Final Report
for
Iowa Highway Research Board
Research Project HR-165

FIBROUS P.C. CONCRETE OVERLAY RESEARCH in GREENE COUNTY, IOWA

Office of
County Engineer
Greene County

December 1978

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FINAL REPORT

FOR

IOWA HIGHWAY RESEARCH BOARD

RESEARCH PROJECT HR-165

A FIVE YEAR PERFORMANCE SUMMARY

OF

FIBROUS PC CONCRETE

OVERLAY RESEARCH

IN

GREENE COUNTY, IOWA

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DECEMBER 5, 1978

SUMMARY

The Greene County, Iowa overlay project, completed in October 1973, was inspected on October 16 & 17, 1978 after five years of service.

The 33 fibrous concrete sections, four CRCP sections, two mesh reinforced and two plain concrete sections with doweled reinforcement were rated relative to each other on a scale of 0 to 100. The rating was conducted by the original members of the Project Planning Committee, Iowa DOT, Iowa Counties, Federal Highway Administration, University of Illinois and industry representatives. In all, there were 23 representatives who rated this project. The 23 values were then averaged to provide a final rating number for each section.

The highest panel rating (90) was assigned to the 5-inch thick, deformed bar reinforced PCC sections; an 86 to a 3-inch thick, 160 lbs. of fiber and 600 lbs. of cement on a partial bonded surface; an 84 to the 4-inch CRCP with elastic joints (bonded) and an 84 to a 4-inch mesh reinforced section.

One of the major factors influencing performance appears to be the thickness. In the fibrous concrete overlays, the greatest influence appears to be the fiber content. Overlay sections containing 160 lb/yd^3 of fiber are, in almost all cases, outperforming those containing 60 or 100 lb/yd^3.

It is obvious at this time that the 3-inch thick fibrous concrete overlays are, in general, out performing the 2-inch thick sections.

The performance of the fibrous concrete overlays appears to be favorably influenced by:

(1) The use of higher aspect ratio fiber (0.025 x 2.5 inches) versus (0.010 x 0.022 x 1.0 inches)

(2) The use of a lower cement content (600 versus 750 lb/yd^3)

However, these trends are less well defined and the improvements in overlay performance attributed to high aspect

ratio fibers and low cement contents are not large and may prove to be insignificant.

The intended type of bonding was referred to as: 1. Bonded; 2. Partial; 3. Unbonded. Based upon performance, the sections where bond was intended are in better condition than the partial or unbonded counterparts. Delamtect survey results that bond was not achieved even in the "bonded" sections.

Research on bonded pavement overlays in 1976 and 1977 by the Iowa DOT, Clayton County, Iowa, City of Waterloo and the Iowa Concrete Paving Association proves that bond can be achieved with grout applied to a prepared dry, clean surface.

The major distress in the fibrous concrete overlays is the presence of numerous longitudinal cracks over the widening section. In many cases, this was brought about by failure to achieve the intended overlay thickness.

The formation of longitudinal cracks in the fibrous concrete is more prevalent in the westbound lane over the widening section where traffic loads are greater. In sections where full width and full depth patching without widening was done there is no evidence of longitudinal cracking.

It is felt that the longitudinal cracks over the widening section could be reduced if higher strengths were attained, minimum overlay thickness was maintained or complete bond was achieved.

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IN

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BACKGROUND

The Greene County, Iowa overlay project, completed in October, 1973, is the most comprehensive study every undertaken of fibrous concrete as an overlay for deteriorated highway pavement. The three-mile overlay project, constructed by Hallett Construction Company, includes 33 test sections of fibrous concrete, four test section of continuously reinforced concrete pavement (CRCP), two test sections of mesh reinforced concrete, and two test sections of dowel reinforced concrete.

The mix and design variables for the fibrous concrete overlays included:

(1) Concrete mix design (3)
(2) Fiber size (2)
(3) Fiber quantity (3)
(4) Special cements (Chem Comp [R])
(5) Overlay thickness (2)
(6) Joint spacing
(7) Type of bonding (3)

Replicate sections of several of the test sections were constructed. Table 1 and Figure 1 summarize the Greene County, Iowa overlay project.

The overlay site is a three-mile section of Greene County, Iowa, Road E-53 east of Jefferson, Iowa. The original Lincoln Highway, U.S. 30, partially reinforced concrete pavement (8.5 inch thick and 18 feet wide) was constructed in 1921 and 1922 without joints. At the time of the overlay (1973), the old pavement was very severely cracked and spalled. The traffic count on the pavement is approximately 1100 vehicles per day with 4 to 4½% trucks (counts not taken during harvest season).

Prior to construction of the overlay, 2 feet wide concrete strips were constructed on each side of the old pavement to increase the width from 18 feet to 22 feet. The widening

TABLE 1. SUMMARY, GREENE COUNTY, IOWA OVERLAY PROJECT

Section Number	Station Numbers Begin	Station Numbers End	Cement (lbs.)	Fiber Content (lbs.) 1"	Fiber Content (lbs.) 2-1/2"	Overlay Thickness (in.)	Bond	Joint Spacing (ft.)	Center Line Joint	Transverse Cracks as of April 2, 1974	Skid No.	Remarks
1	0 + 00	4 + 50	569	(Dowels)		5	Partial	20	Yes	4	43	Steel Dowels 1/2"x12' - 3-ft c/c
2	4 + 50	9 + 00	569	(Mesh)		4	Partial	30	Yes	17	45	Steel Mesh 6" x 6"
3	9 + 00	11 + 00	569	(CRCP Anchor)		4	Bonded	0	Yes	13	43	No crack initiators-welded wire mesh
4	11 + 00	17 + 00	569	(CRCP)		4	Unbonded	8	Yes	114	44	Crack initiators 8-ft c/c--58 transv. cracks over initiators
4A	17 + 00	17 + 97	569	(CRCP)		Transition to 3	Unbonded	8	Yes	24	44	Crack initiators 8-ft c/c--10 transv. cracks over initiators
5	17 + 97	24 + 00	569	(CRCP)		3	Unbonded	8	Yes	140	42	Crack initiators 8-ft c/c--66 transv. cracks over initiators
6	24 + 00	26 + 17	569	(CRCP Anchor)		3	Bonded	0	Yes	20	38	No crack initiators-welded wire mesh
7	26 + 17	31 + 90	600	60	--	3	Partial	40 FD	Yes	7	50	FD-joints sawed full depth
8	31 + 90	34 + 05	750	--	60	3	Partial	40	Yes	5	48	
9	34 + 05	37 + 75	600	100	--	3	Partial	40	Yes	4	47	
10	37 + 75	42 + 00	750	100	--	3	Partial	40	Yes	6	44	
11	42 + 00	45 + 95	750	--	--	3	Unbonded	40	Yes	0	40	
12	45 + 95	50 + 00	750	100	--	3	Bonded	40	Yes	4	43	
13	50 + 00	54 + 40	600	60	--	3	Partial	40	No	6	44	
14	54 + 40	57 + 95	500	100	--	3	Partial	40	Yes	5	54	Fly ash addition 234 lbs.
15	57 + 95	62 + 00	500	--	100	3	Partial	40	Yes	3	54	Fly ash addition 234 lbs.
16	62 + 00	66 + 25	600	--	60	3	Partial	40	Yes	7	45	
17	66 + 25	69 + 90	750	60	--	3	Partial	40	Yes	3	32	
18	69 + 90	73 + 65	600	160	--	3	Partial	40	Yes	1	47	
19	73 + 65	77 + 60	600	160	--	3	Partial	40	Yes	5	46	
20	77 + 60	81 + 70	750	--	100	3	Partial	40	Yes	4	41	
21	81 + 70	86 + 05	750	--	100	3	Bonded	40	Yes	17	35	
22	86 + 05	88 + 63.1	500	160	--	3	On Grade	40	Yes	0	52	Fly ash addition 234 lbs.
23	88 + 63.1	90 + 22.8	750	160	--	2-1/4	Bonded	0	No	0	52	Bridge deck overlay 2-1/4-in. depth
24	90 + 22.8	95 + 70	600	100	--	3	Partial	40	Yes	4	46	Curb section
25	95 + 70	99 + 90	750	--	100	3	Unbonded	See Remarks	No	1	32	Chem Comp ® cement, transverse joints 40-ft c/c east half only
26	99 + 90	104 + 20	750	--	160	2	Partial	40	Yes	2	41	
27	104 + 20	107 + 70	600	100	--	2	Partial	40	Yes	3	44	
28	107 + 70	112 + 00	750	100	--	2	Partial	40 FD	Yes	7	44	FD-joints sawed full depth
29	112 + 00	116 + 05	750	100	--	2	Bonded	40 FD	Yes	11	48	FD-joints sawed full depth
30	116 + 05	119 + 75	750	160	--	2	Partial	40	Yes	8	41	
31	119 + 75	123 + 35	600	100	--	2	Partial	40	No	6	44	
32	123 + 35	127 + 65	750	100	--	2	Partial	40	No	8	40	
33	127 + 65	132 + 10	600	160	--	2	Partial	40	Yes	4	46	
34	132 - 10	136 + 30	750	160	--	2	Partial	40	Yes	7	42	
35	136 - 30	140 + 00	750	--	100	2	Unbonded	40	Yes	2	35	
36	140 + 00	144 + 00	750	--	100	2	Bonded	40	Yes	15	41	
37	144 + 00	147 + 92.9	600	--	60	2	Partial	40	No	9	46	
38	147 + 92.9	151 + 83.8	569	(Mesh)		4	Partial	30	Yes	7	50	Steel mesh 6" x 6"
39	151 + 83.8	155 + 84	569	(Dowels)		5	Partial	20	Yes	11	46	Steel dowels 1/2"x12' - 3-ft c/c
40	155 + 84	158 + 00	500	100	--	3	Partial	Various	No	0	50	Fly ash addition 234 lbs.
40A	158 + 00	160 + 18.1	500	160	--	3	On Grade	40	Yes	0	51	Fly ash addition 234 lbs.

SECTION NUMBER	SECTION 1	SECTION 2	SECTION 3	SECTION 4	TRANS	SECTION 5	SECTION 6	SECTION 7	SECTION 8	SECTION 9	SECTION 10
SECTION THICKNESS	5"	4"	4"	4"	4"3"	3"	3"	3"	3"	3"	3"
CONCRETE	Type A	Type A	← Type A (Sections 3–6) →					600# CEMENT 60#	750# CEMENT 60#	600# CEMENT 100#	750# CEMENT 100#
REIN-FORCEMENT	1/2" X 12' Dowels	6 X 6 Mesh	No Joints	← CRCP With Elastic Joints (Sections 4–5) →			No Joints	1" Fiber	2-1/2" Fiber	1" Fiber	1" Fiber
TYPE OF BOND	P	P	B	UB	UB	UB	B	P	P	P	P
LENGTH OF SECTION	450'	450'	200'	600'	97'	603'	217'	573'	215'	370'	425'

STATION NUMBER: 0+00, 4+50, 9+00, 11+00, 17+00, 17+97, 24+00, 26+17, 31+90, 34+05, 37+75, 42+00

	SECTION 11	SECTION 12	SECTION 13	SECTION 14	SECTION 15	SECTION 16	SECTION 17	SECTION 18	SECTION 19	SECTION 20
SECTION THICKNESS	3"	3"	3"	3"	3"	3"	3"	3"	3"	3"
CONCRETE / REINFORCEMENT	750# CEMENT 100# 2-1/2" Fiber	750# CEMENT 100# 1" Fiber	600# CEMENT 60# 1" Fiber	500# CEMENT 234# Fly Ash 100# 1" Fiber	500# CEMENT 234# Fly Ash 100# 2-1/2" Fiber	600# CEMENT 60# 2-1/2" Fiber	750# CEMENT 60# 1" Fiber	600# CEMENT 160# 1" Fiber	600# CEMENT 160# 1" Fiber	750# CEMENT 100# 2-1/2" Fiber
TYPE OF BOND	UB	B	P	P	P	P	P	P	P	P
LENGTH OF SECTION	395'	405'	440'	355'	405'	425'	365'	375'	395'	410'

STATION NUMBER: 42+00, 45+95, 50+00, 54+40, 57+95, 62+00, 66+25, 69+90, 73+65, 77+60, 81+70

FIGURE 1. SECTION SPECIFICATIONS, GREENE COUNTY, IOWA OVERLAY PROJECT

SECTION 21	SECTION 22	SECTION 23	SECTION 24	SECTION 25	SECTION 26	SECTION 27	SECTION 28	SECTION 29	SECTION 30
3"	3"	3"	3"	3"	2"	2"	2"	2"	2"
750# CEMENT 100# 2-1/2" Fiber	500# CEMENT 234# Fly Ash 160# 1" Fiber	750# CEMENT 160# 1" Fiber	600# CEMENT 100# 1" Fiber Curb Section	750# CHEM COMP 100# 2-1/2" Fiber	750# CEMENT 160# 2-1/2" Fiber	600# CEMENT 100# 1" Fiber	750# CEMENT 100# 1" Fiber	750# CEMENT 100# 1" Fiber	750# CEMENT 160# 1" Fiber
B	OG	B Bridge	P	UB	P	P	P	B	P
435'	258.1'	159.7'	547.2'	420'	430'	350'	430'	405'	370'
81+70	86+05	88+63.1	90+22.8	95+70	99+90	109+20	107+70	112+00	116+05
86+05	88+63.1	90+22.8	95+70	99+90	109+20	107+70	112+00	116+05	119+75

SECTION 31	SECTION 32	SECTION 33	SECTION 34	SECTION 35	SECTION 36	SECTION 37	SECTION 38	SECTION 39	SECTION 40	SECTION 40A
2"	2"	2"	2"	2"	2"	3"	4"	5"	3"	3"
600# CEMENT 100# 1" Fiber	750# CEMENT 100# 1" Fiber	600# CEMENT 160# 1" Fiber	750# CEMENT 160# 1" Fiber	750# CEMENT 100# 2-1/2" Fiber	750# CEMENT 100# 2-1/2" Fiber	600# CEMENT 60# 2-1/2" Fiber	Type A 6 X 6 MESH	Type A 1/" X 12' DOWELS	500# CEMENT 234# Fly Ash 100# 1" Fiber	500# CEMENT 234# Fly Ash 160# 1" Fiber
P	P	P	P	UB	B	P	P	P	P	OG
360'	430'	445'	420'	370'	400'	392.9'	390.9'	400.2'	216'	218.1'
119+75	123+35	127+65	132+10	136+30	140+00	144+00	147+92.9	151+83.8	155+84	158+00
123+35	127+65	132+10	136+30	140+00	144+00	147+92.9	151+83.8	155+84	158+00	160+18.1

FIGURE 1. (Continued)

strips, 4 inches thick, were constructed of good quality, lean unreinforced PCC on grade.

Two basic concretes were used in the majority of the fibrous concrete sections. The mixes were chosen to represent extremes in cement content, (Table 1) namely, 600 and 750 lbs. of cement per cubic yard. Other fibrous concretes used in the project contained a cement/fly ash mixture (five sections) or a shrinkage compensating cement (one section).

The steel fibers used were 0.010 inch by 0.022 inch by 1.0 inch long rectangular slit sheet supplied by the U.S. Steel corporation and 0.025 inch OD by 2.5 inch long drawn fiber supplied by the Atlantic Wire Company, Branford, Connecticut. Fiber addition rates were 60, 100, and 160 lbs. per cubic yard. Twenty-two of the fibrous concrete sections contain the 0.010 x 0.022 x 1.0 inch fiber while eleven contain the 0.025 x 2.5 inch fiber.

All of the conventional PCC and CRCP sections were constructed using the Iowa DOT Class A concrete mix proportion containing 569 lbs. of Type 1 cement, 1499 lbs. of fine aggregate, 1522 lbs. of coarse aggregate (1-1/2 inch maximum size), and 270 lbs. of water per cubic yard of concrete. Two test sections were constructed with PCC reinforced with 12 foot long No. 4 bars placed transversely on 3 foot centers at a depth of 2-1/2 inches. Two test sections were constructed with PCC reinforced with a 6 x 6 inch steel mesh (wire diameter = 1/8 inch) placed at half the overlay depth. Twenty-two of the fibrous concrete test sections were 3 inches thick and eleven were 2 inches thick. The conventional PCC test sections were 4 and 5 inches thick and the CRPR sections were 3 and 4 inches thick.

Most of the fibrous concrete sections had transverse joints (Table 1) saw cut (1/4 inch wide) to 1/3 the overlay depth on 40 foot spacings. Centerline longitudinal joints (1/4 inch wide) were cut in most of the test sections at depths of 1/3 the thickness of the overlay. Transverse joints for the re-bar and mesh reinforced concrete sections were saw cut (1/4 inch wide and 1/3 depth) on 20 or 30 foot spacings. Longitudinal joints were cut (1/4 inch wide and 1/3 depth) in all of these sections.

Three conditions of bonding were utilized for the fibrous concrete test sections:

(1) Five sections intended to be fully bonded (cement paste bonding agent on wetted surface)

(2) Twenty-five sections partially bonded (old pavement swept and cracks cleaned prior to overlay).
(3) Three sections unbonded (double thickness of polyethylene sheet between overlay and old pavement).

Two fibrous concrete sections(3 inch design thickness) were placed on grade. The re-bar and mesh reinforced concrete sections were all partially bonded. The CRCP sections were both bonded and unbonded (Parafin base cure).

A detailed report was prepared by the Iowa Concrete Paving Association giving job data on concrete mixture proportioning, concrete properties, test results, section locations, core locations and costs.[1*] Also a report was written by D.R. Lankard and C. H. Henager.[2*]

The only attempts at rating the performance of the various overlay sections have been in the form of crack surveys conducted by the Greene County Engineer's Office and the Iowa Department of Transportation.[3*] These surveys which detail the location, type (transverse and longitudinal) and length of the cracks were made in April, 1974; Oct., 1974; Oct., 1975; Oct., 1976; Oct., 1977 and Oct., 1978.

The present survey, conducted on October 16 and 17, 1978, represents an effort to rate the performance of the overlay sections on the basis of more comprehensive performance criteria.

The current assessment of the condition of the Greene County, Iowa overlay project was made on October 16 and 17, 1978 by the original members of the project Planning Committee, Iowa Department of Transportation, Iowa counties, Federal Highway Administration, University of Illinois and industry representatives. In all,there were 23 representatives who rated this project.

Each one of the 41 sections in the project was thoroughly examined with particular attention given to:
(1) The type and amount of cracking
(2) The type and amount of other forms of pavement distress (spalling)
(3) The presence of repaired areas and the prognosis for needed repairs in the short-term future
(4) Overall condition relative to the other sections on the project

* References are located on Page 21

Following the examination, each section was given a rating with a maximum value of 100 assigned to a section showing zero distress and wear. The rating number was based upon the criteria just discussed with criteria falling into four categories:

100-75	Good	Minor Maintenance
75-50	Above Average	Average Maintenance
50-25	Poor Condition	Imminent Replacement
25-0	Below Average	Severe Maintenance

Each of the following 23 evaluators arrived at a rating independently:

NAME	COMPANY	TITLE
Don Anderson	Iowa Department of Transportation	District Engineer
Jerry Bergren	Iowa Department of Transportation	P. C. Concrete Engineer
Ron Betterton	Greene County, Iowa	Greene County Engineer
Ralph Britson	Iowa Department of Transportation	Road Design Engineer
Mike Darter	University of Illinois	Professor of C. E.
Charles F. Davis	Hallett Construction Company	Area Manager
Dave Hamilton	Penn-Dixie Industries, Inc.	Service Engineer
Frank Howell	Iowa Division F.H.W.A.	Area Engineer
M. J. Knutson	Iowa Concrete Paving Association	Executive Vice President
O. J. Lane, Jr.	Iowa Department of Transportation	District Materials Engineer, Atlantic
John F. McDermott	U. S. Steel Research Lab.	Assoc. Research Consultant
Len McGill	Universal Atlas Cement	Manager Sales Engineering
Vernon J. Marks	Iowa Department of Transportation	Research Engineer
Mikael Olsen	University of Illinois	Graduate Student, C. E.
E. J. Renier	Portland Cement Association	Senior Regional Paving Engineer
Lowell Richardson	Iowa Department of Transportation	Secondary Roads Engineer
Matt Ross	Iowa Concrete Paving Association	Construction Engineer
John R. Schultz	FHWA - Washington	Highway Engineer
Dick Smith	Iowa Department of Transportation	Research Technician
John H. Stevens	U. S. Steel	General Supv. Methods, I. E.
Jerry Stoner	Jackson Construction Co., Inc.	Executive Vice President
C. K. (Bill) Wilson	U. S. Steel Corporation	Asst. Mgr. - Fibercon Sales
William A. Yrjanson	American Concrete Paving Assn.	Director of Engineering

The twenty-three values were then averaged to provide a final rating number of the section. The rating numbers are given in Table 2 of this report.

It is believed that the rating system used in the current survey gives a meaningful ranking of the experimental section based upon their current condition and on speculation concerning their short-term future performance.

DISCUSSION

The data presented in Table 2 was analyzed with a view to identify the effect of a number of variables on the performance of the overlays to date. Using the rating number as an index of relative performance, the effect of the major material and design parameters on the performance of the overlay sections can be assessed.

Overall Overlay Performance

The overall overlay performance ratings as a function of fiber content are summarized in Table 3. For comparison, the ratings of the CRCP and conventionally reinforced concrete overlays are also presented.

It should be noted at this point that since the number of overlay sections representing each fiber content or reinforcement variable are not the same, a statistical ranking of the mean rating values is less meaningful. Nevertheless, for the data discussed in Table 3 (and for other data discussed subsequently), some trends appear obvious. The best average rating value was achieved by the 5 inch thick re-bar reinforced Type A concrete.

Fiber Content

Fibrous concrete overlays containing 160 lb/yd^3 of fiber on the whole showed better performance than those containing 100 or 60 lb/yd^3. The average and range of the rating value for overlay sections containing the lower two fiber contents were very similar.

Fiber Type

The overall effect of fiber type on the performance of the fibrous concrete overlays is shown in Table 4. On this basis, the average rating number of sections containing the 0.025 x 2.5 inch fiber was the same as those of sections containing the 0.010 x 0.022 x 1.0 inch fiber.

Table 5 shows a "head to head" comparison of overlay sections where the only intended variable is fiber type. In all cases, the overlay sections containing the 2.5 inch fiber have a higher rating.

TABLE 2. RATING OF THE OVERLAY SECTIONS OF THE GREENE COUNTY, IOWA PROJECT FIVE YEARS AFTER CONSTRUCTION

Section Number	Panel Rating[a]	Overlay Thickness, Inches	Fiber and Reinforcement Parameters		Cement Factor (lb/yd^3)	Type of Bond of The Overlay
			Type	Amount (lb/yd^3)		
1	90	5	Steel Dowels	(c)	Type A[f]	P
18	86	3	1 (b)	160	600	P(i)
38	84	4	6x6 mesh	(d)	Type A	P
3	84	4	CRCP	-	Type A	B
20	83	3	2.5(e)	100	750	P
23	83	3	1	160	750	B(h)
39	82	5	Steel Dowels	(c)	Type A[f]	P
19	82	3	1	160	600	P
2	81	4	6x6 mesh	(d)	Type A	P
26	79	2	2.5	160	750	P
24	79	3	1	100	600	P
4	78	4	CRCP	-	Type A	U[k]
40A	76	3	1	160	Fly Ash Mix[g]	OG[j]
33	72	2	1	160	600	P
37	71	3	2.5	60	600	P
30	70	2	1	160	750	P
25	69	3	2.5	100	750	U
9	69	3	1	100	600	P
8	69	3	2.5	60	750	P
34	69	2	1	160	750	P
22	69	3	1	160	Fly Ash Mix	OG
21	68	3	2.5	100	750	B
11	68	3	2.5	100	750	U
27	65	2	1	100	600	P
7	64	3	1	60	600	P
12	64	3	1	100	750	B

TABLE 2. (Continued)

Section Number	Panel Rating(a)	Overlay Thickness, Inches	Fiber and Reinforcement Parameters Type	Fiber and Reinforcement Parameters Amount (lb/yd3)	Cement Factor (lb/yd3)	Type of Bond of The Overlay
36	63	2	2.5	100	750	B
16	60	3	2.5	60	600	P
40	59	3	1	100	Fly Ash Mix	P
10	59	3	1	100	750	P
13	56	3	1	60	600	P
31	56	2	1	100	600	P
29	56	2	1	100	750	B
17	55	3	1	60	750	P
28	55	2	1	100	750	P
6	54	3	CRCP	-	Type A	B
5	52	3	CRCP	-	Type A	U
32	50	2	1	100	750	P
35	44	2	2.5	100	750	U
15	42	3	2.5	100	Fly Ash Mix	P
14	40	3	1	100	Fly Ash Mix	P

(a) The subjective rating system used in this survey is described on Pages 7-8 of this report. A value of 100 indicates a section in perfect condition.
(b) (1) refers to steel fibers 0.010 x 0.022 x 1.0 inch.
(c) Dowels (0.5 x 12 feet) placed transversely every 3 feet.
(d) One layer of 6 x 6 mesh placed at midpoint.
(e) (2.5) refers to steel fibers 0.025 x 2.5 inches.
(f) Iowa State Highway Dept. Type A concrete.
(g) 500 lb/yd^3 of Type I cement plus 234 lb/yd^3 fly ash.
(h) B=bonded (cement paste) overlay.
(i) P=partial bond.
(j) OG=slab placed on grade.
(k) U=unbonded overlay (on polyethylene).

NOTE: Section No. 23 is the bridge deck; Section No. 25 contains Chem Comp® cement.

TABLE 3. OVERALL OVERLAY PERFORMANCE RATINGS AS INFLUENCED BY FIBER CONTENT OR TYPE OF REINFORCEMENT

Fiber Content (lb/yd^3) or Other Type of Reinforcement	Number of Overlay Sections Containing Indicated Fiber Content or Reinforcement	Performance Rating Number[a]	
		Average	Range
(160)	9	76	69-86
(100)	18	61	40-83
(60)	6	63	55-71
CRCP	4	67	52-84
Mesh Reinforced	2	83	81-84
Dowel Reinforced	2	86	82-90

(a) See discussion on Pages 7-8.

TABLE 4. FIBROUS CONCRETE OVERLAY PERFORMANCE RATINGS AS INFLUENCED BY FIBER TYPE

Type of Fiber in Fibrous Concrete Overlay, Inches	Number of Overlay Sections Containing Indicated Fiber		Average	Range
	2-in. Thick Sections	3-in. Thick Sections		
0.010 x 0.022 x 1.0[b]	8	14	65	40-86
0.025 x 2.5[c]	3	8	65	42-83

(a) See discussion on Pages 7-8.
(b) Slit sheet fiber produced by U. S. Steel Corporation.
(c) Drawn, chopped wire produced by Atlantic Wire Company.

Cement Content

The overall performance ratings of the fibrous concrete overlays as influenced by the cement content of the concrete (600 and 750 lb/yd^3) are shown in Table 6. Comparisons of overlay sections in which cement content is the only intended variable are shown in Table 7. In both cases, a somewhat better performance rating is indicated for the concretes containing the lower cement factor (600 lb/yd^3).

Overlay Thickness

The overall effect of the thickness of the fibrous concrete overlays on their performance is shown in Table 8. The average performance rating of the 22, 3-inch sections was about the same as that of the 11, 2-inch,sections 62 versus 67. Sections in which the only intended variable is overlay thickness are compared in Table 9. Here a superior performance for the 3-inch thick sections is considerably more evident.

Type of Bonding

The performance ratings of fibrous concrete overlay sections where the only planned variable was the type of bonding are presented in Table 10. Based entirely on this data, the bonded overlays have exhibited performance superior to partial bonded or unbonded sections.

At the time of construction, no equipment for determining the degree of bond was readily available and no testing of this aspect was conducted. During the five years following construction, a Delamtect testing device was developed to locate delaminations in bridge decks. This device has the capability to indicate when a relatively thin loose layer exists. In October, 1978, the entire length of the project was tested in the outside wheeltrack of both lanes. The project was almost completely delaminated except for the 4 and 5" sections. The "bonded" sections exhibited no greater degree of bonding than "partial" or "unbonded" sections. There is no way to determine how much bond was achieved initially on the "bonded" sections.

It was the opinion of some evaluators that the use of polyethylene sheet to produce an unbonded situation yielded the desired effect of minimizing or eliminating reflective cracking (despite a relatively low performance rating in one of the three unbonded sections).

TABLE 5. PERFORMANCE RATINGS OF FIBROUS CONCRETE OVERLAY SECTIONS WHERE THE ONLY VARIABLE IS FIBER TYPE

Overlay Sections In Which the Only Variable Is Fiber Type	Section Thickness, Inches	Performance Rating Number[a]: Section Containing 0.010x0.022x1-in. Fiber	Performance Rating Number[a]: Section Containing 0.025x2.5-in. Fiber
10 and 20	3	59	83
13 and 37	3	56	71
17 and 8	3	55	69
12 and 21	3	64	68
14 and 15	3	40	42
34 and 26	2	69	79
29 and 36	2	56	63
Grand Average		57	68

(a) See discussion of Pages 7-8.

TABLE 6. OVERALL FIBROUS CONCRETE OVERLAY PERFORMANCE RATINGS AS INFLUENCED BY CEMENT FACTOR

Performance Rating[a] Number For Fibrous Concrete Overlay Sections Containing 750 lb/yd^3 of Cement			Performance Rating[a] Number For Fibrous Concrete Overlay Sections Containing 600 lb/yd^3 of Cement		
Number of Sections	Average Rating	Range of Ratings	Number of Sections	Average Rating	Range of Ratings
17	65	44-83	11	69	56-86

Note: The average rating of the five overlay sections containing the cement-fly ash binder was 57 with a range of 40-76. The one section of Chem Comp® cement was 69.

(a) See discussion on Pages 7-8.

TABLE 7. PERFORMANCE RATINGS OF FIBROUS CONCRETE OVERLAY SECTIONS WHERE THE ONLY VARIABLE IS CEMENT FACTOR

Overlay Sections In Which the Only Intended Variable Is Cement Factor	Section Thickness, Inches	Performance Rating Number [a]: Section Containing 750 lb/yd^3 of Cement	Performance Rating Number [a]: Section Containing 600 lb/yd^3 of Cement
10 and 24(9)[b]	3	59	79(69)[b]
30(34) and 33	2	70(69)	72
8 and 37(16)	3	69	71(60)
17 and 13	3	55	56
32(28) and 27(31)	2	50(55)	65(56)
17 and 7	3	55	64
Grand Average		60	66

(a) See discussion on Pages 7-8.
(b) Numbers in parentheses refer to replicate sections.

TABLE 8. OVERALL PERFORMANCE RATING OF FIBROUS CONCRETE OVERLAYS AS INFLUENCED BY OVERLAY THICKNESS

Section Thickness, Inches	Number of Sections	Performance Rating Number[a]	
		Average	Range
2	11	62	44-79
3	22	67	40-86

(a) See discussion on Pages 7-8.

TABLE 9. PERFORMANCE RATINGS OF FIBROUS CONCRETE OVERLAY SECTIONS WHERE THE ONLY VARIABLE IS OVERLAY THICKNESS

Overlay Sections In Which the Only Intended Variable Is Overlay Thickness	Performance Rating Number[a]	
	3-in. Sections	2-in. Sections
18(19)[b] and 33	86(82)[b]	72
25 and 35	69	44
24 and 27	79	65
12 and 29	64	56
21 and 36	68	63
9 and 31	69	56
10 and 28(32)	59	55(50)
Grand Average	72	58

(a) See discussion on Pages 7-8.
(b) Numbers in parentheses refer to replicate sections.

TABLE 10. PERFORMANCE RATINGS OF FIBROUS CONCRETE OVERLAY SECTIONS WHERE THE ONLY INTENDED VARIABLE IS THE TYPE OF BONDING

Overlay Sections In Which the Only Intended Variable Is The Type of Bonding	Performance Rating Number[a]		
	Bonded Overlays	Unbonded Overlays	Partially Bonded Overlays
12 and 10	64	-	59
21 and 11	68	68	-
36 and 35	63	44	-
29 and 32	56	-	50

(a) See discussion on Pages 7-8.

There were construction problems in placing the overlay on the two layers of polyethylene. The shoving developed wrinkles which in places are visible through the overlay.

Pavement on Grade

The two sections prepared as slabs on grade (40A and 22) rated above average (76 and 69, respectively). However, both sections were also 3 inches thick and contained 160 lb/yd^3 of fiber.

Joint Spacing and Construction

In all of the fibrous concrete overlay sections, the joint spacing (sawed joints) was 40 feet (Table 1). The use of sawed joints did not eliminate the formation of transverse cracks in the overlays. Sawing the joints full depth did not have any beneficial effect on overlay performance (Sections 7, 28, and 29). In fact, two of these three sections (28 and 29) had low performance ratings.

In those sections in which the longitudinal centerline joint was not sawed (sections 13, 31, 32, and 37), a random centerline crack is present.

CONCLUSIONS

Based upon the results of the current survey, the salient observations regarding the relative performance of the experimental overlay sections after five years of service are:

(1) The 5" thick No.4 deformed bar reinforced Type A concrete sections have shown the best performance to date. This was followed closely by the 3" thick fibrous concrete overlays with 160 lb/yd^3 of fibers. The 4" thick sections of mesh reinforced and bonded CRPR show relatively high performance.

(2) For the fibrous concrete overlays, the best overall performance is seen in the fibrous concretes containing 160 lb/yd^3 of fiber.

(3) Overall, the use of 60 and 100 lb/yd^3 of fiber in the fibrous concrete overlays produced about the same performance results.

(4) A number of fibrous concrete overlays containing only 60 or 100 lb/yd^3 of fiber have performed quite satisfactorily to date (sections 20, 24, and 37 with ratings in the range of 71 to 83). This result suggests that, under the right conditions, these lower fiber loadings can provide a satisfactory overlay.

(5) In general, the higher aspect ratio fiber (0.025 x 2.5 inch fiber with an aspect ratio of 100) produced a somewhat higher performance rating than the 0.010 x 0.22 x 1.0 inch fiber with an aspect ratio of around 63.

(6) Despite the generalization made in Item No. 5 above, fibrous concrete overlays with high performance ratings were obtained with both fiber types.

(7) The performance ratings of fibrous concrete overlays containing 600 lbs. of cement per yd^3 of concrete were somewhat better than those of the higher cement content overlays (750 lb/yd^3). If this difference is real, it may be due to the probability that the actual water/cement ratios of the low cement content concretes are lower than those of the high cement content concretes. In any event,it is obvious that in this project, increasing the cement content from 600 to 750 lb/yd^3, with its concomitant increase in cost, did not significantly improve overlay performance.

(8) There is strong evidence that, in general, the 3-inch thick fibrous concrete overlays are outperforming the 2-inch overlay.

(9) Despite the generalization made in (8), several 2-inch thick sections (26, 33, and 30) are performing quite well after five years, suggesting that, if conditions are right, good performance can be obtained with thin overlays. These "right conditions" may include the attainment of the design thickness in these thin overlays. Core measurements showed that the average thickness of sections 26, 33, and 30 was 2.0, 2.2, and 2.0 inches, respectively. These sections

also all used 160 lb/yd^3 of fiber. Section No. 32 showed an average thickness of 2.5 inches (design was 3.0). Both of these sections were rated two of the four lowest on the project (50 and 44).

(10) In the majority of areas where severe deterioration had occurred (blocking, cracking,spalling), the overlay was thinner than the design thickness and in a number of cases less than 1.0 inch thick.

(11) The "bonded" sections provided better performance than the "partial" or "unbonded" sections, however, true bond was not achieved on the "bonded" sections.

(12) Sawed transverse joints did not eliminate the formation of cracks in the fibrous concrete overlays whether sawed partially or full depth.

(13) The primary mode of distress in the fibrous con- concrete overlays is longitudinal cracking with associated spalling. The longitudinal cracking is thought to be primarily load induced over the widening sections.

The results obtained to date from the Greene County, Iowa experiment have shown that fibrous concrete can be used to produce thin, high performance highway pavement overlays. However, at this time (five years service), the most cost-effective overlays have been the 5-inch thick re-bar reinforced concrete.

Based on the panel rating, there is nothing to suggest that the performance rating will be significantly reduced in the short term future.

Improvements in the cost-effectiveness of fibrous concrete are needed if the highway pavement overlay market is expected to develop to any significant degree. Some factors that may be further investigated in regard to improved performance of fibrous concrete overlays, are:

(1) The use of fibers which bond better to the concrete.
(2) The use of super water-reducing admixtures.

(3) The placement of low water/cement ratio concretes (made possible by recent advancements in concrete placing equipment for low slump concrete).

(4) The use of 2 inch fiber section using the current methods of complete bonding developed by the Iowa Department of Transportation.

The use of minimum thickness requirement in design and construction procedure considerations (rather than an average requirement) will help in assuring that very thin (1 inch thick) sections of the pavement overlays do not occur.

ACKNOWLEDGEMENTS

We wish to express our appreciation to the Planning Committee (Appendix A) and especially C. A. Elliott and the Greene County Board of Supervisors who made this project a reality.

We also wish to note the contribution of materials and funding by the paving industry:

U.S. Steel
Portland Cement Association
Ash Grove Cement Co.
Dundee Cement Co.
Lehigh Portland Cement Co.
Lone Star Industries
Marquette Cement Co.
Martin-Marietta Cement
Missouri Portland Cement Co.
Northwestern States Portland Cement Co.
Penn Dixie Cement Corp.
Universal Atlas Cement - Div. U.S. Steel
Battelle Corp.
Wire Reinforcement Institute
Construction Materials
Contractors' Steel Corp.
Des Moines Steel Co.
Master Builders
Sioux City Foundry
Chicago Fly Ash
Gomaco
Rex
CMI

We also wish to express our thanks to Vernon J. Marks for assistance in the final report.

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(3) Crack Surveys, Iowa Department of Transportation, Ames, Iowa, April, 1974, October, 1974; October, 1975; October, 1976; and October, 1977

MJK:mkj

APPENDIX

PLANNING COMMITTEE

Member	Position	Company
M. J. Knutson	Executive Vice President	Iowa Concrete Paving Association
Al Schwarz	Fibrous Marketing	U.S. Steel
John Lane	Dist. 4 Materials Eng.	Iowa DOT
Bill Bester	Portland Cement Eng.	Portland Cement Association
Mack Capper	Vice President	Central Paving Company
W. A. Yrjanson	Director of Engineering	American Concrete Paving Association
Dave Lankard	Research	Battelle Corporation
Gene Hardy	County Engineer	Dallas County
C. A. Elliott	County Engineer	Greene County
Glen Perkins	President	Quad City Construction
Don Anderson	Dist. 1 Engineer	Iowa DOT
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