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Ultrathin Portland Cement Concrete Overlay Extended Evaluation

Construction Report
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REPORT

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Department of Civil and Construction Engineering

Disclaimer

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ABSTRACT

In recent years, ultra-thin whitetopping (UTW) has evolved as a viable rehabilitation technique for deteriorated asphalt cement concrete (ACC) pavement. Numerous UTW projects have been constructed and tested, enabling researchers to identify key elements contributing to their successful performance. These elements include foundation support, interface bonding condition, portland cement concrete (PCC) overlay thickness, synthetic fiber reinforcement usage, joint spacing, and joint sealing. The interface bonding condition is the most important of these elements. It enables the pavement to act as a composite structure, thus reducing tensile stresses and allowing an ultra-thin PCC overlay to perform as intended [1].

The Iowa Department of Transportation (Iowa DOT) UTW project (HR-559) initiated UTW in Iowa. The project is located on Iowa Highway 21 between Iowa Highway 212 and U.S. Highway 6 in Iowa County, near Belle Plaine, Iowa.

The objective of this research was to investigate the interface bonding condition between an ultra-thin PCC overlay and an ACC base over time, considering the previously mentioned variables. This research lasted for five years, at which time it was extended an additional five years. The new phase of the project was initiated by removing cracked panels existing in the 2-inch thick PCC sections and replacing them with three inches of PCC. The project extension (TR 432) will provide an increased understanding of slab bonding conditions over a longer period, as well as knowledge regarding the behavior of the newly rehabilitated areas.

In order to accomplish the goals of the project extension, Falling Weight Deflectometer (FWD) testing will continue to be conducted. Laboratory testing, field

strain gage implementation, and coring will no longer be conducted.

This report documents the planning and construction of the rehabilitation of HR 559 and the beginning of TR 432 during August of 1999.

INTRODUCTION

Portland cement concrete (PCC) whitetopping has been an effective method of pavement rehabilitation for many years. It has been shown to provide improved structural capacity, increased life, low maintenance, and lower cost in comparison to asphalt reconstruction. In addition, whitetopping increases safety by eliminating rutting and various associated problems. Whitetopping also provides environmental benefits and reflects light well.

In recent years, ultra-thin whitetopping (UTW) has emerged as an alternative to the traditional portland cement concrete overlay process. UTW is a process that involves placing a thin layer (2 to 4 inches) of PCC over an existing ACC surface. In addition to the reduced concrete thickness, other factors that distinguish UTW from normal whitetopping include: 1) the existence of interface bonding between the PCC and ACC layers, and 2) closer-than-normal joint spacing [2].

This project involves the continuation of the study of a 7.2-mile section of Iowa Highway 21, near Belle Plaine, Iowa. The original ultra-thin project began in July 1994 and ended on July 1, 1999. The new phase of this research project will consist of a five-year extension beginning on August 3, 1999. It will provide an opportunity for the Department of Transportation and Iowa State University to increase their knowledge of potential rehabilitation methods and other alternatives involving PCC thickness and transverse joint spacing. In addition, the extension of this project will provide a longer evaluation of ultra-thin test section performance.

PROJECTS

Over the course of its brief history, UTW has been used on several rehabilitation projects, with desirable results. UTW's success has resulted in growth and expansion of the procedure. From 1992 through 1996, over 100 projects have begun in North America [3]. Table 1 provides summary information of worldwide reported UTW projects through 1995.

Table 1: Summary information on worldwide reported UTW projects through 1995

State/Country	Number of Projects	Size (yd^2)	Application
Colorado	2	2,670	Roadway
Georgia	4	1,110	Intersection, roadway
Illinois	1	27,000	Parking lot
Iowa	2	40,000	Roadway
Kansas	1	16,534	Roadway
Kentucky	5	4,900	Roadway
Minnesota	1	265	Intersection
Missouri	1	14,000	General aviation apron
New Jersey	1	2,320	Exit ramp
North Carolina	2	2,200	Roadway
Ohio	1	555	Intersection,
Pennsylvania	5	2,610	Intersection, roadway
Tennessee	17	21,493	Intersection, roadway
Virginia	1	5,335	Roadway
Mexico	21	620,948	Unknown
Canada	1	660	Roadway
Sweden	2	3,018	Roadway
Total	68	765,618	

In 1991, the first modern UTW project was constructed on an entrance road to a waste management facility near Louisville, Kentucky [4, 5, 6, 7, 8, 9]. The project focussed on assessing the viability of UTW. An accelerated performance evaluation was possible because more than 3,300 trucks per week used the entrance road [8]. Fast-track paving techniques were employed to construct the project in less than 48 hours. Table 2 shows the UTW construction properties for the project [10].

Table 2: UTW construction properties for the Louisville, Kentucky project

Section Number	Dimensions (ft x ft)	PCC Thickness (in.)	Surface Preparation	Synthetic Fiber Usage (lb/yd^3)	Joint Spacing (ft x ft)
1	275 x 24	3.5	Milled	3.0	6 x 6
2	50 x 24	3.5 - 2.0	Milled	3.0	6 x 6
3	275 x 24	2.0	Milled	3.0	6 x 6, 2 x 2

This experimental project was concluded in the summer of 1993. The UTW was subjected to approximately one million equivalent single axle loads (ESAL's) and remained in a serviceable condition [11].

The Tennessee Department of Transportation has implemented numerous UTW projects with the assistance of local authorities. The projects have focussed on exploring UTW as an economic means to eliminate recurring ACC failures at intersections. In 1992, the first UTW intersection project was constructed at Woodland Street and North First Street in Nashville, Tennessee [12]. The intersection is located in an industrial park and adjoins the exit of a major truck stop. Prior to UTW, the ACC failed every six to seven months, requiring replacement of traffic sensors and complete re-paving. The

UTW project was completed in 24 hours using fast-track paving techniques. Table 3 shows the construction properties for the project [12].

Table 3: UTW construction properties for the Nashville, Tennessee project

Dimensions (ft x ft)	PCC Thickness (in.)	Surface Preparation	Synthetic Fiber Usage (lb/yd^3)	Joint Spacing (ft x ft)
100 x 30	2.5 - 3.0	Milled	3.0	5 x 5

In four years, the intersection was loaded with over four million equivalent single axle loads (ESAL's). Although the UTW was severely cracked, the traffic sensors were still operating and the intersection was still in a serviceable condition.

The 1994 Spirit of St. Louis Airport pavement restoration project marked the first use of UTW at a general aviation airport [13]. The ACC apron, which had deteriorated over the years due to larger planes and fuel spills, became completely unusable and in need of rehabilitation. The project focused on exploring innovative applications of UTW and showing its cost effectiveness. UTW was used to rehabilitate almost 14,000 square yards of apron designated for aircraft weighing less than 12,500 pounds [13]. Construction of the project (including traditional whitetopping sections) took 45 days. Table 4 shows the construction properties for the project [13]. The rehabilitated aprons have performed well and have allowed the airport to expand operations in a cost-effective manner.

Table 4: UTW construction properties for the Spirit of St. Louis project

Area (yd^2)	PCC Thickness (in.)	Surface Preparation	Synthetic Fiber Usage (lb/yd^3)	Joint Spacing (ft x ft)
14,000	3.5	Milled	3.0	4.2 x 4.2

Calhoun County Contracting Corporation of Springfield, Illinois undertook the first UTW parking lot project in 1994 [5]. The project was located at the Holiday Inn in Decatur, Illinois. It focused on demonstrating the economic and construction simplicities of UTW. The parking lot was originally built in the 1960's. It was resurfaced in the late 1970's with ACC, but had begun to deteriorate again. Conventional portland cement paving equipment was used to construct the project in three months. The construction was scheduled to minimize disruptions to normal business operations and to ensure that customers of the hotel always had available parking. Table 5 shows the construction properties for the project [5].

Table 5: UTW construction properties for the Holiday Inn project

Area (yd^2)	PCC Thickness (in.)	Surface Preparation	Synthetic Fiber Usage (lb/yd^3)	Joint Spacing (ft x ft)
27,000	3.0 - 4.0	Milled	-	6 x 6

The first urban arterial UTW project was developed in 1995. The City of Leawood, Kansas constructed it, in conjunction with the Kansas Department of Transportation (KDOT) [14]. The project focused on evaluating synthetic fiber reinforcement usage, joint spacing, joint sealing, and the suitability of UTW in an urban application. The roadway selected was 119th Street between Roe Avenue and Mission Road. The existing ACC had been placed in 1987 and was in need of restoration because it was exhibiting cracking, distortion, and some minor stripping. At the time of construction, the four-lane roadway was carrying nearly 22,500 vehicles daily [15, 16]. The project was completed in two weeks. Table 6 shows the construction properties for the project [17].

Table 6: UTW construction properties for the Leawood, Kansas project

Section Number	Dimensions (ft x ft)	PCC Thickness (in.)	Surface Preparation	Synthetic Fiber Usage (lb/yd^3)	Joint Spacing (ft x ft)	Joint Sealant
1	800 x 24	2.0	Milled	3.0	3 x 3	-
2	800 x 24	2.0	Milled	-	3 x 3	-
3	800 x 24	2.0	Milled	3.0	3 x 3	Silicone
4	800 x 24	2.0	Milled	-	4 x 4	-
5	800 x 24	2.0	Milled	3.0	4 x 4	-
6	800 x 24	2.0	Milled	-	4 x 4	Silicone

RESEARCH OBJECTIVES

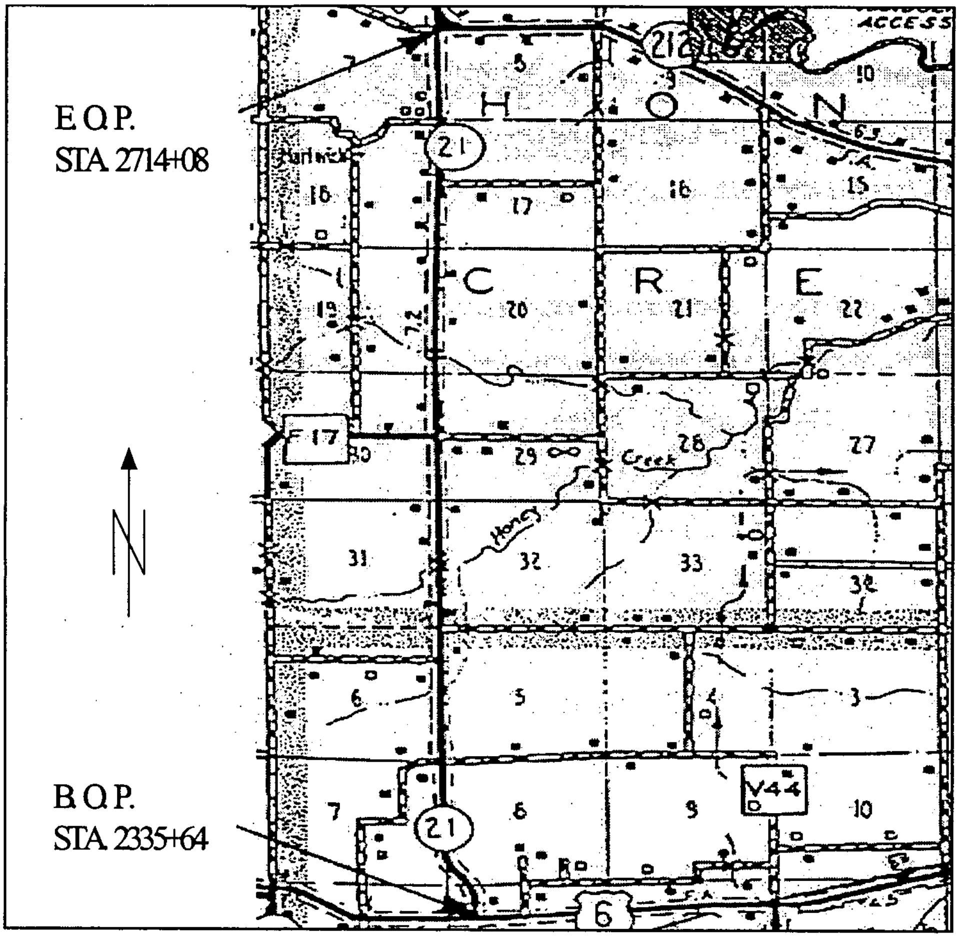
The extension of the Iowa Highway 21 research project should result in increased knowledge concerning acceptable construction practices and highway performance. The specific objectives for TR-432 are as follows:

- The condition of underlying ACC is to be evaluated at specified rehabilitation areas.
- Various slab removal methods are to be evaluated in order to determine effective removal techniques that will not damage the surrounding pavement.
- ACC base preparation is also to be evaluated. This involved the observation of the level of effort that was required to prepare the ACC base on which the new PCC was placed, as well as the condition of the base prior to the placement of PCC.
- An evaluation of the possible methods of joint formation is an objective of this project.
- Due to the absence of three-inch thick PCC test sections during the first five years of the research project, it is now desired to analyze the benefits of fiber addition in such sections.
- The general performance of all rehabilitated pavement areas will be evaluated.
- The extended performance of non-rehabilitated pavement areas will be evaluated.
- It is to be determined whether UTW design procedures are compatible with the standards set by the Portland Concrete Association (PCA) and the American Concrete Paving Association (ACPA).

TEST SITE DESCRIPTION

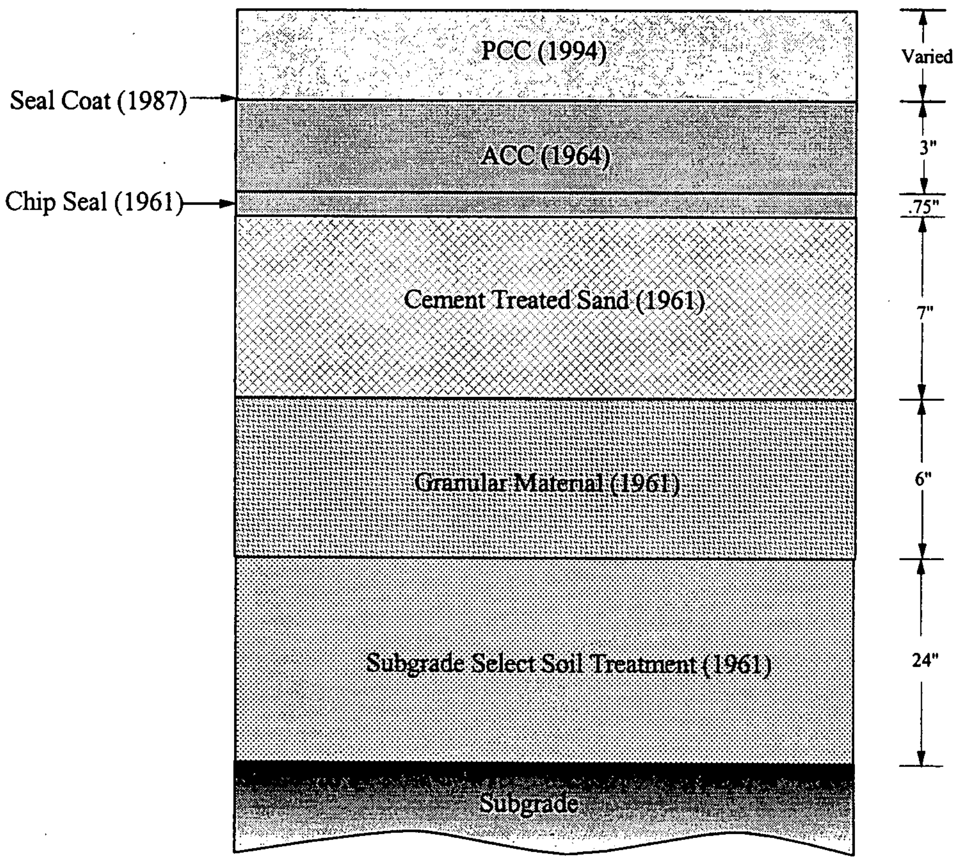
The Iowa Highway 21 project is a 7.2-mile long stretch of roadway that extends from U.S. 6 to Iowa 212 in Iowa County. Figure 1 illustrates the project location.

Figure 1: Project location



This portion of Iowa 21 is a two-lane roadway, 24 feet in width, with 9-foot wide granular shoulders and open ditch drainage. The existing alignment was graded in 1958. A granular driving surface was used until 1961, at which time improvements were made. The improvements included replacing the original sub-grade with select material 2 feet in thickness and 24 feet wide, centered on the roadbed. The select material was overlaid with six inches of granular material, seven inches of cement treated sand (CTS), and 0.75 inches of chip seal. The 9-foot granular shoulders were also constructed at this time. The chip seal was used as the driving surface until 1964, when three inches of type B asphalt cement concrete (ACC) were placed over it. In 1987, a seal coat of negligible thickness was applied to the ACC surface. Ultra-thin whitetopping was placed on the ACC in 1994. All pavement layers were designed and placed according to effective Iowa State Highway Commission (ISHC) or Iowa DOT specifications at the time of contract letting. Figure 2 shows the pavement layers and the dates of their construction [1].

Figure 2: Pavement layers and the dates of their construction



SOIL CONDITIONS

According to the Iowa County Soil Survey Report, Fayett-Downs, Tama-Downs, and Colo-Bremer-Nevin-Nodaway soil associations occur along the project [18]. Fayett-Downs and Tama-Downs are the primary associations along the project. These associations were formed from loess, are generally well drained, and have a moderate to high shrink/swell potential. They are fair sub-grade soils. The Colo-Bremer-Nevin-Nodaway association is along a small portion of the project. This association was formed from alluvium, is generally poorly to moderately drained, and has a moderate to high shrink/swell potential. It is an unsuitable sub-grade soil [1].

More detailed soil information was obtained from a soil survey conducted by the ISHC prior to the 1958 grading operations. Soil borings were taken approximately every 100 feet in cut areas. The soils found were primarily fine grained and had ASSHTO classifications ranging from A-6 (6) to A-7-6 (20). Soils with these classifications are fair to poor sub-grade soils and have moderate to high shrink/swell and frost heave potential. Some very limited pockets of A-1-b, A-2-4, A-3, and A-4 soils were found. Based on the survey findings, select soil treatment for the entire project was specified in the 1961 improvements [1]. Table 7 details the class names and AASHTO classifications of project soils.

Table 7: Class names and ASSHTO classifications of project soils

Station	Class Names	ASSHTO Classifications
2341+00 - 2408+00	Silty Clay Clay	A-7-6 (11,12,13) A-6 (9,11)
2408+00 - 2456+00	Silty Clay Clay	A-7-6 (14,15,17) A-6 (8,9,10,11,12) A-7-5 (20)
2456+00 - 2502+00	Silty Clay Loam Silty Clay Clay Loam Gravel Clay Loam Gravel Sand Clay	A-6 (10) A-7-6 (12) A-6 (9,10,11) A-7-6 (11,12,13,15) A-6 (6) A-6 (4) A-1-b (0) A-6 (8,9,10) A-7-6 (19)
2502+00 - 2561+00	Gravel Clay Loam Clay Loam Silty Clay Sandy Loam Clay	A-6 (10) A-6 (3,5,6,7) A-6 (7,8,10,11) A-7-6 (12,15,17) A-2-4 (0) A-6 (8) A-7-6 (19)
2561+00 - 2615+00	Silty Clay Loam Silty Clay Clay Loam Sandy Loam Gravel Sand Clay Sand	A-6 (8,10) A-6 (10) A-7-6 (10,12,13,14,15,18) A-6 (5) A-2-4 (0) A-3 (0) A-7-6 (20) A-2-4 (0)
2621+00 - 2676+00	Silty Clay Loam Silty Clay Clay Loam Clay	A-6 (10) A-6 (9,11,12) A-6-7 (10,14,18) A-4 (5) A-6 (6,7) A-7-6 (19)
2676+00 - 2706+00	Silty Clay Loam Silty Clay Clay Loam	A-4 (8) A-6 (9, 12) A-6 (10,12) A-7-6 (10,12) A-4 (4)

TRAFFIC CONDITIONS

The portion of Iowa Highway 21 that is under research serves primarily as a farm to market road and as an access route for U.S. Highway 6. Private residences and a few intersections of lightly traveled county roads exist along the project. No commercial or industrial sites are present to create large influxes of traffic or uneven directional distribution. Iowa DOT average daily traffic (ADT), average daily truck traffic (ADTT), classification counts, and typical vehicle axle configurations and weights were used to estimate traffic loading. The average ADT was 1,090 and the average ADTT was 142 in 1994 [1].

EXPERIMENTAL DESIGN

Distress surveys and falling weight deflectometer (FWD) testing will continue over the course of this project. In addition, Roadrater testing will continue to be provided by the Iowa Department of Transportation. Roadrater and FWD tests will be conducted each fall and distress surveys will be conducted during the spring and fall of each year. Field strain gages will not be used during the new phase of this project. Furthermore, neither the direct shear testing of core samples nor composite beam testing will be conducted.

Since the extended performance of non-rehabilitated pavement areas will be evaluated during the new phase of this project, the design variables to be taken into consideration are identical to those that existed during the first five-year phase of this project. The design variables are as follows:

- ACC surface preparation (milled, patched only, and cold-in-place-recycle (CIPR))

- Use or non-use of synthetic fibers
- Pavement thickness (2, 4, 6, or 8 inches)
- Joint spacing (2 x 2, 4 x 4, 6 x 6, 12 x 12, 12 x 15, and 12 x 20 foot panels)
- Use or non-use of joint sealant. (Joints were sealed only during the original construction of the whitetopping and not during the rehabilitation phase of the project).

The Highway 21 project was originally divided into 65 sections according to the previously mentioned variables, including 41 test sections. The test sections ranged from 200 to 2700 feet in length. Each section represented a stretch of roadway in which all of the variables remained constant. A changing variable represented the beginning of a new test section. Table 8 displays the design properties for the project test sections [1].

Table 8: Test section characteristics

Section Number	Section Type	Station	PCC Thickness (in.)	Synthetic Fiber Usage *	Joint Spacing (ft x ft)	Surface Preparation
1	Recon.	2335+64 - 2340+00	8	N	20 x 12	-
2	Trans.	2340+00 - 2342+00	8 - 6	N, F	12 x 12	Milled
3	Test	2342+00 - 2349+00	6	F	12 x 12	Milled
4	Test	2349+00 - 2356+00	6	F	6 x 6	Milled
5	Trans.	2356+00 - 2357+00	6 - 4	F	6 x 6	Milled
6	Test	2357+00 - 2364+00	4	F	6 x 6	Milled
7	Test	2364+00 - 2371+00	4	F	2 x 2	Milled
8	Test	2371+00 - 2378+00	4	F	4 x 4	Milled
9	Trans.	2378+00 - 2380+00	4 - 2	F	2 x 2	Milled
10	Test	2380+00 - 2387+00	2	F	2 x 2	Milled
11	Test	2387+00 - 2394+00	2	M	4 x 4	Milled
12	Trans.	2394+00 - 2396+00	2 - 6	M	4 x 4, 6 x 6	Milled
13	Test	2396+00 - 2403+00	6	M	6 x 6	Milled
14	Test	2403+00 - 2414+00	6	M	12 x 12	Milled
15	Trans.	2414+00 - 2415+00	6 - 4.5	F	12 x 12, 6 x 6	Milled
16	Control	2415+00 - 2425+00	4.5 (1)	-	-	Milled
17	Trans.	2425+00 - 2426+00	4.5 - 6	N	6 x 6, 12 x 12	Milled

Table 8 (continued)

18	Test	2426+00 - 2433+00	6	N	12 x 12	Milled
19	Test	2433+00 - 2440+00	6	N	6 x 6	Milled
20	Trans.	2440+00 - 2441+00	6 - 4	N	6 x 6, 2 x 2	Milled
21	Test	2441+00 - 2448+00	4	N	2 x 2	Milled
22	Trans.	2448+00 - 2449+00	4 - 2	N	2 x 2	Milled
23	Test	2449+00 - 2456+00	2	N	2 x 2	Milled
24	Trans.	2456+00 - 2458+00	2 - 6	N	2 x 2, 6 x 6	Milled
25	Test	2458+00 - 2460+00	6	N	6 x 6	Milled
26	Test	2460+00 - 2468+00	6	N	6 x 6	Patch Only
27	Test	2468+00 - 2479+00	6	N	12 x 12	Patch Only
28	Trans.	2479+00 - 2480+00	6 - 4	N	12 x 12, 4 x 4	Patch Only
29	Test	2480+00 - 2487+00	4	N	4 x 4	Patch Only
30	Trans.	2487+00 - 2489+00	4 - 8	N	4 x 4, 15 x 12	Patch Only
31	Test	2489+00 - 2496+00	8	N	15 x 12	Patch Only
32	Test	2496+00 - 2503+00	8	N	15 x 12 D	Patch Only
33	Trans.	2503+00 - 2505+00	8 - 4.5	N	15 x 12, 6 x 6	Patch Only
34	Control	2505+00 - 2515+00	4.5 (1)	-	-	Patch Only
35	Trans.	2515+00 - 2516+00	4.5 - 6	N	4 x 4, 6 x 6	Patch Only
36	Test	2516+00 - 2538+00	6	N	6 x 6	Patch Only
37	Trans.	2538+00 - 2540+00	6 - 2	N, F	6 x 6, 2 x 2	Patch Only
38	Test	2540+00 - 2547+00	2	F	2 x 2	Patch Only
39	Test	2547+00 - 2554+00	2	F	4 x 4	Patch Only
40	Trans.	2554+00 - 2555+00	2 - 4	F	4 x 4	Patch Only
41	Test	2555+00 - 2562+00	4	F	4 x 4	Patch Only
42	Test	2562+00 - 2569+00	4	F	2 x 2	Patch Only
43	Test	2569+00 - 2576+00	4	F	6 x 6	Patch Only
44	Trans.	2576+00 - 2577+00	4 - 6	F	6 x 6, 12 x 12	Patch Only
45	Test	2577+00 - 2585+00	6	F	12 x 12	Patch Only
46	Test	2585+00 - 2593+00	6	F	6 x 6	CIPR
47	Trans.	2593+00 - 2594+00	6 - 4	F	6 x 6	CIPR
48	Test	2594+00 - 2601+00	4	F	6 x 6	CIPR
49	Test	2601+00 - 2608+00	4	F	2 x 2	CIPR
50	Test	2608+00 - 2615+00	4	F	4 x 4	CIPR
51	Trans.	2615+00 - 2616+00	4 - 2	F	4 x 4, 2 x 2	CIPR
52	Test	2616+00 - 2624+00	2	F	2 x 2	CIPR
53	Test	2624+00 - 2631+00	2	F	4 x 4	CIPR
54	Trans.	2631+00 - 2633+00	2 - 6	F	4 x 4, 6 x 6	CIPR
55	Test	2633+00 - 2640+00	6	N	6 x 6	CIPR
56	Test	2640+00 - 2653+00	6	N	12 x 12	CIPR
57	Trans.	2653+00 - 2654+00	6 - 4	N	12 x 12, 6 x 6	CIPR
58	Test	2654+00 - 2661+00	4	N	6 x 6	CIPR
59	Trans.	2661+00 - 2662+00	4 - 6	N	6 x 6, 12 x 12	CIPR

Table 8 (continued)

60	Test	2662+00 - 2689+00	6	N	6 x 6, 12 x 12	CIPR
61	Trans.	2689+00 - 2691+00	6 - 2	N	12 x 12, 4 x 4	CIPR
62	Test	2691+00 - 2698+00	2	N	4 x 4	CIPR
63	Trans.	2698+00 - 2700+00	2 - 6	N	12 x 12, 4 x 4	CIPR
64	Trans.	2700+00 - 2704+00	6 - 4.5	N	12 x 12, 4 x 4	CIPR
65	Control	2704+00 - 2714+08	4.5 (1)	-	-	CIPR

Recon. = reconstruction
Trans. = transition
Control = ACC control
* N = no fibers
F = fibrillated fibers
M = monofilament fibers
D = dowels
(1) ACC thickness

TEST SITE DEVELOPMENT

Dr. James K. Cable performed the selection of highway rehabilitation areas for this phase of the research project on August 2, 1999. Selection was based on observed pavement distresses in the form of longitudinal and corner cracking. Fractured slabs (individual panels separated into four or more areas by cracks) were observed. Areas exhibiting characteristics of potential de-bonding were also marked for rehabilitation. Table 9 displays information regarding the panel location and size of rehabilitation areas. In addition, the southbound lane of an 804-foot highway section was selected for lane replacement. It is located from station 2690 + 46 to 2698 + 50. This is a section of CIPR surface treatment that had exhibited characteristics of weak ACC base material. Information regarding removal characteristics and the condition of underlying ACC for this area is provided in the "Construction" section of this report.

Table 9: Characteristics of Patch and Lane Replacement Sections

Patch Number	Station	Panel Location *	Lane	Size (ft)	Quantity	Area (ft^2)
1	2369 + 37	R 5,6	NBL	2 x 2	4	16
2	2380 + 32	R 5	NBL	2 x 2	7	28
3	2383 + 06	L 4	SBL	2 x 2	23	92
4	2383 + 46	R 2	NBL	2 x 2	2	8
5	2385 + 46	L 2	SBL	2 x 2	2	8
6	2384 + 17	R 5, 6	NBL	2 x 2	25	100
7	2384 + 60	R 5	NBL	2 x 2	9	36
8	2384 + 91	R 5	NBL	2 x 2	2	8
9	2385 + 13	L 4	SBL	2 x 2	24	96
10	2385 + 52	R 5, 6	NBL	2 x 2	29	116
11	2386 + 37	L 1	SBL	2 x 2	3	12
12	2386 + 43	L 4	SBL	2 x 2	2	8
13	2386 + 59	L 4	SBL	2 x 2	8	32
14	2386 + 75	L 5	NBL	2 x 2	2	8
15	2389 + 11	R 3	NBL	4 x 4	7	112
16	2389 + 83	R 3	SBL	2 x 2	19	304
17	2391 + 20	L 2	NBL	2 x 2	5	80
18	2392 + 18	R 3	SBL	2 x 2	40	640
19	2392 + 50	L 3	SBL	2 x 2	21	336
20	2448 + 14	L 2 - 6	SBL	2 x 2	65	260
21	2454 + 48	R 1 - 6	NBL	2 x 2	390	1560
(end of pave)	2455 + 78					
22	2454 + 48	L 1 - 6	SBL	2 x 2	390	1560
(end of pave)	2455 + 78					
23	2550 + 67	L 3	SBL	2 x 2	8	128
24	2552 + 16	L 3	SBL	2 x 2	3	48
25	2552 + 83	L 3	SBL	2 x 2	12	192
26	2553 + 60	R 3	NBL	2 x 2	1	16
27	2622 + 00	L 3 - 5	SBL	2 x 2	17	68
28	2623 + 00	L 5, 6	SBL	2 x 2	16	64

NBL = North bound lane
SBL = South bound lane
* For example, "R 3" indicates that a removal area is located three panels to the right of the center line when oriented from South to North

The rehabilitation of most highway sections consisted of full depth PCC patching. However, the removal and replacement of entire lane segments was required at two sections. The first of these sections is located from station 2455 + 78 to 2454 + 48. Both lanes of this 130-foot section were replaced. (Refer to patch numbers 21 and 22 of table 9). The second section was an 804-foot highway segment located from station 2690 + 46 to 2698 + 50. Only the northbound lane of this section was replaced. The removal of entire lane segments was based on evidence of poor ACC base material due to the observation and testing of core samples. In addition, large amounts of surface cracking had resulted in fractured slabs.

CONSTRUCTION SITE ADMINISTRATION

The construction project was under the supervision Ken Yanna, Resident Engineer, of the Iowa DOT. The project inspectors included Doug Foster and Jim Jakubec, both from the Iowa DOT. Tom Ciha represented the Iowa State University staff on this project. All construction was performed by Hawkeye Paving and supervised by Don Hamilton.

CONSTRUCTION

Project construction consisted of joint sawing, panel removal, preparation of removal areas, and the replacement with PCC. Construction began on August 4 and ended on August 20, 1999.

Panel removal began by re-sawing the joints around the perimeter of a removal area. A standard concrete saw was used in this operation. Joints were sawed to a depth of approximately 2 ¾ inches. All of the joints were cut to match the existing joints in the PCC pavement.

A variety of techniques were employed to remove the selected panels. The removal method depended on the number of panels to be removed, their orientation along the cross section of the highway, and the size of the removal area.

A backhoe was the most used method of panel removal. The backhoe was used on larger removal areas, including the two sections requiring entire lane replacement. A bobcat loader was used to pry out strips of panels that were not wide enough to be removed with the backhoe. In some instances, panels were pulled out by drilling two holes into the pavement and inserting metal rods connected to the backhoe by chains. This procedure was performed when removing a panel in which none of its four sides were exposed to allow removal by backhoe or bobcat loader.

Rehabilitation sections underwent preparation prior to placing PCC. Following the removal of PCC panels, portions of remaining underlying ACC were removed through the use of shovels, pick axes, and air-powered chipping hammers. Remaining ACC was removed from the perimeters of removal areas through the use of a demolition saw (a hand-held portable saw) when necessary. The ACC base was then scarified or chipped to increase bonding with the new PCC that was to be placed. Scarification and chipping were also used to attain the minimum PCC depth of three inches if the requirement had not already been satisfied. Use of a portable scarifier was the most popular scarification technique. The portable scarifier is shown is figure 3. Scarification was also achieved through the use of a demolition saw. In these instances, transverse and longitudinal lines were cut in the ACC base. The lines were approximately 1/8 inch deep and spaced between 0.5 and 1.0 inches apart. Following scarification, removal areas were cleaned of debris by using a high-pressure air hose.

Figure 3: Portable scarifier

All paving and patching areas were filled with an M-4 portland cement concrete mix. This is a high early strength concrete mix and is suitable for many applications. It is composed of 50 % coarse aggregate and 50 % fine aggregate. The absolute volumes of materials to unit volume of the concrete are as follows: cement minimum = 0.156; water = 0.161; entrained air = 0.060; fine aggregate = 0.312; coarse aggregate = 0.311. The PCC mix contained coarse aggregate of gradation number 5 (refer to table 10) [19]. The mix also contained a durability of class 3. Class 3 durability aggregates will produce concrete of protracted serviceability, causing little or no deterioration of pavements in excess of 20 years of age on non-interstate segments of the primary road system [19]. Polypropylene fibers were added to the PCC at twice the manufacturer's recommended dosage rate in order to match the rate that was used in the original HR 559 project. The fibers were incorporated into the PCC that was placed in all full-depth patching and paving locations, with the exception of the northbound lane of the 130-foot replacement section.

Table 10: Gradation data for aggregate (Gradation # 5):

Sieve Size	Percent Passing (%)
1	100
¾	90-100
½	-
3/8	20-55
# 4	0-10
#8	0-5
#30	-
# 50	-
#100	-
#200	0-1.5

Joints were cut in the PCC as soon as the concrete had cured to the point that sawing could be performed without excessive raveling and the concrete could support the weight of the saw and operator. In addition, the joints were cut to prevent the occurrence of shrinkage cracking. A "soft-cut" saw cut joints to a width of 1/8 inch and a depth of one inch. Typically, there was period of 2-2.5 hours between the placement of PCC and the "soft-cutting" of the joints.

Curing blankets were placed over all patching and paving sections. Maturity probes were placed at various locations of newly paved PCC. The probes indicated the amount of hydration that the PCC had experienced. Figure 4 displays the insertion of a maturity probe into the PCC. The amount of time between placing the PCC and reopening the rehabilitated areas to highway traffic ranged from 8 to 13.5 hours. Table

11 displays various characteristics of the PCC at locations of maturity probe placement when the pavement was reopened to traffic.

Figure 4: Maturity probe insertion into newly placed PCC

The documentation of observed underlying ACC conditions and interface bonding was a main goal on this project. Table 12 displays the removal depth and ACC/bonding conditions for all full-depth patching sections as well the 130-foot lane replacement section.

Table 11: PCC Characteristics at Maturity Probe Locations

Station	Location	Date Placed	Curing Time (hr)	Air (%)	Slump (in.)	Air Temp. (°C)	PCC Temp. (°C)
2369 + 37	Section 1	8/5/99	10	5.5	1.5	27.4	25.8
2383 + 06	Section 3	8/9/99	11	6.8	2	20.1	30.9
2385 + 52	Section 10	8/5/99	13.5	6	2	28.7	20.3
2392 + 18	Section 18	8/5/99	11	6.2	2	31.6	23
2392 + 50	Section 19	8/9/99	9.5	6.3	2	24.1	34.7
2448 + 14	Section 20	8/10/99	11	8	2	26.4	33.2

Table 11 (continued)

2454 + 48	Section 22	8/10/99	8.5	-	2	36.2	42
2454 + 48	Section 21	8/11/99	9	6.4	2	28.3	40
2550 + 67	Section 23	8/6/99	9	6.4	2	30.6	37.4
2552 + 82	Section 25	8/6/99	10	7	1.5	29.2	33.6
2553 + 60	Section 26	8/11/99	10	6.5	1.5	22.7	34.6
2622 + 00	Section 27	8/13/99	11	7	1.5	21.6	31.5
2690 + 48	804' CIPR	8/20/99	8.5	6.5	2	32.6	50
2692 + 46	804' CIPR	8/20/99	8	7.1	2	24.4	52.5
2692 + 48	804' CIPR	8/19/99	8.5	6.8	2	27.9	45.4
2694 + 48	804' CIPR	8/17/99	8.5	8	2	21.4	47
2697 + 00	804' CIPR	8/17/99	8	6.8	2	36.1	53.7
2697 + 52	804' CIPR	8/13/99	9.5	7.1	2	22.7	44
2698 + 51	804' CIPR	8/13/99	8	8	2	37.4	51.8
2698 + 52	804' CIPR	8/13/99	9.5	7	2	23.1	45.1

Table 12: Removal Depth and ACC/Bonding Conditions at Rehabilitation Sections

Section	Panel Removal	Removal Depth (in.)	Bonding Condition/ACC Quality
1	Backhoe	4	Good condition; PCC adhered to ACC to a high degree and ACC maintained form
2	Bobcat	4.5 - 5.25	ACC looser and more prone to crumbling when compared to section 1, yet still retaining some form; ACC did not come out with panels - nearly all of it had to be chipped away
3	Pulled with backhoe, then used Bobcat	3.5	High degree of bonding; nearly all of the ACC stuck with the PCC, and remained in good condition
4	Bobcat	3.5 - 4	Subsurface condition similar to section 2; little of the ACC came up with the panels
5	Pulled with backhoe, then used Bobcat	3 - 3.5	Difficult to determine; only 2 panels at this section; the first panel was pulled out, which may have disrupted the second one; it is suspected that the condition is much like that of Section 3
6	Bobcat	3.5 - 4	ACC in good condition with significant amount remaining with the panels
7	Bobcat/pulled with backhoe	4 - 4.75	At least half of the ACC did not remain with the PCC; ACC partially maintained it's form
8	Unknown	4.5 - 4.75	ACC was partially loose and crumbled somewhat; about half of it remained with the panels
9	Pulled with backhoe, then used Bobcat	4	Very good condition; nearly all of the ACC came up with no problems

Table 12 (Continued)

10	Pulled with backhoe, then used Bobcat	4	ACC crumbled somewhat; some remained with the PCC
11	Pulled with backhoe	4	ACC came out nicely; good bonding
12	Pulled with backhoe	3.75 - 4	High degree of bonding; nearly all of the ACC remained with the PCC
13	Pulled with backhoe, then used Bobcat	3.75 - 4	High degree of bonding with ACC in good condition
14	Pulled with backhoe	3 - 3.25	Situation was similar to that of section 5
15	Backhoe	4 - 4.5	Very good bond; nearly all of the ACC adhered to the PCC, and ACC was in good form
16	Backhoe	3.5 - 4	Situation was similar to that of section 15
17	Pulled with backhoe, then used Bobcat	3.75	Situation was similar to that of section 15
18	Backhoe	Unknown	Good bond; nearly all of the ACC adhered to the PCC; ACC was in good form
19	Backhoe	4	Situation was similar to that of section 18
20	Backhoe	3 - 4.25	ACC crumbled; much of it did not remain with the panels during removal
21	Backhoe	3.25 - 5; generally more shallow on the outer half of the lane	Poor interface bonding; ACC crumbled easily
22	Backhoe	3.25 - 5	Situation was similar to that of section 21
23	Backhoe	3 - 4.5	Unknown
24	Backhoe	4.5	ACC adhered to the panels according to the backhoe operator
25	Backhoe	4 - 4.25	Situation was similar to that of section 24
26	Unknown	Unknown	Unknown
27	Backhoe	4	A portion of ACC adhered to most of the panels; ACC crumbled somewhat
28	Backhoe, then chipping hammer	4	Unknown

In addition to the 28 replacement areas identified in table 8, an 804-foot long highway section (station 2690 + 46 to 2698 + 50) exhibiting a CIPR-treated sub-base was selected for rehabilitation. Construction proceeded from North to South during every segment of the 804-foot section and was located in the southbound lane only.

The northern-most 104 feet of the CIPR section (station 2698 + 50 - 2797 + 46) was rehabilitated on August 13, 1999. Pavement was prepared for removal by re-sawing the existing centerline joint and placing intermittent cuts through transverse joints across the width of the removal lane. Joints located within the removal lane were not re-sawed. This was the practice over the course of the entire 804-foot replacement area. The ACC maintained form and did not crumble apart during the first 104 feet of lane removal. Ultimately, all of the ACC was removed throughout the length of this section, and scarification penetrated into the cement-treated sand at times. The PCC thickness was seven inches at the northern end of the section and transitioned to 3.5 inches at the southern end. The overall depth of removal remained constant at nine inches. In all locations of full-lane rehabilitation, the placement of fresh PCC was accomplished by the use of an oscillating screed.

An additional 308 feet of the CIPR section (station 2697 + 50 - 2694 + 42) was rehabilitated on August 17. Beginning on this date, an attempt was made to remove only the PCC layer whenever possible. This practice was then maintained throughout the remainder of construction. ACC that had maintained its structural integrity was left in place. At all rehabilitation areas, paving operations were performed using PCC; asphalt was never placed during rehabilitation. Table 13 details each section of full-lane rehabilitation where the ACC was either entirely removed, entirely left in place, or partially left in place. Figure 5 displays a section of the full lane pavement rehabilitation that was performed on August 17 (station 2697 + 50 - 2696 + 20). The condition of the ACC was somewhat worse than that of the northern-most rehabilitation section, as the

ACC crumbled apart if it required removal by backhoe. The same ACC/bonding condition was evident throughout this section.

Figure 5: Characteristics of a full-lane rehabilitation section (station 2697 + 50 - 2698 + 20) where ACC was partially removed

The rehabilitation of 204 feet of pavement occurred on August 19. The ACC crumbled when disturbed by the backhoe. Overall, the ACC appeared to be brittle and in poor condition. The PCC thickness was observed to be 1.5 - 2 inches in the outer 4 - 5 feet of the lane, beginning at station 2693 + 00. Badly cracked (epoxied) panels began at station 2693 + 42 and ended at 2692 + 42 (working from North to South). The severe level of distress in these panels is most likely attributed to the thinness of the PCC. Figure 6 shows the condition of the ACC and interface bonding that was typical along this 204-foot length of rehabilitation.

Figure 6: ACC and interface bonding conditions at station 2693 + 50

The final 200 feet of construction took place on August 20. The ACC condition was similar to that of the previous two rehabilitation sections. The ACC was brittle, and it crumbled when disturbed by the backhoe. The PCC was thin toward the outer edge of the road, but maintained a thickness of at least two inches.

Table 13: ACC/PCC Removal Characteristics on 804-foot full lane rehabilitation area

Station	Length (ft)	Date of Removal	Removal Depth (in.) *	Removal Status
2698+50 - 2697+46	104	8/13/99	9.0	All ACC was removed
2697+50 - 2697+38	12	8/17/99	8.5	All ACC was removed
2697+38 - 2697+18	20	8/17/99	3.5	All ACC was left in place
2697+18 - 2696+94	24	8/17/99	7	All ACC was removed
2696+94 - 2696+74	20	8/17/99	3.5	All ACC was left in place
2696+74 - 2696 +66	8	8/17/99	U=3.5 L=8.0	7.5' long x 2' wide ACC removed at mid-lane; the rest left in place
2696+66 - 2696+62	4	8/17/99	3.5	All ACC was left in place
2696+62 - 2696+58	4	8/17/99	U=3.25 L=9.0	4' long x 3.5' wide ACC removed at mid-lane; the rest left in place
2696+58 - 2696+54	4	8/17/99	3.25	All ACC was left in place
2696+54 - 2695+78	76	8/17/99	U=3.75 L=9.0	ACC only left in place for 4.5' closest to center line
2695+78 - 2695+38	40	8/17/99	9	All ACC was removed
2695+38 - 2695+12	26	8/17/99	U=4.0 L=7.25	ACC only left in place for 4.0' closest to center line
2695+12 - 2694+42	70	8/17/99	9	All ACC was removed
2694+46 - 2694+42	4	8/19/99	9	All ACC was removed
2694+42 - 2694+26	16	8/19/99	U=4.25 L=9.0	ACC only left in place for 4.0' closest to center line
2694+26 - 2693+18	108	8/19/99	8.5	All ACC was removed
2693+18 - 2693+14	4	8/19/99	U=3.5 L = 8.5	Only 4.7' wide ACC closest to center line was removed
2693+14 - 2692+94	20	8/19/99	3.5	All ACC was left in place
2692+94 - 2692+77	17	8/19/99	U=3.5 L=7.75	Only 4.0' wide ACC closest to center line was removed
2692+77 - 2692+70	7	8/19/99	3.5	All ACC was left in place
2692+70 - 2692+42	28	8/19/99	U=3.5 L=7.75	Only 4.0' wide ACC closest to the edge was left in place
2692+46 - 2692+40	6	8/20/99	7.75	All ACC was removed
2692+40 - 2692+14	26	8/20/99	3.25	All ACC was left in place
2692+14 - 2692+02	12	8/20/99	U=3.25 L=7.5	All ACC was removed except for 4.0' wide ACC closest to center line
2692+02 - 2690+46	156	8/20/99	8.25	All ACC was removed

* U = depth from surface to ACC left in place
L = depth from surface to ACC removal area

CONSTRUCTION CONCERNS

Difficulty was experienced in attempting to remove full-lane rehabilitation areas by backhoe. In sections 21 and 22 as well as the 804-foot CIPR rehabilitation, joints were only re-sawed longitudinally around the perimeter of the respective removal area. This involved sawing the road centerline joint and intermittent transverse joints. It was observed that it was easier to remove pavement located close to the centerline than toward the outer edge of a lane. It is thus recommended that at least one additional longitudinal joint be re-sawed if possible to aid in the removal process.

Other problems regarding the construction process were minor in nature. Equipment breakdowns produced only slight delays. These consisted of a damaged hose linking a joint saw to the water supply and the repair of the portable scarifier. In addition, adverse weather conditions resulted in the postponement of construction for several days.

Regarding section 22, 2 x 2-foot panels were replaced with 6 x 6-foot panels during the rehabilitation process. However, section length limitations required the construction of two 5 x 6-foot panels on the north end of the rehabilitation area.

CONSTRUCTION SUMMARY

The rehabilitation of HR 559 was in accordance with specified construction procedures and progressed with no major concerns or setbacks. Chosen methods of panel removal were effective in most cases, with the exception of the aforementioned difficulty in situations of full-lane removal. Proper construction of the project should provide a solid foundation for data collection, observation, and analysis over the five-year phase of this project. Ultimately, it is desired to increase knowledge pertaining to the bonding characteristics associated with a PCC/ACC interface in terms of joint spacing, PCC thickness, surface preparation, use of fibers, and the sealing of joints.

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