

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION



TRANSPORTATION RESEARCH DIVISION
BUREAU OF PLANNING

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EXPERIMENTAL CONSTRUCTION PROJECT ME 98-08

CONSTRUCTION REPORT

EXPERIMENTAL UTILIZATION OF PERMEABLE BASE

INTRODUCTION

The effects of excessive water within pavement structural sections has been shown to decrease the service life of our nation's roadways. Some of the problems associated with this excessive water include premature rutting, cracking, faulting, increased roughness, and a relatively rapid decrease in the level of service ability. These problems are caused by a decrease in the ability of the structural section to transmit the dynamic loading of traffic, and also through the development of excessive pore pressure which can cause pumping of the subbase material up through the cracks in the pavement surface. Beginning in 1970, there has been an increasing interest in pavement drainage, as premature failure of pavements has become a significant problem. A recent trend has been toward the use of permeable base systems along with longitudinal pipe edge drains as a means to address premature pavement failure.

The National Cooperative Highway Research Program sponsored a research project to investigate the effectiveness of permeable base on pavement performance. (Project 1-34 FY '95) An interim report was published in February 1997 which includes an extensive literature review, and a survey of current State pavement drainage practices. The NCHRP reports that most states that have experimented with permeable bases report improved pavement performance. The three main types of permeable bases are: untreated (PAGG, permeable aggregate), asphalt-treated (PATB, permeable asphalt-treated base), and cement treated (PCTB, permeable cement-treated base). Of the three types, asphalt-treated is the most common. Other references on permeable bases are NCHRP Synthesis 239 Pavement Subsurface Drainage Systems published in 1997, and National Asphalt Pavement Association report, Asphalt Treated Permeable Material-It's Evolution and Application published in 1994.

The increased material and labor of permeable bases increases construction costs. Some research has indicated however, that due to the structural contribution of an asphalt treated permeable base, some cost offset savings can be achieved by reducing surface pavement thickness.

In an effort to gain knowledge on this method, and also to assess the potential for increasing the performance of Maine's roadways, an experimental construction project was initiated to investigate the use of a permeable base layer in the pavement structural section. Areas to be investigated are the ease of construction, and increased costs. Performance of the permeable base will be monitored over time and those results will be beneficial in determining the overall feasibility of the method. Reductions of future rutting and cracking will be evaluated. A final report will be done after sufficient performance data has been gathered.

Project Description

The area selected for this experimental construction was a portion of State Route 139 located in the town of Fairfield. (See Figure 1.)

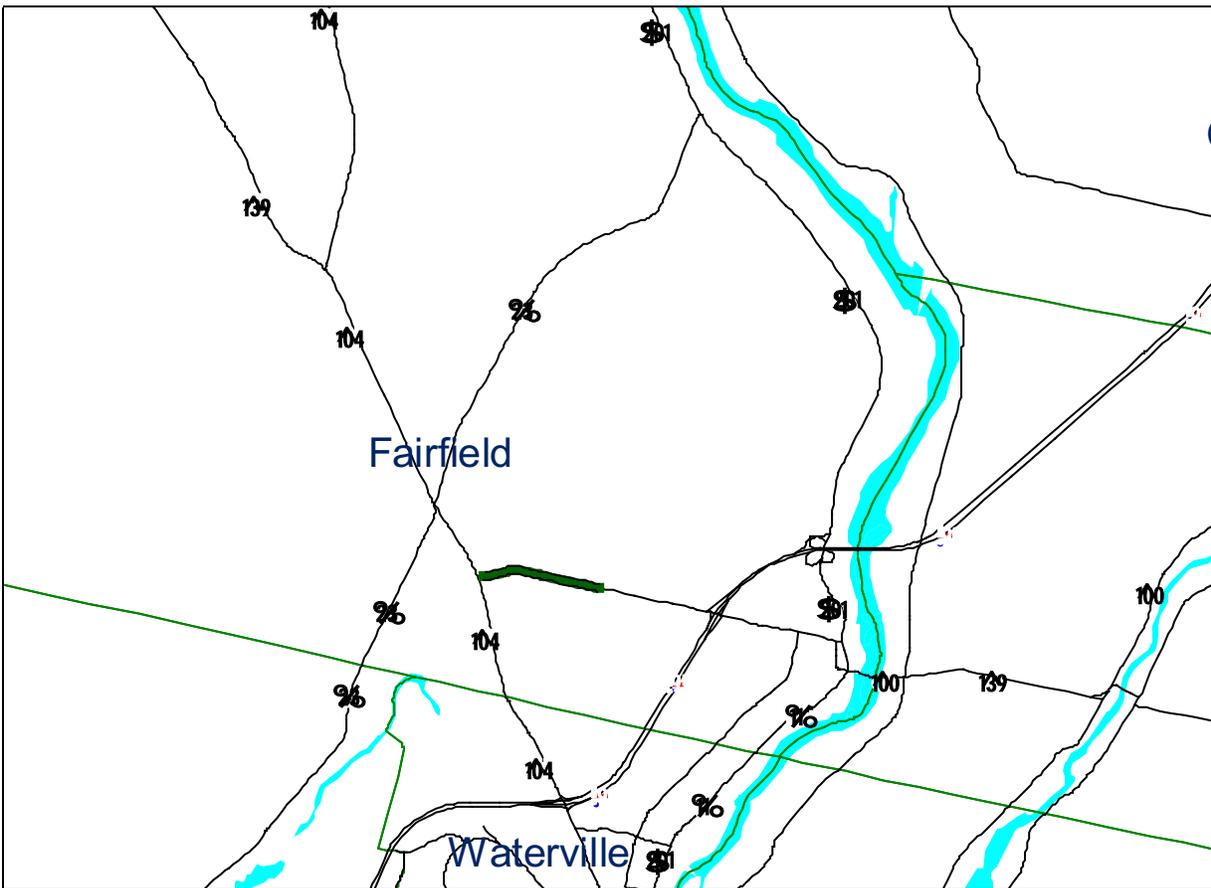


Figure 1 Project Location

The project, STP-2731(20)x is a highway reconstruction beginning at State Route 104 and extending 1.5 km (0.95 mi.). The experimental construction sections extend from Station 34+20 to 52+00. Adjacent sections will be used as control sections. The project utilized two types of permeable base materials, untreated aggregate and asphalt treated aggregate. In both cases the permeable base was placed in direct contact with the top of the underdrains within the section.

The success of this project owes much to the flexibility and cooperation among everyone involved. Without the cooperation of the contractor, the plant operator and the field personnel, this project would not have succeeded.

As with any new method, unforeseen problems occurred. The cooperation and helpful suggestions by all involved contributed to its successful completion.

Research Methodology

In order to assess the performance of asphalt treated base material versus untreated aggregate, treated aggregate material was placed from Station 43+10 to Station 52+00. Paving operations were monitored to evaluate the ability to pave over the permeable base material.

The pavement will be monitored over a five year period for pavement rutting and cracking. The adjacent control sections will serve as a comparison. In addition, FWD deflection tests were conducted and will be repeated annually to analyze section uniformity. These tests will be repeated to evaluate deflection over a five year period.

Construction Process

General Construction Procedure

The 4 inch layer of permeable base was placed and compacted in a single layer, between the aggregate subbase and the 6 ¼ inch surface paving. The layer extended laterally to cover the under drain trenches and extended through the shoulder slope. The order of construction was as follows:

- Fine grade the base

- Excavate a 30 inch wide box trench over

- Fill with permeable untreated base material and compact trench in two lifts

- Install permeable base with paver. (Let treated base cool somewhat before compacting.)

- Install pavement before allowing traffic on the section

Underdrain Construction

The box trenches for the underdrains were excavated after the fine grading was completed. Crushed stone was placed in the trenches in two lifts. The first lift was compacted with one pass by a vibratory whacker, the second by passing over it several times with the tire on the excavator. Compaction appeared to be adequate using this method. Normal sections showing the underdrain trench are shown below. Both untreated and treated sections are depicted.

Permeable Base Construction

Both treated and untreated experimental sections were constructed on August 25 and 26, 1998. On the first day test the north side of the road was constructed; on the second day the south side was completed. The permeable sections were made 15 feet wide in the travel lanes and extended over the longitudinal underdrains. The shoulders were finished at a later date. The permeable base was installed using a paving machine for both treated and untreated sections. Installation of both treated and untreated sections test sections on the north side took about 4 ½ hours.

Permeable Base Mix and Lay Down

On the first day of base placement, the aggregate and asphalt were mixed at the plant without any heating. Using unheated asphalt the bitumen remained in small clumps and stuck onto the paver screed. Due to this problem it was determined that a heated mix was necessary. On the second day the mix was heated at the plant. Due to some constraints at the asphalt plant, the exact mix specified could not be produced, however, through excellent contractor cooperation a workable solution was found. At the plant, the PG58-22 asphalt was heated to 300° and the stone to 250°, with 25 seconds wet mixing time, but no drying time. The bitumen mix was 2%. At that

proportion, occasionally there were stones with very little coating; the mix looked like very lean asphalt mix having a very coarse gradation. The untreated permeable base installed more quickly than the treated section since the trucks did not have to wait at the plant. In the treated section, untreated stone was used over the under drain trenches, due to the fact that it would have been impractical for the plant to heat and mix the small amount of stone needed in that section.

Permeable Base Compaction

Both treated and untreated sections were compacted using five passes of a 10 ton static roller. On the second day, a heated mix was used for the treated section. After placement, the temperature of the mix dropped 50 to 60 degrees very quickly, but then rate of cooling slowed. After two hours it was still at 175°. Two passes of a water truck cooled the material sufficiently to allow compaction. Initially, there was some reluctance to use much water. This proved to be unwarranted since after watering things went better. Since the treated base layer was softer due to heating, only three passes of the static roller were needed. Perhaps another pass might have been warranted as the water truck tires made ½ inch ruts, however, car traffic only left marks on the very edge of the sections.

Paving over Permeable Base Layer

In both treated and untreated sections the stability of the aggregate was a problem. A major problem occurred on the first day when the surface course was placed. The permeable base did not have adequate stability to support the small front wheels of the paver. Ridges of stones were pushed up to the sides of the paver causing thin areas in the surface pavement layer. Workers raked and smoothed the alleviate this problem. Paving was suspended on this section, however, until a tracked paver could be obtained. After switching to the tracked machine the process went more smoothly.

It was originally planned to reduce the total pavement thickness by 1 inch over the treated permeable base due to the structural contribution of the base. This would take advantage of the added structural value of the treated material. However, it was felt that the layer coefficient of the base was not adequate, and probably less than the recommended 0.23 AASHTO standard. In addition, it would have been difficult to match up with the pavement elevation and thickness in the untreated sections, so the pavement layer was not reduced. The construction process is shown in the series of photographs in the Appendix of this report.

Construction Testing

The pavement density tests are shown in the table below.

	Bituminous Core Density Tests			
	Treated		Untreated	
	Test 1	Test 1	Test 2	Test 2
8/25/98	92.1%	94.1%		
8/26/98		93.4%	94.3%	95.7%

Costs

The contract unit price was \$26 per cu. yd. for the untreated aggregate and \$37 per cu. yd. for the asphalt treated aggregate. An additional cost of \$2 per cu. yd. was incurred due to the heating requirements. In the future, cost data from this project could be used to prepare engineer’s estimates and life-cycle cost analysis for other projects.

Post-Construction Testing

Initial FWD tests were conducted on the two test sections and the two control sections on October 19, 1998. Air temperature was around 61° F, and surface temperature ranged from 69-78 ° F. Test Section 1 extends from Sta. 43+50 to Sta. 52+25. Test Section 2 extends from Sta. 34+50 to 43+25. Control Section 1 extends from Sta. 52+50 to Sta. 57+25 and Control Section 2 from Sta. 29 +75 to Sta. 34+25.

Statistical Analysis

An analysis was done on the 1st sensor FWD deflection measurements. The difference in the sample means for the control sections is almost 20%. Despite that apparently large difference, the difference is not statistically significant at the 95% confidence level. Data from both sections was “pooled” for the rest of the analysis.

Due to the construction difficulties encountered with the unheated asphalt mixture, it was expected that there might be some observed differences between measurements on Test section 1 between the left and right lanes, which used unheated and heated aggregate mixtures respectively. In fact, the means differ by almost 13% between the left and right lane. Nevertheless, the mean difference between the two sets of lanes measurements are not statistically significant. This will be monitored over time as future testing is done to determine how these lanes perform differently over time.

Subgrade Uniformity

Analysis of the subgrade resilient modulus indicates good subgrade uniformity. In addition, there are no unusually low measurements. With the exception of a few measurements in the 4600 psi range, all measurements are at least 5,000 psi.

Section Uniformity

In 1996, as part of it's Long Term Pavement Performance program (LTPP), the Federal Highway Administration, published a study on section uniformity using FWD testing. The report hypothesizes that non-uniformity of pavement response to load, leads to larger tensile and shear stresses in the adjacent section areas, precipitating fatigue cracking and leading to pot-holing. A statistic that can be used to assess section uniformity is the coefficient of variation (COV) of the first sensor deflection readings. The COV is a measure of the relative dispersion of a set of observations, and is useful in evaluating sets of measurements. It is generally expressed as a percentage. The value of the COV lies in the fact that the mean and standard deviation tend to vary together in many sets of data. A statistic that measures relative change between the mean and standard deviation avoids this problem. The research literature suggests that lower COV values are associated with longer pavement life. There is limited evidence to support this hypothesis. Existing evidence suggests that newly constructed pavements should have COVs below 15%, and definitely below 20%.

On this project, the sensor COVs on this project show a wide range of values. Both test sections would be classified in the “Good” range, however the control sections show widely different COV ranges. One would be classified as “Excellent” while the other would be only “Fair”. Both test sections are remarkably consistent, having COVs of about 10%. If the COV hypothesis is true, the Test sections should perform better over time than Control 1. Control 2 would be expected to have the lowest performance characteristics in the future.

Falling Weight Deflectometer Data						
Test Sections						
Section 1 (Asphalt Treated)				Section 2 (Untreated)		
	Pavement Modulus (psi)	Subgrade Resilient Modulus (psi)	First Sensor Deflection (mils)	Pavement Modulus (psi)	Subgrade Resilient Modulus (psi)	First Sensor Deflection (mils)
Ave.	93,107	6,394	10.53	88,909	5,826	11.166
Std. Dev.	12,692	530	1.088	10,726	604	1.201
COV			10.33%			10.76%
Control Sections						
Section 1				Section 2		
	Pavement Modulus (psi)	Subgrade Resilient Modulus (psi)	First Sensor Deflection (mils)	Pavement Modulus (psi)	Subgrade Resilient Modulus (psi)	First Sensor Deflection (mils)
Ave.	81,276	8,166	11.324	112,351	6,491	9.089
Std. Dev.	14,853	3,289	1.942	8,525	659	0.668
COV			17.15%			7.35%

Comparison of Section Coefficient of Variation								
Section	N	Mean	%-Diff.	Std. Dev.	COV	%-Diff.	Diff. in Means	t test
Control 1	20	11.32		1.94	17.2%			
Control 2	19	9.09	19.7%	0.67	7.4%	9.8%	2.23	0.3734
Test 1(Left)	18	11.25		0.55	4.9%			
Test 1(Right)	18	9.80	12.9%	1.01	10.3%	-5.4%	1.45	0.1714
Test 1	36	10.53		1.01	10.3%			
Control	39	10.24	2.8%	1.84	18.0%	-7.7%	0.29	0.9664
Test 2	36	11.17		1.20	10.8%			
Control	39	10.24	8.3%	1.84	18.0%	-7.3%	0.93	0.5282

Coefficient of Variation (COV)	Classification
< 10%	Excellent
> 10% and < 15%	Good
> 15% and < 20%	Fair
> 20% and < 25%	Fair-Poor
> 25%	Poor

Future Testing

The sections will be visually observed twice each year for evidence of rutting and cracking. Visual monitoring during springtime will include observation of the outflow from the underdrain system. The Department's Automatic Road Analyzer (ARAN) will also be used to gather data on these sections. Rutting and cracking compared to the control section will be evaluated. FWD tests will be repeated each year during springtime thawing conditions. After five years destructive testing (core analysis) may be performed, if determined to be necessary. In the longer term, the Department intends to contact other agencies having experience with pavement durability for ideas on future monitoring.

Conclusions

Based on the experience gained under this experimental construction, the method requires attention to asphalt mix, compaction, and allowable length of daily lane closure. The operational side of this project developed several important lessons for future projects.

First, to ensure adhesion between the asphalt and aggregate, the aggregate must be heated. The higher temperatures involved however lead to longer cooling times. Liberal watering can then be used to speed cooling and improve workability. As an alternative to asphalt, an emulsion might be used for the aggregate treatment, thereby avoiding heating. Future research is needed, though, to determine if the fines required in the emulsion mix would reduce permeability of the final mixture.

Second, if untreated aggregate is used, a tracked paver must be used to pave over the untreated aggregate. Since untreated aggregate has no adhesion and reduced stability, a wheeled paver will sink into it, forcing aggregate to the sides and reducing final pavement layer thickness. On this project the stability gained from a 2% asphalt mix adhering to the stones was apparent.

Third, the first lift of pavement must be in place before traffic is allowed on the section. To this end the construction manager should specify a maximum length of lane closure so as to assure that both travel lanes are completed during a working day. This would eliminate problems caused by leaving adjacent areas with large differences in pavement elevations.

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Distribution A

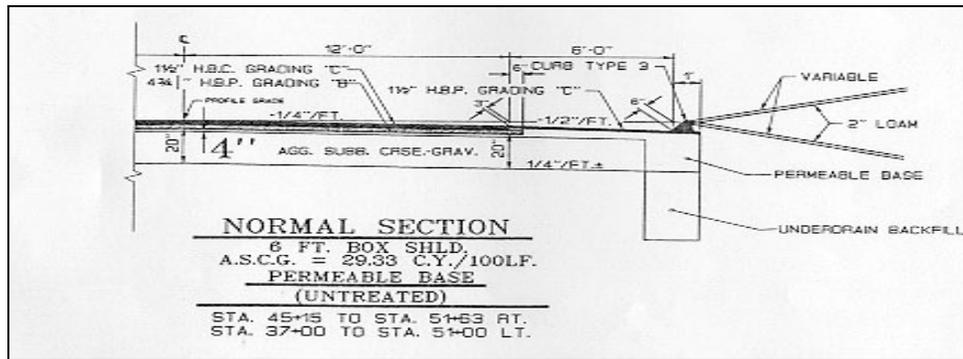


Figure 2 Normal Section Untreated Base

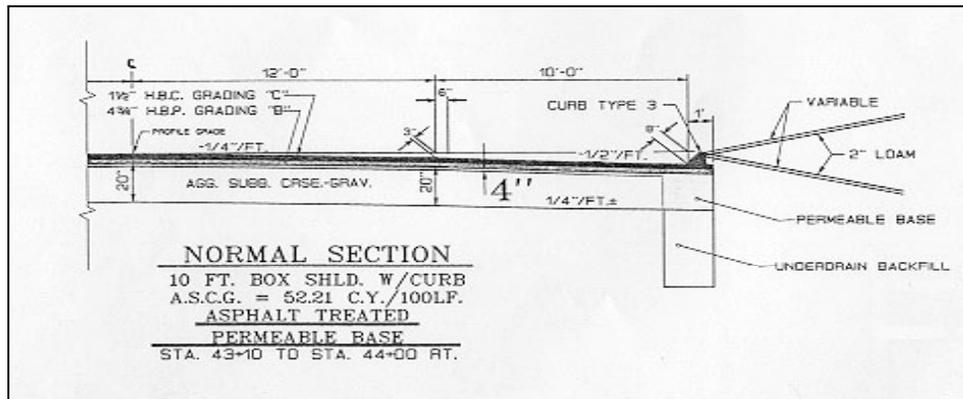


Figure 3 Normal Section Treated Base



Figure 4 Box Trench Construction



Figure 5 Permeable Base Placement



Figure 6 Permeable Base Compaction



Figure 7 Permeable Base after Compaction



Figure 8 Untreated Base



Figure 9 Treated Base



Figure 10 Paver Wheels on Untreated Base



Figure 11 Paver Tracks on Treated Base



Figure 12 Joining of Treated and Untreated Sections



Figure 13 Adjacent Base Sections



Figure 14 Paving Operation with Tracked Paver



Figure 15 Paving Operation with Wheeled Paver



Figure 16 Close-Up of Treated Base



Figure 17 First Pavement Lift over Base