PB98-115850

ULTRA-THIN PORTLAND CEMENT CONCRETE OVERLAY

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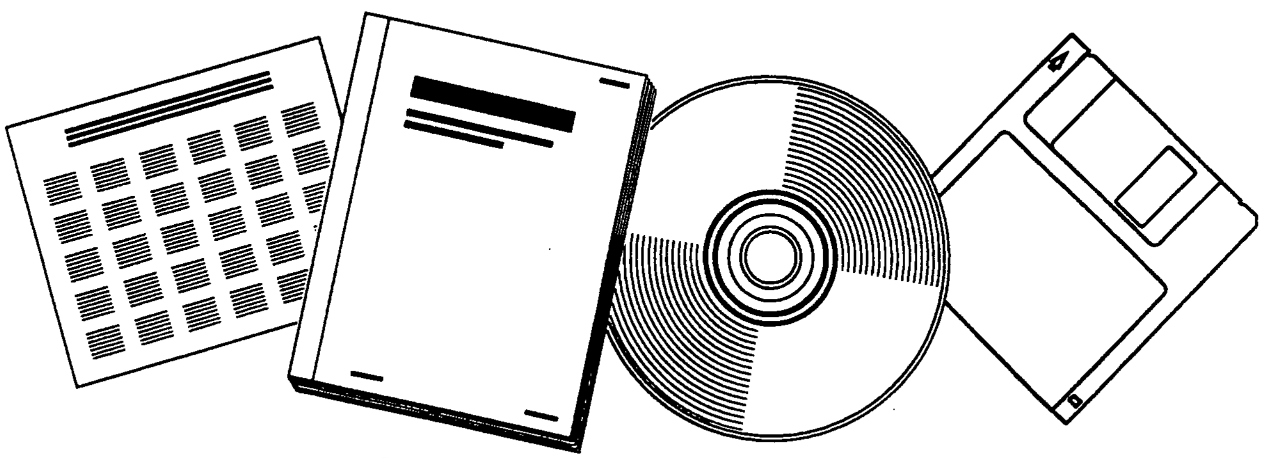

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ULTRA-THIN PORTLAND CEMENT CONCRETE OVERLAY

PB98-115850

RESEARCH PROJECT
FINAL REPORT

Commonwealth of Pennsylvania
Department of Transportation
Prepared by: Bureau of Maintenance and Operation

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13. ABSTRACT *(Maximum 200 words)*

Ultra-thin Portland Cement Concrete Overlays have been used in other states on full depth bituminous pavements. Areas of particular interest in using this technology are those subject to rutting and shoving, such as ramps and intersections. In October of 1995, this technology was implemented on a reinforced concrete ramp that was overlaid with bituminous concrete. This report evaluates the performance of the ultra-thin portland cement concrete overlay (Whitetopping) thus far. Also, an attempt is made to evaluate the cost effectiveness of this practice as an alternative for the maintenance of high volume traffic areas which are subject to excessive rutting and shoving.

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Research Project

Ultra-Thin Portland Cement Concrete Overlay

Final Report

by

Paul E. King, P.E.

May 1997

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Introduction

During October 1995, PennDOT, with the cooperation of the Federal Highway Administration began construction of an ultra-thin portland cement concrete overlay (whitetopping or UTW) for the maintenance of a curbed reinforced cement concrete ramp that had been overlaid with asphalt concrete. This project differed from previous applications of this technology in that prior projects were thin whitetopping overlays on full depth bituminous pavements. This project placed the thin whitetopping overlay onto a bituminous overlay of a concrete pavement.

This report evaluates the performance of the whitetopping overlay thus far. An attempt is made to evaluate the cost effectiveness of this practice as an alternative for the maintenance of high volume traffic areas which are subject to excessive rutting and shoving. The cost evaluation included uses a predicted life expectancy of the whitetopping and makes a comparison to that of the maintenance history of the bituminous overlays done on the ramp.

Project Location

The project is located on ramp D at the interchange of U.S. Route 22 and Interstate 83 in Dauphin County, Engineering District 8-0. The project starts on SR 8031 Segment 0510 Offset 0000 and ends at SR 8031 Segment 0510 Offset 0737. The actual planned construction stations were from station 0+00 to station 9+40.87. Figure 1 and Figure 2 give a location map and plan view of the project.

The original pavement at this site was constructed in 1960 with 6" of special subbase and 10" of Reinforced Cement Concrete Pavement. According to the pavement history records in PennDOT's Roadway Management System (RMS) Pavement History, a 1.5" ID-2 bituminous overlay was placed in 1992. In May 1993, the overlay was mechanically patched. The preliminary analysis of the site included eight core samples taken in the spring of the year and indicated that the bituminous layer had an average depth of 3.25". This depth should have been sufficient to allow milling and still leave adequate depth of bituminous material for the whitetopping overlay. However, at the time of construction, the overlay showed increasing signs of severe distress that created problems after milling.

FIGURE 1 – LOCATION

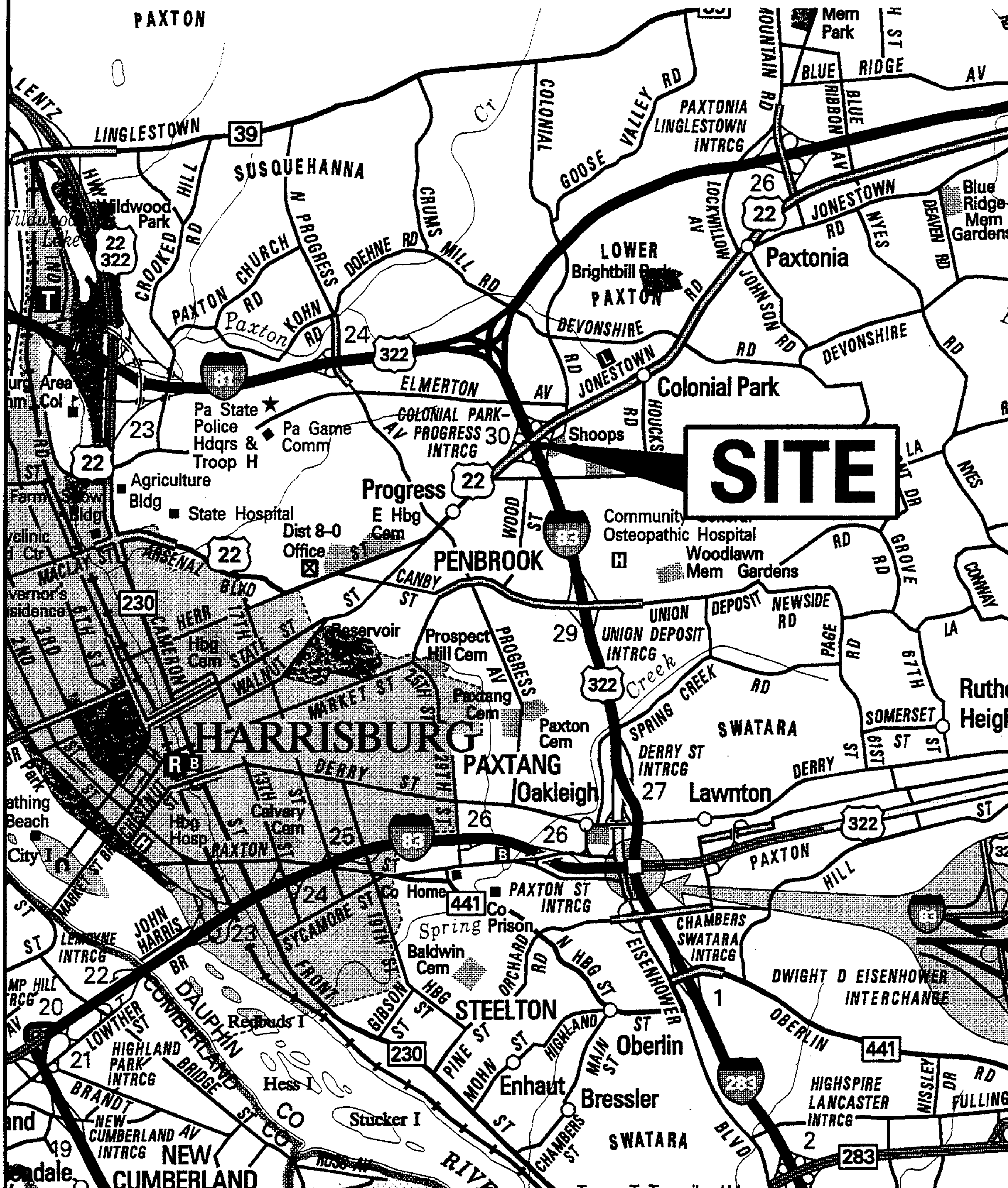

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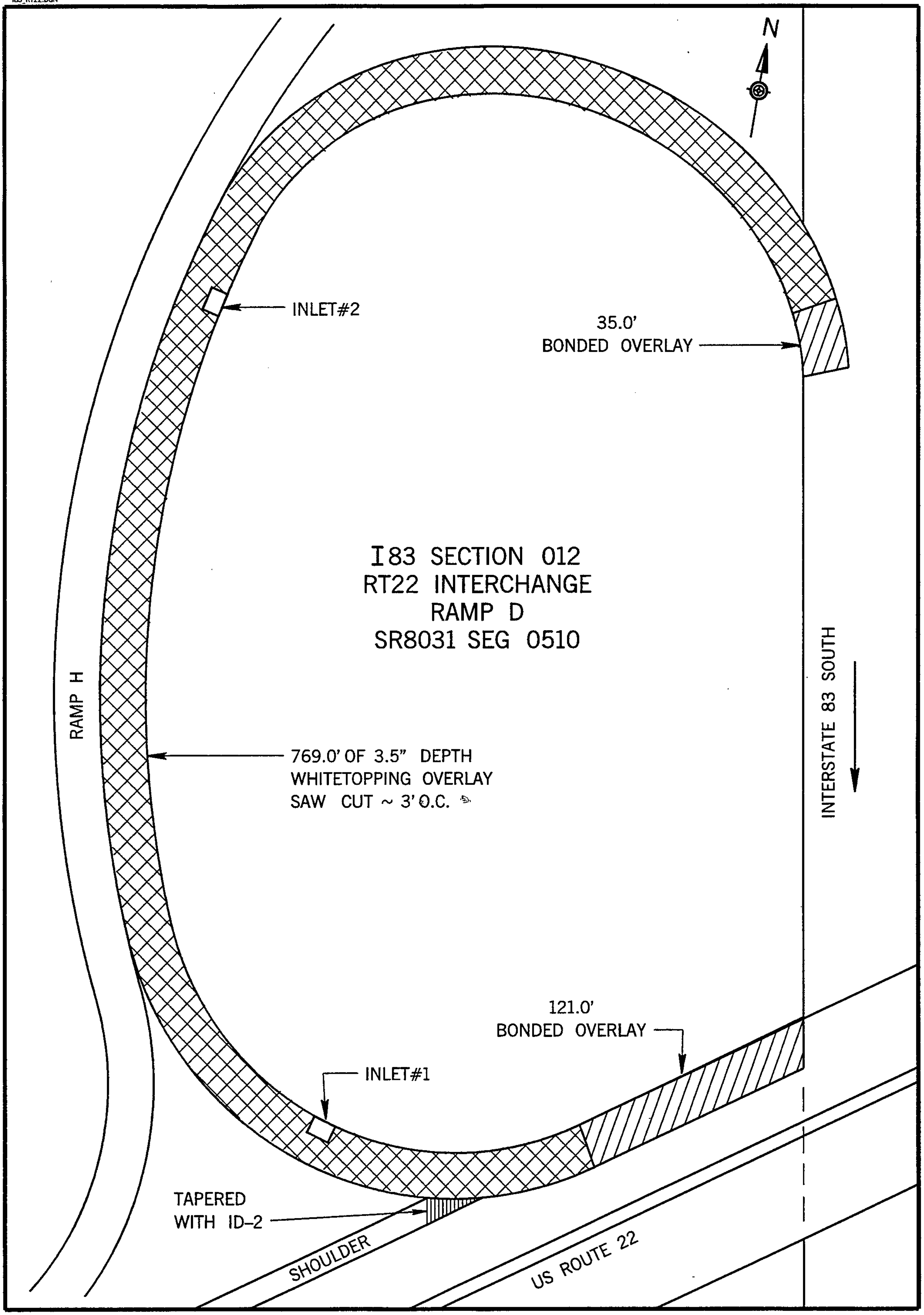
FIGURE 2 – PLAN VIEW SKETCH



Background

This report provides only a brief discussion of the highlights and problems encountered during construction of the whitetopping overlay. A more thorough description of the construction details can be found in the construction report for this project, FHWA-PA-96-002C.

The total duration of construction for this project was originally scheduled for one week. The original plan included the use of an accelerated concrete mix design with fibers. However, due to the additional work, replacement of barriers and shoulders, the duration of construction was extended to three weeks. As a result, the concrete mix design was changed from the accelerated mix to a Class AA with lower cement content. The mix included flyash which is used to reduce alkaline-silica reactivity (ASR) with the aggregate. It also became necessary to construct a temporary ramp and install a traffic signal.

Work began on October 3, 1995. The existing bituminous pavement was shoved to the extent that milled areas of the RCC pavement were exposed after removing less than 1". The bituminous material that remained had lost its bond to the RCC pavement and could easily be scraped loose by hand. A decision was made to remove all of the old bituminous material and replace it with a 2" bituminous concrete base course (BCBC). Though the American Concrete Pavement Association (ACPA) and the National Ready Mixed Concrete Association recommend a 3" minimum flexible layer under the whitetopping, it was agreed prior to construction to try the overlay with only 2" of bituminous material at this site due to constraints on the final grade.

The condition of the existing bituminous overlay led to some skepticism as to the legitimacy of the research. Though the material was deteriorated beyond a point where it could be practical to use for this project, the site should still provide a good test of the performance of whitetopping. The scenario that is being tested is a whitetopping overlay of a bituminous overlay on a RCC ramp.

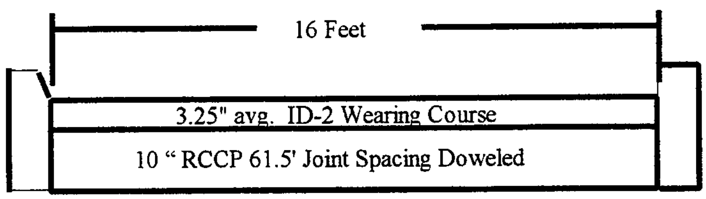
The UTW was placed in two pours on separate days. To finish the concrete, it was simply floated and textured with a Burlap drag. Joints were sawed as recommended with a spacing of one foot per inch depth of overlay. On the first pour, some of the joints were damaged as a result of sawing too early. The joints have the appearance of raveling or spalling where aggregate was pulled out. However no random cracking occurred.

Due to cooler temperatures on the day of the second pour (40° - 45° F) and experience from the first pour, a decision was made to wait until early the next morning to saw the joints so that the concrete had enough time to set. However, one transverse crack formed at inlet #2 and two days later another crack had formed adjacent to a sawed transverse joint.

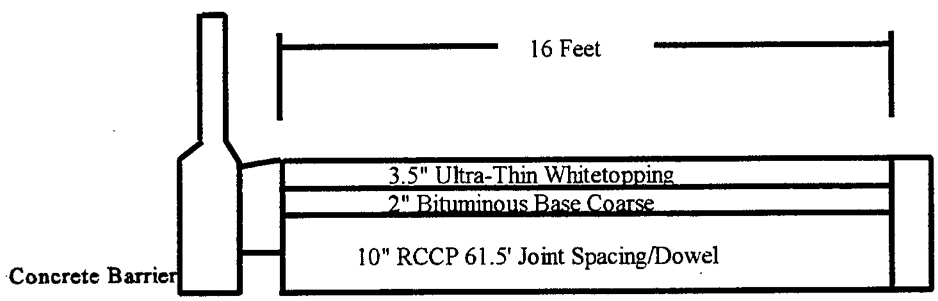
Difficulties were encountered with the concrete during the construction of the whitetopping overlay. The change in the mix design from an accelerated mix to one including the use of flyash may have contributed to a slow set time. Although the conditions were ideal for placing the concrete, sunny with temperatures in the upper 50's, the concrete did not set enough on the first pour to allow completion of sawing in one day. This also contributed to the decision made to wait until the following day to saw joints on the second pour, which resulted in transverse cracking.

As mentioned, on the initial pour date some joints were sawed while the concrete was too green. These damaged joints showed progressive deterioration by spalling within one month of placement. However, there appears to be no further deterioration to this point in time.

Figure 3 provides a typical cross-sectional view of the ramp before and after the whitetopping overlay.



Cross Section Prior to Whitetopping



Cross Section After Whitetopping

FIGURE 3 - CROSS SECTION SKETCHES

Performance

As of April 1996, the overlay had experienced one winter season. That particular season included record breaking snowfalls with thawing and rains in January that produced flooding followed by more freezing and snowfall. Though the ramp was not directly affected by flooding, it did experience the extreme temperature ranges which produced freeze-thaw cycles. As a result of the unusual winter, the ramp was exposed to more snow plows, antiskid, and deicing materials than the average winter. There were no new distresses observed over that winter. Also, the progression of the spalling of the joints damaged by the premature sawing appears to have slowed.

Cores were taken in the spring of 1996 at different locations along the ramp. For two of the cores, any bond that may have existed between the whitetopping and the bituminous layer was broken during drilling. The other sample was tested in shear. The asphalt yielded at 55.84 psi, but the bond was not broken. The two broken cores may indicate poor bond at some locations along the ramp. If this is the case, based on findings in other studies, the areas of questionable bond should deteriorate faster. However, there is no evidence of deterioration of the pavement in the vicinity of the borings at this time.

The whitetopping overlay has now experienced two winters. As described in the construction report, there were transverse cracks that appeared prior to opening to traffic. The crack that formed at inlet #2 is showing some signs of minor spalling. However, the remainder of the whitetopping overlay is performing quite well. The construction report also described the transition that was made from a bonded concrete overlay into the whitetopping of the bituminous material. At the beginning of the transition area there is one square that has cracked, however, at this point all of the pieces are remaining intact. All visual observation and comments from others are very favorable. It does appear at this point that the whitetopping, based on performance thus far, will be a viable alternative to milling and overlaying with Hot Mix Asphalt (HMA).

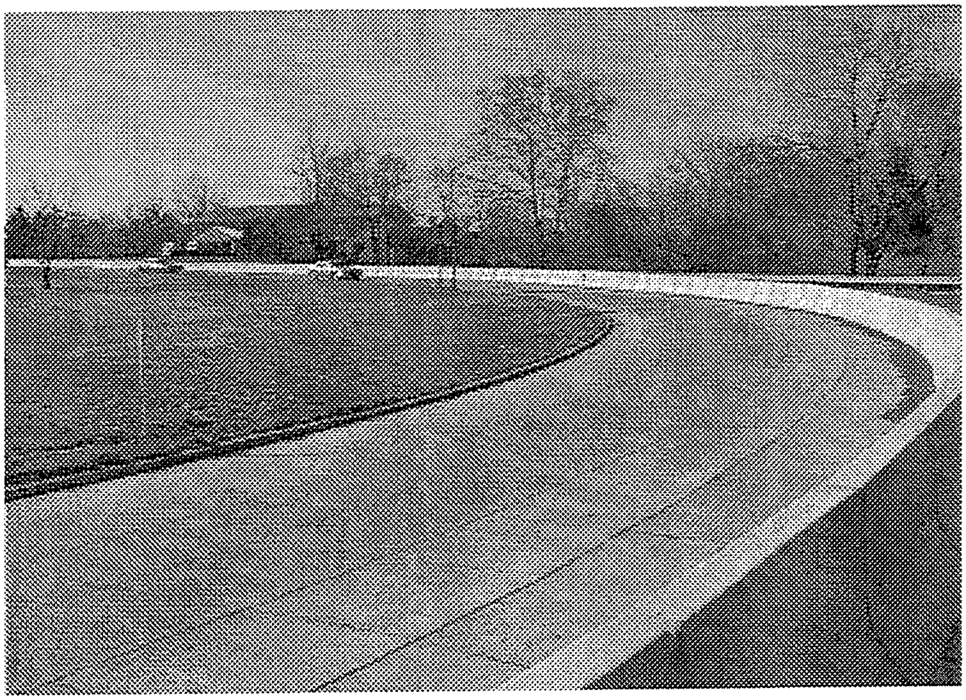


Figure 4. View of ramp after experiencing two winters.

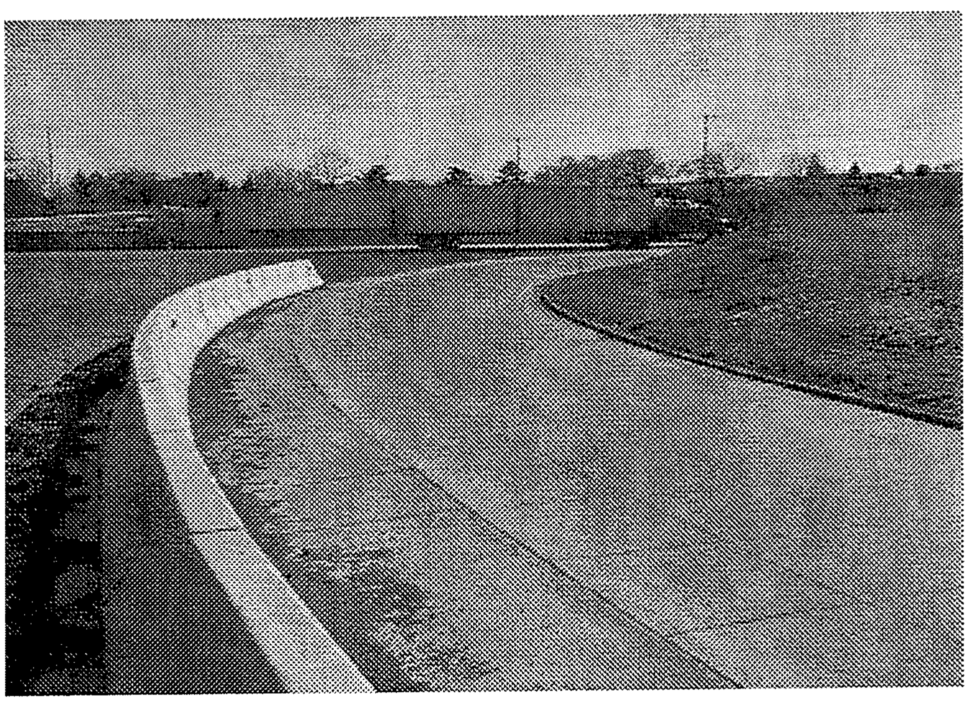


Figure 5. View looking at end of ramp toward I-83.

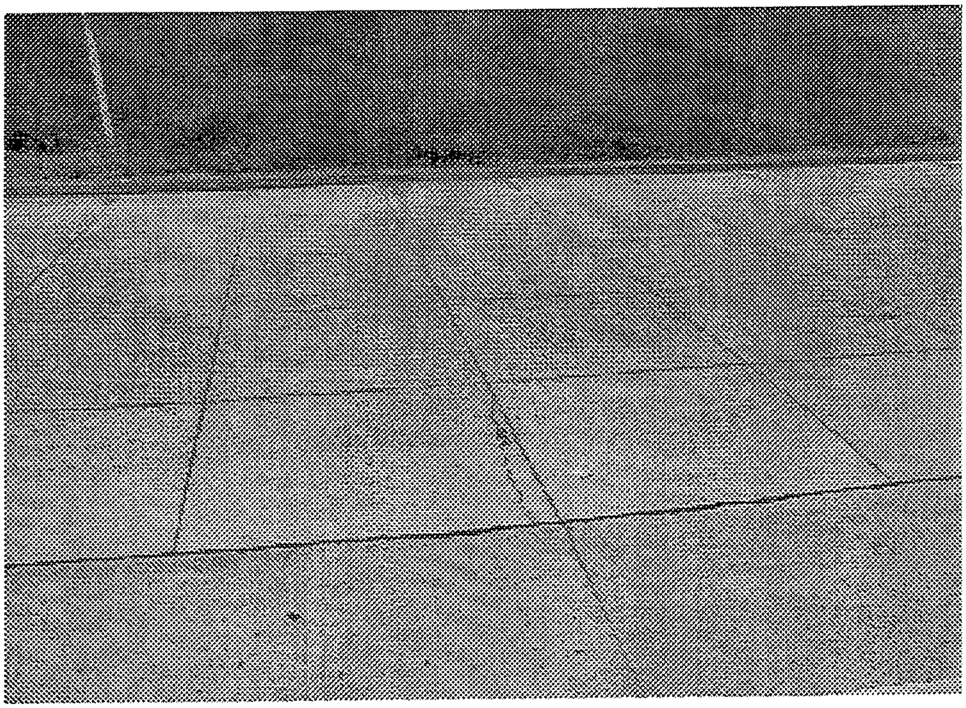


Figure 6. Crack that occurred before opening to traffic as it appears at this time.

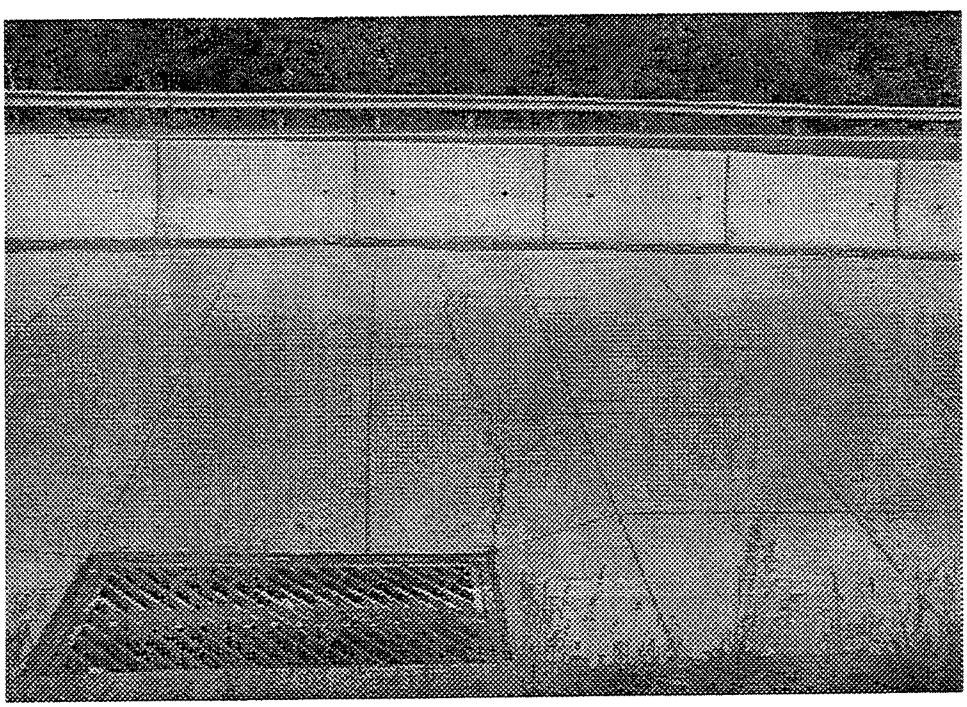


Figure 7. Transverse crack at inlet #2 after two winters.

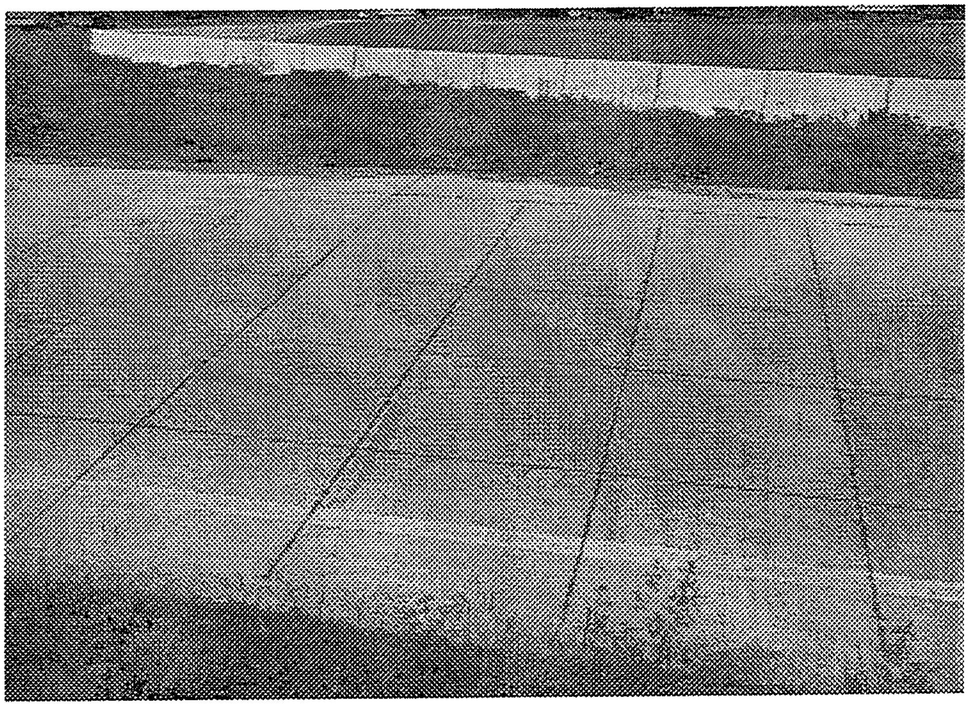


Figure 8. Joints that were sawed while the concrete was too green have not deteriorated significantly since being opened to traffic.

Figure 9. View of transition from bonded overlay to whitetopping overlay showing one cracked panel.

Cost Analysis

An attempt was made, based on the limited study period, to predict a life for the whitetopping overlay at which benefit would be realized compared to following the maintenance history of placing a bituminous overlay. The following assumptions were used:

1. The cost comparison of the bituminous overlay versus the whitetopping overlay only includes the milling and overlaying operations. Other extraneous items such as the concrete barrier and reconstructed concrete shoulders are not included in the analysis.
2. An accelerated cement concrete mix design is used for the whitetopping. (This reduces the ramp closure.) Also assume a detour would be employed for both overlay alternatives for both initial construction and maintenance.
3. The future performance and maintenance needs of a HMA overlay to be consistent with the maintenance history of this ramp.
4. A ramp closure of 1 day for HMA initial construction, and 1/4 day for each maintenance activity.
5. A ramp closure of 4 days for whitetopping overlay construction.

Using these assumptions and a 10 year analysis period, the present worth analysis for the HMA overlay was calculated to be $86,620. The whitetopping overlay was calculated to be $84,273. The calculations are shown in Appendix B.

Based on these assumptions and results, at least a 10 year life would be needed from the whitetopping overlay before benefit would be realized in cost at this site. However, there are possible added benefits other than cost which cannot be measured. For example, as the HMA deteriorates, ride quality will deteriorate. Also, past maintenance cycles indicate that the ramp requires repair every other year. This indicates a possible rapid decrease in ride quality.

The whitetopping overlay on the ramp has not reached the end of its life and therefore final conclusions cannot be made. However, the performance thus far is promising, and has already exceeded the performance of the original HMA overlay from 1992.

Conclusions

This site and study has provided PennDOT with valuable experience. The condition of the existing surface to be overlaid should be considered carefully when selecting sites to use whitetopping. The extensive shoving of the pavement on this ramp suggested that there was a poor bond of the asphalt overlay to the RCC pavement below. This was confirmed during the milling operation. If the asphalt material had been in relatively fair condition, it may have been able to be used successfully. With the favorable results thus far, it is suggested to continue the use of whitetopping overlays on pavements with sufficient depth bituminous material (>1 ½"), at locations such as intersections. However more attention will be given to existing pavement conditions when selecting sites such as ramp projects.

APPENDIX A

REVISED DRAFT CONSTRUCTION SPECIFICATION

FOR THE USE OF

ULTRA-THIN PORTLAND CEMENT CONCRETE OVERLAYS

ITEM 9524- ____ - ULTRA-THIN PORTLAND CEMENT CONCRETE OVERLAY, __" DEPTH

I Description - This work is the construction of an accelerated strength ultra-thin portland cement concrete overlay as indicated.

II Material -

(a) Accelerated Strength Portland Cement Concrete. Section 704.1(b) and 704.1 (c), except as following:

1. Section 704.1(b) Material, except as follows:
   Delete Table A
   Add the following:
   - Concrete Curing Material - Sections 711.1 and .2(a), Type 2
   - Concrete Reinforced with Polypropylene Fibers - ASTM C-1116, Type III 4.13 and ASTM C-1116 (Ref: ASTM C-1018) Performance Level 1 I_5 outlined in Section 21, Note 17 and Residual Strength. Use 100% virgin polypropylene (PE) manufactured to an optimum gradation for use as concrete reinforcement.
2. Section 704.1(c) Design Basis. Except as follows:
   Revise the first sentence as follows:
   Make trial mixtures and computations for accelerated strength portland cement concrete (ASPCC) including the molding and curing of test specimens.
   Revise the first sentence and add a second sentence to the second paragraph as follows:
   Design a concrete mix for ASPCC having a 28 day minimum compressive strength of 4000 psi for acceptance when tested in accordance with PTM 604 and a 24 hour minimum compressive strength of 3000 psi. Concrete consistency will be measured in inches of slump in accordance with Section 501.3(v) of this special provision.
   Add the following sentence to the third paragraph:
   When the overlay depth is less than 3 inches, use No. 8 coarse aggregate instead of No. 57 coarse aggregate.
   Revise the fifth paragraph as follows:
   Use a cement factor of 650 pounds minimum per cubic yard and a water/cement ratio of 0.42 maximum. Flyash may be substituted at a maximum rate of 10% by weight for cement. Include flyash with cement when determining the water/cement ratio. Add PE fiber at the rate of 3.0 pounds minimum per cubic yard.
3. Section 704.1(c)2. Class of Cement Concrete, except

as follows:
Revise heading and first sentence as follows:
Section 704.1(c)2. Accelerated Strength Portland Cement Concrete. The concrete design submitted for review is required to comply with the specified ASPCC requirements, supported by air content and compressive strength test data in accordance with Bulletin 5.
Delete last paragraph.

III CONSTRUCTION -

Construct the ultra thin cement concrete overlay in accordance with Section 501.3 and as follows:

Section 501.3(a) General. Add the following:

Prepare a quality control plan, as specified in Section 106, detailing the timing and sequence of the work, including timing of mixing, hauling, placing, curing, monitoring of concrete temperature, joint sawing, and sampling and testing for compressive strength for opening to traffic. Indicate variations on timing in response to anticipated variations in the ambient temperature for the time of placement. Submit the quality control plan for review before the start of the project. Do not start work until the quality control plan has been approved.

Section 501.3(e) Conditioning of Subbase. Revise completely as follows:

Section 501.3(e) Bituminous Surface Preparation. Completely clean milled pavement surface. Limit cleaning to area that will be overlaid the same day. Protect the cleaned and prepared surface from oil or grease drippings from compressors, concrete trucks, spreaders, pavers, etc. by using protective covers. Remove all deleterious materials prior to overlaying. Sprinkle to throughly dampen the bituminous surface immediately prior to placement of cement concrete without causing pooled or puddled water.

Section 501.3(g) Handling and Placing Reinforcement. Delete.

Section 501.3(h) Transverse Joints. Delete; Replace with the following:

Section 501.3(h) Joints. Saw joints as soon as concrete has hardened sufficiently to permit sawing without excessive raveling. Space joints equidistant longitudinally and transversely (Determine spacing using formula of 1 foot of joint spacing per 1 inch depth of cement concrete overlay). Saw joints with a green cut saw to a depth of D/3 and a minimum width of 1/8 inch. The joints are not to be sealed. Clean joints of all deleterious material after sawing.

Sawing must be done soon enough after placement to prevent random cracking. If necessary, conduct sawing operations continuously, both day and night, regardless of weather conditions. Omit sawing if a crack occurs at or within 1.5 feet of a joint location, prior to the time of the sawing or during sawing. If a crack occurs prior to acceptance of pavement, remove and replace one full panel width and length.

Other than white curing compound, remove curing materials from overlay, at the location where a joint is to be cut. Remove only sufficient covering to provide space necessary for sawing joints. As soon as the joint is made, replace the covering. The maximum time period allowed for pavement curing covers to be removed is ½-hour. When white membrane curing compound is used, cure the joint area, as specified in the first three paragraphs in Section 501.3(k)1.c.

Displacing coarse aggregate from the joint location by use of vibrating T-bar, or by use of a filler strip at the joint, is not permitted.

Section 501.3(I) Longitudinal Joints. Delete.

Section 501.3(k) Curing Concrete. Revise as follows:

Section 501.3(k)1. Normal Curing. Replace with the following:

Allow curing materials to remain in place and maintain as specified, for a period of 24 hours or until the concrete has reached 3000 psi compressive strength.

Provide adequate insulating blankets to prevent rapid heat loss when the ambient air temperature is 65° F or less. Remove any insulation when a minimum compressive strength of 3000 psi has been attained. Remove insulation at such a rate that the temperature change in the concrete does not exceed 40° F within any one hour period. If a temperature change in the concrete in excess of 40° F occurs within any one hour period, whether insulation is used or not, the work is defective.

The application or removal of insulation covers may be controlled by the use of maturity concepts, provided the minimum degree-hours of curing has been achieved at the top of the slab.

Section 501.3(n) Sealing Joints and Cracks. Delete.

Section 501.3(r) Opening to Traffic.

Sample plastic concrete, for compressive strength testing (PTM No. 604) for opening to traffic, in accordance with the approved quality control plan. Sample locations will be selected in accordance with PTM No.1. Test the concrete for compressive strength prior to opening to traffic. Concrete pavement that has not attained a minimum 24 hour compressive strength of 3000 psi at the time of opening to traffic will be considered defective work.

Section 501.3(t) Test for Depth. As specified in 501.3(t) and add the following:
For projects at intersections, drill two cores per intersection.

Section 501.3(u) Defective Work. Revise the first paragraph as follows:

Unless otherwise directed in writing by the District Engineer, remove and replace, at no expense to the Department, pavement that is: defective in surface tolerance, as specified in Section 501.3(p); defective in compressive strength as specified in Section (r) of this special provision; defective in depth, as specified in Section 501.3(t); defective in air content, as specified in Section 704.1(c)1.; where the temperature change in concrete in excess of 40°F occurs within a one hour period; or showing surface defects resulting from the effects of rain, hail, improper final finish, excessive raveling of joints during sawing, or honeycombing which, in the Engineer's opinion, cannot be repaired.

Section 501.3(v) Test Slab. An off-site test slab is required 2 weeks prior to placement of accelerated concrete pavement on the project. Construct the test slab one lane width wide and 12' long. Use the concrete mix design in accordance with section 704.1(c) of this special provision in the test slab. Establish a target value for the consistency during placement of the test slab. The slump for production shall be the consistency of the test slab plus or minus 1-inch. Submit any adjustments for review.

When maturity concept is being used, correlate degree-hours of cure to compressive strength breaks at 8, 12, 16 and 24 hours following placement of the test slab. Establish the minimum number of degree-hours of cure by correlation with compressive strength tests. Verify maturity curves with first 2 days production work, regardless of quantity placed, by recording compressive strength breaks at 8, 12, 16, and 24 hours following placement.

Appropriately time joint saw cut operations as they are proposed for the actual work. The results of this test slab will be used to adjust the timing of joint sawing during construction of the actual project.

Cure the test slab as proposed for the actual work and demonstrate by compressive cylinder breaks, and maturity data when maturity concepts are used, that the mix meets the opening to traffic requirement within 24 hours of placement.

MEASUREMENT AND PAYMENT - Section 501.4 and as follows:

Construction of test slab is incidental to this item of work.

APPENDIX B

LIFE CYCLE COST ANALYSIS

CALCULATIONS

INITIAL CONSTRUCTION
ALTERNATE 1 - BITUMINOUS OVERLAY

Description	Quantity		Unit Cost	Total	
Milling	1795	SY	$1.35/SY	$ 2,424	
Leveling	54	Ton	$ 30/Ton	$ 1,620	
1 ½" ID-2	1795	SY	$ 4.20/SY	$ 7,539	
			Subtotal	$ 11,583	
Mobilization (5% of Subtotal)				$ 580	
Engineering and Inspection (5% of Subtotal)				$ 580	
Maintenance & Protection of Traffic (10% of Subtotal)				$ 1158	
			Total	$ 13,901	≈ $13,900

INITIAL CONSTRUCTION
ALTERNATE 2 - ULTRA-THIN CONCRETE OVERLAY

Description	Quantity		Unit Cost	Total	
Milling	1795	SY	$1.35/SY	$ 2,424	
UTW	1795	SY	$ 23/SY	$ 41,285	
			Subtotal	$ 43,708	
Mobilization (5% of Subtotal)				$ 2,185	
Engineering and Inspection (5% of Subtotal)				$ 2,185	
Maintenance & Protection of Traffic (10% of Subtotal)				$ 4,371	
			Total	$ 52,449	≈ $ 52,450

10 YEAR LIFE CYCLE MAINTENANCE COST
ALTERNATIVE 1 - BITUMINOUS OVERLAY

At Year 1:

Based on Maintenance History for this Ramp, mechanized patching was required at year 1 at a cost to the Department of $5,593 or about $5,600. We will assume this trend continues for the purpose of this analysis, based on our experience on this ramp and similar ones.

	Subtotal	= $ 5,600
User Delay cost: [1330 veh. x 0.083 hrs.(added time) x $11.57/veh. hrs]		= $ 1,277
	Total	$ 6,877

At Year 3:

Even with the patching immediately after the original placement, the bituminous overlay rapidly deteriorated to the point that within 3 years the ramp needed another overlay. For the purpose of this analysis, we will assume the same performance for the subsequent overlays. Therefore the cost at year three will be the same as the original overlay.

	Subtotal	= $ 13,900
User Delay cost: [8000 veh. x 0.083 hrs.(added time) x $11.57/veh. hrs]		= $ 7,682
	Total	$ 21,582

At Year 4:

Same as year 1.

	Total	$ 6,877

At Year 6:

Same as year 3.

	Total	$ 21,582

At Year 7:

Same as year 1.

	Total	$ 6,877

At Year 9:

Same as year 3.

	Total	$ 21,582

10 YEAR LIFE CYCLE MAINTENANCE COST
ALTERNATIVE 2 - ULTRA-THIN CONCRETE OVERLAY

Based on the short term performance and the experience of others with the use of UTW we can assume there will be no maintenance required in the first 10 years. Therefore the cost of life cycle maintenance is $0.

User Delay cost of initial construction:

32,000 veh. x 0.083 hrs.(added time) x $11.57/veh. hrs = $ 30,730

PRESENT WORTH ANALYSIS
ALTERNATE 1 - BITUMINOUS OVERLAY

1. Initial Construction Cost = $13,900

2. Maintenance Present Worth Costs = Activity Cost x (P/F)

Year 1	$ 5,600	x	0.9434	=	$ 5,283
Year 3	13,900	x	0.8396	=	11,670
Year 4	5,600	x	0.7921	=	4,436
Year 6	13,900	x	0.7050	=	9,800
Year 7	5,600	x	0.6651	=	3,725
Year 9	13,900	x	0.5919	=	8,227

Total Maintenance Cost (@ 6.0% Interest) = $43,141

3. Annual Maintenance Cost (@ 6.0% Interest) =

(Annual Cost / lane mile) x (# of Lanes) x (Project Length) x (P/A)

1825 x 1 Lane x 0.18 Miles x 7.3601 = 2,418

Total Annual Maintenance Cost = $ 2,418

4. User Delay Present Worth Costs = User Delay Cost x (P/F)

Initial Construction = $ 7,682

Year 1	1,277	x	0.9434	=	1,205
Year 3	7,682	x	0.8396	=	6,450
Year 4	1,277	x	0.7921	=	1,012
Year 6	7,682	x	0.7050	=	5,416
Year 7	1,277	x	0.6651	=	849
Year 9	7,682	x	0.5919	=	4,547

Total User Delay Cost (@ 6.0% Interest) = $ 27,161

5. Total Present Worth Cost, Alternate 1 = $ 86,620

PRESENT WORTH ANALYSIS
ALTERNATE 2 - ULTRA-THIN CONCRETE OVERLAY

1. Initial Construction Cost	=	$ 52,450
2. Maintenance Present Worth Costs = Activity Cost x (P/F)		
Total Maintenance Cost (@ 6.0% Interest)	=	$ 0
3. Annual Maintenance Cost (@ 6.0% Interest) =		
(Annual Cost / lane mile) x (# of Lanes) x (Project Length) x (P/A)		
825 x 1 Lane x 0.18 Miles x 7.3601 = 1,093		
Total Annual Maintenance Cost	=	$ 1,093
4. User Delay Present Worth Costs = User Delay Cost x (P/F)		
Initial Construction = $ 30,730		
Total User Delay Cost (@ 6.0% Interest)	=	$ 30,730
5. Total Present Worth Cost, Alternate 2	=	$ 84,273

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
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