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Transportation Research Division

Technical Report 05-6

Full Depth Reclamation with Cement along Rt. 2A in Reed Plantation

Construction and First Interim, February, 2007

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, MaineDOT 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 MaineDOT.

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 MaineDOT 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 MaineDOT 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.

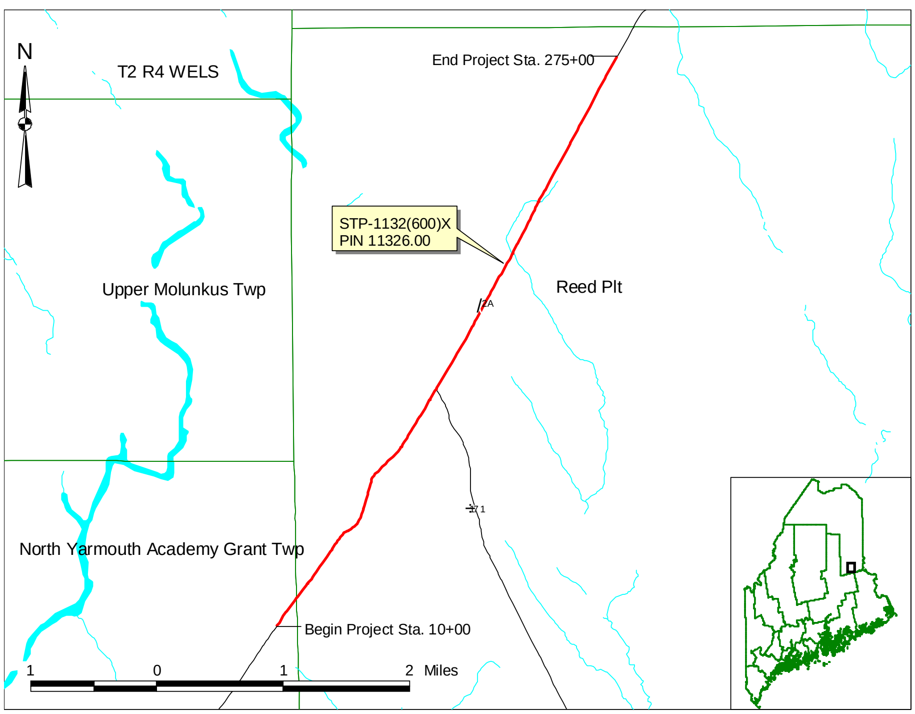

Figure 1: PIN 11326.00 Location Map

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

Initial Reclaim

Construction began in June of 2005. The process begins with pulverizing the HMA plus a portion of aggregate subbase material to a depth of 10 inches with a Wirtgen 2500 recycler. The Wirtgen can reclaim to a maximum depth of 20 inches and width of 8 feet. The roadway is 24 feet wide from pavement edge to pavement edge with a variable width gravel shoulder. In order to reclaim the entire roadway the recycler made four passes with a minimum of one foot overlap between passes.

The final width of the roadway will be 30 feet from pavement edge to pavement edge. Excess pulverized material from the initial pulverizing process was graded to the shoulder and compacted to extend the width of roadway. A typical cross section is displayed in Figure 2.

The contractor reclaimed 2500 feet per day. Each 2500 foot section was split into two subsections of equal length. Traffic was diverted to the right side of the roadway. The contractor began with reclaiming at an offset of 5 feet left to 13 feet left of centerline (Photo 2) for a distance of 1250 feet. Water was added and the RAP was pre-compacted with a vibratory pad foot roller (Photo 3). The recycler set back to the beginning of the section and the second pass was at an offset of 2 feet right to 6 feet left of centerline for 1300 feet. Water was added and the RAP was again pre-compacted with a vibratory pad foot roller. After pre-compaction, RAP is graded from centerline to 15 feet left then compacted with a vibratory steel drum roller. Water was added if necessary for proper compaction. After a short curing period traffic was diverted to the left side of the roadway and the recycler set back to the beginning of the section and reclaimed at an offset of 1 foot right to 9 feet right of centerline. The RAP was watered and pre-compacted with the pad foot roller. The final pass of the recycler in this section was at an offset of 5 feet right to 13 feet right of centerline. This pass was also watered and compacted with the pad foot roller. The RAP was graded from centerline to an offset of 15 feet right, watered and compacted with a vibratory steel drum roller.

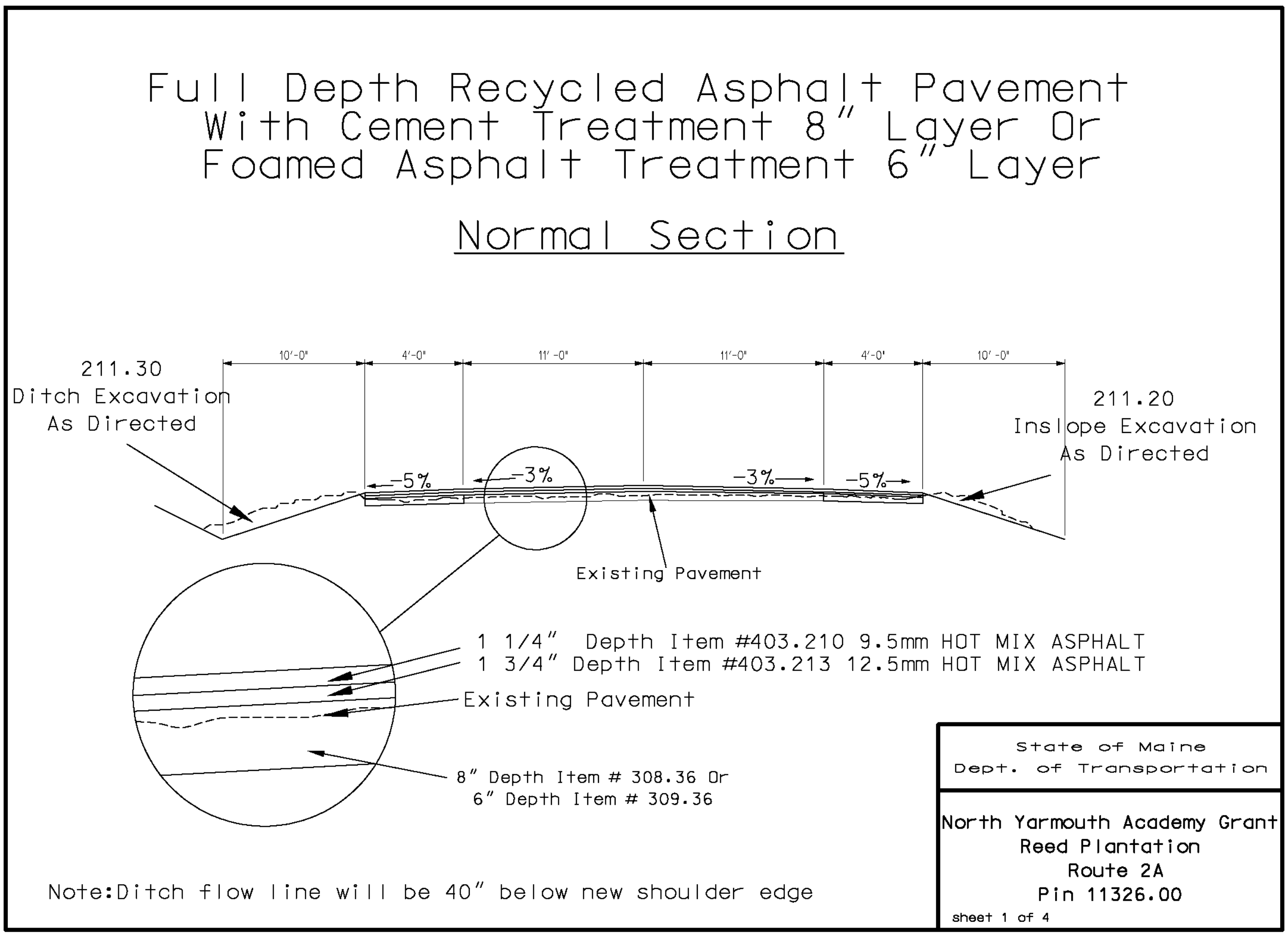

Figure 2: Typical Cross Section

Photo 2: First Pass with the Wirtgen 2500 Recycler

Photo 3: Pad Foot Vibratory Roller

Cement Stabilization

Cement stabilization begins with applying water to the RAP ahead of the cement delivery vehicle. Cement was delivered to the roadway using a cement truck with a bar and nozzles attached to the end of the truck (Photo 4). A canvas tube was attached to the end of each nozzle to reduce the distance the cement had to travel to coat the roadway and minimize the amount of cement dust. Air pressure was used to force cement out of each nozzle. The nozzles and bar frequently plugged and the truck had to make many stops to correct the problem. Even with the canvas tubes this type of delivery system created clouds of cement and a health hazard for the employees and nearby foliage (Photo 5). Another type of delivery system that can accurately dispense cement and reduce or eliminate the amount of cement dust should be considered for future projects.

Photo 4: Cement Delivery System

Photo 5: Cement Cloud Hazard

The first pass with the recycler was at an offset of 7 to 15 feet right. The RAP is moistened then cement is placed on the roadway ahead of the recycler at an offset of 7.5 feet to 15 feet right and a length of 1250 feet. Depth of cement should be between 0.45 and 0.5 inches. The cement and RAP are pulverized into a minus 2 inch material to a depth of 8 inches. The water truck moistens the cement treated RAP and the vibratory pad foot roller compacts the lower portion of the loose material. The second pass with the recycler is at an offset of 0.5 foot left to 7.5 foot right. Cement is placed ahead of the recycler from centerline to 7.5 feet right. The RAP and cement is recycled and compacted with the pad foot roller. After the pad foot roller makes its final pass the cement treated RAP is brought to grade from centerline to an offset of 15 feet right and the material is compacted with a vibratory steel drum roller. A rubber tired roller was used to seal the surface to prevent water infiltration before the material is sealed with HMA.

After a short curing period, traffic is diverted to the right lane and the same procedure is followed for the left lane. The 2500 foot section is opened to traffic until a HMA surface is placed.

A total of 28 in-place soil density tests resulted in an average density of 100.3 percent with a standard deviation of 2.1 percent. The specification minimum density is 98 percent.

The cement treated RAP is allowed to cure for a minimum of 48 hours before the surface is sealed with new pavement. Just prior to placing HMA, the contractor is required to run a vibratory roller over the entire area that is to be sealed. This introduces micro cracks in the cement treated RAP in order to reduce the possible formation of transverse thermal cracks. The project was sealed with a total of 3 inches of HMA. Construction was completed in September of 2005

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.

Project Evaluation

Structural Summary

Pre-construction FWD deflections were compared to post-construction deflections to monitor the structural condition of the stabilized subbase. Deflections were recorded every 250 feet in the north lane only on June 21, 2004 and April 11, 2006. The Department wanted to check post-construction ESN values in early spring when the supporting soils are saturated and at its weakest condition.

Figure 3 contains a summary of the test results. Cement stabilized RAP structural numbers that were collected in April are on average 44 percent higher than pre-construction values.

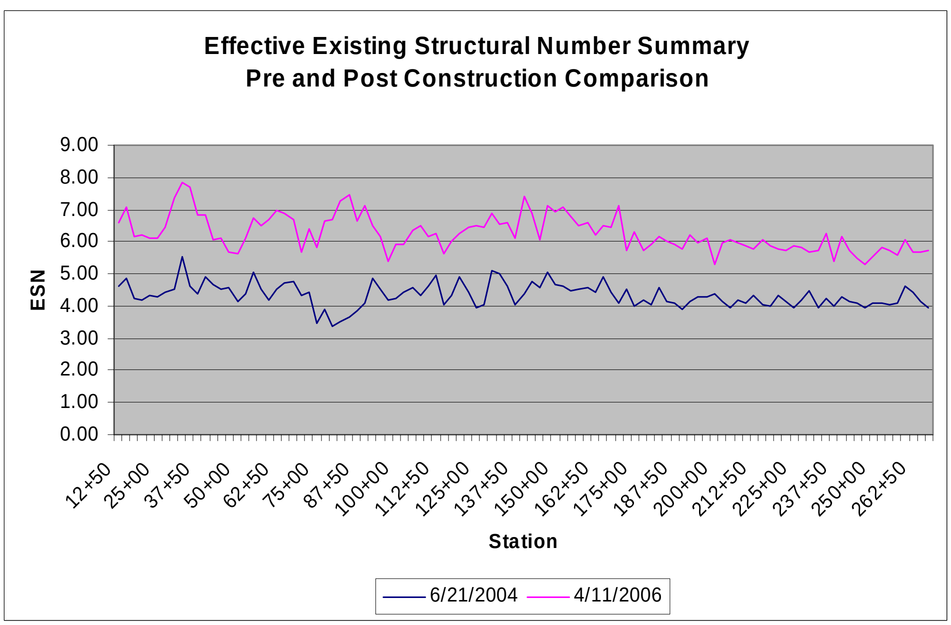

Figure 3: Pre and Post Construction Structural Number Comparison

Deflections were measured on the Control and Experimental Sections in April and September 2006 to compare structural differences between cement treated and untreated RAP when supporting soils are in a saturated and well drained state. Ten tests were collected in each section; five in each lane. Average ESN values are displayed in Table 4.

Table 4: Spring and Fall Structural Number Comparison

	Average Effective Existing Structural Numbers (ESN)		
	April 11, 2006	September 27, 2006	Difference
Experimental	5.70	6.27	10%
Control	4.86	5.09	5%
Difference	17%	23%	

Cement treated RAP has greater strength than untreated RAP in both spring and fall tests. The Experimental Section had ESN values that are 17 percent higher on average than the Control Section when tested in April. In September, average structural numbers were 23 percent higher than the Control Section.

When comparing spring and fall ESN values within each section the Experimental section has a 10 percent difference and the Control Section only increased 5 percent.

Visual Summary

A major concern with treating materials with cement is the formation of cracks during the curing process. Cracks in the stabilized base can reflect through the HMA surface decreasing the life of the pavement.

To decrease the likelihood of this type of cracking, micro cracks were introduced into the cement treated RAP prior to sealing with HMA. Micro cracks allow the treated base to expand and contract with the HMA surface resulting in reduced surface cracking of the HMA layer.

When the project was inspected in September 2006 there were no cracks in the mainline except for a few transverse cracks above cross pipe locations. Cross pipe associated cracking was due to frost movement not failure of the cement treated RAP.

Conclusions

After one year's exposure to traffic and weather, the project is performing very well. FWD tests show a significant increase in structural stability compared to untreated RAP. Cracking was limited to cross pipe locations and were the result of frost movement. The project will be visually inspected and tested with the FWD over a five year period. An interim report will follow each inspection.

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