding the use of and optimal timing for micro cracking operations.
- It is recommended that VTrans consider requesting training regarding the development and use of statistical specifications to better understand the principles as step towards performance specifications, such as the National Highway Institute Course # 131141, Quality Assurance for Highway Construction Projects.

7. ACKNOWLEDGEMENTS

The authors wish to thank VTrans staff for their cooperation and support of our shadowing effort. Particular thanks is extended to Research Bureau Dr. Emily Parkany, and Tanya Miller for their assistance in complying with VTrans requirements, and Resident Engineer’s Jace Curtis and Tim Pockette, for their insights of the workings of the Contractor**.**

8. APPENDIX

VERMONT AGENCY OF TRANSPORTATION (VTrans)
CONSTRUCTION & MATERIALS BUREAU

PRELIMINARY STABILIZING AGENT SELECTION PROCEDURE FOR FULL DEPTH RECLAMATION (FDR) VTM No. xxx

1.0 SCOPE

1.1 This method covers the procedure for preliminary selection of a stabilizing agent for Full Depth Reclamation of pavements.

1.2 This method may involve hazardous materials, operations, and equipment and may not address all the all of the safety problems associated with the use of the test method. Users are responsible for establishing appropriate safety and health practices and determining the applicability of the regulatory limitations prior to use.

2.0 SIGNIFICANCE AND USE

2.1 This method is used to determine the appropriate stabilizing agent for Full Depth Reclamation of an individual asphalt roadway based on preliminary testing of sampled materials from the pavement.

2.2 The stabilizing agent indicated by this method should be confirmed by performing a mix design using materials properly sampled from the proposed Full Depth Reclamation project.

3.0 REFERENCES

3.1 AASHTO Standards

T 11	Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing
T 27	Sieve Analysis of Fine and Coarse Aggregates
T 89	Liquid/Plastic Limit
T 176	Sand Equivalent
M 145	Soil Classification

4.0 TERMINOLOGY

4.1 FDR Full Depth Reclamation

4.2 RAP Reclaimed Asphalt Pavement

4.3 Constant Mass- shall be defined as the mass at which further drying does not alter the mass by more than 0.5 percent in 2 hours.

4.4 Base Material- aggregate type materials directly below an asphalt pavement.

4.5 Subgrade- upper portion of a roadbed upon which the pavement structure and shoulder are constructed.

5.0 SAMPLING

5.1 The procedure for preliminary selection of a stabilizing agent shall be performed with the materials recovered from in-place pavements along with aggregate base and subgrade.

5.2 Core samples of the existing pavement are to be collected and shall represent the full depth of the existing pavement.

5.3 The minimum sampling frequency for selecting the appropriate stabilizing agent is one sample per lane mile.

6.0 PREPARATION OF MATERIALS FOR ANALYSIS

6.1 Sample Preparation Procedure

6.1.1 Pavement samples shall be cut, if necessary, to a depth that accurately represents the FDR treatment to take place, also accounting for pre-milling that may take place in the field.

6.1.2 Sample pavement shall be crushed using a laboratory crusher or other methods to pass the 1.5-inch sieve, although care should be taken to avoid fracturing the aggregate.

6.1.3 Ensure materials, including RAP, aggregate base and/or other additional materials are stored and prepared separately. Prior to batching specimens, ensure these materials are dried to a constant mass in a forced draft oven and thoroughly mixed. Dry RAP at 140 ± 2 °F and other materials at 230 ± 2 °F.

6.1.4 The material proportions should be determined by dry weight in direct proportion to the thickness of RAP, aggregate base, subgrade, encountered during sampling and other additional materials.

7.0 PRELIMINARY SELECTION OF STABILIZING AGENT

7.1 Batching and Testing of Materials

7.1.1 Batch pavement samples to the proportions determined in section 6.1.4. Perform the following tests and classify the materials according to AASHTO M 145.

7.1.1.1 AASHTO T 11 and T 27
7.1.1.2 AASHTO T 89
7.1.1.3 AASHTO T 176

7.1.2 Use Table 7.1.1 and the results from 7.1.1 to select a preliminary stabilizing agent. There is overlap in Table 7.1.1 and more than one stabilizing agent may be acceptable. In that case select the stabilizing agent based on other considerations such as cost, agency preference and contractor availability.

7.1.3 If the analysis in section 7.1.2 indicates cement as the stabilizing agent, the sample gradations from section 7.1.1.1 needs to be compared with the gradation tolerances in Table 7.1.2 to confirm agent selection. If gradation tolerances do not compare, corrective aggregates may need to be included or an alternative stabilizing agent considered.

7.1.4 Additives, such as cement or lime may be used with bituminous stabilizing agents to allow use with a wider range of materials.

7.1.5 The preliminary selection of a stabilizing agent, and the necessity of any additives should be evaluated by a mix design.

Table 7.1.1 Stabilizing Agent Selection Guide for FDR Mixtures Including RAP

Material Type – Including RAP	Well Graded Gravel	Poorly Graded Gravel	Silty Gravel	Clayey Gravel	Well Graded Sand	Poorly Graded Sand	Silty Sand	Clayey Sand	Silt, Silt with Sand	Lean Clay	Organic Silt/Organic Lean Clay	Elastic Silt	Fat Clay, Fat Clay with Sand
USCS[2]	**GW**	**GP**	**GM**	**GC**	**SW**	**SP**	**SM**	**SC**	**ML**	**CL**	**OL**	**MH**	**CH**
AASHTO[3]	**A-1-a**	**A-1-a**	**A-1-b**	**A-1-b A-2-6**	**A-1-b**	**A-3 or A-1-b**	**A-2-4 or A-2-5**	**A-2-6 or A-2-7**	**A-4 or A-5**	**A-6**	**A-4**	**A-5 or A-7-5**	**A-7-6**
Emulsified Asphalt **SE > 30 or PI < 6 and** **P_{200} < 20%**	**X**	**X**	**X**	**X**	**X**	**X**	**X**						
Foamed Asphalt **PI < 10 and** **P_{200} 5 to 20%**	**X**		**X**	**X**	**X**		**X**						
Cement, CKD or Self-Cementing Class C Fly Ash **PI < 20** **SO_4 < 3000 ppm**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Lime/LKD **PI > 20 and P_{200} > 25%** **SO_4 < 3000 ppm**								**X**		**X**		**X**	**X**

P_{200} = Percent passing No. 200 (0.075 mm) sieve; **SE** = Sand equivalent (AASHTO T 176 or ASTM D2419); **PI** = Plasticity Index (AASHTO T 90 or ASTM D4318)

[1]Additives may also be used in combination with a stabilizing agent to optimize performance of the FDR section

[2]*USCS: Unified Soil Classification System, ASTM D2487*

[3]*AASHTO: American Association State Highway Transportation Officials, AASHTO M 145*

Table 7.1.2 FDR with Cement Recommended Blend Gradation

Sieve Size		Percent Passing
2 in.	50 mm	100%
1 in.	25 mm	95-100%
No. 4	4.75 mm	≥ 55%
No. 200	0.075 mm	2-20%

VERMONT AGENCY OF TRANSPORTATION (VTrans)
CONSTRUCTION & MATERIALS BUREAU

MIX DESIGN PROCEDURE FOR FULL DEPTH RECLAMATION (FDR) WITH CEMENT VTM No. xxx

1.0 SCOPE

1.1 This method covers the procedure for roadway mix designs of Full Depth Reclamation of pavements using cement.

1.2 This method may involve hazardous materials, operations, and equipment and may not address all the all of the safety problems associated with the use of the test method. Users are responsible for establishing appropriate safety and health practices and determining the applicability of the regulatory limitations prior to use.

1.3 The Mix Design is to be developed by a design laboratory that is AASHTO Material Reference Laboratory, AMRL, accredited.

2.0 SIGNIFICANCE AND USE

2.1 This method is used to determine the appropriate mix design for an individual asphalt roadway by ensuring the sampled materials and corresponding mix design meets specification requirements.

2.2 This method is used to perform and standardize mix design procedures for Full Depth Reclamation with Cement projects.

3.0 REFERENCES

3.1 AASHTO Standards

M 85 Standard Specification for Portland Cement, Type II
T 11 Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing
T 27 Sieve Analysis of Fine and Coarse Aggregates
T 99 Moisture-Density Relations of Soils, Method C
T 265 Moisture Content

3.2 ASTM Standards

D1632 Creating and Curing Soil-Cement Specimens
D1633 Compressive Strength of Molded Soil-Cement Cylinders

4.0 TERMINOLOGY

4.1 FDR- Full Depth Reclamation

4.2 RAP Reclaimed Asphalt Pavement

4.3 Constant Mass- shall be defined as the mass at which further drying does not alter the mass by more than 0.5 percent in 2 hours.

4.4 Base Material- aggregate type materials directly below an asphalt pavement.

4.5 Subgrade- upper portion of a roadbed upon which the pavement structure and shoulder are constructed.

4.6 Mix Design Blend- selected percentages of aggregate, by weight of RAP, Reclaimed Base Materials, Subgrade, and supplemental Aggregates to be used in the mix design that accurately represents the chosen depth of treatment, materials proportion, and material types that will encountered during FDR construction operations.

5.0 APPARATUS

5.1 Cure Room, or cabinet capable of maintaining room temperature of 73.5 ± 3^0 F and relative humidity of no less than 95%, in accordance with ASTM D1632.

5.2 Compaction Hammers and molds in accordance with AASHTO T 99.

5.3 Compression Testing Machine meeting the requirement of Section 5.1 of ASTM D1633.

5.4 Scale, capable showing the reading to the nearest 0.1 gram.

5.5 Miscellaneous lab equipment including scoops, pans, mixing bowls, and containers.

6.0 SAMPLING

6.1 The FDR Mix Design shall be performed with the materials anticipated to be encountered during FDR Construction operations including in-situ pavements, aggregate base, corrective aggregate, and subgrade if applicable. Typically, sampling needs to follow the initial pulverization and grade correction operations. If construction materials change significantly between the time of sampling and construction, additional mix designs may be required to establish a representative mix design for the project.

6.2 Samples of the existing pavement are to be collected using test pits. Samples that represent the entire depth of treatment shall be collected, including any underlying materials, which are to be kept separately. A minimum of 160 lbs. shall be collected for each mix design.

6.3 Samples from significantly different pavement sections, shall be grouped separately, with separate mix design performed for each. Example of these variations include different asphalt mixes, and areas with significant grade corrections including areas with 0%, 50%, or 100% supplemental aggregates.

6.4 The minimum frequency for mix design sampling shall be approximately at the quarter points of the project and may include additional locations as determined by the Engineer. All sampling locations will be identified by date, station, offset and/or pavement lane.

7.0 PREPARATION OF TEST SPECIMENS

7.1 Sample Preparation Procedure

7.1.1 Pavement samples shall be cut, if necessary, to a depth that accurately represents the FDR treatment to take place, also accounting for pre-milling that may take place in the field.

7.1.2 Sample pavement shall be crushed using a laboratory crusher or other methods to pass the 1.5-inch sieve, although care should be taken to avoid fracturing the aggregate.

7.1.3 Ensure materials, including RAP, aggregate base and/or other additional materials are stored and prepared separately. Prior to batching specimens, ensure these materials are dried to a constant mass in a forced draft oven and thoroughly mixed. Dry RAP at 140 ± 2 °F and other materials at 230 ± 2 °F.

7.2 Material Proportioning for Mix Design Blend

7.2.1 The material proportions should be determined by dry weight in direct proportion to the thickness of Supplemental Aggregate, RAP, aggregate base, subgrade encountered to be reclaimed. These materials should then be subjected to sieve analysis, in accordance with AASHTO T 11 and T 27. If gradation in accordance with Table 7.2.1 is not achieved, corrective aggregate will be needed to be added to the mix design.

Table 7.2.1 FDR Mix Design Blend Gradation

Sieve Size		Percent Passing
2 in.	50 mm	100%
1 in.	25 mm	95-100%
No. 4	4.75 mm	≥ 55%
No. 200	0.075 mm	2-20%

7.2.2 Once the gradation is in accordance with Table 7.2.1, the mix design blend shall be subject to a moisture-density relationship test in accordance with AASHTO T 99, Method C. The resulting maximum dry density (MDD) value shall be used to determine the weight of cement to be added for each specimen set. The optimum moisture content (OMC) shall be used to determine the moisture content of the mixture prior to introduction of cement.

7.3 Cement Content Selection

7.3.1 Mix designs shall be performed using Type II Portland cement in accordance with 701.02 of the Standard Specifications.

7.3.2 Select a minimum of three cement contents in increments of 0.5 to 1.0 percent within a suggested range of 2.0 to 4.0 percent by dry weight of the mix design blend.

7.4 Mixing Procedure

7.4.1 Mixing occurs at room temperature. One specimen shall be mixed at a time.

7.4.2 Add water to the batched material to bring it to the optimum moisture content, plus 0.25%, and using a mechanical bucket mixer, begin mixing batched material at 50-75 revolutions/minute. The mixture may also be incorporated by hand.

7.4.3 Mix for no less than 60 seconds in the mechanical mixer or 120 seconds by hand. Cover the mixed material with a damp cloth to prevent moisture loss and allow to stand for 5 to 10 minutes to aid in dispersion of moisture and permit absorption by the mixture.

7.4.4 Add pre-weighed amount of cement.

7.4.5 Mixing time to incorporate cement shall be approximately one minute.

7.5 Generation of Test Specimens

7.5.1 After mixing create unconfined compression strength specimens in accordance with ASTM D1632.

7.5.2 Store specimens in cure room in accordance with ASTM D1632 for 7 days.

7.5.3 After curing, remove from the cure room and immerse the specimens in water for 4 hours.

7.5.4 After the 4-hour soak, cap the sample ends, if required, in accordance with ASTM D1633. Keep specimens moist by wrapping in wet burlap or blanket covering until testing.

8.0 UNCONFINED COMPRESSION STRENGTH TESTING

8.1 Test each specimen to failure in accordance with ASTM D1633.

9.0 CALCULATIONS

9.1 Unconfined Compression Strength. Calculate unconfined compression strength of each test specimen according to ASTM D1633. The average strength of 2 test specimens for a particular cement content shall constitute the final result.

9.2 Selecting a Final Design Cement Content.

9.2.1 Graph the strength vs. cement content data and draw a trend line.

9.2.2 Select and report the minimum cement content that meets or exceeds mix design requirements detailed in the project specifications.

10.0 REPORT

10.1 Report at a minimum, the following Mix Design information**.**

10.1.1 Executive Summary of Testing and Results.

10.1.1.1 Recommended Cement Percentage

10.1.1.2 Recommended Target Moisture Content

10.1.1.3 Resulting 3 and 7-Day Strengths

10.1.2 Name/location of the laboratory, AASHTO Accreditation and where the Mix Design was developed

10.1.2.1 Name and Certification of Technician(s) who performed the sampling and testing

10.1.3 When and where roadway samples were taken

10.1.4 Cement Type, Source and Certification

10.1.5 Laboratory Gradation and Mixing Procedures

10.1.6 Mix Design Test Results to be reported.

10.1.6.1 Gradation Summary Reports and Plots including Individual and combined materials

10.1.6.2 Maximum Dry Density and Optimum Moisture contents

10.1.6.3 Dry Density, Moisture Content and Unconfined Compressive at each of the Cement contents used

10.1.6.4 Wet Density of specimens before and immediately after moist curing period

10.1.6.5 Optimum Cement Content as a percentage of Dry Materials

10.1.6.6 Procedure used to determine optimum or target gradation

10.1.6.7 Supplemental Aggregates Determination

10.1.7 Recommended 3 and 7-day strength results with plot of strength vs. Cement Contents

VERMONT AGENCY OF TRANSPORTATION (VTrans)
CONSTRUCTION & MATERIALS BUREAU

CONTRACTOR QUALITY CONTROL PLAN (QCP) PROCEDURES
FOR
FULL DEPTH RECLAMATION (FDR)
VTM No. xxx

1.0 SCOPE

1.1 This procedure covers the preparation of Quality Control Plans for Full Depth Reclamation Projects. This QCP shall be provided, maintained, and followed to assure all materials are furnished and used in accordance with the contract specifications.

1.2 This method may involve hazardous materials, operations, and equipment and may not address all the all of the safety problems associated with the use of the procedure. Users are responsible for establishing appropriate safety and health practices and to determine the applicability of the regulatory limitations prior to use.

2.0 REFERENCES

2.1 VTrans, AASHTO, ASTM, NETTCP and other referenced standards shall be identified under each of the Contractor's QCP sections.

3.0 TERMONOLGY

3.1 Definitions for terms and abbreviations shall be in accordance with VTrans Standard Specification for Construction, Subsection 101.12. Other specific terms and abbreviations relative to the Contractor's operations shall be defined within the QCP sections.

4.0 SIGNIFICANCE AND USE

4.1 This method presents the format to be utilized and minimum information required by the contract specification that is to be included in Quality Control Plans for VTrans review. The Contractor is expected to expand upon additional quality elements to match their companies' operations.

5.0 GENERAL REQUIREMENTS

5.1 Shall be signed and dated by the Contractor's principle representative at the time the QCP is submitted to VTrans.

5.2 The QCP shall be contract specific and specifically state how the Contractor plans to control the materials, equipment, construction operations, and execution of QC sampling and testing on the project.

5.3 The QCP shall contain the names, qualifications, cell phone number, duties, employer, plus specific contract specification requirements of all quality control personnel necessary to implement the QCP elements.

5.4 The QCP shall be maintained to reflect the current status of operations, and revisions shall be provided in writing prior to initiating changes. Changes shall not be implemented until the revision has been accepted.

5.5 The QCP shall include an organizational chart beginning with the head of the office including construction and quality control personnel.

6.0 QUALITY CONTROL PERSONNEL

6.1 Quality Control Plan Administrator

6.2 Quality Control Technician (QCT)

7.0 MATERIALS

7.1 Aggregates. Detail the plans for controlling gradation and moisture in the aggregate stockpiles, identification of stockpile locations, construction techniques for charging stockpiles and loading procedures for transportation to the project.

7.2 Cement. Provide the source and location of the cement plant or terminal.

7.3 Materials sampling and testing, provide detail descriptions

7.3.1 Field moisture sampling, testing and tolerances

7.3.2 Field density testing. Manufacture of the Nuclear or Non-Nuclear gauges

7.3.3 Sampling of materials. Frequency and sample size

7.3.4 Location of testing laboratory and description of the testing equipment to be used in the determination of compressive strength results

7.3.5 Compressive strength sample preparation, curing, testing and tolerances

7.3.6 Specific statement regarding accessibility that allows the VTrans personnel to witness any and all QC testing procedures and to review QC testing results.

7.3.7 Emulsion. List the source

7.4 Process Control of Construction Operations. Sequencing of operations, equipment, and personnel.

7.4.1 Pulverization of existing pavement

7.4.2 Grade reconstruction

7.4.3 FDR operations including water trucks

7.4.4 Rate and controls of cement application including daily calibration

7.4.5 Motor grader(s) for establishing grade and cross slope

7.4.6 Compaction. List type, weight and specific sequencing of rollers for preliminary and final compaction operations

7.4.7 Emulsion application, including timing

7.5 Response to testing results

7.5.1 Field testing regarding moisture and density results

7.5.2 Laboratory 3- and 7-day compressive strength results

7.6 Documentation

7.6.1 Reporting of QC test results to VTrans

8.0 PROJECT SPECIFICATIONS

8.1 Other required elements to be reported on

FULL DEPTH RECLAMATION (FDR) WITH PORTLAND CEMENT

1. DESCRIPTION.

This work shall consists of the Pulverization and Full Depth Reclamation (FDR) of the pavement by removing a volume of material by cold-planing the surface (when specified) pulverizing and stabilizing the existing roadway with Portland cement with specific equipment to the specified lines, grades, and dimensions in accordance with subsection 105.03. This work includes the shaping, finishing, fine grading, curing and compaction of the stabilized base materials together with the addition of supplemental aggregate which may include reclaimed asphalt pavement, reclaimed aggregate material, and/or subgrade material if/when required.

2. MATERIALS.

Materials shall meet the requirements of the following:

Portland Cement 701.02
Emulsified asphalt.. 702.04
Subbase of Crushed Gravel, Fine Graded 704.05
Water 745.01

3. LOTS AND SUBLOTS.

For FDR operations, lots are defined as full directional width for 6,000 LF which are further sub-divided into six sublots not to exceed 1,000 LF each. Partial sublots of 200 LF or less will be added to the previous sublot. Partial sublots of greater than 200 LF will constitute a full sublot. Partial lots of two sublots or less will be added to the previous lot.

4. DEFINITIONS.

Pulverization - Initial pass of the reclaimer designed to break up the existing pavement and blend the materials into a homogeneous mixture.

Reclamation – Second pass of the reclaimer to blend the mixture with supplemental aggregate and introduce the stabilizing agent into the mixture.

Reclaimer – Specialized equipment designed to pulverize and mix in-situ asphalt materials with base or subbase materials by crushing and breaking mechanics to a specific depth and width.

Reclaimer Pass - A single pass is defined as full drum width coverage, with the required overlap, in a single direction.

5. WEATHER LIMITATIONS

The Contractor shall monitor the weather conditions and sequence operations accordingly. FDR operations will not be permitted from September 1 to May 15 unless it has been approved in writing by the Resident Engineer. Cement stabilization shall not be performed when soil temperatures are expected to be less than 40ºF anytime within the next 72 hours and/or freezing temperatures within seven days of curing operations. Cement stabilization shall not occur when rainfall is anticipated within four hours of starting operations. The Contractor shall make all necessary repairs of the reclaimed areas that has been damaged by inclement weather.

6. QUALITY CONTROL PROGRAM.

The Contractor shall prepare and submit a Quality Control Plan (QCP) developed in accordance with VTM xxx to the Resident Engineer a minimum of 14 days prior to commencing pulverization. Pulverization or initial FDR operations shall not commence until the QCP is accepted by the Resident Engineer.

The Resident Engineer and Contractor will jointly review on-going operations to ensure compliance with the QCP. The Resident Engineer will document and provide the Contractor, in writing, notice of major violations. The Contractor has 24 hours to resolve the violations. Continual violation of the QCP may result in suspension of all project operations.

The QCP shall address each phase of the construction including pulverization and regrading of the roadway, adding supplemental materials, cement application, reclamation pass, compaction, final grading, curing and protection of reclaimed surface, dust mitigation, and micro cracking. The QCP shall address all reasonably anticipated factors including but not limited to weather, materials quality, material availability, traffic, equipment availability, and materials delivery. Process control requirements that are directly affected by contingency factors such as moisture content, gradation, time delay, cement application, and compaction must have specific action limits defined for field implementation. Additionally, Contractor suspension limits shall also be identified in the QCP considering the same criteria defined above.

The Contractor shall define an appropriate sampling and testing frequency for quality control purposes but not less than VTrans frequency.

The Contractor is responsible for field confirmation of the FDR Mix Design and for monitoring of the field operations. The Contractor shall provide a sufficient quantity of all related equipment required to conduct the compressive strength testing. The Contractor shall provide equipment necessary to fabricate soil cement test specimens, including the wetting and drying of compacted soil-cement mixtures, and other equipment in accordance with ASTM D1633. The Contractor shall also provide the compression testing equipment in accordance with ASTM D559 and a minimum of 24 molded soil-cement cylinders for quality control and VTrans acceptance testing.

The QCP shall incorporate the following personnel with the specified minimum requirements and qualifications itemized:

(a) QC Plan Administrator. The QC Plan Administrator shall be identified and required to document past experience on FDR projects. The following requirements are required:

(1) Full-time employee of the Contractor or an independent consultant not involved with the acceptance activities on the project;

(2) Minimum four years of experience in quality control activities in construction operations;

(3) Full authority to institute actions necessary for successful implementation of the QCP.

(b) Quality Control Technician (QCT). The person(s) responsible for conducting quality control and inspection activities to implement the QCP. There may be more than one QCT on a project. The following requirements are required:

(1) Full-time employee of the Contractor or an independent consultant with a minimum two years of experience in quality control activities in field construction operations;

(2) Completed the requirements for the applicable testing by the Northeast Transportation Training and Certification Program (NETTCP) for Soils and Aggregate Inspector, or an equivalent Regional Program;

(3) Full authority to institute actions necessary for successful implementation of the QCP.

(c) QCP Minimum Requirements.

(1) The QCP shall be signed and dated by the Contractor's representative at the time the QCP is submitted to the Resident Engineer;

(2) QCP shall be contract specific and include how the Contractor intends to control the materials, equipment, and construction operations including subcontractors and suppliers.

(3) The QCP shall include an organizational chart showing all quality control personnel and how these personnel integrate with other management/production and construction functions and personnel. The contact information for all quality control personnel necessary to implement the QCP shall be included;

(4) The QCP shall be maintained to reflect the current status of the operations, and proposed revisions shall be provided in writing. The QCP revisions shall not be implemented until the accepted by the Resident Engineer;

(5) A statement included that the Resident Engineer or its designated Agent has unrestricted access to the Contractor's testing operations and all QC records;

(6) Quality Control inspection and testing records shall be made immediately available and additionally, submitted to the Resident Engineer within 30 days of completion of the FDR operations;

(7) Contractor's plan for incorporation of advanced process control technologies e.g., Intelligent Compaction, Automated Machine Guidance, Global Navigation Satellite Systems, etc.

(8) Contractor's procedures for minimizing and mitigating the release of airborne particles (dust) from the roadway onto adjacent properties and when opened to traffic;

(9) The Resident Engineer will review, sign, and date the QCP, via DOC Express, if the contents of the QCP are in compliance with the VTrans requirements as stated herein;

(d) <u>QCP Technical Requirements:</u>

Written description of the technical elements of the QCP is to be provided including the construction process procedures, equipment, testing standards, testing tolerances, and specification limits if applicable. References to the VTrans Standard and Supplemental Specifications, VTrans Procedures, AASHTO, ASTM and related test procedures, shall be included.

(1) Procedure, equipment, and technical requirements for Global Navigation Satellite Systems;

(2) Procedure and frequency for monitoring weather conditions;

(3) Procedure, equipment, and frequency proposed for monitoring gradation of the pulverized materials;

(4) Proposed operating speed of FDR equipment;

(5) Procedure, equipment, and frequency proposed for monitoring the water addition to the reclaimer;

(6) Procedure, equipment and frequency for monitoring the reclaimed material moisture requirements during production;

(7) Procedure for monitoring the depth of pulverization and reclamation during operations;

(8) Procedure, equipment, for monitoring and reporting for pH testing per sublot;

(9) Procedure, equipment, and frequency proposed for monitoring the amount of stabilizing additives e.g., cement (canvas patch test or equivalent), and/or mechanical;

(10) Procedure for curing the stabilized base including the initiation and duration;

(11) Procedure, equipment, and proposed frequency for monitoring and reporting sublot compressive strength gains at 3- and 7-days;

(12) Procedure, equipment and frequency for obtaining compaction and the monitoring of the moisture content of the reclaimed material;

(13) Other information on the Contractor's process or quality control operations necessary to bring the processes back into tolerances e.g., if outside of the contract limits, specification limits or QCP limits.

(e) Quality Control (QC) Records.

Quality control records shall include all sampling events, testing results, and process changes with accurate time and location data. All QC records shall be bound or electronically submitted to the Resident Engineer within 30 calendar days of the completion of FDR operations.

7. FULL DEPTH RECLAMATION MIX DESIGN REQUIREMENTS.

The Contractor will conduct unconfined compressive strength testing, in accordance with ASTM D1633 Method A, or equivalent, and AASHTO T 99, Method C for moisture density testing. The project's 7-day target compressive strength target is 250 ±75 psi.

For quantity calculation purposes only, a Portland cement content of 2.0% may be considered as an estimate the cement quantities for the project. The Contractor or its designated Agent, will develop a FDR Mix design considering the sensitivity of RAP and supplemental aggregates and its relationship to various cement contents.

The Contractor shall provide the equipment and personnel to conduct mix designs in accordance with VTM xxx following the initial pulverization and grade correction operations, if applicable. Mix design sampling shall be conducted at approximately the quarter points of the project and may include additional locations as determined by the Resident Engineer. Sampling shall be conducted on materials anticipated to be encountered during the full depth reclaiming operations that includes in-situ pavements, aggregate base, RAP, supplemental aggregate, or subgrade materials, as applicable. A minimum of 160 lbs. of loose material are required to be collected at each location. In addition, at one of the locations, as directed by the Resident Engineer, an additional (160 lbs.) sample shall be collected and immediately provided to the Resident Engineer for VTrans mix design verification testing. All samples shall be identified by date, station, offset and/or pavement lane.

If reclaimed materials change significantly between the time of original sampling/testing and construction, additional mix designs shall be performed and re-submitted to the Resident Engineer for verification to establish a more representative design for the project. FDR operations shall not commence until the Mix Design(s) are approved by the Resident Engineer.

The supplemental aggregate shall not deviate from the mix design gradation by more than the tolerances listed in <u>CONSTRUCTION REQUIREMENTS</u> and subsection (g).

8. <u>CONSTRUCTION REQUIREMENTS</u>.

(a) <u>General</u>.

Any manholes, valve covers, or other buried structures shall be protected from damage prior to beginning construction operations. If required, cold planing of the roadway, shall be in accordance with section 210.

The Contractor shall protect any surface or buried structures (bridges, culverts, slabs, utilities, shallow drainage pipes, manholes, valve covers, etc.) during pulverization, including suspending the operations at these obstructions when required. When approaching any surface or shallow buried structures, the Contractor shall terminate mechanical pulverization or mixing a minimum distance of two feet from the structures. The Contractor shall remove the pulverized material through other means and ensure no damage to the structure. Replace the removed material with full depth treated material that has been mixed and treated with the applicable stabilization materials. Damage to these structures will be repaired at the expense of the Contractor.

(b) Geometry and Limits of Pulverization, Reclamation and Grading.

The Pulverization, Reclamation and Grading operations shall not exceed six inches beyond the plan width of the roadway. The Contractor is responsible for checking the depth of the pulverization and reclamation, and providing the Resident Engineer thickness measurement of the operations for each reclaiming pass of each sublot.

The design depth and line of cement stabilized material shall be a fully homogenous mixture of cement stabilizer, shaped, graded and compacted to within ±0.5 inch of the plan grade in accordance with subsection 105.03.

(c) Cement Spreading Calibration.

Off-site calibration of the cement spreader is required prior to initiating on-site reclaiming operations. The Resident Engineer shall be notified of the date, time and location of the pre-construction cement calibration operations. In-addition, on-site daily calibration checks of the cement spreader is required, as well as, following the recharging of the spreader, prior to unrestricted spreading of cement ahead of the reclaimer. Each on-site calibration checks shall not exceed 50 ft.

(d) Reclamation Equipment.

The reclaimer shall be a self-propelled, rotary reclaimer with a minimum operational power of 500 HP and capable of mixing water, dry additives, and the pulverized materials into a homogenous mixture to a depth of 14 inches in a single pass. The cutting drum shall be a minimum of seven feet in width and have the ability to operate at various speeds (rpm), independent of the reclaimer forward speed. During pulverization the cutting head shall rotate in an "up-cut" rotation or opposite to the forward direction of travel of the reclaimer.

The reclaimer shall be equipped with a means for the Resident Engineer to continually monitor the depth of reclamation and the speed of the reclaimer.

The reclaimer shall be equipped with a computerized integral water proportioning system capable of metering the water application rate (±2% by weight) relative to depth, width, and speed of operations. The spray bar shall be mounted to allow the water to be injected directly into the cutting drum/mixing chamber. The water pump shall be connected to the supply tanker or distributor by a hose, and mechanically or electronically interlock the flow of water with the forward ground speed of the machine. Calibration records shall be provided to the Resident Engineer to confirm the injection capabilities.

The cutting teeth on the drum shall be inspected and all worn or broken teeth replaced as necessary during the day.

Equipment such as road planers or cold-planing machines designed to mill or shred the existing roadway materials are not allowed as an alternative to the reclaimer.

(e) Pulverization and Grading.

The equipment used in the Pulverization of the Existing Pavement shall consist of the same equipment to be used in the reclamation, and compaction of the stabilized base. A motor grader for pre-shaping, spreading, and final shaping of the roadway to the planned grade and cross slope shall be provided. The motor grader shall be equipped with an electronic cross slope indicator.

The pulverization shall blend the existing material into a homogeneous mixture. Within the each sublot, the Contractor is to sample the pulverized materials to verify the maximum size of pulverized mixture does not exceed 3 inches.

(f) Stabilization Agent.

Portland cement shall be placed using a spreader truck designed to be non-pressurized mechanical vane-feed, cyclone or screw type capable of providing a consistent, accurate and ensure a uniform distribution of cement across the reclaiming pass while minimizing the release of cement in the air. Pneumatic application, including through a slotted pipe, will not be permitted. Other systems such as slurry applications, fog systems, or vacuum systems may be considered by the Resident Engineer upon a written request and documentation of the system being proposed.

The Contractor shall ensure a full and homogeneous distribution of the cement and provide the means for verifying the uniformity of the materials for the full depth of the reclaimed layer.

Longitudinal joints between successive passes shall overlap a minimum of six inches.

(g) Supplemental Aggregate.

Supplemental aggregate to be added shall be within the following tolerances of the Mix Design Gradation.

Sieve Designation	Percent by Weight Passing
2 inch (50 mm)	100
1-1/2 inch (37.5 mm)	+/- 8%
No. 4 (4.75 mm)	+/- 6%
No. 100 (150 µm)	+/- 4%
No. 200 (200 µm)	+/- 3%

Estimated quantities for full depth undercut corrections are included in the plans. Areas identified for full depth correction will be determined by the Resident Engineer. Undercut areas shall be constructed as directed and by placing and compacting 12 inches of dense graded coarse aggregates topped by 12 inches of supplemental aggregates.

(h) Moisture Content.

The moisture content of reclaimed materials shall be within -1% to +2% of the optimum moisture content. The Contractor shall monitor the moisture content, independent of the reclaimer speed of operations. If the optimum moisture content is not attained, the material shall be reworked and retested.

(i) Compaction.

The Contractor shall provide a minimum 25-ton vibratory pad-foot roller, (10 to 14 tons) single or double drum vibratory steel drum roller(s) and a minimum 20-ton pneumatic-tired roller for both the pulverization and reclamation passes. At a minimum, the pneumatic roller will be used to close-up the surface of the stabilized base before initial curing.

(i) Control Strip.

Control strip testing shall begin upon completion of the stabilization pass and will consist of a series of tests following each pass of the steel drum roller. After each pass of the roller, the QCT may use a nuclear gauge, to measure the density of the section at four locations spaced no less than 100 LF apart, and within the width of the single roller pass. The number of roller passes and density readings per roller pass will be recorded and the target density will be the peak of the four readings to be labeled as the Target Maximum Density (TMD). The TMD peak is defined when there less than a 3-pcf change in two successive roller pass density readings. The total number of passes of the rolling equipment will be documented. VTrans will be conducting adjoining density testing to confirm the Contractor's TMD determination.

Upon acceptance of the control strip by VTrans, the Contractor shall use the same equipment and construction methods for the remainder of FDR operations, unless changes are proposed to and are approved by VTrans. If changes are accepted, the Contractor shall conduct a new control strip determination.

If the control strip fails to meet the TMD the Contractor shall repair and/or replace the control strip in accordance with subsection 105.13. Any repairs, replacement, or duplication of the control strip will be at the Contractor's expense.

(k) Curing and Treatment of Stabilized Base.

The Contractor shall protect the stabilized base from drying by continuously watering the surface until the emulsion seal coat can be applied. The wet curing of the surface shall be initiated following the final compaction of the stabilized base.

(l) Emulsion Seal Coat.

The surface shall be swept and a single application of RS-1h be applied at a rate of 0.10 gal/yd^2 (±0.025 gal/yd^2). The emulsion application shall cure no less than 5 calendar days before subsequent pavement courses are placed.

(m) Traffic Considerations.

Completed portions of the FDR may be opened to local traffic prior to applying the emulsion seal coat, provided that the curing operations are not affected and operations to control the dust are continuous. The Contractor shall provide access for adjoining property owners if the roadway is closed to through traffic and maintain the integrity of the stabilized base in accordance with subsection 105.17.

(n) Maintenance.

The Contractor shall maintain the stabilized base in good condition until subsequent pavement courses are placed at no cost to VTrans. Maintenance activities shall include immediate repairs with similar materials, of any damage that may occur. No skin patches will be permitted.

9. Acceptance Criteria.

Acceptance of the FDR operations will be based on lots and sublots for both density and compressive strength testing. Completed lots may extend over multiple days as necessary to complete the operations.

The Resident Engineer will randomly select one random location within each sublot for density testing. Density of the compacted stabilized materials will be determined by VTrans using nuclear density gauges in accordance with AASHTO T 310, Method B, and shall meet a minimum of 94.0% of the TMD. All density results will be reported to 0.01%. If the sublot density is less than 94.0%, the full sublot shall then receive additional rolling and then will retested at the same location.

Resident Engineer will randomly select one stratified location within each sublot for strength testing. Compressive strength testing of the stabilized base will be determined in accordance with ASTM D1633 Method A, by VTrans and will consist of one split mold test per sublot. The All compressive strength results will be reported to 0.01%.

10. Pay Adjustments.

The Lot compressive strength determination will be the average of the six sublot compressive strength results.

The 7-Day Compressive Strength Lot Pay Adjustment will be determined in accordance with the following:

Test Result (psi)	Pay Adjustment
≥ 500.1	-0.200
425.1 – 500.0	-0.100
400.1 – 425.0	-0.040
375.1 – 400.0	-0.020
325.1 – 375.0	+0.020
175.1 – 325.0	+0.040
150.1 – 175.0	+0.020
125.1 – 150.0	-0.020
100.1 – 125.0	-0.040
< 100.0	-0.100

If the Contractor's 3-day Compressive Strength Sublot Test Results are equal to or exceeding 400 psi, the Contractor shall initiate micro cracking operations within 24 hrs. on the identified sublot at no cost to VTrans. Micro cracking will consist of the re-rolling of the full directional width of the stabilized base of the full sublot with three passes using vibratory steel drum roller(s) with the frequency and amplitude set on high.

12. METHOD OF MEASUREMENT.

Pulverization of the Existing Pavement will be measured for payment by the number of square yards, per lot, at the depth specified, complete in place. No allowance for overlapping areas will be included.

Full Depth Reclamation with Portland cement will be measured for payment by the number of square yards, per lot, at the depth specified, complete in place. No allowance for overlapping areas will be included.

The quantity of Portland cement used will be measured for payment by the number of tons delivered per lot, from the load tickets.

The quantity of Supplemental Aggregates for Full Depth Reclamation will be measured for payment, by the number of tons placed per lot, from the load tickets.

13. BASIS OF PAYMENT.

Accepted quantities for Pulverization of the Existing Pavement will be paid for per square yard, at the depth specified for Pulverization of Existing Pavement, using special provision 900.xxx.

Accepted quantities for Reclaimed Stabilized Base, Portland Cement will be paid for at the adjusted contract unit price for compressive strength, per square yard, per lot at the depth specified for Reclaimed Stabilized Base, Portland Cement, using special provision 900.675.

Accepted quantities for Supplemental Aggregates will be paid for at the contract unit price per ton for Supplemental Aggregate for Full Depth Reclamation, using special provision 900.680.

Payment for the reclamation work includes the full compensation for the pulverizing, reclamation, grading, compacting, curing, and maintaining the completed base until it is paved over. Payment also includes development and operation of the QCP, development of the Mix Design(s), development of the Quality Control and Process Control plans, sampling and testing, field laboratory, and all incidentals necessary to complete the work.

Payment for Supplemental Aggregates is full compensation for furnishing, blending, transporting, testing, placing, grading, and compacting the material specified and for furnishing all labor, tools, equipment, and all incidentals to complete the work.

Costs for water used to adjust the moisture content prior to stabilization, for reclamation, compaction, curing of the pulverized material, and for dust control will not be paid for directly, but shall be included in the cost of other pay items within this section.

Costs for emulsified asphalt will be made separately for Fog Seal Surface Treatment, using special provision 900.683.

Costs for repair of any damages incurred to utility structures within the roadway other than what is included in subsection 105.03 will not be included for payment in other pay items within this section.

Costs of removing and replacing soft and yielding areas shall be included in other sections as approved by the Resident Engineer.

Costs for curing and maintaining the stabilized base in good condition shall be included in the cost of other pay items within this section.

Costs for repairing the stabilized base during the periods of partial traffic operations shall be included in the cost of other pay items within this section.

Costs for additional compaction or other operations to meet the minimum density requirements shall be included in the cost of other pay items within this section.

Costs associated with the transportation, storage, and application of the cement will be included in the pay item for the specific agent.

Pay Item		Pay Unit
900.650	Special Provision (Compressive Strength Adjustment) (N.A.B.I)	Lump Unit
900.675	Special Provision (Reclaimed Stabilized Base, Portland Cement)	Square Yard
900.680	Special Provision (Supplemental Aggregate for Full Depth Reclamation)	Ton
900.xxx	Special Provision (Pulverization of the Existing Pavement)	Square Yard