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14. Supplementary Notes

15. Abstract

Purpose and Need

As construction and material costs increase, NDDOT is investigating innovative ways of improving construction processes to benefit pavement performance. There is a need for cost effective methods of reducing material demands in areas were the supply of aggregates are limited and expensive. Soil stabilization can increase soil strength and stability reducing the required base material to construct a structurally adequate pavement system. Pacific Enzymes Inc. has developed Permazyme 11x™ and promotes its capabilities system to provide additional soil strength and stability. The system uses an enzymatic soil stabilizer along with conventional compaction to create a permanent dense weather resistant subgrade.

Objective

The objective of this experimental project is to evaluate the long term performance benefits of Permazyme 11x™ enzymatic soil stabilizer ability to increase subgrade strength and stability as a method to reduce aggregate material demands. The long term pavement performance of the test sections will be compared with a control section that will consist of a standard grade raise practices of the same thickness.

Scope

The NDDOT has identified a grade raise project scheduled for construction in the Minot District during the 2014-2015 seasons. The following project has been selected to evaluate the enzymatic soil stabilizer. SS-4-053(015)030, PCN 20764
Requirements for the stabilized subgrade will be incorporated into the bid and construction documents by plan details and the following plan note.

Evaluation

The field evaluation for these projects will consist of observing and documenting the construction process of the enzymatic soil stabilizer and an annual inspection of the pavement distresses with FWD testing.
During the construction of the project the following data will be collected for both the experimental and control section:
AASTHO T-87,88,89 Soil Classification and Properties
AASTHO T-180, Moisture Density Curves
AASTHO T-208-10, Unconfined Compressive Strength
The research project will last five years with a construction report, an annual evaluation report, and a final report.

Reporting

A final field collection of FWD data will be performed during the summer of 2023 and a final performance report will follow.

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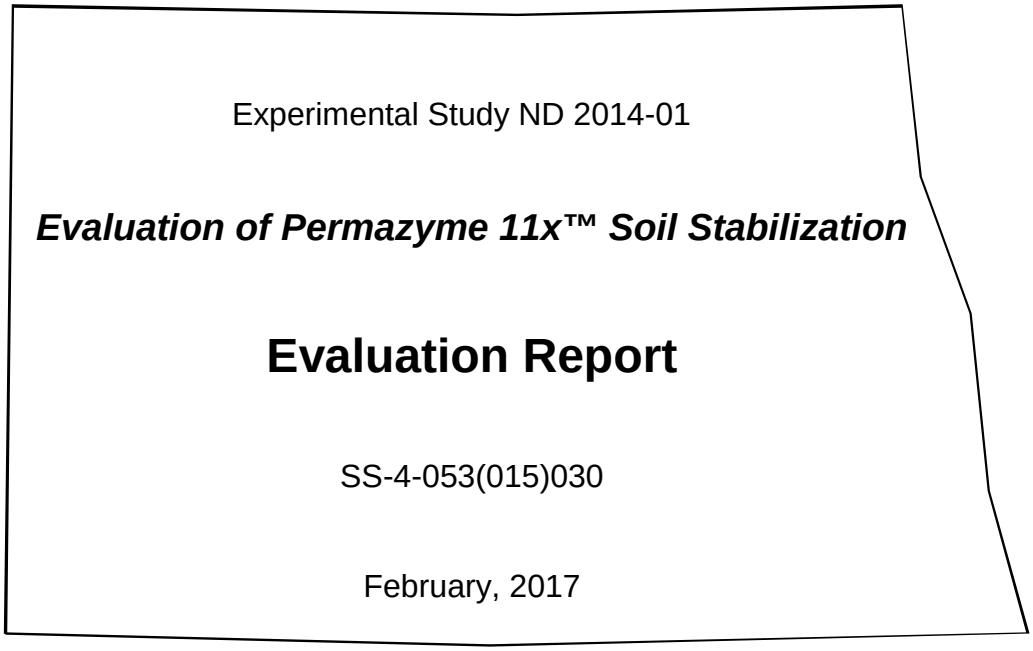
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION



Experimental Study ND 2014-01

Evaluation of Permazyme 11x™ Soil Stabilization

Evaluation Report

SS-4-053(015)030

February, 2017

Prepared by

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Evaluation of Permazyme 11x™ Enzymatic Soil Stabilizer

Purpose and Need

As construction and material costs increase, NDDOT is investigating innovative ways of improving construction processes to benefit pavement performance. There is a need for cost effective methods of reducing material demands in areas were the supply of aggregates are limited and expensive. Soil stabilization can increase soil strength and stability reducing the required base material to construct a structurally adequate pavement system. Pacific Enzymes Inc. has developed Permazyme 11x™ and promotes its systems capabilities to provide additional soil strength and stability. The system utilizes an enzymatic soil stabilizer along with conventional compaction to create a permanent dense weather resistant subgrade.

NDDOT management has requested that Materials & Research incorporate Permazyme 11x™ into an upcoming construction project to evaluate its potential benefit and performance.

Objective

The objective of this experimental project is to evaluate the long term performance benefits of Permazyme 11x™ enzymatic soil stabilizer ability to increase subgrade strength and stability as a method to reduce aggregate material demands. The long term pavement performance of the test sections will be compared with a control section that will consist of standard grade raise practices of the same thickness.

Scope

The NDDOT has identified a grade raise project scheduled for construction in the Minot District during the 2015 construction season. The following project has been selected to evaluate the enzymatic soil stabilizer.

SS-4-053(015)030 PCN 20764

Requirements for the stabilized subgrade will be incorporated into the bid and construction documents by plan details and the following plan note.

234-P01 STABILIZED SUBGRAGE-6IN: The contractor shall stabilize the top 6” of subgrade as indicated in the typical section with Permazyme 11x in accordance with all manufactures recommendations. The contractor shall use a rotary mixer equipped with an injection system to accomplish mixing of the soil and Permazyme 11x using the manufacturer’s recommended rate.

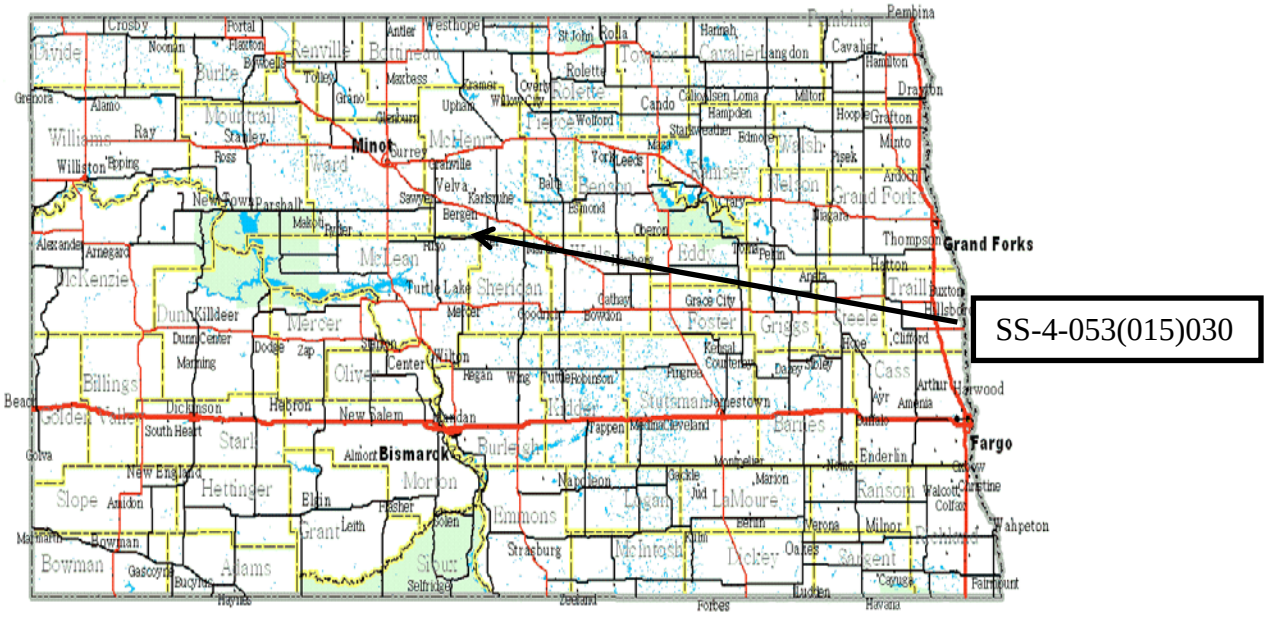
The contractor shall provide a manufacturer representative on site during the incorporation of the Permazyme 11x enzymatic soil stabilizer.

The manufacturer contact is Skip LeMaster, President, and Road Specialist
Phone: 916-813-0326
Email: Skip@pacificenzymes.com

The contractor shall coordinate with the project engineer and Materials and Research two weeks prior to the stabilizing process so Materials and Research engineer can be onsite during stabilization.

Payment will be plan quantity of XX SY STABILIZED SUBGRADE-6IN. This will be full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

Location



Design

NDDOT has identified a grade raise project located near Benedict, ND on the ND 53 corridor for this experimental project. The product will be incorporated into the subgrade of the emergency grade raise project SS-4-053(015)030. The Permazyme 11x™ system will be incorporated into the top 6" of all the subgrade in the primary road prism according to manufacturer's guidelines and recommendations. The first 575' of SS-4-053(015)030, station 522+90 to station 528+65 will be used as a control section and constructed with typical grade raise practices for comparison. The manufacturer specifications and recommendations are included in Appendix A.

The Permazyme 11x™ will be incorporated with a rotary mixer equipped with an injection system from Station 528+65 to Station 534+40 The Contractor also will provide a manufacturer's representative onsite during incorporation of the product.

SS-4-053(015)030 (Experimental Feature)

The experimental test section was designed using AASHTO 1993 DARWin Pavement Design methodology. The typical section consists of 4.0" FAA 40 HMA on 12" of dense graded base with the top 6" of subgrade enzymatically stabilized with Permazyme 11x™.

The required structural number of 2.63 was based on 60 two-way daily flexible ESALs; 1.5 % annual ESAL growth rate; 253,204 accumulated one-way flexible ESALs; 6,000 psi soil modulus; 70% reliability and a 20 year design period.

Evaluation

The field evaluation for these projects will consist of observing and documenting the construction process of the enzymatic soil stabilizer and an annual inspection of the pavement distresses with FWD testing.

During the construction of the project the following data will be collected for both the experimental and control section:

- AASTHO T-87,88,89 Soil Classification and Properties

- AASTHO T-180, Moisture Density Curves
- AASTHO T-208-10, Unconfined Compressive Strength

The research project will last five years with a construction report, an annual evaluation report, and a final report.

Reporting

Data collected will be analyzed and reported annually. A final report will be published at the conclusion of the project.

Construction

The emergency grade raise project selected for this research is in the Minot District and is summarized below.

- **SS-4-053(015)030**

  Project SS-4-053(015)030 an emergency grade raise 0.280 Miles long construction was administered by the Wold Engineering. The construction of the 6" Permazyme 11x™ stabilized soil was performed Tuesday, October 6th 2015 by Foothills Contracting, Inc.

Ray Arevalo, International Director from Pacific Enzymes (manufacture of Permazyme 11x) was onsite to assist with application rates and assure the Permazyme 11x™ was properly incorporated into the soil.

The subgrade moisture conditions were analyzed the morning of incorporation and were found to be at 9% approximately 2% points below the soils optimum of 11%. The manufacturer's recommended dilution rate is 1 gallon of Permazyme 11x™ into 750 gallons of water for a total project quantity of 2 gallons of Permazyme 11x™ to treat 2,788 square yards to a depth of 6 inches. Each lane was treated with 1 gallon of Permazyme 11x™; approximately 750 gallons of diluted solution. At the manufacturer's recommended application rate; a gallon of Permazyme 11x™ treated approximately 1,394 square yards of subgrade.

The incorporation of Permazyme 11x™ started at 9:30am on the west bound lane. The water truck loaded with 1,500 gallons of diluted Permazyme 11x™ was tied to the reclaimer with injection capabilities and in one pass the enzymatic stabilizer was incorporated as seen below in photo 1.

Photo 1: Application of diluted Permazyme 11x on EB ND 53, RP 30

The compaction process began around 10:30am. Compaction was achieved with approximately five passes of a sheep's foot and pneumatic roller. The same application process was repeated on the west bound lane and stabilization was completed around 3:00 PM that afternoon. Immediately after compaction the treated subgrade was put in service. The final subgrade surface provided a competent construction platform and exhibited no notable signs of distress throughout aggregate placement.

Once the 12" of aggregate was placed a 4.0" FAA 40, HMA was placed in two lifts and the remaining dirt work on the shoulders was completed resulting in the final roadway pictured below in photo 5.

Photo 2: Completed Experimental Section

Coring of the pavement showed the HBP thickness to be 4". HBP Compaction control documented for quality control of SS-4-053(015)030 is outlined below in Table 1.

Table 1: SS-2-053(015)030, Experimental section, HBP compaction control results

Lane	Station	Density %	Air Voids %
WB	527+45	91.5	8.5
EB	530+69	92.5	7.5
WB	530+84	94.8	5.2
EB	533+94	94.4	5.6

A proctor was performed during placement of embankment on SS-4-053(015)030 the results showed the soil type to be a sandy lean clay with a maximum dry density of 121.0 lbs/cu.ft. with an optimum moisture content of 12.0%. All embankments were placed in accordance to compaction control, Type A, ND T 180. Which requires 90 % of the maximum dry density is achieved with moisture content no less than the optimum moisture and no more than 5.0 percentage points above the optimum moisture.

Laboratory Results

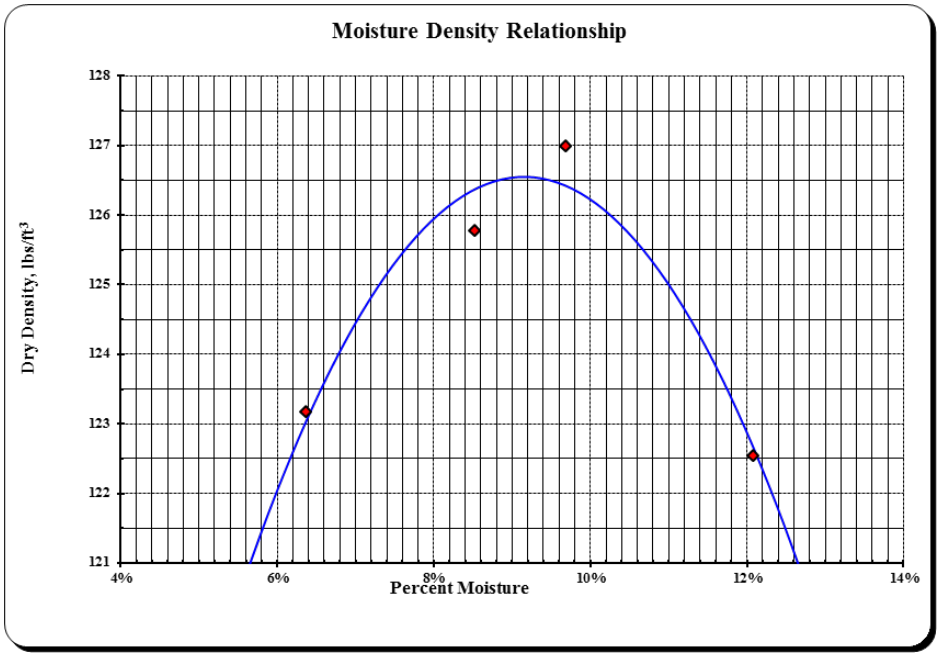
Soil classification testing was completed by Materials & Research central laboratory on the top six inches of in-place subgrade of both the control and experimental test section. The soil composition and classification break down is outlined in Table 3.

Table 2: Soil Classification Summary

Soil Property	Control	Experimental
%Pass 3/8" Sieve	84	89
%Pass No. 4 Sieve	81	84
%Pass No. 10 Sieve	78	80
% Coarse Sand	8	10
% Fine Sand	19	19
% Silt	21	19
% Clay	30	32
Liquid Limit	47	26
Plasticity Index	27	12
Plastic Limit	20	14
Soil Class	A-7-6(10)	A-6(3)

A moisture density proctor curve was developed in accordance to AASHTO T-180 on an untreated soil sample from the subgrade of the experimental section at SS-4-053(015)030. The results are illustrated in Chart 1 below.

Chart 1: AASHTO T-180, Untreated Control Moisture Density Proctor Curve



After the Permazyme 11x™ had been incorporated four locations where selected at random for soil sampling. From those four locations soil samples A, B, C, D were collected and bagged for transport. Six specimens were then compacted in accordance with AASHTO T-180, two specimens from each soil sample A&B, and only one specimen from both C&D due to soil sample size. AASHTO T-180 specimens were tested to measure any density benefits gained by the incorporation of Permazyme 11x™, and to assess the field moisture content at the time of compaction. The proctor point results of the specimens are summarized in Table 3, and are illustrated in contrast to the proctor curve in Chart 2.

Chart 2: AASHTO T-180, Control Moisture Density Proctor Curve with Treated Points

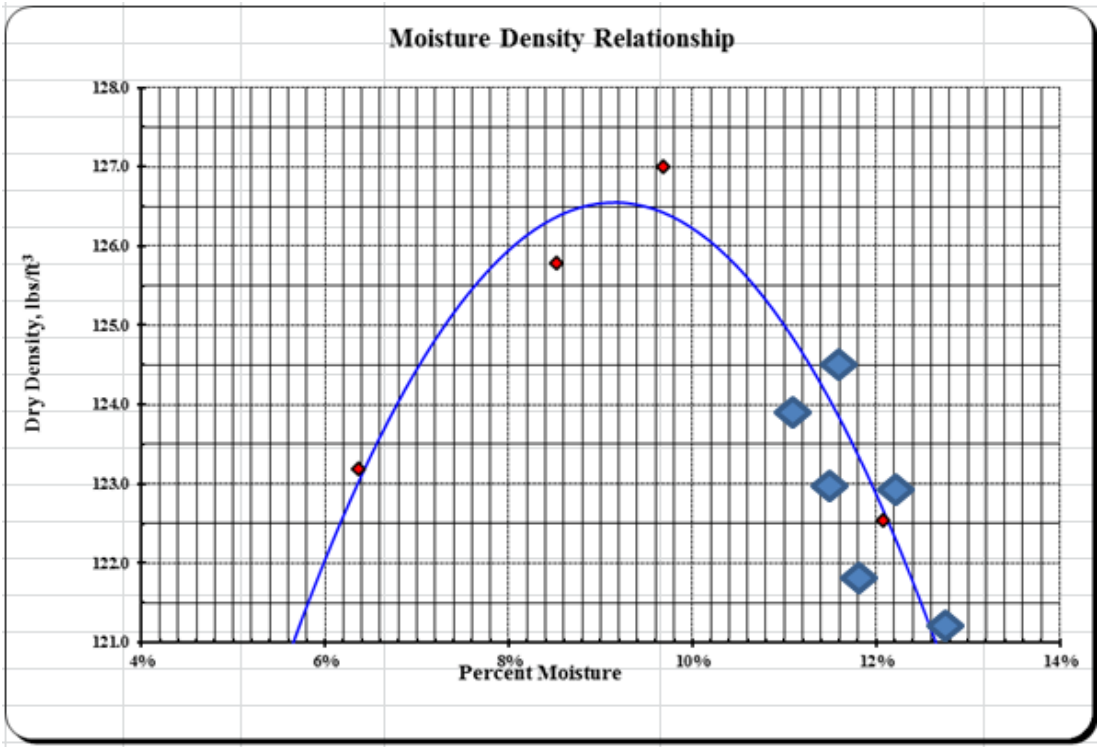
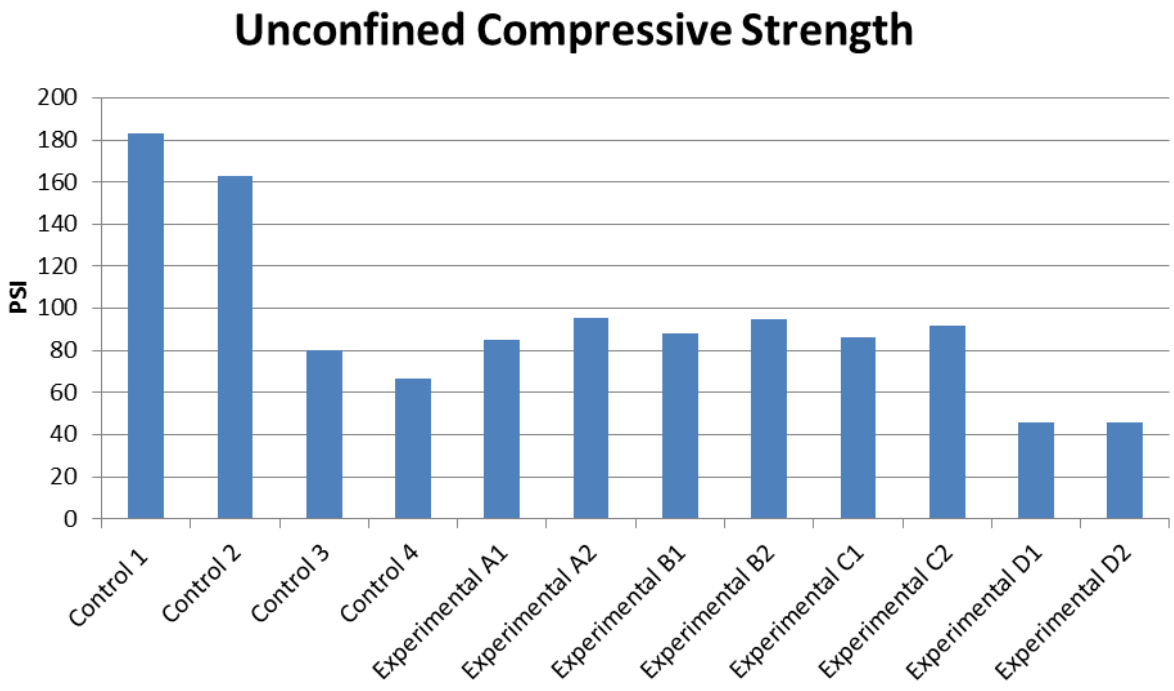


Table 3: AASHTO T-180, compaction of treated soils on SS-4-053(015)030

Location(ID)	A1 Treated	A2 Treated	B1 Treated	B2 Treated	C Treated	D Treated
Dry Density	122.9	123.7	124.6	122.8	121.1	121.7
% Compaction	99.4	97.7	98.4	97.0	95.6	96.1
% Moisture Content	11.5	11.1	11.6	12.2	12.6	11.8

AASTHO T-208-10, Unconfined Compressive Strength testing was also performed on the field treated soil samples A,B,C&D. Eight specimens were constituted and compacted in the lab, once compacted the samples were bagged and allowed to cure for 72 hours. In addition to the Permazyme 11x treated specimens four control specimens were constituted and compacted in the lab from soil sampled from the adjacent embankment of untreated soil. Control specimens one and two were wetted to optimum moisture of 10%, while control specimens three and four were wetted to the average of the field moisture conditions 12.6% observed the day of Permazyme 11x incorporation, the specimens were also bagged and allowed to cure for 72 hours. Results are displayed in Chart 3.

Chart 3: AASHTO T-208-10, Unconfined Compressive Strength



1st Evaluation

The FWD data was collected and analyzed from the two sections on July 7, 2016. The averages for both sections are summarized in the table below.

Table 4: FWD Summary, SS-4-053(015)030

Section	No1m mils	HMA E* ksi	Base E* ksi	Subgrade E* ksi
Experimental	18.14	347.1	33.2	14.60
Control	16.52	363.1	37.5	19.66

Analysis of the FWD data shows the control section to be performing at a higher structural level than the experimental treated section. The control section when loaded by the FWD responded with 1.6 less mils of deflection indicating a higher structural value then the experimental section, and the corresponding back calculated elastic modulus for subgrade showed the experimental section to be weaker by 5 ksi from the control section.

The roadway had no transverse cracking and no rutting; both control and experimental sections have no signs of distress as of the July 7, 2016 roadway survey.

Summary

The Permazyme 11x soil stabilizer was successfully incorporated into the top six inches of subgrade according to the plans and manufacturer's recommendation. No notable issues occurred during aggregate base placement and HMA paving both treated and untreated subgrades provided adequate support.

Laboratory results indicated a reduction of the plastic index of the soil after treatment, while the moisture density relationship was relatively unaffected. Unconfined compressive testing results showed no significant increase in unconfined compressive strength. Both control samples constituted at optimum moisture exhibited the highest unconfined compressive strength results. FWD testing performed on July 7, 2016 showed the control section to have a higher structural capacity indicating the performance benefits of the Permazyme 11x to be limited in its ability to increase structural capacity of a paved roadway. Both sections are still performing exceptional with no signs of distress. The Permazyme 11x installation will be monitored for durability and performance over the next three years.

Appendix A

Permazyme 11x Specifications

Construction:

The aggregate, water and Permazyme 11X shall be mixed and placed by the following method.

Preparation of Surface:

The in-place soil to be stabilized must be ripped, scarified, disced or rototilled into a well-pulverized mixture. If the stabilization area involves the treatment of heavy clay soils, the Project Representative may specify the use of a cross-shaft rotary mixer to assure proper pulverization and mixing. If the material to be treated is already at or above optimum moisture content, it must be dried to four percentage points below optimum in preparation for addition of the Permazyme solution. Do not prewet the soil material ahead of applying the Permazyme solution. When filling the water truck, add enzyme to water to avoid a truck full of foam. No mixing is necessary.

Application of Stabilizer:

Application of the Permazyme 11X solution should be limited to the area specifically shaped and sized to receive the solution. The daily extent of work should be limited to an area the size of which allows all operations, including mixing and compaction, to be continuous and completed in one day.

Permazyme 11X solution should not be applied or mixed with in-place material if atmospheric temperature falls below 50F/10C.

Application of the Permazyme 11X must be limited to periods when rainfall is not expected during the application or during the 24 hour period following application. If rainfall is encountered during application, stop construction.

The Permazyme 11X Solution is applied at the rate of one gallon per 150 cubic yards (1 liter per 30 cubic meters) of material to be treated. The variance from the specified dilution rate will be +/- ten percent.

The amount of water to be used should be calculated to bring the soil or aggregate material to be treated to optimum moisture content. Permazyme solution should be added in increments and mixing continued so as to carefully approach optimum moisture content.

In conditions where the in-place material to be treated is already close to optimum moisture content, be aware that no less than two percent moisture must be added as part of the Permazyme 11X solution in order to properly disperse the highly concentrated Permazyme 11X. In this case, a ratio of 1:500 gallons is recommended.

The Permazyme solution can be applied to the material to be treated with a pressurized spreader truck or a water truck with a pressurized spreader bar. Uniform distribution can be accomplished by thoroughly working the enzymed soil by blading, tractor drawn spike, disk, or harrows, or by using a mixing/grinding or pulveriizing machine, i.e., Asphalt Zipper, or similar.

Water should not be added to the material prior to adding the Permazyme solution. Mixing equipment shall follow no more than one quarter mile behind spray application truck.

If the entire Permazyme 11X solution has been added without achieving the range of allowable moisture content, more water may be added at a 1:10,000 dilution to bring it to the specified moisture range.

Compaction is the key to a perfect road:

Compaction operations can begin immediately following the shaping of the road. The moisture content of the material at the time of compaction shall not exceed nor be less than two (2) percentage points below the optimum moisture content. Compaction equipment should be capable of achieving compaction of the untreated material to a density no less than 95 percent of the density prescribed in ASTM D-1557-66T (Modified Proctor). 100% or more is frequently obtained with Permazyme 11X.

If site conditions warrant or compaction equipment is not of sufficient size, the road must be compacted in lifts of 3 to 4 inches maximum. However, with heavy road equipment, 6″ lifts are standard. Prior to placing and compacting a second lift, the surface shall be pre-wetted to insure bonding between the lifts.

Upon completion, the surface should be smooth and in conformance with the typical sections, lines and grades of the design plans. The surface shall be properly sloped to allow runoff of surface moisture. The thickness of the compacted treated base material shall be six inches (15cm) or more. The compacted thickness should not vary one-half inch over the entire area.

Curing and Return to Service:

Following final completion, the prepared soil shall be allowed to cure for three (3) days. No surface watering or curing membrane is required during this period. If the surface must be rapidly returned to service under traffic, it should be dried-back adequately so that it is not susceptible to rutting or damage by rapid acceleration or braking. The completed road will continue to harden over an extended period. The cementaion effect of Permazyme in the soil is irreversible.