J.K. Cable, J.M. Hart, T.J. Ciha

Thin Bonded Overlay Evaluation

Construction Report

August 1999

Sponsored by the
Project Development Division of the
Iowa Department of Transportation,
the Iowa Highway Research Board and
the Federal Highway Administration

Iowa Department of Transportation

Iowa DOT Project HR-559
FHWA Work Order No.: DTFH71-94-TBO-IA-37

REPORT

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Department of Civil and Construction Engineering

Disclaimer

"The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Iowa Department of Transportation nor the United States Department of Transportation, Federal Highway Administration."

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

ACKNOWLEDGMENTS

This report would not have been possible without the assistance of John Hart of the Iowa DOT and members of the research staff that have been involved in the construction of this project. Marcia McCarthy, Tom Powers, and Adnan Ali, of Iowa State University, made a special effort in the installation of the sensors in the pavement during construction.

This type of project represents the continuing partnership between the Iowa DOT, Iowa State University (ISU), the Iowa Concrete Paving Association (ICPA), and the Federal Highway Administration (FHWA). The construction of this project would not have been possible without the cooperation of Manatt's Inc. and the Iowa Department of Transportation Construction Office staff from Cedar Rapids, Iowa. The cooperation and professionalism of all involved in the partnership are appreciated.

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, the 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. Although the main factors affecting UTW performance have been identified in previous research, neither the impact that external variables have on the elements nor the element interaction have been thoroughly investigated.

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.

Laboratory testing and full scale field-testing were planned to accomplish the research objective. Laboratory testing involved monitoring interface strains in fabricated PCC/ACC composite test beams subjected to either static or dynamic flexural loading. Variables investigated included ACC surface preparation, PCC thickness, and synthetic fiber reinforcement usage. Field testing involved monitoring PCC/ACC interface strains and temperatures, falling weight deflectometer (FWD) deflection responses, direct shear strengths, and distresses on a 7.2 mile Iowa Department of Transportation (Iowa DOT)

UTW project (HR-559). The project was located on Iowa Highway 21 between Iowa Highway 212 and U.S. Highway 6 in Iowa County, near Belle Plaine, Iowa. Variables investigated included ACC surface preparation, PCC thickness, synthetic fiber reinforcement usage, joint spacing, and joint sealing.

This report documents the planning, equipment selection, and construction of the project built in 1994.

INTRODUCTION

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

In recent years, ultra-thin whitetopping (UTW) has emerged as an alternative to the traditional portland 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 depth, 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 [1].

This project involves the study of a 7.2-mile section of Iowa Highway 21, near Belle Plaine, Iowa. Despite the number of past UTW projects, a quantitative comparison of the various design elements has not yet been offered to the extent that is needed. The goal of this project is to provide such an analysis, broadening knowledge pertaining to the usefulness of UTW as an alternative method in roadway rehabilitation.

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 [1]. 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 (Sq. yds.)	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	General Aviation Apron, 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 [2, 3, 4, 5, 6, 7]. 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 [6].

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./c.y.)	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 [9].

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 [10]. 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 [10].

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

Dimensions (ft. X ft.)	PCC Thickness (in.)	Surface Preparation	Synthetic Fiber Usage (lb./c.y.)	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 [11]. 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 [15]. Construction of the project (including traditional whitetopping sections) took 45 days. Table 4 shows the construction properties for the project [15]. 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 (sq. yds.)	PCC Thickness (in.)	Surface Preparation	Synthetic Fiber Usage (lb./c.y.)	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 [3]. The project was located at the Holiday Inn in Decatur, Illinois. It focussed 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 was beginning 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 [3].

Table 5 - UTW construction properties for the Holiday Inn project

Area (sq. yds.)	PCC Thickness (in.)	Surface Preparation	Synthetic Fiber Usage (lb./c.y.)	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) [12]. 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 [13, 14].

The project was completed in two weeks. Table 6 shows the construction properties for the project [15].

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./c.y.)	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

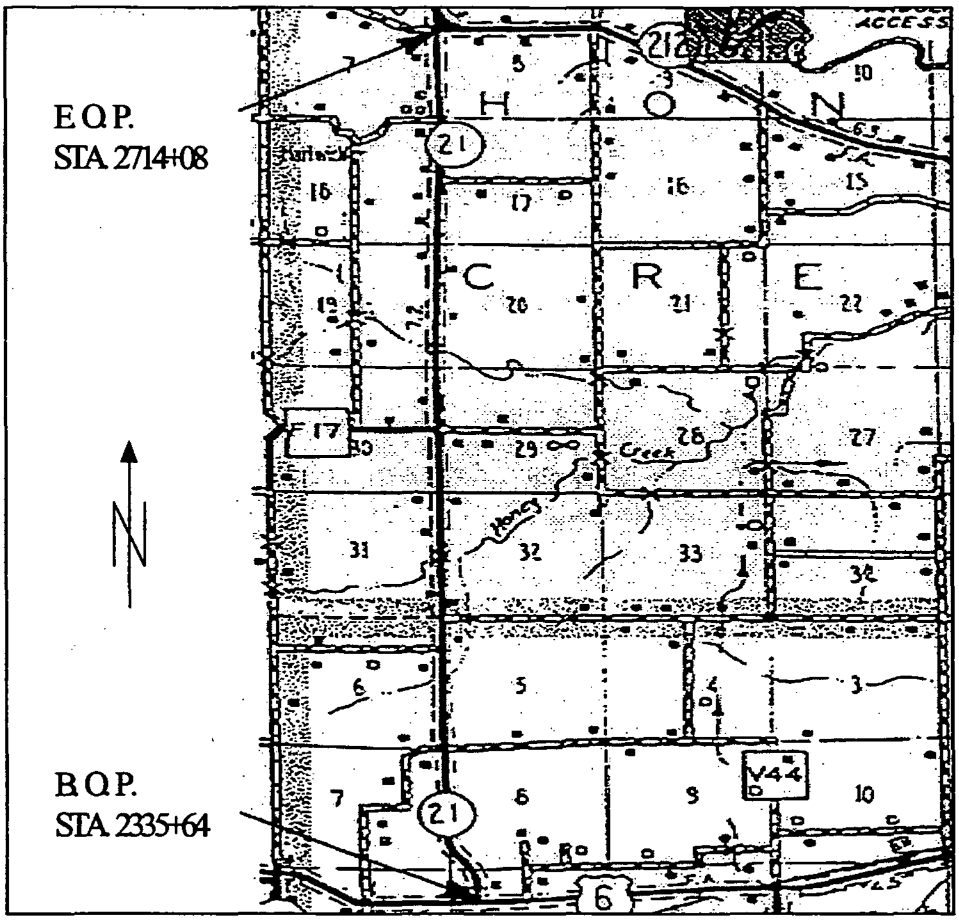
RESEARCH OBJECTIVES

The goal of this project is to evaluate the degree of interface bonding between PCC and ACC layers over time. In conducting research, joint spacing, PCC thickness, use of concrete fibers, surface preparation, and joint sealing are to be under consideration. The objective of this research is to be accomplished by conducting laboratory and field tests, collecting data, and analyzing the data appropriately. Following these steps, a report containing information regarding the various research components will be produced. The report will document practices and results, as well as information concerning the achievements of the research.

TEST SITE DESCRIPTION

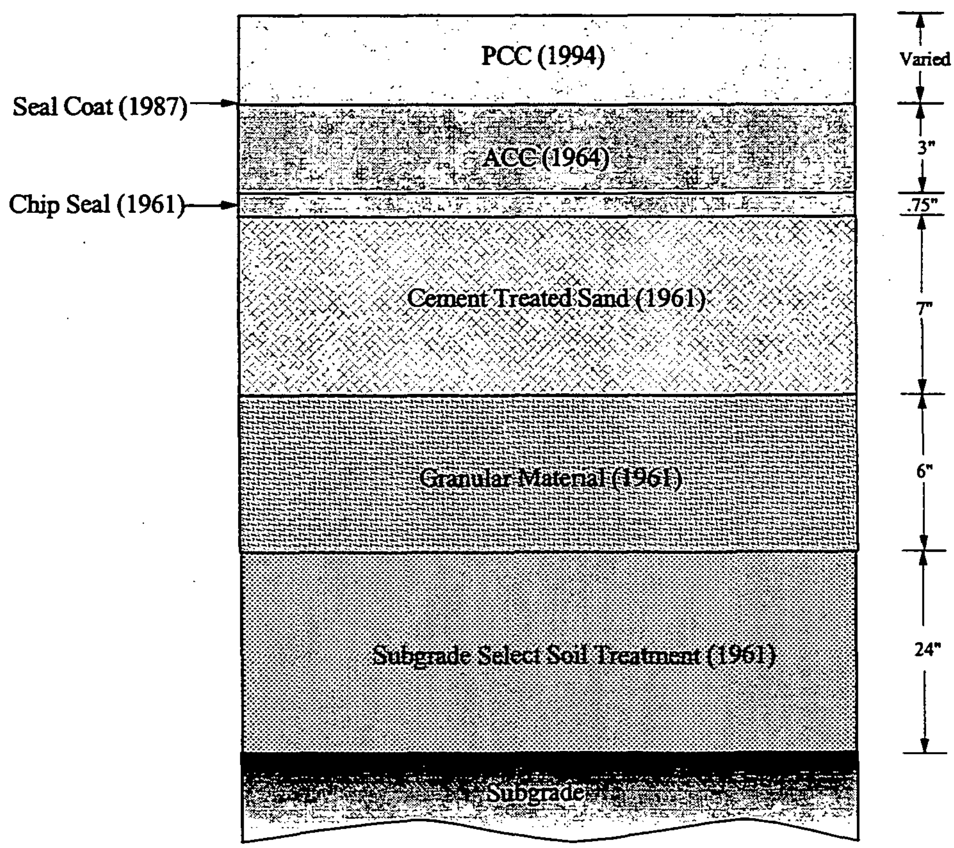
The Iowa Highway 21 project is a 7.2-mile long stretch of roadway that extends from U.S. 6 to Iowa 212 in Iowa County. Figure 1 illustrates the project location.

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) was 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.

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 [16]. 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.

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

EXPERIMENTAL DESIGN

In considering other current UTW projects, Iowa Highway 21 has an advantage in terms of the variation of design specifications within each variable. The design variables considered in this project include ACC surface preparation (milled, patched only, and cold-in-place-recycle (CIPR)); use or non-use of concrete 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 sections); and the use or non-use of joint sealant. Table 8 shows the design characteristics of this project and other current UTW projects [1].

Table 8 – Design characteristics of current UTW projects

Project Reference	A	**B**	C	D	E	F
Location (date)	Kentucky, Louisville, Rd. to Disposal Facility (1991)	**Iowa, Rt. 21 between Victor and Belle Plaine (1994)**	Missouri, Spirit of St. Louis Airport (1994)	Colorado, Denver area, W. of Santa Fe, Frontage Rd. of S. Santa Fe Dr. (1996)	Colorado, Denver area, Colo. 119, E of Longmont (1996)	Colorado, SE corner of state, U.S. 287, N. of Campo (1996)
Concrete thickness (in)	2, 3.5	**2, 4, 6, 8**	3.5	4, 5	4, 5, 6	6
Joint spacing (ft)	2, 6 squares	**2, 4, 6, 12 squares**	4 squares	4, 5, 5.5 squares	6, 12 squares	6X6, 8X12, 10X12, 12X12
Asphalt treatment	Milled	**Patch and scarify, patch only, cold-in-place-recycle**	Lightly milled	Milled, unmilled	Milled, unmilled	Milled
Fiber reinforced PCC	Yes	**Some**	Yes	No	No	No

The project was 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 would represent the beginning of a new test section. Table 9 displays the design properties for the project test sections.

Table 9 – 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

Table 9 (continued)

Section Number	Section Type	Station	PCC Thickness (in.)	Synthetic Fiber Usage *	Joint Spacing (ft. X ft.)	Surface Preparation
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
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	2X2	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

Table 9 (continued)

Section Number	Section Type	Station	PCC Thickness (in.)	Synthetic Fiber Usage *	Joint Spacing (ft. X ft.)	Surface Preparation
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
60	Test	2662+00 - 2689+00	6	N	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	4 X 4, 12 X12	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

CONSTRUCTION

Full depth ACC surface patching was performed two months prior to UTW. Weakened areas exhibiting alligator cracking, raveling, and/or potholes were identified by means of a visual survey. The perimeter of the weakened area was sawed and the

ACC lying within the damaged area was removed. A tack coat was applied to the sides and bottom of the excavation, followed by two lifts of hot mix asphalt (HMA). Each lift was uniformly spread and then compacted with a small steel-wheeled roller. Enough HMA was used on the second lift to ensure the patch would be even with the surrounding ACC after it was compacted. Table 10 shows the location and size of ACC full depth and surface patches on a patch-only surface preparation section.

Table 10 – Location and size of full depth ACC patches

Station	Lane	Dimensions (ft. X ft.)
2340+00 - 2343+00	NBL	300 X 4
2375+00 - 2377+00	SBL	200 X 4
2380+00 - 2384+00	SBL	400 X 4
2381+00 - 2384+00	NBL	300 X 4
2386+00 - 2388+00	SBL	200 X 4
2389+00 - 2391+00	SBL	200 X 4
2393+50 - 2394+50	SBL	100 X 4
2397+00	Both	15 X 12
2397+50	SBL	8 X 12
2399+00 - 2400+00	SBL	100 X 4
2401+00 - 2414+00	SBL	1,350 X 4
2402+00 - 2404+00	NBL	200 X 4
2410+00 - 2413+00	SBL	300 X 4
2411+00 - 2416+00	NBL	500 X 4
2416+00 - 2424+00	SBL	800 X 4
2423+00 - 2425+00	NBL	200 X 4
2435+00 - 2436+25	SBL	125 X 4
2446+00 - 2461+00	NBL	1,500 X 4
2467+00	NBL	6 X 12
2477+00 - 2478+00	NBL	100 X 4
2479+00 - 2482+00	NBL	300 X 4
2488+00 - 2491+00	NBL	300 X 4
2492+00	SBL	6 X 12
2495+00 - 2496+00	NBL	100 X 4
2498+00 - 2502+00	NBL	400 X 4
2508+00 - 2509+00	NBL	100 X 4

Table 10 (continued)

2511+00 - 2514+00	NBL	300 X 4
2520+50 - 2522+50	NBL	200 X 4
2524+00 - 2524+70	NBL	70 X 4
2525+00 - 2526+00	NBL	100 X 4
2526+50	SBL	10 X 12
2544+00 - 2545+00	NBL	100 X 4
2547+00 - 2549+00	SBL	200 X 4
2555+00 - 2559+00	NBL	400 X 4
2555+50 - 2557+00	SBL	150 X 4
2574+00 - 2575+00	SBL	100 X 4
2575+00	SBL	6 X 12
2575+00	NBL	12 X 12
2576+00 - 2577+00	NBL	100 X 4
2579+00 - 2582+00	NBL	300 X 4

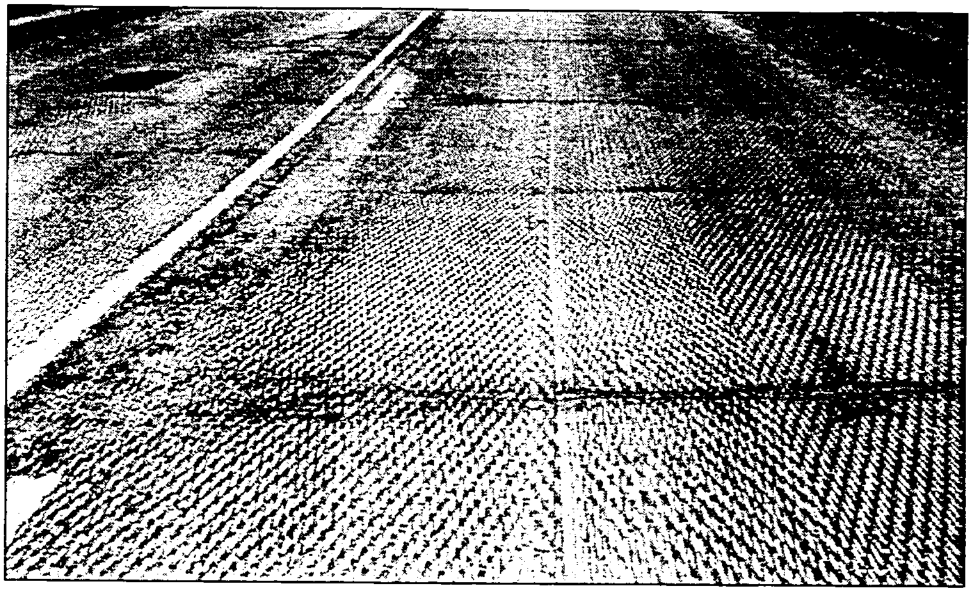
NBL = Northbound lane
SBL = Southbound lane

Cold-in-place-recycling was performed one month in advance of UTW to allow time for adequate traffic compaction and curing. A continuous recycling train was used to place the CIPR. A 12-foot wide milling device at the front of the recycling train removed ACC. The milling device followed the crown of the road and used grade control with a constant removal depth of 3.75 inches. The removed material was fed into a crushing and screening unit where it was sized. It was then moved into the pugging chamber and combined with approximately 2.3 % CSS – 1 emulsion by weight of material. The rejuvenated material was evenly deposited back onto the milled surface. Compaction was achieved with nine passes of a pneumatic-tired roller, followed by a steel-wheeled roller in a non-vibratory mode. Figure 3 shows a typical CIPR surface on highway 21.

Figure 3 - CIPR surface

Milling was performed three weeks before the placement of UTW. A 12-foot wide Roto-Mill made by Construction Machinery Incorporated was used to remove the ACC. The Roto-Mill followed the crown of the road and used grade control with a constant removal depth of 0.25 inches. The removed material was deposited onto the shoulder so that less granular material would be required to build up the shoulder following the placement of UTW. Figure 4 displays a typical milled surface on Highway 21.

Figure 4 - Milled surface



ACC surface patching was conducted one week before the placement of UTW. Small areas exhibiting minor cracking, distortion, and/or raveling were cleaned and sealed with a tack coat. Hot mixed asphaltic cement concrete (HMA) was placed over the area and compacted with a vibratory plate. Excess HMA was then removed. Figure 5 shows ACC full depth and surface patches on a section with patch only surface preparation.

Figure 5 - Full depth and surface patches on a patch only section

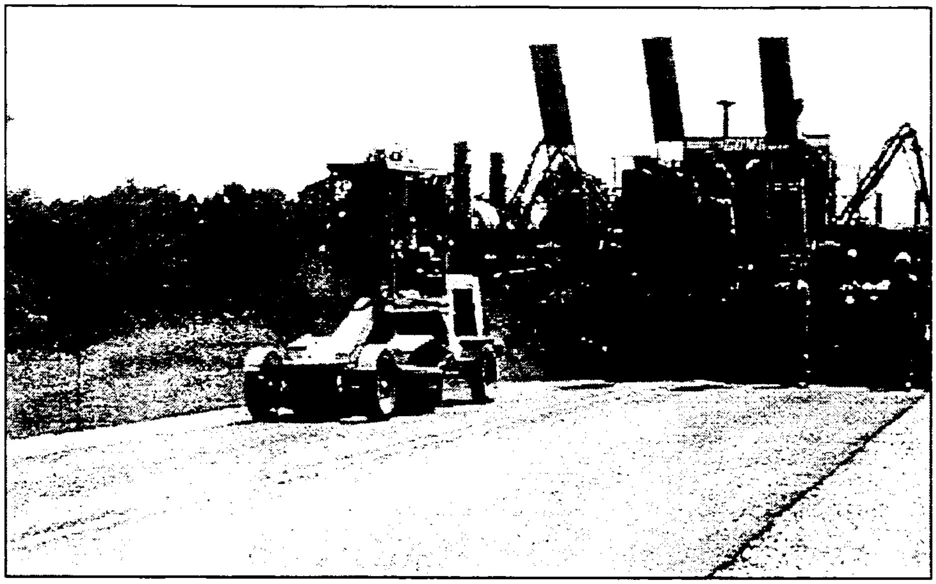
Paving operations took place from June 26 to July 27, 1994. The PCC mixes used included Iowa DOT type C - 3 WR and C - 3 WR - C. The mixes contained a water to cement/fly ash ratio of 0.43 and a target entrained air content of 6 %. Type C - 3 WR was used for sections 46 through 48 and 53 through 56, while type C - 3 WR - C was used for the remaining PCC sections. Table 11 shows the mix proportions by absolute volume of materials per unit volume of PCC.

Table 11 - Mix proportions by absolute volume of materials per unit volume of PCC

Mix	Cement Minimum	Fly Ash	Water	Entrained Air	Fine Aggregate	Coarse Aggregate
C-3WR	0.108	-	0.146	0.060	0.309	0.377
C-3WR-C	0.092	0.019	0.146	0.060	0.308	0.375

Materials were stored, proportioned, and mixed at a portable central plant located at the north end of the project. Agitator trucks and dump trucks transported the mix to the construction location. Power brooming was conducted just prior to the placement of PCC. The brooming removed loose contaminants on the ACC surface. Figure 6 shows the power broom in action.

Figure 6 - Power brooming



A Gomaco slip form paver, with track mounting and electronic horizontal and vertical grade control, was used to pave both lanes of the project simultaneously. In test sections that did not contain synthetic fiber reinforcement and with a PCC thickness of greater than four inches, #4 by three foot epoxy coated steel tie bars were placed across the longitudinal joints. The tie bars were mechanically inserted 30 inches on center across longitudinal joints prior to concrete consolidation. Sixteen horizontally projected vibrators provided consolidation of the concrete. Following vibration, the PCC was struck off to achieve its final thickness and a 2 % crown. Bullfloating, initial texturing, transverse tining, and curing were performed by construction workers.

The sawing of joints began immediately after joint marking, typically 2.5 to 3.5 hours after the application of the curing compound. Joints were cut such that 2, 4, 6, and 12-foot square panels were formed. In addition, 12 X 15-foot and 12 X 20-foot panels were formed. Sawing was performed in segments of approximately 100 feet in length. Table 12 summarizes the joint widths and depths that were constructed. In order to avoid internal stresses, every third transverse joint was cut first, followed by the remaining joints. Longitudinal joints were then sawed continuously from south to north. All joints were formed using the dry sawing method. The rate of placement required as many as eight saws being used simultaneously.

Table 12 - Joint widths and depths

PCC Thickness (in.)	Joint Width (in.)	Joint Depth (in.)
2	$^1/_8$	$^1/_2$
$2 < t \leq 4$	$^1/_8$	1
> 4	$^1/_4$	$1^1/_8$

Joints were sealed one to three days after they were sawed. The process of joint sealing consisted of cleaning the joints with a high-pressure air blast and hot pouring the sealer. Joint sealing was performed when the PCC thickness was greater than four inches. When the PCC thickness was four inches or less, joint sealing was done only in selected trial areas. Sealant is used to prevent sand or debris from entering the joints. This usually occurs with unsealed joints during cold temperatures when the joint openings are at their widest. Subsequently, edge spalling can result when the joints narrow due to warm temperature expansion [18].

Two varieties of synthetic polypropolene fiber reinforcement (fibrillated and monofilament) were used in this project. Fibers were added to the PCC mix at three pounds per cubic yard. The performance of the PCC will be evaluated in terms of the absence or presence of such fibers.

CONSTRUCTION CONCERNS

Difficulties were encountered on numerous occasions in constructing the appropriate PCC thickness. Generally, concerns with thickness involved the actual PCC layer being thicker than designed. However, there was also an occurrence where PCC thicknesses were below that which was specified. These occurrences were the result of survey/grade problems and were resolved by the second day of construction.

The use of fibers caused concerns for construction workers who were trying to finish the slab. The tining process caused fibers to be pulled up to the pavement surface, forming clumps. Both fiber types presented problems with surface finishing. However, the use of monofilament fibers resulted in slab finishing problems to be more pronounced. All clumps disappeared after one day of pavement use by highway traffic.

Section 62 exhibited rutting of the CIPR due to truck traffic. This problem is most likely attributed to areas of weak base material.

The inability to saw joints in a timely manner was a concern. This was limited to the thinner PCC sections that were constructed when air temperatures were extremely high. Also, excess concrete forced the paver pan upward during the paving process on July 18 [17]. This caused the string line to break. A great deal of handwork was required to finish the slab, which resulted in a rough surface in a smaller area.

Other construction concerns were quickly remedied, causing only minor delays. On July 11, a tie bar jammed in the paver [17]. A hydraulic line was disconnected while trying to remove the bar. This happened twice. Other concerns included rainstorms, running out of cement and fly ash, and other equipment breakdowns.

FIELD CHANGES

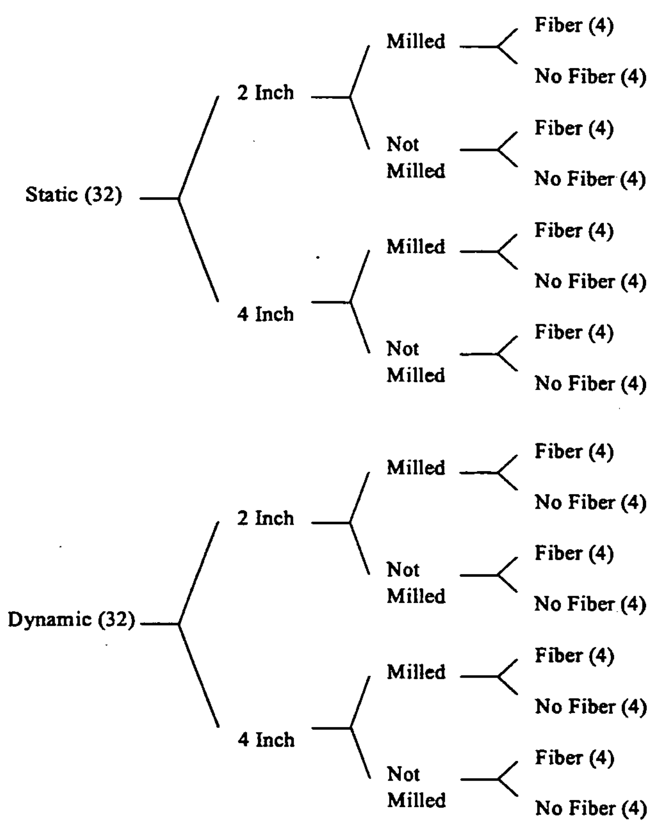
Initial pavement construction practices included wetting the ACC base prior to placing the PCC. This was observed on June 30, and the procedure was stopped. Thus, sections 1 through 15 (approximately half of the patch and scarify sections) were constructed on a wet ACC surface [18]. This is not recommended practice on this type of overlay.

TESTING FREQUENCY AND METHODS

LAB TESTING

Laboratory testing will involve monitoring interface strains in fabricated PCC/ACC composite beams subjected to either static or dynamic flexural loading. Variables to be investigated will include ACC surface preparation (milled or not milled), PCC thickness (2 or 4 inches), and synthetic fiber reinforcement usage (fiber or no fiber). Joint spacing will not be evaluated in the laboratory testing. A total of 64 PCC/ACC composite beams will be constructed. Half of the beams will be used for static testing and the other half will be used for dynamic testing. The static and dynamic test groups are to consist of eight sets of four beam groupings. The groupings will represent the different variable combinations. Figure 7 illustrates the static and dynamic test groups and their beam groupings.

Figure 7 - Static and dynamic test groups



FIELD TESTING EQUIPMENT

Specially constructed deflectometers were assembled for the purpose of monitoring concrete strains. Each deflectometer consisted of a 4 inch long by 0.5 inch wide piece of galvanized 26 gage steel, two Micro-Measurement type CEA-06-125-UN-120 strain gages, two 10-foot segments of AT&T shielded telephone wire, a 1 inch square by 1 inch long section of aluminum tubing, a 1.5 inch long piece of 0.125 inch diameter thread-all, and four 0.125 inch diameter nuts. Figure 8 details the dimensions of the steel piece and the location of the strain gages. Figure 9 shows an assembled deflectometer.

Figure 8 – Location of strain gages on a steel piece

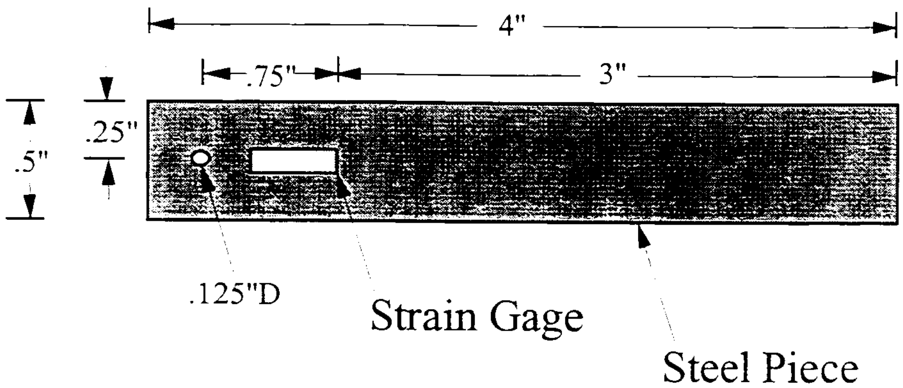
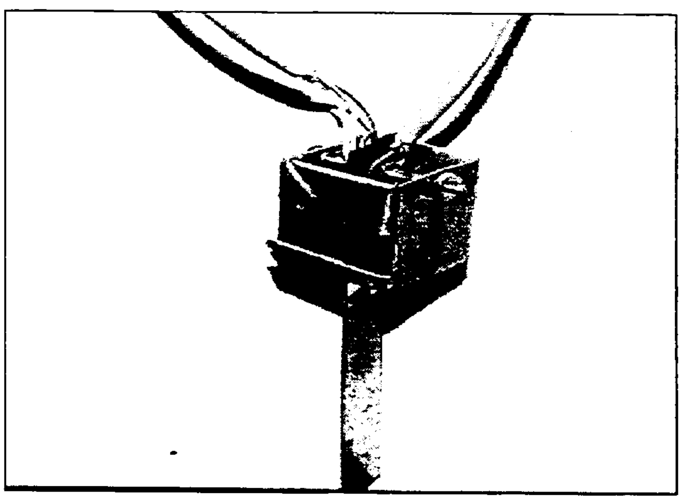


Figure 9 - Assembled deflectometer



FIELD TESTING

Pavement instrumentation was installed approximately 500 feet in front of the paver as paving operations were taking place in order to obtain strain and temperature data. 35 sites (with constant variable properties) were selected for instrumentation. No

ACC sections were instrumented. Approximately 75 % of the sites were located in the northbound lane while the remaining 25 % were in the southbound lane. Table 13 shows the location and as-built properties of the sites selected for instrumentation.

Table 13 – Location and properties of instrumentation sites

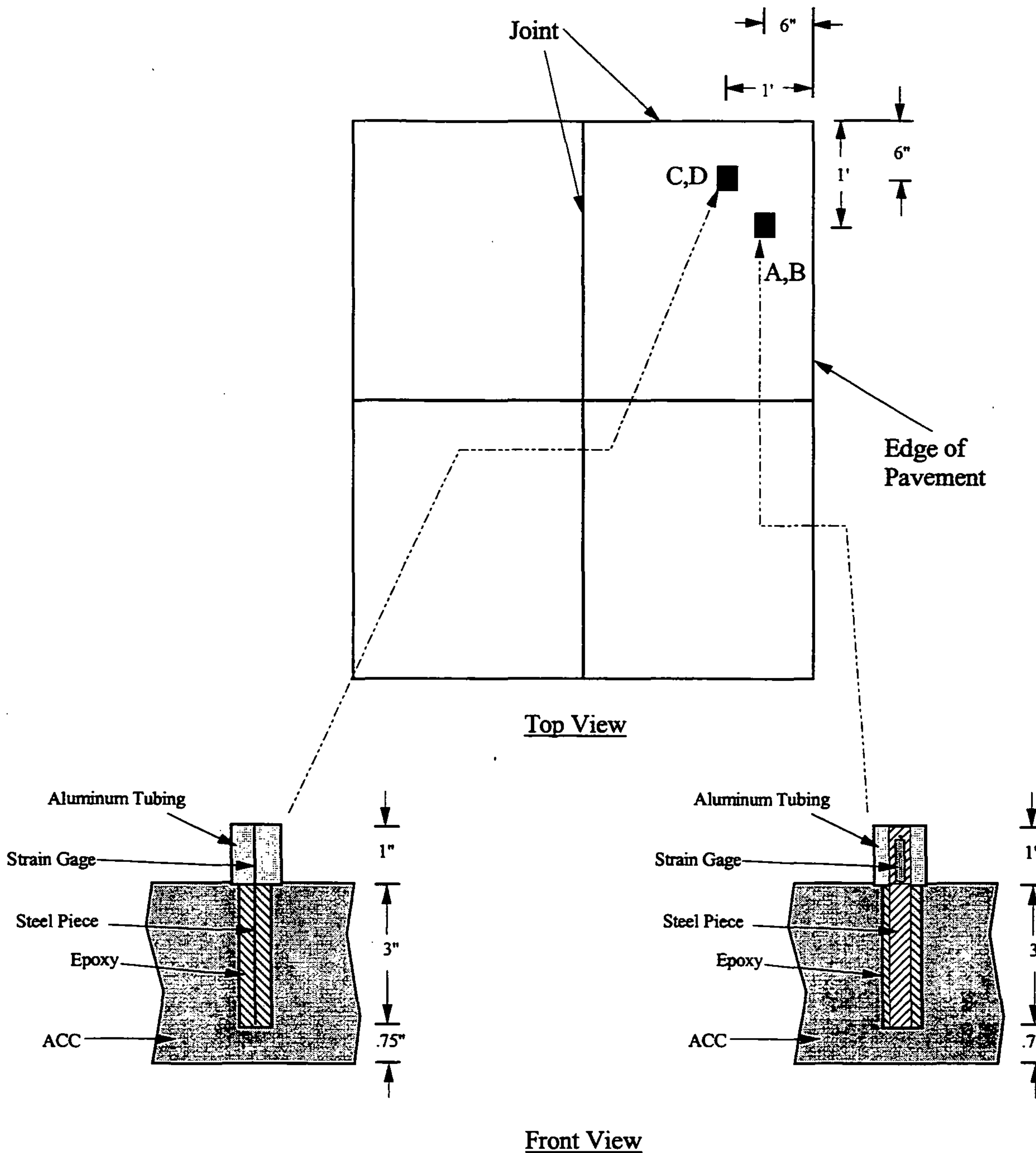
Section Number	Site Number	Station	PCC Design Thickness (in.)	Actual PCC Thickness (in.)	Synthetic Fiber Usage	Joint Spacing (ft. X ft.)	Surface Preparation
3	1	2346+00	6	8.8	F	12 X 12	Milled
4	2	2354+00	6	5.0	F	6 X 6	Milled
6	3	2359+50	4	6.0	F	6 X 6	Milled
7	4	2370+00	4	5.0	F	2 X 2	Milled
8	5	2374+50	4	7.0	F	4 X 4	Milled
10	6	2385+50	2	3.0	F	2 X 2	Milled
11	7	2391+50	2	3.0	M	4 X 4	Milled
13	8	2399+50	6	7.3	M	6 X 6	Milled
14	9	2409+50	6	7.0	M	12 X 12	Milled
18	10	2428+25	6	7.0	N	12 X 12	Milled
19	11	2436+50	6	9.0	N	6 X 6	Milled
21	12	2445+00	4	4.0	N	2 X 2	Milled
23	13	2455+00	2	3.0	N	2 X 2	Milled
26	14	2465+00	6	7.5	N	6 X 6	Patch Only
27	15	2475+50	6	6.3	N	12 X 12	Patch Only
29	16	2485+00	4	5.3	N	4 X 4	Patch Only
31	17	2494+50	8	8.9	N	15 X 12	Patch Only
32	18	2502+00	8	9.8	N	15 X 12 D	Patch Only
36	19	2534+00	6	7.3	N	6 X 6	Patch Only
38	20	2545+50	2	2.8	F	2 X 2	Patch Only
39	21	2550+00	2	4.2	F	4 X 4	Patch Only
41	22	2560+00	4	4.6	F	4 X 4	Patch Only
42	23	2565+00	4	4.0	F	2 X 2	Patch Only
43	24	2574+00	4	4.0	F	6 X 6	Patch Only
46	25	2590+00	6	6.5	F	6 X 6	CIPR
48	26	2596+00	4	4.8	F	6 X 6	CIPR
49	27	2605+50	4	5.0	F	2 X 2	CIPR
50	28	2610+00	4	4.9	F	4 X 4	CIPR
52	29	2620+00	2	3.0	F	2 X 2	CIPR
53	30	2630+00	2	2.8	F	4 X 4	CIPR
55	31	2635+50	6	7.0	N	6 X 6	CIPR
56	32	2650+00	6	6.0	N	12 X 12	CIPR
58	33	2659+50	4	4.8	N	6 X 6	CIPR
60	34	2685+50	6	8.0	N	12 X 12	CIPR
62	35	2694+50	2	5.0	N	4 X 4	CIPR

N = no fibers
F = fibrillated fibers
M = monofilament fibers
D = dowels

Two deflectometers and a thermocouple were installed at each site. The thermocouples used were type IRAD GAGE TH-1. The thermocouples were completely assembled by the manufacturer. They consisted of a thermistor covered in high impact epoxy and encapsulated in an extruded stainless steel shell.

Pavement instrumentation began by using a tape measure to accurately locate the station of the site. Offset measurements from the located station and the edge of pavement were then made to determine the exact positioning of the deflectometers. For all sites, the positioning of the deflectometers relative to the pavement edge and a transverse joint were identical. The deflectometers were installed by drilling holes 0.75 inches in diameter and 3 inches deep into the ACC. The holes were filled with epoxy and a deflectometer was inserted into each one. The deflectometers were oriented at right angles to each other. Each thermocouple was placed horizontally on the ACC between the pair of deflectometers. Figure 10 provides a schematic and the orientation of installed deflectometers prior to PCC placement.

Figure 10 – Schematic and orientation of deflectometers prior to PCC placement

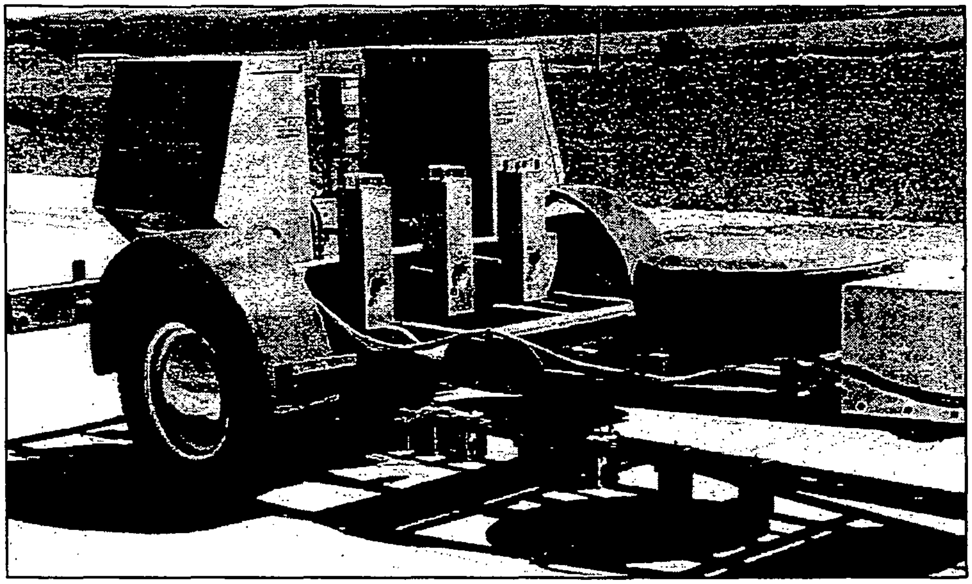


Following installation of the strain gages, shallow trenches with a downward slope away from the roadway were constructed. Each trench extended from the edge of the pavement through the foreslope. A section of two-inch diameter PVC pipe was installed for the length of the trench and protruded slightly out of the foreslope. Wiring from the instrumentation was fed through the PVC pipe. The pipe was sealed at the pavement end and capped with a threaded nut at the foreslope end. Drain holes were placed in the bottom of the pipe near the foreslope end of the pipe. Gage wires were labeled A through D according to their position.

Falling Weight Deflectometer (FWD) testing was conducted before and after the construction of the project. Before construction, the original pavement structure was tested in the outer wheel path of the north and southbound lanes every 300 feet and at locations selected for instrumentation. Each location was tested once. After construction, the new pavement structure was tested at instrumented sites in the center of panels located in the outer wheel path of the instrumented lane.

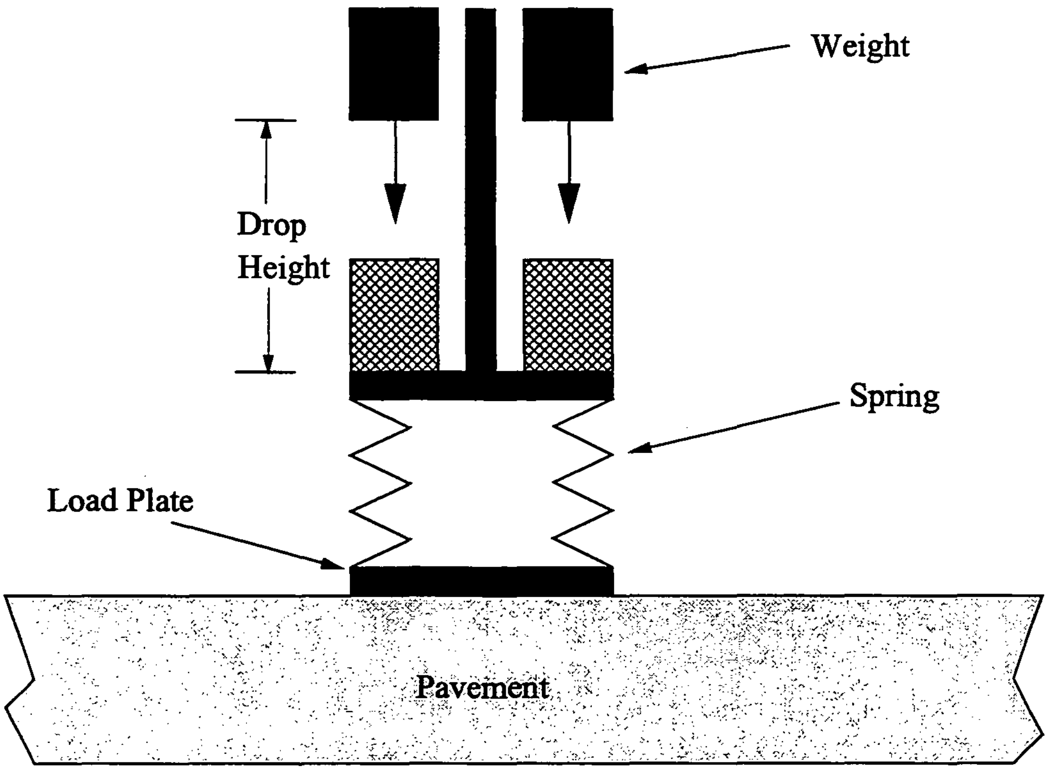
Testing was conducted by ERES Consultants Incorporated of Champaign, Illinois using a Dynatest Model 8081 FWD with a segmented 5.9-inch radius load plate and seven seismic transducers. One transducer was located at the center of the load plate while the others were spaced at radial 12-inch intervals from the plate. A van equipped with a closed circuit television (CCTV), computer, and system processor was used to pull the FWD trailer. The CCTV aided the van driver in positioning the load plate. The computer and system processor controlled testing operations and recorded maximum deflection responses measured by each transducer. Figure 11 shows the FWD testing device.

Figure 11 – FWD testing device



Testing began by preparing the FWD testing device and setting the computer to the appropriate stationing. The distance the van traveled was directly linked to the stationing displayed and recorded on the computer. Tracking of the distance traveled by the van was initiated when the beginning point was reached. At each test location, the van driver positioned the load plate using the CCTV. The computer was then used to lower the load plate and transducers onto the pavement surface and initiate the loading. The load sequence consisted of a seating load followed by test loads of approximately 6, 9, and 12 kips. The different loads were obtained by varying the drop height of the weight. Figure 12 details the FWD loading apparatus.

Figure 12 – FWD loading apparatus



Following the construction of the project, visual distress surveys have been conducted. The types of distresses considered in the survey include transverse cracks, longitudinal cracks, corner cracks, diagonal cracks, popouts, joint spalls, and fractured panels. Surveys typically were conducted during the first Saturday in February, May, August, and November. All surveys were scheduled to begin at approximately 9:00 A.M. and to proceed from south to north. Distress surveying involved one person walking on each shoulder of the highway, recording the type and location of every observed distress.

CONSTRUCTION SUMMARY

Overall, the Iowa Highway 21 project was developed efficiently and according to acceptable construction practices. Construction concerns were relatively minor in nature with the exceptions of difficulty in maintaining proper PCC thickness and the likely areas of weak base material.

Proper construction of the project should provide a solid basis for data collection and analysis. Ultimately, it is desired to gain a better understanding of 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. The number and range of design variables will prove valuable to such research efforts.

REFERENCES

1. Hart, John Michael. "Evaluation of Bonding Between Ultra-thin Portland Cement Concrete Overlays and Asphalt Cement Concrete." Draft Thesis, Iowa State University, 1998.

2. Haisch, Jocelyn Marie. "Investigation of Composite Action in Concrete/Asphalt Pavements." Draft Thesis, Iowa State University, 1999.

3. Heyer, Melinda and Marks, Vernon J. Ultra Thin PCC Overlays. Ames: Iowa Department of Transportation, 1995.

4. Cable, James K., Grove, James D., and Heyer, Melinda. Ultrathin Pavements Making the Grade. Ames: Iowa State University, 1997.

5. ACPA. "Whitetopping – State of the Practice." Engineering Bulletin.

6. Hawbaker, Lon. "Ultra-Thin Whitetopping." The Construction Specifier Aug. 1995: 61-62.

7. Cleaver, Lisa. "Whitetopping Project Upgrades Holiday Inn Parking Lot." Pavement Maintenance and Reconstruction Aug./Sept. 1996: 1-4.

8. Cole, Lawrence W. "Pavement Condition Surveys of Ultrathin Whitetopping Projects." Sixth International Purdue Confrence on Concrete Pavement Design and Materials for High Performance Vol. 2. 18-21 Nov. 1997. Indianapolis: Purdue University, 1997.

9. Mack, James W. et al. Model Development and Intrim Design Procedure Guidelines for Utra-thin Whitetopping Pavements (Report No. 2136). Skokie: American Concrete Pavement Association, 1995.

10. Hawbaker, Lon. "Ultra-thin Whitetopping Spreads." Concrete Products Nov. 1995: 72-73.

11. Civil Engineering Department University of Louisville. High-Strength Whitetopping Performance Evaluation Preliminary Final Report Submitted to Portland Cement Association (Report No. 91-05). Louisville: University of Louisville, 1992.

12. Risser, Robert J. et al. "Ultra-thin Concrete Overlays on Existing Asphalt Pavement." Fifth International Conference on Concrete Pavement Design and Rehabilitation. 20-22 Apr. 1993. West Lafayette: Purdue University, 1993.

13. "List of UTW Projects 1990-1995." UTW Promotion Guide Dec. 1995: 6-1–6-2.

14. LaHue, Sanford P., and Robert Risser Jr. "Ultra-thin Concrete Overlay Supports Truck Loads." Concrete Construction Sept. 1992: 664-667.

15. LaHue, Sanford P. "Ultra-thin Concrete Overlays on Asphalt." Better Roads June 1994: 35-36.

16. Speakman, Jim and Harris N. Scott III. "Ultra-Thin, Fiber Reinforced Concrete Overlays for Urban Intersections." Transportation Research Record 1532 (1996): 15-20.

17. Mowris, Susan. "Whitetopping Restores Air Traffic at Spirit of St. Louis." Concrete Construction June 1995: 532-541.

18. "Leawood, Kansas." Concrete Pavement Progress 35.4 (1995).

19. Tritsche, Steve. "Whitetopping Technique Revives Burgeoning Kansas Thoroughfare." Roads and Bridges Sept. 1995: 52-55.

20. "Experimenting with Ultra-Thin Whitetopping." Midwest Contractor 26 June 1995: 100-102.

21. Wojakowski, John B. Thin Bonded Concrete Inlay Over Asphalt Annual Report (Report No. KS-9301 RE-0049). Kansas: Kansas Department of Transportation, 1995, 1996.

22. Waddel, Joseph J., and Joseph A. Dobrowolski. Concrete Construction Handbook Third Edition. New York: McGraw-Hill, Inc., 1993.

23. Highland, J.D., and R.I. Dideriksen. Soil Survey Report. Washington: U.S. Government Press, 1967.

24. Anderson, Donald A. and Theodore L. Welp. An Engineering Report on the Soils, Geology, Terrain and Climate of Iowa. Ames: Iowa State Commission, 1960.