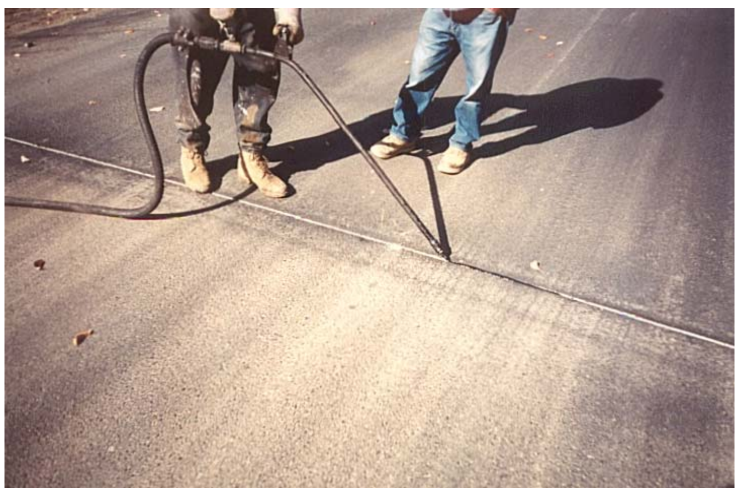
Child Street
16 State House Station
Augusta, Maine 04333

Maine Department of Transportation

Transportation Research Division



Technical Report 00-19

Comparison of "Saw and Seal" Procedure and Performance Grade Binder to Minimize Thermal Cracking

Interim Report - Fourth Year/Final Report, December 2008

Transportation Research Division

Comparison of "Saw and Seal" Procedure and Performance Grade Binder to Minimize Thermal Cracking

Introduction

In an effort to compare performance and cost effectiveness of the "Saw and Seal" procedure and Performance Grade (PG) binders, the Maine Department of Transportation (MaineDOT) constructed an experimental project in Weston, Maine during the fall of 2000. Both the Saw and Seal method and PG binder are designed to minimize thermal cracking.

Saw and Seal is the process of introducing uniformly spaced sawed joints to a bituminous overlay in an attempt to eliminate or retard the formation of thermal and/or reflective cracking. Several states, including Minnesota, New York and Massachusetts have successfully used the saw and seal process. MaineDOT is currently evaluating two saw and seal projects to determine the effectiveness of this process in minimizing thermal cracking.

Performance Grade binder is a modified asphalt binder designed for use in harsh temperature conditions. Its application is intended to minimize thermal cracking. PG binder 58-34 is designed for a maximum pavement design temperature of 58 ºC and a minimum temperature of -34 ºC.

Project Location/Description

This project is located on a section of Route 1 in the town of Weston in Aroostook County. This is a highway improvement project scheduled for full depth reclamation. Figure 1 contains a location map of the project. Project number STP-9430(00)X begins at the Danforth town line and extends northerly 5.09 km (3.14 miles). The designed pavement thickness consists of a base course of 60 mm (2.5 in) of 19.0 mm (0.75 in) superpave and a wearing surface of 40 mm (1.5 in) of 12.5 mm (0.5 in) superpave.

The experimental feature of this project contains three test sections between stations 20+200 and 20+800. The saw and seal portion is between stations 20+200 and 20+500. The control section begins at station 20+500 and ends at station 20+778 and the full depth PG binder section begins at station 20+800 and ends at station 21+088.

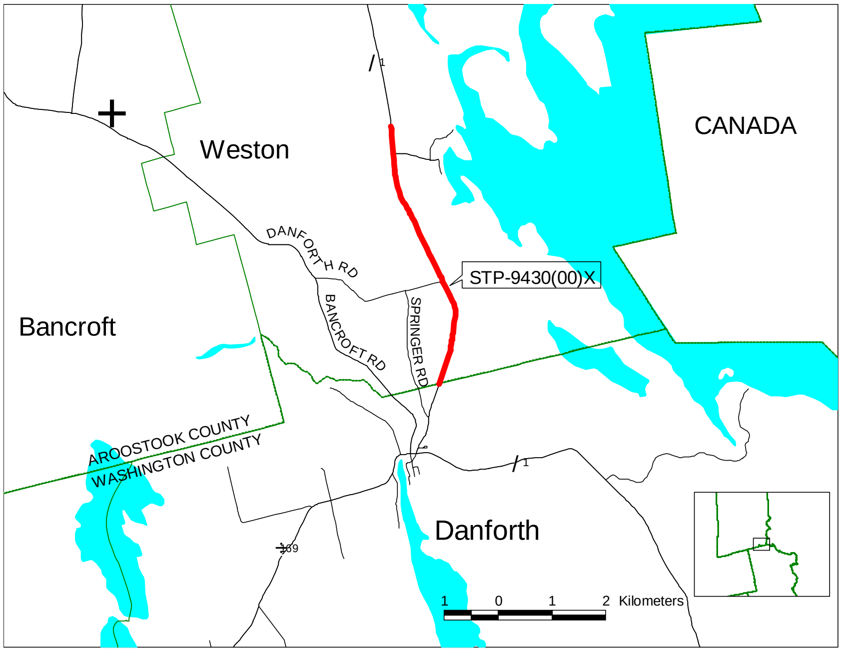


Figure 1: Project location map

Construction Procedures

Saw and Seal Section

Paving of the base course in the Saw and Seal section was completed on September 5 and 6, 2000. The wearing surface material was applied on October 2, 2000. Both the base and wearing surface materials were superpave design with MDOT's standard PG 64-28 binder.

The saw and seal process was completed on October 13, 2000. Full width joints, 7.2 meters (23.6 feet) in length were introduced to the surface using two passes of the pavement saw. The first pass completed the 15.75 mm (5/8 inch) reservoir; the second and final pass completed the approximate 50 mm (2 inch) depth of joint as recommended. Figure 2 contains dimensions of a typical Saw and Seal joint.

Contrary to the work plan, detailed later in the report, full width and two-pass cutting of the joints was accepted and traffic was allowed to travel on the cut joints. Unsealed joints were exposed to traffic for approximately two hours, during which time they were closely monitored and no detrimental effects were reported. The project resident deemed this deviation of the work plan necessary because of equipment

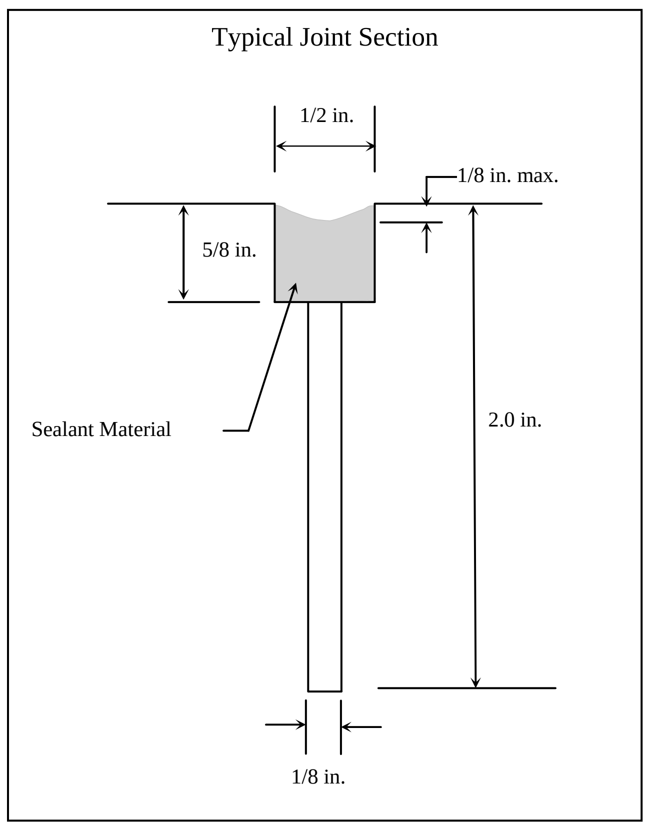


Figure 2: Saw and Seal details

availability, the remote project location, and the impending winter weather season. After sawing, joints were blown clean and sealed with Crafco Roadsaver 222 sealing material, manufactured by Crafco Inc., 6975 W. Crafco Way, Chandler, AZ. Thirty-four joints were introduced to the 300-meter section at a spacing interval of 9.15 meters (30 feet). The Saw and Seal process took approximately ten man-hours to complete. Overall cost of this process was $4,896.00.

The following Special Provision was included in the work plan.

SPECIAL PROVISION
SECTION 419
SAWING AND SEALING JOINTS IN BITUMINOUS PAVEMENT

Description: This work shall consist of sawing a cut transversely across the newly finished bituminous concrete pavement as shown on the plans or as directed, and in accordance with this Special Provision. Upon the satisfactory completion of each cut, it shall be sealed with hot rubber asphalt joint sealer. The work is to establish a weakened plane joint to control thermal cracking in the newly placed bituminous concrete pavement.

MATERIALS

Joint Sealer. Joint sealer shall be an asphalt rubber compound of the hot poured type conforming to AASHTO M301 and ASTM D3405.

CONSTRUCTION REQUIREMENTS

Weather. Joint sealer shall not be applied when weather conditions are unfavorable for proper construction procedures. Specifically; when atmospheric temperature is below 10 ºC (50 ºF) at the work site, when pavement surface is wet. Joint sealer shall not be applied before sunrise and after sunset.

Equipment. Equipment used in the performance of the work shall be subject to the Engineers approval and shall be maintained in a satisfactory working condition at all times.

a) Air Compressor: Air compressors shall be portable and capable of furnishing not less than 3.0 m^3 (100 cu.ft.) of air per minute at not less than 600 kPa (90 psi) pressure at the nozzle. The compressor shall be equipped with traps that will maintain the compressed air free of oil and water.

b) Hand Tools: Shall consist of brooms, shovels, metal bars with chisel shaped ends and any other tools which may be satisfactorily used to accomplish this work.

c) Melting Kettle: The unit used to melt the joint sealing compound shall be a double boiler, indirect fired type. The space between inner and outer shells shall be filled with a suitable heat transfer oil or substitute having a flash point of not less than 315 ºC (600 ºF). The kettle shall be equipped with a satisfactory means of agitating and mixing the joint sealer at all times. The kettle must be equipped with thermostatic control calibrated between 90 ºC and 290 ºC (200 ºF and 550 ºF).

Sawing Joints. The bituminous concrete shall be in place a minimum of 48 hours prior to sawing to allow a clean cut to be made, and to withstand the eroding effects of the saw or other cutting device.

The joint shall be cut with an abrasive blade or blades of such size and configuration that the resulting depth and reservoir shape are in accordance with the plans. Sawed joints will be made with a single pass. Either dry or wet cutting will be allowed.

Joints shall be sawed using a 9.15 mm (30 foot) spacing interval.

The completed cut shall extend in a straight line transversely across the travel way and shall extend 300 mm (12 inches) into the paved shoulder.

Sealing Joints. The sawed joints shall be sealed immediately after the cut has been made. Traffic shall not be allowed to knead together or damage the sawed joint. Each joint shall be clean and dry prior to the placement of sealing compound by blowing out all dirt, dust and deleterious matter that may have accumulated in the saw joints. Sufficient air pressure shall be provided to insure thorough cleaning and drying.

The joint seal shall be applied with a mobile carriage and rubber shoe and have a flow control valve which allows all joints to be filled to refusal, so as to eliminate all voids or entrapped air, and not leave surplus sealer on the pavement surface. Any depression in the sealer greater than 3 mm (1/8 inch) below the pavement surface shall be brought up flush to the pavement by the further addition of hot sealer. The recommended melting temperature of the sealer shall be furnished to the Contractor by the manufacturer and the actual temperature of the material in the melter shall not fluctuate from this recommended temperature by more than 5.5 ºC (10 ºF).

Workmanship. All workmanship shall be of the highest quality. Excess of spilled sealer shall be removed from the pavement by approved methods and discarded. Any workmanship determined to be below normal acceptable standards will not be accepted and will be corrected and/or replaced as directed by the Engineer.

Method of Measurement. This work shall be measured for payment by the number of linear feet of joint sawed and sealed in the bituminous concrete surface, measured in place and accepted.

Basis of Payment. Payment for this work shall be at the contract unit price per linear foot for sawing and sealing joints in bituminous concrete pavement, complete in place.

Payment will be made under:

Pay Item		Pay Unit
419.20	Sawing, Sealing Joints in Bituminous Concrete Surface	Meter (Linear Foot)

Control Section (PG64-28)

Paving of the base coarse and wearing surface was completed on the same dates as the Saw and Seal section. Identical paving materials and standard paving practices were used.

Performance Grade Binder (58-34) Section

The 19.0 mm base course containing PG 58-34 binder was completed on September 8, 2000. The 12.5 mm wearing surface was placed on September 26, 2000. Standard paving practices were followed and only minimal problems were encountered at the bituminous plant when the asphalt type was changed to accommodate the experimental feature of this section.

Use of the PG 58-34 binder added an approximate total of $3800.00 to the completion cost of this section.

Monitoring of the project will consist of annual visual evaluations with a focus on the formation of transverse cracks. Sawed joints will also be monitored for deterioration.

Visual Evaluation

The experimental sections were evaluated on October 1, 2004 as part of the fourth year evaluation and on September 28, 2005 as part of the fifth and final, scheduled evaluation. Overall, deterioration is considered typical for a roadway of this age. Sections are displaying cracking and rutting at various levels, which is detailed below.

Saw and Seal Section

Overall pavement condition remained good for both the 2004 and 2005 evaluations. The average wheel rut depth increased slightly from 6 mm (0.25 in) in 2003 to a measured depth of 7 mm (0.25 in) in both 2004 and 2005. The centerline joint has separated throughout the entire section. Saw joint sealant continues to be pliable and well adhered to the sidewalls of the sawed joints. The two transverse cracks noted as part of the 2003 evaluation continue to be the only transverse cracks observed in this section. The length of each of these cracks has increased minimally. Longitudinal and Load Associated cracking increased in each of the evaluations and is summarized in Table I below.

Beginning with the 2004 evaluation, cracks extending from one or both ends of the sawed joints were identified and recorded. In 2004, eight sawed joints had a crack extending from one end, while ten showed cracks extending from both ends of the joint. For 2005, seven joints had a crack extending from one end and 17, or half of the total number of 34 joints introduced to the pavement, had cracks extending from both ends. This cracking has also been identified on each of the other two Saw and Seal experimental sections constructed and monitored previously within the State. Those projects will be discussed in more detail in the Conclusion section of this report.

In 2004, three sawed joints showed some signs of raveling. This number increased to 15 in 2005. Nine of the sawed joints were also noted as having some parallel cracking during the 2005 evaluation.

Two cross-pipes located within the Saw and Seal section were resurfaced sometime between the 2004 and 2005 evaluations. It is unclear if this impacted the crack evaluation for this section.

Table I: Saw and Seal Section

	Type of Cracking		
Year	**Longitudinal (meters)**	**Initial Load (Sq. Meters)**	**Moderate Load (Sq. Meters)**
2003	78	40	-
2004	131	162	5
2005	322	399	54

Control Section

Pavement condition for both the 2004 and 2005 evaluations was considered good. The average wheel rut depth for the 2004 evaluation did not show an increase from the 2003 value of just less than 6 mm (0.25 in). In 2005 however, the average rut depth increased to just less than 12 mm (0.5 in). The centerline joint has separated the entire length of the section. The three transverse cracks identified as part of the 2003 evaluation remain the only transverse cracks within the section. As noted in 2003, two of the transverse cracks are occurring at cross-pipes. The third is the result of a poor quality construction joint and is not considered a thermal related transverse crack for this evaluation. Table II summarizes the Longitudinal and Load Associated cracking for the 2003, 2004 and 2005 visual evaluations.

Table II: Control Section

	Type of Cracking		
Year	**Longitudinal (meters)**	**Initial Load (Sq. Meters)**	**Moderate Load (Sq. Meters)**
2003	18	10	-
2004	52	150	16
2005	105	276	20

Performance Grade Binder (58-34) Section

As with the other two sections in this experimental area, cracking has increased in each of the evaluation years. For the 2004 evaluation, the centerline joint had opened to a total length of 151 meters (495 feet). In 2005 that length had expanded to 192 meters (630 feet). Rutting continued to be more significant in this section. In 2004 the average rut depth increased to 12 mm (0.5 in) and for 2005 that depth had increased to 18 mm (0.75 in). No transverse cracks were identified in either the 2004 or 2005 evaluation. One cross-pipe was resurfaced in this area some time between the 2004 and 2005 evaluations. As was the case with the Saw and Seal section, it is unclear if this had any impact on the crack evaluation. Longitudinal and Load Associated cracking reported for each of the three evaluations is summarized in Table III below.

Table III: PG Binder Section

Year	Type of Cracking		
	Longitudinal (Meters)	Initial Load (Sq. Meters)	Moderate Load (Sq. Meters)
2003	54	48	-
2004	59	60	-
2005	166	299	-

Conclusions

The objective of this Research was to evaluate the Saw and Seal procedure and Performance Grade Binder (58-34) to determine if either or both of these additions to the construction process might minimize the formation of transverse cracking.

It is recognized that the Saw and Seal section is slightly longer than the Control and PG Binder sections. In addition, the PG Binder section is 10 meters (33 feet) longer than the designated Control section.

Two transverse cracks, less than 1 meter (3 feet) in length, developed in the Saw and Seal section, while no transverse cracks were recorded in the PG binder section throughout the five year evaluation period. Three transverse cracks developed in the control section. **As noted above, neither of these is considered to be a result of thermal cracking.**

When compared as a percentage, other cracking types that were identified in each section are actually more significant in the experimental sections than the control section. Overall, longitudinal cracking was the most severe in the Saw and Seal section with 322 meters (1,056 feet) being identified. The PG Binder section had the second most Longitudinal cracking, with 166 meters (545 feet) present. Load Associated cracking was also the most prominent in the Saw and Seal section with 453 square meters (1,486 square feet) identified. As a percentage of the total area within each section, the Control and PG Binder sections displayed approximately the same amount of Load Associated cracking. These percentages are summarized in Table IV below.

Table IV: Percentage Comparisons

Section	Total Length Longitudinal Cracking	*Total Square Meters/ Load Cracking	* Percentage Longitudinal Cracking	* Percentage Load Cracking
Saw and Seal	322	453	54	6.3
Control	105	296	19	4.4
PG Binder	166	299	29	4.3

* Total Square Meters of Load cracking includes both Initial and Moderate severities.
* Percentage of Longitudinal Cracking = (Total Length of Longitudinal Cracking/(Section Lengthx2))
For this evaluation, cracking was considered Longitudinal when occurring between wheel paths only.
* Percentage of Load Cracking = (Total Load Cracking/Total Section Area)

Several conditions identified within the Saw and Seal section of this evaluation were also present in one or both of the other two experimental projects previously evaluated by the Maine DOT. That evaluation was detailed in a Final report dated August, 2004 titled "Experimental Use of Sawed and Sealed Joints to Minimize Thermal Cracking" (Technical Report #'s 96-25 and 97-19). Cracks extending from one or both ends of the sawed joint were present in each of the three Saw and Seal projects evaluated. Pavement raveling and parallel cracks near the sawed joints were identified on both this Saw and Seal section and the Saw and Seal section located on Interstate 95 in T1R6/Sherman. On the Interstate 95 location, a phenomenon referred to as "tenting" was identified and detailed in the technical report. Briefly, tenting is when both edges of a joint or transverse crack rise higher than the surrounding pavement to form a "tent" that is noticeably rough when traveled over at highway speeds. Although no known reports of "tenting" have been recorded for this section, it is theorized that this "tenting" is quite possibly the cause of the raveling and parallel cracks present in both the T1R6 section and this experimental section.

Intuitively, a snowplow impacting these "tented" areas could potentially cause the raveling and subsequent parallel cracking that is present. Heavy loads passing over the "tented" areas may cause the elevated edges to "bend", resulting in parallel cracking.

It is further theorized that pavement thickness plays a part in the "tenting" phenomenon. The Saw and Seal project located on Route #9 in Beddington has a pavement depth of 240 mm (9.5 in) and has shown no signs of "tenting". The T1R6 location has 115 mm (4.5 in) pavement depth, very similar to the 100 mm (4 in) depth present on this experimental section. As noted above, both of these sections are displaying raveling and parallel cracking near the sawed joints.

The Saw and Seal process appears to minimize the formation of transverse cracks and is slightly outperforming the control section. However, raveling and parallel cracking near the sawed joints will eventually lead to problems. Therefore Saw and Seal is not recommended for an effective treatment.

The PG58-34 Binder also appears to minimize transverse cracking and is slightly outperforming the control section. It is recommended to consider the use of lower temperature PG binders when thermal cracking is a concern. Although not originally part of this evaluation, the PG58-34 section displayed higher average rut depths than either of the other two sections, which used a PG64-28 binder. An extensive review of results from testing at the time of construction, results from core samples taken in July, 2006 and Falling Weight Deflectometer (FWD) results also gathered in July, 2006 are inconclusive as to the exact cause of this rutting. However failing volumetric values from laboratory tests during construction and the fact that the high end PG binder temperature was reduced from 64 to 58 degrees C, may be the cause.

In addition, traffic information was reviewed and it was concluded that the actual heavy truck traffic was much higher for this section. At the time of project design, 1994 traffic information was the most current available. It indicated an average of 19 heavy trucks per day traveled this section. A 2004 survey indicated that the number of heavy trucks increased significantly to an average of 127 per day. This resulted in the section being under-designed.

Table V: HMA Core Sample Test Summary

		Core Sample Test Results					
	Rut	% Compaction		% Air Voids		% Binder	
Section	Depth (mm)	Surface	Base	Surface	Base	Surface	Base
Control	27	96.7	96.2	3.3	3.8	5.96	4.63
Control	5	96.6	96.6	3.4	3.4	5.53	5.57
Control	4	-	95.5	-	4.5	-	5.20
PG 58-34	14	-	96.1	-	3.9	-	4.57
PG 58-34	42	-	95.7	-	4.3	-	5.57
PG 58-34	24	96.9	-	3.1	-	5.19	-

* Cores were cut on July 7, 2006
* Surface mix was separated from the cores by saw cutting
* Cores 3, 4, 5 and 6 were not intact. As a result, there was not enough material to run tests on both the surface and base.

Table VI: Nuclear Compaction Test Summary – Cold In-Place Recycled Pavement

Section	Station	Offset	DBFG	% Moist.	% Comp.	% Min.
Control	21+600	1.6 m lt.	TOG	10.3	99.4	98
Control	20+500	2.1 m lt.	TOG	8.9	99.4	98
Control	21+500	1.8 m rt.	6 inches	1.5	99.7	98
PG 58-34	20+900	1.0 m rt.	TOG	9.2	103.6	98
PG 58-34	20+901	0.6 m lt.	TOG	9.2	99.5	98

Table VII: Falling Weight Deflectometer Test Summary

Control Section – PG 64-28							
South Bound Lane				North Bound Lane			
	Modulus				Modulus		
Station	Subgrade	Pavement	SN	Station	Subgrade	Pavement	SN
20+550	5210	55051	4.28	20+725	4872	49854	4.14
20+600	4826	47183	4.07	20+675	5351	52320	4.21
20+650	4297	65756	4.54	20+625	4740	48504	4.1
20+700	5024	58566	4.37	20+575	4584	46623	4.05
20+750	5223	59194	4.38	20+525	4759	49268	4.12
Mean	**4916**	**57150**	**4.33**	**Mean**	**4861**	**49314**	**4.12**
Experimental Section – PG58-34							
South Bound Lane				North Bound Lane			
	Modulus				Modulus		
Station	Subgrade	Pavement	SN	Station	Subgrade	Pavement	SN
20+850	5099	49548	4.13	21+025	4354	36679	3.74
20+900	5004	52006	4.2	20+975	4800	37913	3.78
20+950	4976	52477	4.21	20+925	4918	44165	3.98
21+000	6107	58288	4.36	20+875	4457	34302	3.66
21+050	5890	62172	4.46	20+825	4592	41054	3.88
Mean	**5415**	**54898**	**4.27**	**Mean**	**4624**	**38823**	**3.81**

Table VIII: Laboratory Test Report Summary – Hot Mix Asphalt

Control Section – PG 64-28

HMA Base – 19.0 mm (Initial Sample)			Bulk Specific Gravity			
Test Type	**Result**	**Tolerance**	**Station**	**Offset**	**Results**	**Tolerance**
% Air Voids	4.3	2.5 to 5.5	20+375	0.9 lt.	94.1	92.5 to 97.5%
% VMA	15.1	13.0 % min				
% VFB	72	63 to 80 %				
Fines to Binder	0.8	0.6 to 1.4				
Gmm	2.487	2.480 ± 0.030				
% Binder	5.1	5.1 ± 0.4%				
HMA Surface – 12.5 mm (Initial Sample)			**Bulk Specific Gravity**			
% Air Voids	4.5	2.5 to 5.5	20+679	3.0 rt.	93.3	92.5 to 97.5%
% VMA	16.4	14.0 % min	20+587	0.5 lt.	94.4	92.5 to 97.5%
% VFB	73	63 to 80 %	20+608	0.9 rt.	92.6	92.5 to 97.5%
Fines to Binder	0.7	0.6 to 1.4				
Gmm	2.481	2.491 ± 0.030				
% Binder	5.1	5.2 ± 0.4%				

Experimental Section – PG 58-34

HMA Base – 19.0 mm (Initial Sample)			Bulk Specific Gravity			
Test Type	**Result**	**Tolerance**	**Station**	**Offset**	**Results**	**Tolerance**
% Air Voids	**2.1**	2.5 to 5.5	20+958	1.0 rt.	96.1	92.5 to 97.5%
% VMA	14.3	13.0 % min	20+993	3.1 lt.	96.3	92.5 to 97.5%
% VFB	**86**	63 to 80 %	20+911	1.7 rt.	97.2	92.5 to 97.5%
Fines to Binder	0.7	0.6 to 1.4	20+827	2.4 lt.	95.3	92.5 to 97.5%
Gmm	2.460	2.480 ± 0.030				
% Binder	5.4	5.1 ± 0.4%				
HMA Surface – 12.5 mm (Initial Sample)			**Bulk Specific Gravity**			
% Air Voids	4.4	2.5 to 5.5	20+839	0.9 lt.	94.4	92.5 to 97.5%
% VMA	15.0	14.0 % min	21+063	1.2 lt.	95.8	92.5 to 97.5%
% VFB	71	63 to 80 %				
Fines to Binder	0.8	0.6 to 1.4				
Gmm	2.482	2.491 ± 0.030				
% Binder	**4.7**	5.2 ± 0.4%				
HMA Surface – 12.5 mm (Initial Sample)			**Bulk Specific Gravity**			
% Air Voids	4.0	2.5 to 5.5	20+847	2.0 rt.	**92.2**	92.5 to 97.5%
% VMA	15.1	14.0 % min	21+003	2.7 rt.	93.4	92.5 to 97.5%
% VFB	73	63 to 80 %				
Fines to Binder	0.8	0.6 to 1.4				
Gmm	2.478	2.491 ± 0.030				
% Binder	5	5.2 ± 0.4%				

* Shaded Areas are Failing Results

Prepared by:

Stephen Colson
Senior Technician

Reviewed By:

Dale Peabody
Director, Transportation Research Division

Other Available Documents:

Construction Report, April 2001
Interim Report - First Year, June 2002
Interim Report - Second Year, July 2004
Interim Report - Third Year, December 2004

For more information contact:

Stephen Colson
Maine Department of Transportation
P.O. Box 1208
Bangor, Maine 04402 - 1208
207-941-4529
E-mail: stephen.colson@maine.gov