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MaineDOT

Transportation Research Division

Technical Report 05-6

Full Depth Reclamation with Cement

Second and Third Interim, December, 2008

Transportation Research Division

Full Depth Reclamation with Cement

Introduction

Due to the rising cost of virgin aggregate and asphalt products the Maine Department of Transportation (MaineDOT) utilizes a number of reconstruction and rehabilitation processes to cost effectively maintain Maine's highway system. One rehabilitation process in particular is full-depth reclamation (FDR) with cement. This process rebuilds deteriorated roadways by recycling the existing Hot Mix Asphalt (HMA). The old HMA and a portion of base material are pulverized in-place, mixed with cement and water, then shaped and compacted to produce a strong and durable stabilized base material that is sealed with a HMA surface. With the added strength of the stabilized base, thickness of the HMA surface can be reduced resulting in additional cost savings. By recycling the existing HMA materials, construction costs are reduced by 25% to 50% as compared to conventional construction methods.

Problem Statement

There are a number of reasons for roadway failure but one major reason is insufficient support for the HMA surface. Maine has a variety of aggregate base soils that range from well draining granular soils in the southeast and sandy soils in the southwest that provide sufficient roadway support to fine grained, silty, moisture retaining soils in the central and northern portions of the state that have less stability which in turn reduces pavement life.

On projects that have somewhat sufficient aggregate base support, the Department utilizes the FDR process combined with stabilizing agents to increase aggregate base stability. With the added subbase support, the amount of HMA to resurface the project can be reduced resulting in a cost savings for the Department.

In an effort to increase support of the HMA surface and bridge the various soil types or reduce the amount of HMA to resurface a project, the Department has been using the FDR process and blending the material with stabilizing agents such as calcium chloride, lime, emulsion, or asphalt. Stabilizing methods utilizing asphalt products have worked well and were cost effective until recent price increases. To reduce the cost of stabilizing reclaimed HMA, the Department experimented with the use of cement as a stabilizing agent. Cement is a lower cost material that is easily incorporated into reclaimed HMA.

The process involves determining existing HMA layer thickness and obtaining HMA and aggregate base material samples from the project by means of test pits or core samples. The samples are tested for maximum dry density and optimum moisture content. The mix design is determined in the same manner as for soil-cement. Construction begins with pulverizing the existing HMA and aggregate base to a depth of between 6 and 10 inches. If areas of the project do not have sufficient HMA thickness to meet design, stockpiled reclaimed asphalt pavement (RAP) can be spread ahead of the reclaiming machine. A pad foot roller is utilized to compact the lower portion of the RAP. The reclaimed material is then shaped, graded and compacted. At this point traffic can use the roadway until cement is added. To stabilize the reclaimed material, cement is spread in the desired quantity in either a dry or slurry form ahead of the pulverizing equipment and the reclaimed HMA and cement are blended. A pad foot roller is used to compact the lower portion of the stabilized RAP then water is added and the stabilized RAP is shaped, graded and compacted with a vibratory roller. A rubber tired roller is used to seal the surface to prevent water infiltration prior to surfacing. After a short curing period the stabilized base is sealed with HMA. Total layer thickness of new HMA can be reduced by as much as 50 percent with the added strength of the stabilized base.

Project Information

Project Identification Number (PIN) 11326.00 is located in Aroostook County on US Route 2A between the townships of North Yarmouth Academy Grant and Reed Plantation (Figure 1). The project is 5.02 miles in length and is scheduled for Highway Rehabilitation with drainage and safety improvements. Annual Average Daily Traffic is somewhat low at 700 in 2005 with 38 percent heavy trucks. Table 1 contains current (2005) and future (2017) traffic data. Prior treatments include a resurfacing in 1995 and a thin overlay of maintenance mix in 2001. The project has many areas with transverse, alligator, and block type cracks as displayed in Photo 1.

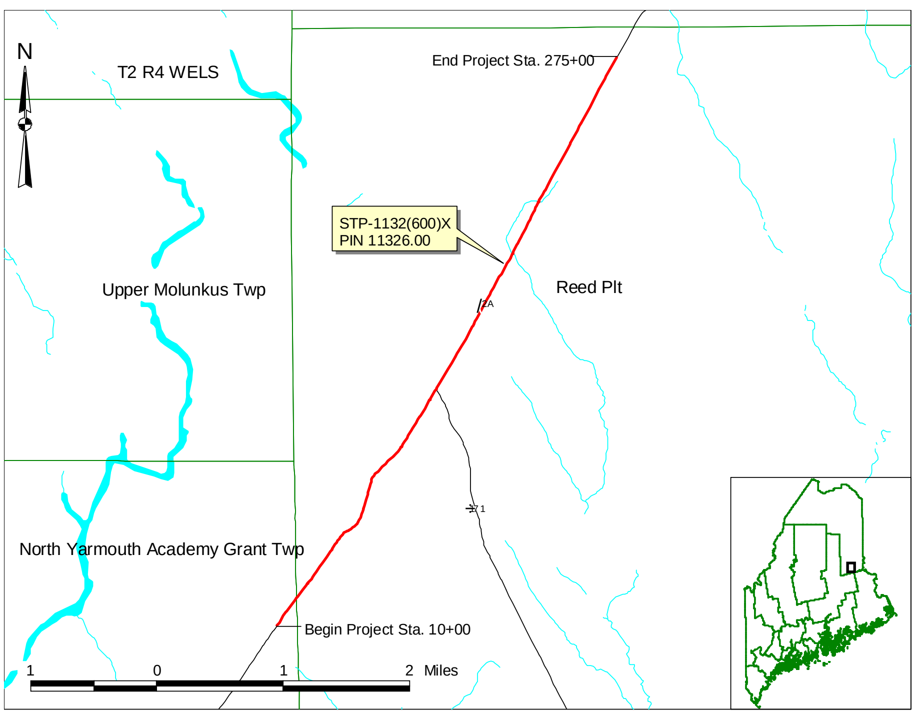


Figure 1: PIN 11326.00 Location Map

Table 1: Traffic Data

Current (2005) AADT………………	700
Future (2017) AADT………………...	780
DHV - % of AADT…………………..	11
Design Hour Volume………………...	92
% Heavy Trucks (AADT)……………	38
% Heavy Trucks (DHV)……………..	26
Directional Distribution (DHV)……...	59
18 kip Equivalent P 2.0………………	402
18 kip Equivalent P 2.5………………	382
Design Speed (mph)………………….	50

Photo 1: Typical Cracking in the North Lane

Rut depth and smoothness measurements were collected prior to construction in 2005. The Automatic Road Analyzer (ARAN) was utilized to collect these measurements. Rut depth data is collected using two synchronized, laser based devices to measure transverse profile of a lane up to 13 feet wide. Transverse profile measurements of the roadway are sampled every 4 inches across the lane at a sampling rate of 3.7 feet at a speed of 50 mph. Rut depths can be measured to an accuracy of 0.04 inches. The ARAN is classified as an ASTM Class I profile-measuring device that is capable of accurately measuring roadway smoothness. The ARAN utilizes lasers and accelerometers to measure the lateral profile of each wheel path every 0.5 inches then averages those measurements every 66 feet. Smoothness is displayed in International Roughness Index (IRI) units.

The average rut depth was 0.11 inch with a high of 0.7 inch and low of 0.0 inch and a standard deviation of 0.09 inch suggesting the aggregate subbase material is supporting the roadway sufficiently.

International Roughness Index readings averaged 145.2 inches/mile in 2005 with a standard deviation of 109.7 inches/mile which is somewhat smoother than a typical project scheduled for rehabilitation.

Falling Weight Deflectometer (FWD) tests were collected in 2004. The FWD measures pavement deflections by dropping the equivalent weight of 9000 pounds onto a platform that is lowered to the pavement. Seven sensors record pavement deflections. One sensor is positioned at the load platform and six others extend away from the platform parallel to the roadway. Pavement deflections indicate the structural stability of the roadway to a depth of 5 feet. FWD data is processed using DARWin Pavement Design Analysis System. DARWin utilizes FWD deflections plus pavement and gravel depths to determine Subgrade Resilient Modulus, Existing Pavement Modulus, Effective Existing Pavement Structural Number, and Structural Number for Future Traffic.

The Effective Existing Pavement Structural Number (ESN) measures the structural ability of a roadway to carry traffic loads. Deflections of HMA and subbase material above subgrade are used to calculate the ESN making it a good tool to monitor roadway stability.

Average ESN results were 4.33 with a standard deviation of 0.36 which is relatively stable for a project with 4 to 6 inches of pavement. There were a few isolated areas with weak subgrade material at stations 72+50 to 85+00, 175+00 to 217+50, and 232+50 to 257+50.

Mix Design

In the summer of 2004, HMA and aggregate subbase material were sampled from a variety of locations within the project to develop a cement stabilized recycled asphalt pavement mix design. The HMA was crushed to a minus 2 inch size then mixed with aggregate subbase gravel to create a blend of 50% HMA and 50% subbase gravel. The material was used to determine maximum dry density, optimum water content, optimal cement content, and moisture susceptibility.

AASHTO T-180 test method was used to determine moisture-density properties. Maximum dry density of the 50/50 blended material was 129 lb/ft^3. Optimum moisture content was 7 percent.

Portland cement (Type I or II) was added to the RAP/aggregate material in the amounts of 3, 4, and 5 percent by weight. Three cylinders of each cement/RAP blend were compacted to create a total of 12 specimens. Compressive strength was measured using AASHTO T-22 test method. Test results are displayed in Table 2. Five percent cement produced the greatest strength.

Table 2: Concrete Cylinder Compressive Strength Summary

Cement (%)	Avg. Dia. (in)	Area (in²)	Load (lb)	Strength (psi)
3	6.01	28.37	6910	244
4	6.00	28.27	8860	313
5	6.01	28.37	10740	379

The Tube Suction Test was utilized to determine moisture susceptibility of cement treated RAP samples with varying cement contents. Moisture susceptibility is the measure of a soils ability to hold water by capillary action. The more water retained the less structural capacity a soil sample has.

Three sets of cylinders were compacted using RAP blended with 0, 3, 4, and 5 percent cement for a total of 12 specimens. Each specimen was soaked for 240 hours in a water bath and dielectric measurements were recorded on top of each specimen every 24 hours. Test results are displayed in Table 3. A dielectric value below 10 is considered a good candidate for base material. A value between 10 and 16 is marginal and a value above 16 is considered a poor candidate. Four percent cement produced the lowest dielectric value.

Based on compressive and Tube Suction Test data it was determined to use 4 percent cement by weight with between 2 and 6 percent water for proper compaction. This equates to 31 lb/yd² of cement to treat recycled asphalt material to a depth of 8 inches. It will take four bulk cement delivery trucks to treat a 2500 foot by 30 foot section.

Table 3: Tube Suction Test Summary

Cement Content	Specimen	Height (in)	Dry Density (pcf)	Initial Water Content (%)	Initial Dielectric Value	Final Water Content (%)	Final Dielectric Value
0	1	4.25	123.6	1.0	2.9	5.1	11.0
	2	4.42	128.3	0.8	2.7	5.2	10.0
	3	4.45	125.3	0.7	3.0	4.9	9.9
	Average	4.37	125.7	0.8	2.9	5.1	10.3
	Std. Dev.	0.11	2.4	0.2	0.2	0.2	0.6
3	1	4.46	130.0	2.8	3.9	4.5	5.8
	2	4.50	130.1	2.8	3.1	4.6	5.4
	3	4.39	131.4	2.3	3.1	4.9	8.0
	Average	4.45	130.5	2.6	3.4	4.7	6.4
	Std. Dev.	0.06	0.8	0.3	0.5	0.2	1.4
4	1	4.46	131.0	2.6	3.2	4.4	4.7
	2	4.41	133.5	3.2	3.3	4.2	4.7
	3	4.48	131.2	2.9	3.2	4.5	4.2
	Average	4.45	131.9	2.9	3.2	4.4	4.5
	Std. Dev.	0.04	1.4	0.3	0.1	0.2	0.3
5	1	4.41	131.9	2.8	3.2	4.5	4.8
	2	4.40	133.0	3.1	3.8	4.5	5.2
	3	4.47	131.5	3.2	3.7	4.6	5.2
	Average	4.43	132.1	3.0	3.6	4.5	5.1
	Std. Dev.	0.04	0.8	0.2	0.3	0.1	0.2

Construction

For Construction information, please refer to Construction and First Interim Report dated February, 2007.

Project Evaluation

An experimental section was established between stations 265+00 and 270+00. A control section is located between stations 270+00 and 275+00. The Control Section was constructed using the same pulverizing and compaction procedures as the cement treated areas with the exclusion of cement.

The Control section had in-place densities of 96 percent at station 273+50, 8' Rt. and 99 percent at station 273+00, 8' Lt.

Structural Summary

Structural strength measurements were collected in October of 2007 and 2008 utilizing the Departments FWD. Readings were taken at 50 foot intervals in both the experimental and control sections. FWD data was then analyzed using DARWin Pavement Design software to develop Existing Structural Numbers for each test location. Comparisons were then completed for 2006-2007 and 2007-2008 to determine levels of weakening or strengthening within the two areas.

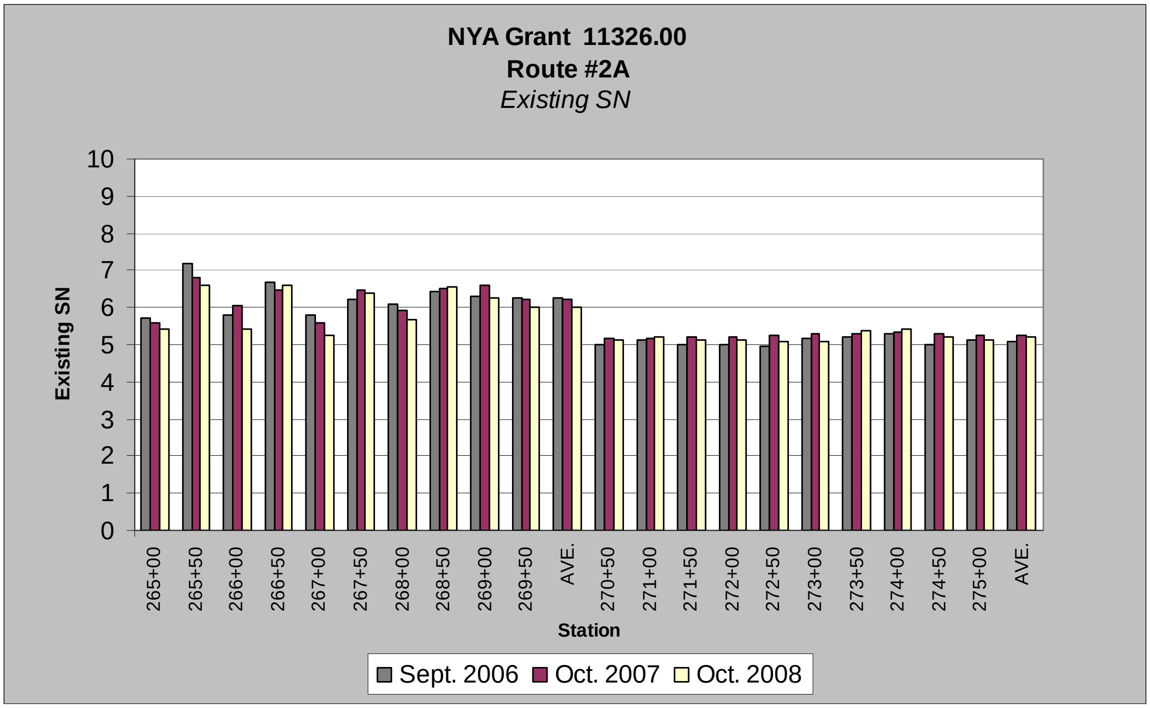
The Experimental area had a 2006 average ESN of 6.242. In 2007, that number decreased by 0.22 percent to 6.228. The 2008 ESN decreased an additional 3.6 percent to 6.01, an overall decrease in strength of 3.82 percent.

The Control section actually showed an increase in strength from 2006 to 2007. The average ESN for 2006 was 5.088. For 2007, that number increased 3.1 percent to 5.252. In 2008, the ESN decreased approximately 1 percent to 5.194.

Overall, the experimental section continues to be stronger than its control counterpart by almost 14 percent.

These results are summarized below.

Station (Feet)	Existing Structural Number (in.) (September, 2006)	Existing Structural Number (in.) (October, 2007)	Existing Structural Number (in.) (October, 2008)	**Change** 2006 - 2007	**Change** 2007 - 2008
265+00	5.7	5.59	5.4	**-0.11**	**-0.19**
265+50	7.18	6.81	6.59	**-0.37**	**-0.22**
266+00	5.8	6.07	5.4	**0.27**	**-0.67**
266+50	6.66	6.48	6.61	**-0.18**	**0.13**
267+00	5.78	5.6	5.27	**-0.18**	**-0.33**
267+50	6.21	6.47	6.37	**0.26**	**-0.1**
268+00	6.08	5.93	5.66	**-0.15**	**-0.27**
268+50	6.43	6.52	6.57	**0.09**	**0.05**
269+00	6.3	6.59	6.24	**0.29**	**-0.35**
269+50	6.28	6.22	5.99	**-0.06**	**-0.23**
AVE.	**6.242**	**6.228**	**6.01**	**-0.014**	**-0.218**
270+50	4.99	5.15	5.13	**0.16**	**-0.02**
271+00	5.12	5.18	5.22	**0.06**	**0.04**
271+50	5.02	5.19	5.14	**0.17**	**-0.05**
272+00	4.99	5.23	5.13	**0.24**	**-0.1**
272+50	4.95	5.27	5.1	**0.32**	**-0.17**
273+00	5.15	5.3	5.07	**0.15**	**-0.23**
273+50	5.2	5.31	5.38	**0.11**	**0.07**
274+00	5.31	5.34	5.43	**0.03**	**0.09**
274+50	5.02	5.3	5.21	**0.28**	**-0.09**
275+00	5.13	5.25	5.13	**0.12**	**-0.12**
AVE.	**5.088**	**5.252**	**5.194**	**0.164**	**-0.058**



Rut Depth Summary

Rut depth readings were recorded using a straight edge, as part of the October, 2007 evaluation. Readings were taken at 50 foot intervals in the left and right wheel paths of each lane. The average rut depth in the Control section was 0.09 inches and the average depth in the Experimental section was 0.075 inches. Rut depth readings were not collected as part of the 2008 evaluation, but will be collected in 2009.

Readings from the 2007 evaluation are summarized below.

	Control		Soil Cement	
	Northbound Lane	**Southbound Lane**	**Northbound Lane**	**Southbound Lane**
Average (in.)	0.106	0.075	0.094	0.056
Standard Dev.	0.093	0.094	0.090	0.064
Minimum (in.)	0	0	0	0
Maximum (in.)	0.25	0.25	0.25	0.125
# of Samples	20	20	20	20

Visual Summary

Visual evaluations were completed in October 2007 and 2008. Cracking patterns typical of Maine highways (Longitudinal, Transverse, Load Associated and pavement joint failure) were recorded when present. After three years of service life, cracking in the experimental area is more prevalent than in the control section. In 2007, no transverse cracking was present in the control section and 90 feet of transverse cracking was identified in the experimental area. For 2008, six feet of transverse cracking was recorded in the control section, while the total feet of transverse cracking increased to 105 in the experimental section. No load associated cracking was identified in the control section for either the 2007 or 2008 evaluation. The experimental section had no load cracking present during the 2007 review, but

148 feet of initial load cracking was identified in 2008. There was no longitudinal cracking present in either section for the 2007 or 2008 evaluations. Although pavement joint failure is not considered a failure with the experimental feature of this project, joint failures were identified and recorded nonetheless. These totals and the totals of all cracking identified in both evaluations are summarized below.

	Control		Experimental	
	2007	2008	2007	2008
Transverse/Feet	-	6	90	105
Load Associated/Feet (Initial)	-	-	-	148
Longitudinal/Feet	-	-	-	-
Pavement Joint Failure/Feet (Centerline Joint)	139	306	265	357

In addition, a crack was identified in the northbound shoulder of the Control section as part of the 2007 evaluation. This crack measured approximately 24 feet in length and less than ½ inch in width. The 2008 evaluation found the crack had extended to 45 feet in length and approximately 1 inch in width. This crack is outside the typical evaluation area of the travel lanes and is noted for the purpose of documentation. Photos 2 and 3 show the crack as it was in the 2007 and 2008 inspections.

Photo 2: Shoulder Crack – 2007

Photo 3: Shoulder Crack – 2008

Conclusions

After three year's exposure to traffic and weather, the project continues to perform well. 2008 FWD results show a slight decrease in strength from 2006 of 3.8 percent in the experimental section, while the control section actually showed an increase of approximately 2 percent. Existing Structural Numbers indicate the experimental section continues to be approximately 14 percent stronger than the control section. Rut measurements taken in 2007 show very minimal rutting is occurring in both sections. Cracking is more prevalent in the experimental section, but still well within expected ranges.

A full field evaluation will be completed in 2009, with the Fourth Year Interim Report to follow.

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