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Maine Department of Transportation

Transportation Research Division

Technical Report 99-11

Innovative Solutions to Buried Portland Cement Concrete Roadways

Interim Report - Third Year, May 2003

Transportation Research Division

Innovative Solutions to Buried Portland Cement Concrete Roadways

Introduction

Maine has hundreds of miles of highway that were constructed of Portland Cement Concrete (PCC) roughly 5.5 to 6.0 m (18 to 20 ft) wide forty or more years ago. Since that time these same highways have been paved and widened to 6.7 or 7.3 m (22 or 24 ft) with hot bituminous pavements to accommodate increased traffic volumes and enhance roadway safety. Bituminous materials were used in place of concrete due to the ease of placement and price of material.

PCC is a rigid pavement capable of supporting weight with little deflection. In contrast, hot bituminous pavement is flexible and will flex to distribute weight across the roadway. When the highway is expanded beyond the concrete slab, there is a sharp decrease of support for this bituminous pavement resulting in settlement over prolonged use. This settlement may also be compounded by poor drainage capabilities of the underlying soils causing the unsupported pavement to drop lower than the existing height of the concrete supported pavement. This creates a longitudinal crack aligning with the concrete slab edge about 0.3 to 1 m (1 to 3 ft) from the right edge of pavement. Pavement to the right of this crack deteriorates to the point where maintenance crews attempt to smooth it out with cold patch year after year. Paving over the entire roadway is an option but, due to reflective cracking, the edge of pavement begins to deteriorate within 2 or 3 years.

It is the intent of this experimental project to explore various shoulder treatments to increase support of the extended roadway and hopefully decrease or eliminate deterioration of the shoulder pavement.

Background

Project No. STP-8651(00)X on Route 100 between the towns of Benton and Pittsfield is 26.9 km (16.7 mi) long and scheduled for an overlay of maintenance mix. This is a 7.3 m (24 ft) bituminous roadway over 6.2 m (20 ft) of PCC. The 0.6 m (2 ft) edge of pavement on both sides has deteriorated, creating a traffic hazard and maintenance problem for years. Condition of the drainage ditch is poor along the entire project and there is very little underdrain. A section of this project beginning 4.5 km (2.8 mi) north of the junction of Route 100A in Benton and extending north 2.5 km (1.6 mi) to the town of Clinton was selected to construct four experimental shoulder rehabilitation sections. This project was activated

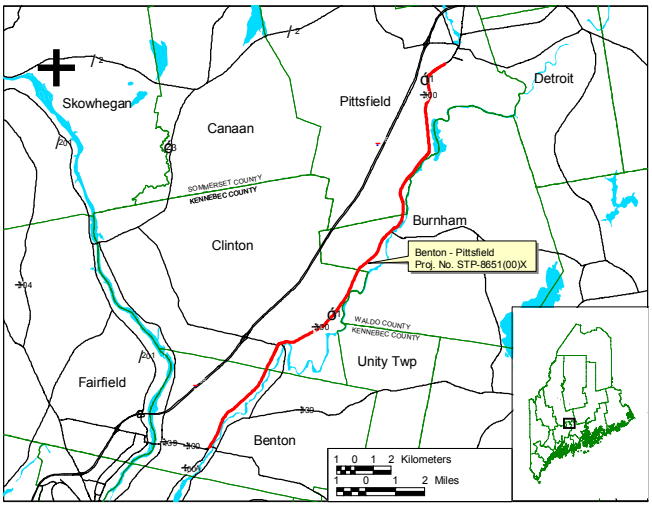

Fig. 1 Location map

in August with a deadline of October 30, 1998, so time and available money to develop experimental sections was limited. An E-mail request, phone interviews, and literature search of AASHTO members were conducted to gather information on techniques used to correct composite roadway shoulder problems. A panel, with personal from Highway Design, Construction, and Geotechnical Divisions plus the Bureau of Maintenance and Operations, used this information as well as ideas of their own to design four experimental sections, each 500 m (1640 ft) in length plus a control section 500 m (1640 ft) in length.

Another shoulder rehabilitation experiment that is not part of the Benton - Clinton project but will be included in this report was constructed in 1997-98 on Route 2 in Veazie. This is a 6.6 m (22 ft) bituminous highway over 5.2 m (18 ft) of PCC. This project also had poor drainage and a deteriorated pavement edge causing traffic hazards and maintenance headaches. The experimental section begins 100 m (328 ft) north of Chase Road in Veazie and extends north 190 m (623 ft).

Construction

Benton - Clinton Project No. STP-8651(00)X

Construction of each shoulder treatment went smoothly. Most of the material excavated from the shoulders consisted of granular soil not clay as expected and the depth of each trench did not penetrate the clay subgrade.

Figures 1 - 4 contain cross sections for each experimental treatment. Limits and a brief description for each section is as follows:

Control Section, Maintenance Mix

This section is located between station 0+500 and 1+000. There is no shoulder rehabilitation and the roadway is treated with an estimated average thickness of 20 mm (0.75 in) of 9.5 mm (0.374 in) maintenance mix.

Section 1, Cold Recycled Pavement

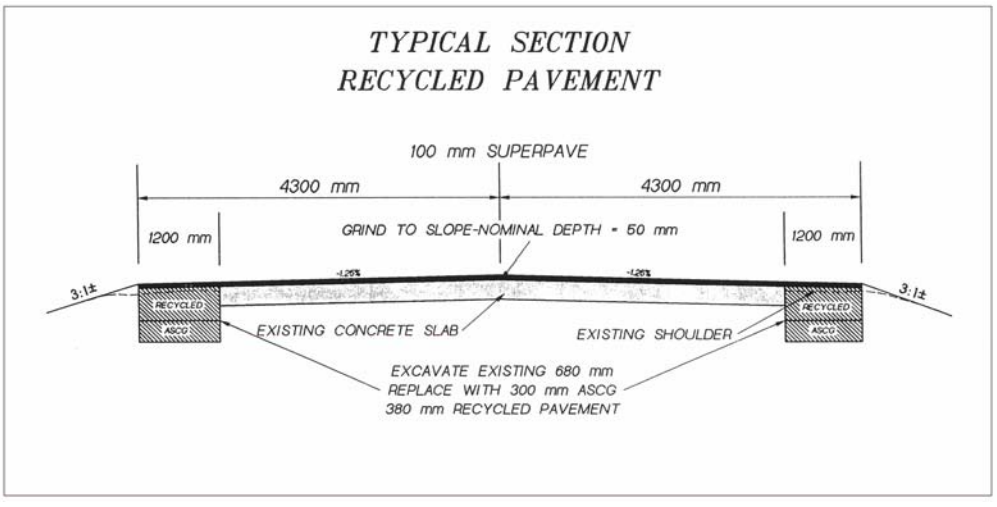

Fig. 2 Section 1

This section is located between station 1+000 and 1+500. Figure 2 contains a typical cross section of the section. The existing pavement was ground to slope to a nominal depth of 50 mm (2 in). The shoulders were excavated adjacent to the existing PCC slab edge to a depth of 680 mm (27 in) and width of 1200 mm (47 in). This boxed shoulder was then filled with 300 mm (12 in) of

Type D Aggregate Subbase Coarse Gravel (ASCG) MDOT Standard Specifications Item Number 703.06 and 380 mm (15 in) of Cold Recycled Pavement.

The roadway and shoulders were then paved with a 60 mm (2.4 in) layer of 19 mm (0.75 in) Superpave Binder and topped with a 40 mm (1.6 in) layer of 12.5 mm (0.5 in) Superpave wearing coarse.

Section 2, Flowable Fill

Flowable Concrete Fill is a concrete mixture that includes 245-105 kg cement/M³ with a water-cement ratio low enough to prevent segregation of the mix and a target Air Content of 5-15 percent. A modified slump test spread of 225 - 350 mm (8.9 - 13.8 in) is considered flowable. The slump spread is obtained by setting a 75 mm x 150 mm (3 in x 6 in) cylinder mold, open on both ends, on a flat surface, then filling the cylinder and striking off the top. During a count of three seconds, lift the cylinder straight up allowing the sample to spread on the flat surface. The spread diameter is measured to the nearest 15 mm (0.6 in).

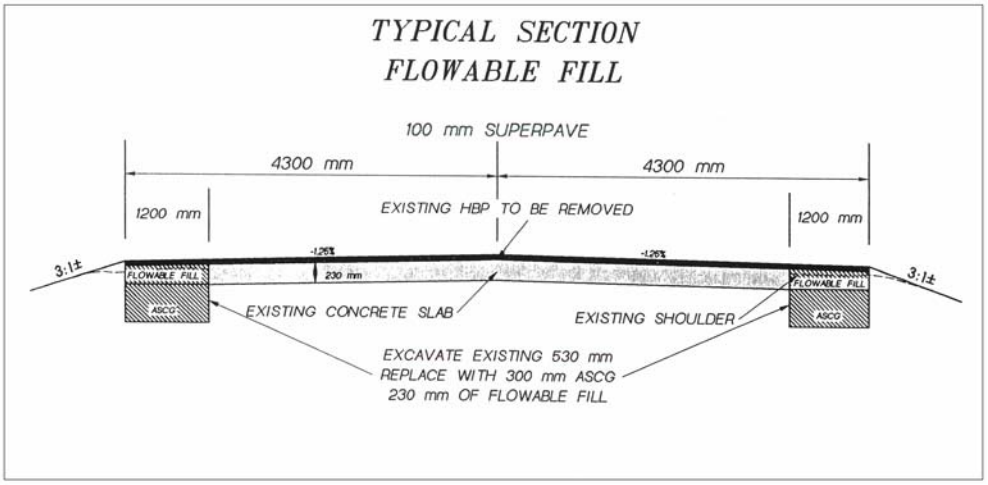

Fig. 3 Section 2A

All existing pavement was removed to the PCC surface and the shoulders were excavated adjacent to the PCC slab to a depth of 530 mm (21 in) and width of 1200 mm (47 in). The exposed PCC slab could not hold up to traffic and had to be shimmed with 9.5 mm (0.374 in) bituminous mix.

There are two separate shoulder treatments within this section. Section 2A located between station 1+500 to 1+970 right and 1+500 to 2+000 left. This section has 300 mm (12 in) of ASCG and 230 mm (9 in) of Flowable Fill. Figure 3 contains a cross section of Section 2B.

Section 2B is located between station 1+970 and 2+000 right. This section has no ASCG and 530 mm (21 in) of Flowable Fill.

Surface treatment for Section 2 consists of 60 mm (2.4 in) of 19 mm (0.75 in) Superpave Binder and 40 mm (1.6 in) of 12.5 mm (0.5 in) Superpave wearing coarse.

Section 3, Superpave

This section is located between station 2+000 and 2+500. The existing pavement was removed and shoulders were excavated beside the PCC slab to a depth of 530 mm (21 in) and width of 1200 mm (47 in). As with Section 2, the exposed PCC slab could not hold up to traffic and had to be shimmed with 9.5 mm (0.374 in) bituminous mix. A typical cross section of Section 3 is displayed in figure 4.

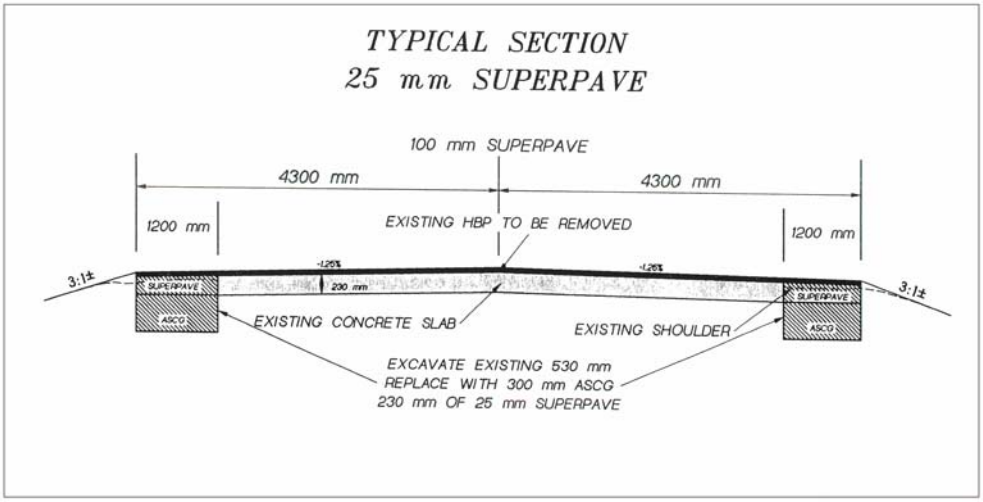

Fig. 4 Section 3

MDOT specifies that traveled way surface mix can be placed between the dates of April 15th and the Saturday following October 15th. The surface deadline was nearing before Section 3 shoulder construction was completed. To avoid the deadline, the roadway was paved with 60 mm (2.4 in) of 19 mm (0.75 in) Superpave Binder and 40 mm (1.6 in) of 12.5 mm (0.5 in) Superpave wearing coarse to an offset of 3 m (10 ft) left and right of centerline. Reconstruction of the shoulder continued after the roadway was paved. The shoulder treatment consists of 300 mm (12 in) of ASCG and 230 mm (9 in) of 25 mm (1 in) Superpave Binder. Binder and surface mix was placed on the shoulders after shoulder reconstruction was complete. This left a longitudinal joint 3 m (10 ft) left and right of centerline.

Section 4, Heavy Overlay

Section 4 is located between station 2+500 and 3+000. The existing shoulders were graded and compacted. All unsuitable material was removed and areas that were below grade were filled with ASCG and compacted to required grade. The roadway was then shimmed with a minimum of 13 mm (0.5 in) of 9.5 mm (0.374 in) bituminous mix. Then the roadway and shoulders were paved with 40 mm (1.6 in) of 12.5 mm (0.5 in) Superpave wearing coarse. A typical cross section of this treatment is displayed in figure 5.

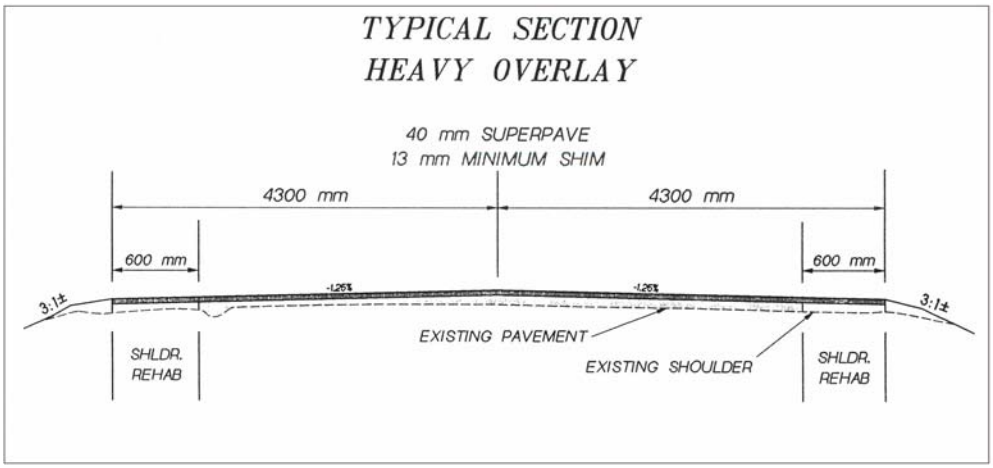

Fig. 5 Section 4

Veazie - Orono Project No. STP-6683(00)X

Construction of this shoulder treatment and application of the self-adhesive mesh went smoothly with no setbacks.

A description and location for each section is as follows:

Self-Adhesive Mesh Section

Figure 6 contains a cross section of the Self-Adhesive mesh section. This experimental area begins at station 2+140 and ends at 2+330. The project entails grinding 75 mm (3.0 in) of existing pavement then shimming with 5 mm (0.2 in) of 4.75 mm (0.187 in) bituminous mix.

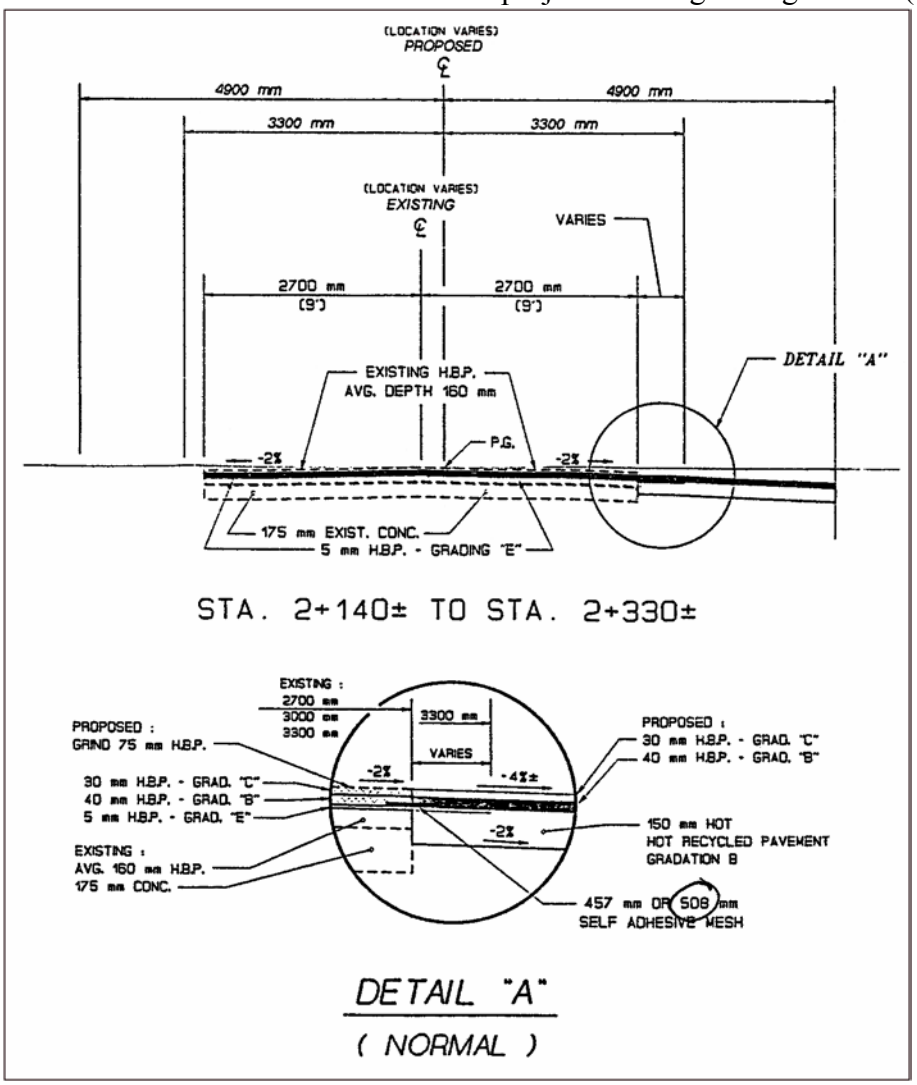

Fig. 6 Self-adhesive mesh

The shoulders were trenched to a depth of 150 mm (6 in) below height of the milled and shimmed pavement and to a variable width of 0.6 to 2.5 m (2 to 8 ft). This trench is then filled with 150 mm (6 in) of Hot Recycled Pavement made up of a blend of 60 percent virgin aggregate and 40 percent recycled pavement with an asphalt content of 2.5 to 4.5 percent using AC-20 grade asphalt cement. A layer of PavePrep SA7 self-adhesive mesh, manufactured by Contech Construction Products Incorporated, 508 millimeters (20 inches) wide was placed to bridge the transition between concrete supported pavement and Hot Recycled shoulder.

The roadway and shoulders were then paved with 40 mm (1.5 in) of 19 mm (0.75 in) binder and 30 mm (1.2 in) of 12.5 mm (0.5 in) wearing coarse.

Control Section

This section is located between station 3+230 and 3+420. The existing pavement was milled to a depth of 75 mm (3.0 in) then shimmed with 5 mm (0.2 in) of 4.75 mm (0.187 in) bituminous mix.

Shoulders were excavated to a width of 600 mm (22 in) beyond the PCC edge and depth of 150 mm (6 in) below the milled pavement surface. This boxed shoulder area was filled with 150 mm (6 in) of Hot Recycled Pavement.

The highway and shoulders were then surfaced with 40 mm (1.5 in) of 19 mm (0.75 in) binder and 30 mm (1.2 in) of 12.5 mm (0.5 in) wearing coarse.

Cost Analysis

A cost summary of each shoulder treatment for the Benton - Pittsfield project is listed in Table 1. The Cost column represents the cost per centerline meter from shoulder to shoulder. Please note that the Control Section and Section 4 shoulder treatment costs represent a 0.6 m (2 ft) wide shoulder whereas Section 1, 2A, 2B, and 3 costs are for a 1.2 m (4 ft) shoulder.

TABLE 1. ROUTE 100, BENTON - PLYMOUTH COST SUMMARY

Section	Treatment	Station	Cost
Control	Maintenance Mix Overlay	0+500 - 1+000	$12.59
1	Cold Recycled Pavement	1+000 - 1+500	$156.60
2A	230 mm Flowable Fill	1+500 - 2+000 Left 1+500 - 1+970 Right	$174.44
2B	530 mm Flowable Fill	1+970 - 2+000 Right	$199.98
3	230 mm 25 mm Superpave	2+000 - 2+500	$223.70
4	Heavy Overlay	2+500 - 3+000	$58.87

A review of the data reveals that Section 3 with Superpave had the highest cost followed by Section 2B with Full Depth Flowable Fill, Section 2A with 230 mm (9 in) Flowable Fill, Section 1 with Cold Recycled Pavement, Section 4 with Heavy Overlay and finally Control Section Maintenance Mix.

Table 2 contains a summary of costs per meter for the Veazie - Orono project. The cost column represents the cost per centerline meter from shoulder to shoulder. Since the Experimental Section has a wider shoulder treatment than the Control Section, the cost analysis for this section is based on a 0.6 m (2 ft) shoulder.

TABLE 2. ROUTE 2, VEAZIE - ORONO COST SUMMARY

Section	Treatment	Station	Cost
SAM	Self Adhesive Mesh	2+140 - 2+330	$78.85
Control	150 mm Hot Recycled Pavement	3+230 - 3+540	$60.85

Falling Weight Deflectometer Test Results

Falling Weight Deflectometer (FWD) readings were collected for the Benton - Clinton project on August 15, 2001. Deflections were recorded on the experimental shoulders and on the PCC supported roadway adjacent to each shoulder test. Table 3 illustrates average FWD deflections recorded from sensor # 1 as well as the difference between roadway and shoulder deflections and the average four-year variance. Raw deflections were used due to software limitations when processing data collected on composite roads containing PCC. FWD data was not collected on the Veazie - Orono project.

Average roadway deflections per Section are very consistent throughout the four-year test period.

Shoulder deflections on the other hand are consistent for 1998, 2000 and 2001 but low for all Sections in 1999 with the exception of Section 3. FWD tests in 1999 may have been collected on or very close to the PCC edge resulting in low deflection readings. For this reason we will be evaluating 1998, 2000 and 2001 data only. Section 3 shoulder tests for all three years are typical readings possibly due to the defined

longitudinal pavement joint (see Photo 1) paralleling the PCC edge directing the FWD operator more toward the shoulder. In the future, FWD tests will be monitored to assure accurate data collection.

Section 4, heavy overlay, and the Control Section with maintenance mix, have the highest shoulder deflections at 26.23 and 25.93 mils respectively. Section 4 also has the greater amount of PCC related longitudinal cracking (summarized later).

All sections that have shoulder treatments are outperforming the Control Section and Section 4.

Section 2B with 530 mm of Flowable Fill has the lowest average deflection at 6.73 mils and the least amount of PCC related edge cracking.

Section 3 with Superpave is also very stable and has an average shoulder deflection of 10.58 mils. This section also has a low amount of PCC related edge cracking.

Photo 1. Section 3

Section 1, Recycled Pavement, and Section 2A, 230 mm Flowable fill, have the highest shoulder deflections of the four treated shoulders with an average of 15.82 and 16.57 mils respectively. These sections also have the greatest amount of PCC related edge cracking.

TABLE 3. FALLING WEIGHT DEFLECTOMETER SUMMARY

Benton - Clinton Project No. STP-8651(00)X

Section	Treatment Type	Average Shoulder Deflection (mils)				Average Roadway Deflection (mils)				Shoulder vs Roadway Comparison Variance (mils)				Average Variance
		1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001	
Control	Maintenance Mix	30.26	20.37	34.73	25.93	10.85	11.44	11.88	9.79	19.41	8.93	22.85	16.14	16.83
1	Recycled Pavement	15.46	13.46	14.73	15.82	9.44	8.96	9.76	8.12	6.02	4.5	4.97	7.70	5.80
2A	230 mm Flowable Fill	17.87	13.60	17.30	16.57	9.29	8.07	10.31	8.78	8.58	5.53	6.99	7.79	7.22
2B	530 mm Flowable Fill	N/A	4.73	9.44	6.73	N/A	6.12	8.24	5.82	N/A	-1.39	1.2	0.91	0.24
3	Superpave	8.44	9.32	9.05	10.58	7.49	6.63	7.45	6.36	0.95	2.69	1.6	4.22	2.36
4	Heavy Overlay	29.66	24.11	30.65	26.23	7.39	7.14	8.35	7.13	22.27	16.97	22.3	19.10	20.16

Lower deflection (mils) denotes stronger highways

Visual Evaluation

A visual evaluation was conducted on August 15, 2001. Table 4 contains a pavement condition summary for the Benton - Clinton and Veazie - Orono projects.

Table 4. Pavement Condition Summary

Benton - Clinton Project No. STP-8651(00)X

	Rutting (%)									Centerline joint condition						Number of transverse cracks									PCC related longitudinal cracking (%)			Shoulder elevation change (mm)		
	< 6 mm			6 - 13 mm			> 13 mm			Ravel (%)			Separation (%)			Full width (across two lanes)			Half width (across one lane)			Between Wheelpath								
Section	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"
Control	65	32	25	0.8	64	65	4	4	10	0	0	2.4	0	6.1	51.4	25	47	47	12	20	36	102	321	348	49.5	85.7	92.7	0	0	4
1	100	100	100	0	0	0	0	0	0	90	90	3	0	0	95.1	0	0	1	1	2	10	0	2	40	0.6	7.7	28.5	0	0	0
2A	100	96.7	83.4	0	3.3	10.8	0	0	5.8	83	83	0	0	0.2	98.5	1	3	12	0	5	10	0	4	10	0	25.3	49.2	0	0	0
2B	100	100	100	0	0	0	0	0	0	0	0	0	0	3	73	0	1	1	0	0	0	0	0	0	0	3.3	8.3	0	0	0
3	100	91.7	77	0	6.4	18	0	1.9	5	30	30	24	0	0	8.1	0	0	1	0	0	4	0	0	5	10.7	14.5	22.7	6	13	25
4	100	100	88.9	0	0	11.1	0	0	0	85	85	7.2	0	0.3	85.1	8	9	21	11	12	12	13	16	20	0.4	14.6	40.3	0	0	0

Veazie - Orono Project No. STP-6683(00)X

	Rutting (%)									Centerline joint condition						Number of transverse cracks									PCC related longitudinal cracking (%)			Shoulder elevation change (mm)		
	< 6 mm			6 - 13 mm			> 13 mm			Ravel (%)			Separation (%)			Full width (across two lanes)			Half width (across one lane)			Between Wheelpaths								
Section	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"	"99"	"00"	"01"
SAM	100	100	0	0	0	100	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	5.9	0	0	0
Control	100	100	0	0	0	68.4	0	0	31.6	0	0	0	0	0	0	2	2	2	0	0	1	1	1	3	28	30.6	33.3	0	10	6

Benton - Clinton Project No. STP-8651(00)X

Control Section, Maintenance Mix

Rut depths have increased throughout this section. Twenty-five percent had rut depths less than 6 mm (0.25 in), 65% were in the range of 6 to 13 mm (0.25 to 0.5 in), and rut depths greater than 13 mm in depth have increased from 4% in 2000 to 10% in 2001.

Centerline joint separation has increased from 6.1% to 51.4%.

Transverse cracking has increased slightly since last year's evaluation. PCC edge related cracking has increased 7% to 92.7%. This section is experiencing a 4 mm change in shoulder elevation.

Section 1, Cold Recycled Pavement

Slight rutting, less than 6mm (0.24 in) in depth, was observed throughout the entire section.

Centerline joint condition has deteriorated from 90% ravel to 95.1% cracked in the past year.

Transverse cracks across one lane and between wheel paths have increased significantly.

PCC related longitudinal cracking increased from 7.7% to 28.5%. This is the third lowest increase of PCC edge cracking within the experimental sections.

Section 2A, 230 mm Flowable Fill

Rut depths in the range of 6 - 13 mm have increased 7.5% to 10.8% and 5.8% of the section has rut depths greater than 13 mm in depth.

More than ninety eight percent of the centerline has cracked. Transverse cracking has also increased in this section.

PCC related edge cracking has almost doubled to 49.2% with no elevation change. This is still the highest amount of PCC related edge cracking within the experimental sections.

Section 2B, 530 mm Flowable Fill

Although this section is small, it is outperforming all other experimental sections.

Centerline cracking has increased from 3 to 73% and PCC related edge cracking has increased from 3.3 to 8.3%. The remainder of the section appears very stable

Section 3, 230 mm of 25 mm Superpave

The longitudinal shoulder construction joint, 3 m (10 ft) left and right of centerline, has separated from the roadway throughout 96.5% of this section (see Photo 1).

Rut depths have increased since the last evaluation with 77% at less than 6 mm (0.25 in), 18% at 6 - 13 mm (0.25 - 0.5 in) an increase of 11.6%, and 5% at greater than 13 mm (0.5 in) an increase of 3.1%.

Centerline joint ravel has decreased from 30 to 24%, but cracking was observed on 8.1% of the section.

Transverse cracks have started to appear with one full width, four half width and five between wheel path cracks.

PCC related edge cracking has increased from 14.5 to 22.7% and shoulder elevation has increased from 13 mm (0.5 in) to 25 mm (1.0 in).

Section 4 Heavy Overlay

Rut depths have increased slightly this year with 11.1% in the 6 -13 mm range.

Centerline joint cracking has increased from 0.3% to 85.1%.

Transverse cracking has also increased.

PCC related edge cracking has increased from 14.6 to 40.3% with no elevation change.

Veazie - Orono Project No. STP-6683(00)X

A natural gas pipeline was installed at an offset of between 4 and 5 m (13 and 16 ft) right of centerline on the entire project.

Self Adhesive Mesh Section

This section is still performing very well. Rutting has increased in depth to 6 - 13 mm. Joint condition and transverse cracking has remained the same. PCC edge cracking has increased from 2 to 5.9%.

Control Section

Rut depths have increased, 68.4% is in the 6 - 13 mm range and 31.6% is greater than 13 mm in depth.

Centerline joint condition has remained the same. Transverse cracking has increased. There is an additional half width crack and two additional between wheel path cracks.

PCC related cracking has increased from 30.6 to 33.3% and shoulder elevation has improved from 10mm (0.4 in) to 6 mm (0.2 in).

Summary

Benton - Clinton Project No. STP-8651(00)X

Section 2B - 530 mm of Flowable Fill - continues to outperform all other sections. Although this section is short (30 m (100 ft) in length) and has the second highest cost per meter, it has the lowest amount of PCC related edge cracking, lowest average shoulder deflection, and very little pavement cracking and rutting. Shoulder deflections are only 15% higher than the adjacent roadway confirming that this application can be used to widen composite roadways.

Section 3 – Superpave - is also proving to be a stable shoulder treatment. Shoulder deflections continue to be low with a small increase in PCC related cracking. Costs associated with this treatment are greater than the other sections.

Section 1 - Cold Recycled Pavement - is ranked third in performance. This section has 28.5% of the PCC edge cracking through and has stable FWD deflections. This application has the lowest cost of the experimental treatments and could be considered as a cost effective construction treatment for composite roadways.

Nearly fifty percent of PCC related edge cracks have reflected through Section 2A - 230 mm of Flowable fill. This section also has the highest deflections of the experimental shoulder treatments and should not be used to rehabilitate shoulders on composite roadways.

Section 4 – Heavy Overlay – is outperforming Section 2A and the Control Section. Shoulder deflections are the highest of all sections which is an indicator of shoulder deterioration in the future. This type of shoulder treatment should not be considered.

The Control Section has failed in all categories and should not be used to support shoulder extensions on composite roadways.

Veazie - Orono Project No. STP-6683(00)X

The Self Adhesive Mesh combined with recycled pavement continues to reduce the amount of PCC related edge cracking. Only 5.9% of the PCC edge has cracked through making Self Adhesive Mesh combined with recycled pavement a reliable treatment to bridge the transition between PCC and shoulder.

The Control Section experienced a 2.7% increase in PCC related edge cracking from last year and the shoulder elevation change has settled from 10 to 6 mm. Most of the PCC related cracking is adjacent to the gas pipeline construction. It's possible that construction of the pipeline could have caused the shoulder to shear aiding in the development of PCC edge cracking. The opposite lane has very little PCC edge cracking. Although there is a slight increase in edge cracking and rutting, the section appears to be performing well.

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