Ten Year 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

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In Cooperation with the Highway Division

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TEN YEAR REPORT
FOR
IOWA HIGHWAY RESEARCH BOARD
RESEARCH PROJECT HR-165

A TEN YEAR PERFORMANCE SUMMARY
OF
FIBROUS PC CONCRETE
OVERLAY RESEARCH
IN
GREENE COUNTY, IOWA

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TABLE OF CONTENTS

SUMMARY

The Greene County, Iowa, overlay project, completed in October, 1973, was evaluated in October, 1978, after five years of service and most recently in October, 1983, after ten 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 original members of the Project Planning Committee, Iowa DOT, Iowa County, Federal Highway Administration, University of Illinois and industry representatives. In all, there were 23 and 24 representatives who rated the project in 1978 and 1983 respectively. The 23 or 24 values were then averaged to provide a final rating number for each section or variable.

All experimental overlay sections had performed quite well in the period from five through 10 years, experiencing only limited additional deterioration. Based upon this relatively good performance through 10 years, the sections will be maintained for further research with another evaluation at 15 years. The 4" thick nonfibrous mesh reinforced continuous reinforced concrete pavement overlay sections provided the best performance in this research project. Another nonfibrous 5" thick bar reinforced overlay section performed almost as well. The best performance of a fibrous reinforced concrete section was obtained with 160 pounds of fiber per cubic yard.

The use of 750 pounds of cement per cubic yard in the fibrous concrete overlays provided no benefit over the use of 600 pounds of cement per cubic yard.

The performance of the fibrous overlays was directly related to fiber content of the concrete mix. The 160 pounds per cubic yard provided the best performance with the poorest performance exhibited by the 60 pounds of fiber per cubic yard. The 2-1/2" long higher aspect ratio fibers produced a higher performance rating than the 1" long lower aspect ratio fiber.

The 3" thick fibrous concrete overlays yielded substantially better performance than the 2" fibrous overlays.

Substantial bonding was not achieved on any of the fibrous concrete overlay sections and, therefore, no conclusion can be reached in regard to type of bonding.

In general, the thicker, nonfibrous pavement overlay sections performed better than the fibrous reinforced concrete overlays. The additional cost of the fibrous concrete overlays cannot be justified based upon the comparitive performance of the fibrous and thicker nonfibrous overlay sections.

A TEN YEAR PERFORMANCE SUMMARY

OF

FIBROUS PC CONCRETE OVERLAY RESEARCH

IN

GREENE COUNTY, IOWA

BACKGROUND

The Greene County, Iowa, overlay project, completed in October, 1973, is the most comprehensive study ever 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 sections of continuously reinforced concrete pavement (CRCP), two test sections of mesh reinforced concrete, and two sections of dowel reinforced concrete.

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

(1) concrete mix design (3)
(2) fiber size (2)
(3) fiber quantity (3)
(4) special cement (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. Tables 1A and 1B 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 inches thick and 18 feet wide) was constructed in 1921 and 1922 without joints. At the time of the overlay (1973), the old pavement was severely cracked and spalled. The traffic count on the pavement is approximately 1100 vehicles per day with 4 to 4-1/2% trucks.

Prior to construction of the overlay, concrete strips two-feet wide were constructed on each side of the old pavement to increase the width from 18 feet to 22 feet. The widening 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, namely, 600 and 750 lbs. of cement per cubic yard. Some fibrous concrete research had indicated that a greater cement content (750 lb.) was needed to derive total benefit of the fiber reinforcement. Other fibrous concretes used in the project contained a cement/fly ash mixture (five sections) or a shrinkage compensating cement (one section).

TABLE 1A 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"	14 Day Flexural Strength (PSI)	Overlay Thickness (In.)	Bond
1	0 + 00	4 + 50	569	(Dowels)		563	5	Partial
2	4 + 50	9 + 00	569	(Mesh)		559	4	Partial
3	9 + 00	11 + 00	569	(CRCP Anchor)		575	4	Bonded
4	11 + 00	17 + 00	569	(CRCP)		565	4	Unbonded
4A	17 + 00	17 + 97	569	(CRCP)		---	Var.	Unbonded
5	17 + 97	24 + 00	569	(CRCP)		671	3	Unbonded
6	24 + 00	26 + 17	569	(CRCP Anchor)		614	3	Bonded
7	26 + 17	31 + 90	600	60	--	575	3	Partial
8	31 + 90	34 + 05	750	--	60	730	3	Partial
9	34 + 05	37 + 75	600	100	--	603	3	Partial
10	37 + 75	42 + 00	750	100	--	680	3	Partial
11	42 + 00	45 + 95	750	--	100	739	3	Unbonded
12	45 + 95	50 + 00	750	100	--	811	3	Bonded
13	50 + 00	54 + 40	600	60	--	718	3	Partial
14	54 + 40	57 + 95	500	100	--	664	3	Partial
15	57 + 95	62 + 00	500	--	100	615	3	Partial
16	62 + 00	66 + 25	600	--	60	662	3	Partial
17	66 + 25	69 + 90	750	60	--	769	3	Partial
18	69 + 90	73 + 65	600	160	--	705	3	Partial
19	73 + 65	77 + 60	600	160	--	811	3	Partial
20	77 + 60	81 + 70	750	160	--	809	3	Partial
21	81 + 70	86 + 05	750	--	100	775	3	Bonded
22	86 + 05	88 + 63.1	500	160	--	677	3	On Grade
23	88 + 63.1	90 + 22.8	750	160	--	775	2 1/4	Bonded
24	90 + 22.8	95 + 70	600	100	--	644	3	Partial
25	95 + 70	99 + 70	750	--	100	719	3	Unbonded
26	99 + 90	104 + 20	750	--	160	674	2	Partial
27	104 + 20	107 + 70	600	100	--	680	2	Partial
28	107 + 70	112 + 00	750	100	--	755	2	Partial
29	112 + 00	116 + 05	750	100	--	741	2	Bonded
30	116 + 05	119 + 75	750	160	--	834	2	Partial
31	119 + 75	123 + 35	600	100	--	612	2	Partial
32	123 + 35	127 + 65	750	100	--	726	2	Partial
33	127 + 65	132 + 10	600	160	--	664	2	Partial
34	132 - 10	136 + 30	750	160	--	808	2	Partial
35	136 - 30	140 + 00	750	--	100	731	2	Unbonded
36	140 + 00	144 + 00	750	--	100	791	2	Bonded
37	144 + 00	147 + 92.9	600	--	60	668	3	Partial
38	147 + 92.9	151 + 83.8	569	(Mesh)		605	4	Partial
39	151 + 83.8	155 + 84	569	(Dowels)		602	5	Partial
40	155 + 84	158 + 00	500	100	--	621	3	Partial
40A	158 + 00	160 + 18.1	500	160	--	865	3	On Grade

TABLE 1B SUMMARY, GREENE COUNTY, IOWA OVERLAY PROJECT

Section Number	Spacing (ft.)	Center Line Joint	Panel Rating Oct.75	Panel Rating Oct.83	Remarks
1	20	Yes	90	86	Steel Dowels 1/2" x 12' - 3-ft c/c
2	30	Yes	81	80	Steel Mesh 6" x 6"
3	0	Yes	84	82	No crack initiators-welded wire mesh
4	8	Yes	78	72	Crack initiators 8-ft c/c
4A	8	Yes	-	-	Crack initiators 8-ft c/c
5	8	Yes	52	46	Crack initiators 8-ft c/c--66
6	0	Yes	54	53	No crack initiators-welded wire mesh
7	40 FD	Yes	64	56	FD-joints sawed full depth
8	40	Yes	69	60	
9	40	Yes	69	65	
10	40	Yes	59	55	
11	40	Yes	68	66	
12	40	Yes	64	62	
13	40	No	56	50	
14	40	Yes	40	40	Fly ash addition 234 lbs.
15	40	Yes	42	43	Fly ash addition 234 lbs.
16	40	Yes	60	60	
17	40	Yes	55	50	
18	40	Yes	86	80	
19	40	Yes	82	77	
20	40	Yes	83	73	
21	40	Yes	68	59	
22	40	Yes	69	55	Fly ash addition 234 lbs.
23	0	No	83	86	Bridge deck overlay 2-1/4-in. depth
24	40	Yes	79	76	Curb section
25	See Remarks	No	69	60	Chem Comp R cement
26	40	Yes	79	64	
27	40	Yes	65	58	
28	40 FD	Yes	55	45	FD-Joints sawed full depth
29	40 FD	Yes	56	50	FD-Joints sawed full depth
30	40	Yes	70	60	
31	40	No	56	52	
32	40	No	50	48	
33	40	Yes	72	62	
34	40	Yes	69	56	
35	40	Yes	44	37	
36	40	Yes	63	52	
37	40	No	71	52	
38	30	Yes	84	70	Steel mesh 6" x 6"
39	20	Yes	82	76	Steel dowels 1/2" x 12' - 3 ft c/c
40	Various	No	59	45	Fly ash addition 234 lbs.
40A	40	Yes	76	51	Fly ash addition 234 lbs.
	Gr. Ave.		67	60	

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-three of the fibrous concrete sections contain the 0.010 x 0.022 x 1.0 inch fiber while ten 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 I 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 No. 4 bars 12 feet long 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 three inches thick and eleven were two inches thick. The conventional PCC test sections were four and five inches thick and the CRCP sections were three and four inches thick.

Most of the fibrous concrete sections had transverse joints 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 rebar 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 rebar 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]

PERFORMANCE EVALUATIONS

The performance of the various overlay sections was documented by crack surveys during the first five years. These surveys, which detail the location, type (transverse and longitudinal) and length of the cracks were made six times in the first five years. The first crack survey was conducted in April, 1974, followed by five crack surveys in October of the years 1974 through 1978. A report documenting these crack surveys is available from the Iowa Department of Transportation.[3] Much of the cracking and deterioration is due to the longitudinal joints between the original slab and the two feet of widening on each side. In retrospect, an evaluation of fibrous concrete overlay variables would have been better on a pavement without widening.

A 23-member rating panel evaluated all research sections in October, 1978, at an age of five years. The five-year evaluation was an effort to rate the performance of the overlay sections on the basis of more comprehensive performance criteria. The personnel participating in the original planning committee, the five-year rating panel and the ten-year rating panel are listed in Table 2. There were 13 members on the original planning committee. There were 23 participants in the five-year evaluation rating panel and 24 participants in the 10-year evaluation rating panel.

The current assessment of the condition of the Greene County, Iowa, overlay project at 10 years was made on October 12, 1983, by members of the original planning committee, Iowa DOT, Iowa County, Federal Highway Administration, University of Illinois, and industry representatives. Each 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 or removal of the entire test section.
4. Overall condition relative to the other sections on the project.

After the careful evaluation, each participant was requested to utilize a "Greene County Evaluation Form" that had been provided to them (Appendix A). Each evaluator was to assign a rating to each section with a maximum value of 100 assigned to a section showing zero distress and wear. The rating number was based upon the criteria previously noted with four general categories:

1. 100-75 good with minor maintenance.
2. 75-50 above average - average maintenance.
3. 50-25 below average - repairs are needed.
4. 25-0 poor condition - major repairs needed.

Table 2 Planning and Rating Personnel

	Name	Company	Planning Committee	5 Year Rating Panel	10 Year Rating Panel
1.	Don Anderson	Iowa DOT	X	X	X
2.	Clair Ball	Portland Cement Association	X		X
3.	Bill Bester	Portland Cement Association	X		
4.	Mack Capper	Central Paving Company	X		
5.	Charles Davis	Hallett Construction Company	X	X	
6.	C. A. Elliott	Greene County	X		
7.	Gene Hardy	Dallas County	X		
8.	M. J. Knutson	Iowa Concrete Paving Assoc.	X	X	X
9.	John Lane	Iowa DOT	X	X	X
10.	Dave Lankard	Battelle Corp.	X		
11.	Glenn Perkins	Quad City Construction	X		
12.	Al Schwarz	U.S. Steel	X		
13.	W. A. Yrjanson	American Conc. Paving Assoc.	X	X	X
14.	Jerry Bergren	Iowa DOT		X	X
15.	Ron Betterton	Greene County		X	X
16.	Ralph Britson	Iowa DOT		X	X
17.	Mike Darter	University of Illinois		X	
18.	Dave Hamilton	Penn-Dixie Industries Inc.		X	X
19.	Frank Howell	FHWA - Iowa		X	X
20.	John F. McDermott	U.S. Steel		X	
21.	Len McGill	Universal Atlas Cement		X	
22.	Vernon J. Marks	Iowa DOT		X	X
23.	Mikael Olsen	University of Illinois		X	
24.	F.J. Renier	Portland Cement Assoc.		X	
25.	Lowell Richardson	Iowa DOT		X	
26.	Matt Ross	Iowa Concrete Paving Assoc.		X	X
27.	John R. Schultz	FHWA-Washington		X	
28.	Dick Smith	Iowa DOT		X	X
29.	John H. Stevens	U.S. Steel		X	
30.	Jerry Stoner	Jackson Construction Co., Inc.		X	X
31.	C. K. (Bill) Wilson	U.S. Steel		X	
32.	Frank Botelho	FHWA - Washington			X
33.	George Calvert	Iowa DOT			X
34.	Chuck Huisman	Iowa DOT			X
35.	Mel Galinet	Michell Fibercon, Inc.			X
36.	Ron Palmien	University of Illinois			X
37.	R. C. Richardson	Davis Walker Corporation			X
38.	Peter Tatnall	Bekaert Steel Wire Corp.			X
39.	Shiraz D. Tayabji	Portland Cement Assoc.			X
40.	William V. Wagner, Jr.	Wire Reinforcement Institute			X
41.	Al Walker	Battelle Development Corp.			X

The 23 values of 1978 and the 24 values of 1983 were averaged to provide a final rating number of each section. The ratings are given in Table 1 and also in Table 3, where the sections have been listed in an order corresponding to the panel rating. The highest rating is listed first, descending to the lowest rating last. It is believed that the rating systems used in the five and 10 year evaluation gives a meaningful ranking of the experimental sections based on their current condition and on speculation concerning their short term future performance.

A careful analysis of project records would indicate that construction problems or the absence thereof exhibited a definite effect on performance ratings. If few or no problems are noted in the project log and paving progressed rapidly, the ratings are higher than for sections where problems resulted in delays. A correlation of this factor is not realistic as numeric values were not assigned to the problems.

DISCUSSION

The data presented in Table 1 was analyzed with a view to identify the effect of a number of variables on the performance of the overlays through 10 years. Using the rating number as an index of relative performance, the effect of major material and design parameters on the performance of the overlay sections can be assessed.

General Comparison

A schematic display of the various variables of each section is given in Figure 1. The bonding condition and the admixture type were not considered major variables and are disregarded for some evaluations within the report. The section identification numbers are contained in the individual spaces in the schematic display. A schematic display of the 10-year rating numbers is provided in Figure 2. The bonding condition and admixture type were disregarded for this schematic summary. Sections 23 (A bridge), 22 and 40A (on grade) and 25 (Chem Comp cement) were excluded from the rating summary. Using this summary rating chart, one can easily compare different variables of the fibrous concrete overlay. These can also be compared with the nonfibrous sections listed beneath the schematic display with the panel rating listed at the bottom of each block. Utilizing this schematic summary, it may be noted that the section receiving the highest 10-year rating was section 3, which was four inches thick utilizing a mesh continuous reinforced concrete pavement. The second highest average rating was achieved by the five-inch thick rebar reinforced Type A concrete. The third highest rating (79) was given to a fibrous reinforced concrete section with 600 pounds of cement and 160 pounds of 1" long fiber. The fourth highest rating was obtained by a four-inch mesh reinforced jointed section.

The average cost of the various overlay sections (Appendix B) was determined using 1973 prices. In general, the use of fibrous reinforcement results in a unit price greater than that of thicker conventionally reinforced overlays.

Figure 1

SCHEMATIC SUMMARY OF THE
VARIABLES OF EACH OVERLAY SECTION

FIBROUS SECTIONS

AS BUILT

Pavement Thick. (in.)	Cement Content (lbs.)	Bonding Condition	Fiber Size (in.)	1									2 1/2								
			Fiber Content (lbs.)	60			100			160			60			100			160		
			Admixture Type	O	N	R	O	N	R	O	N	R	O	N	R	O	N	R	O	N	R
3	600	U																			
		B						Curb													
		P		7	13		9	24			18 19			16	37						
	750	U																11 25		← Chem.	
		B						12			23 ←	Bridge					21			Comp.	
		P			17		10				20			8							
	500+ 234 FA	U																			
		B										On Grade									
		P						14	40		22	40 A ←					15				
2	600	U																			
		B																			
		P						27 31			33										
	750	U																35			
		B						29										36			
		P						28 32			30 34									26	
	500+ 234 FA	U																			
		B																			
		P																			

Admixture
- O None
- N Water Reducer
- R Set Retarder

Bonding
- P Partial
- B Bonded
- U Unbonded

NON-FIBROUS SECTIONS

Sections 1 and 39	Sections 2 and 38	Section 3	Section 4	Section 5	Section 6
5 in.	4 in.	4 in.	4 in.	3 in.	3 in.
Type A	Type A	Type A	Type A	Type A	Type A
Plain	6x6 Mesh	CRC Mesh	CRC Mesh	CRC Mesh	CRC Mesh
Partial Bond	Partial Bond	Anchor Bonded	Unbonded	Unbonded	Anchor Bonded
No Admix.	No Admix.	No Admix.	No Admix.	No Admix.	No Admix.

FIGURE 2 SCHEMATIC SUMMARY OF OVERLAY VARIABLES AND PERFORMANCE RATINGS AT 10 YEARS

FIBROUS SECTIONS

AS BUILT

Pavement Thick. (in.)	Cement Content (lbs.)	Fiber Size (in.)	1			2 1/2		
		Fiber Content (lbs.)	60	100	160	60	100	160
3	600		*53	*70	*79	*56		
3	750		*50	*59	*73	*60	*63	
3	500+ 234 FA			*42			*43	
2	600			*55	*62			
2	750			*48	*58		*45	*64
2	500+ 234 FA							

*Average Performance Rating at 10 Years

Note: Sections 22, 23, 25 & 40A were not included in the average performance ratings.

NON-FIBROUS SECTIONS

Sections 1 and 39	Sections 2 and 38	Section 3	Section 4	Section 5	Section 6
5 in. Type A Plain Partial Bond No Admix.	4 in. Type A 6x6 Mesh Partial Bond No Admix.	4 in. Type A CRC Mesh Anchor Bonded No Admix.	4 in. Type A CRC Mesh Unbonded No Admix.	3 in. Type A CRC Mesh Unbonded No Admix.	3 in. Type A CRC Mesh Anchor Bonded No Admix.
*81	*75	*82	*72	*46	*53

Table 3 OVERLAY SECTIONS ARRANGED IN ORDER OF THE TEN YEAR PERFORMANCE RATING

Section Number	Panel Rating	Cement Content (Lb/yd^3)	Reinforcement or Fiber Type	Amount Of Fiber (Lb/yd^3)	Overlay Thickness Inches	Types Of Bond
23	86	750	1"	160	2 1/4	B.B.
1	86	569	Dowels	-	5	P
3	82	569	CRCP	-	4	B
2	80	569	Mesh	-	4	P
18	80	600	1"	160	3	P
19	77	600	1"	160	3	P
24	76	600	1"	100	3	P
39	76	569	Dowels	-	5	P
20	73	750	1"	160	3	P
4	72	569	CRCP	-	4	U
38	70	569	Mesh	-	4	P
11	66	750	2 1/2"	100	3	U
9	65	600	1"	100	3	P
26	64	750	2 1/2"	160	2	P
12	62	750	1"	100	3	B
33	62	600	1"	160	2	P
8	60	750	2 1/2"	60	3	P
25	60	750	2 1/2"	100	3	U
30	60	750	1"	160	2	P
16	60	600	2 1/2"	60	3	P
21	59	750	2 1/2"	100	3	B
27	58	600	1"	100	2	P
34	56	750	1"	160	2	P
7	56	600	1"	60	3	P
10	55	750	1"	100	3	P
22	55	500*	1"	160	3	O.G.
6	53	569	CRCP	-	3	B
36	52	750	2 1/2"	100	2	B
37	52	600	2 1/2"	60	3	P
31	52	600	1"	100	2	P
40A	51	500*	1"	160	3	O.G.
17	50	750	1"	60	3	P
13	50	600	1"	60	3	P
29	50	750	1"	100	2	B
32	48	750	1"	100	2	P
5	46	569	CRCP	-	3	U
40	45	500*	1"	100	3	P
28	45	750	1"	100	2	P
15	43	500*	2 1/2"	100	3	P
14	40	500*	1"	100	3	P
35	37	750	2 1/2"	100	2	U

*500 lb of cement + 234 lb of fly ash
B.B. Bonded on Bridge Deck
P Partial Bond
B Bonded
U Unbonded
O.G. On Grade

Personnel who had been on the evaluation panel for both the five-year evaluation and the 10-year evaluation expressed the fact that they were pleasantly surprised with the relative condition of all overlay sections at the 10-year performance evaluation. It was the general consensus that based upon the five-year performance evaluation, substantially greater deterioration between five and 10 years had been expected. The grand average of the rating numbers of October, 1978, (Table 1) was 67 and the grand average of all ratings of October, 1983, had decreased to 60. Based upon the five-year rating evaluation, many of the evaluators expressed the opinion that at 10 years, consideration would need to be given for substantial rehabilitation. The general consensus of the 10-year evaluation panel was that the pavement had performed quite well and a substantial effort should be aimed at maintaining the research sections with a further evaluation at 15 years.

Cement Content

Most of the fibrous concrete overlays were placed with concrete made with either 600 or 750 pounds per cubic yard of cement. There were, however, five overlay sections placed with 500 pounds of cement and 234 pounds of fly ash as the binder material. One section was placed using 750 pounds of Chem Comp cement per cubic yard. Comparisons of overlay sections in which the cement content is the only intended variable are shown in Table 4. In five of six comparitive sections where the only major variable is the cement content, the 600 pounds per cubic yard of cement mix outperformed that containing the 750 pounds per cubic yard. The grand average also favored the 600 pounds per cubic yard of cement. This is a relatively small difference and may not be significant when considering other variables. The only explanation for this result would be the drying shrinkage caused by the additional cement with the relatively thin overlay sections being either 2" or 3". Obviously, the 750 pounds per cubic yard cement content does not provide better performance and, therefore, cannot be justified in view of the additional cost. The performance ratings of the sections with 500 lbs of cement and 234 lbs of fly ash were somewhat less than the sections with 600 or 750 lbs of cement. The only direct comparisons are sections 14 and 40 with a rating of 42 vs. comparitive sections for the 750 and 600 pounds of 59 and 70 respectively. This mix can also be compared with the 750 pounds per cubic yard mix with sections 15 vs. 11 and 21 ratings of 43 and 63 respectively. Sections 11 and 25 provided a comparison of Chem Comp expansive cement and a standard 750 pound cement concrete mix. There was no significant benefit derived from the use of the Chem Comp expansive cement.

Fiber Content

Fiber contents of 60 pounds, 100 pounds, or 160 pounds per cubic yard were studied under this research. These fiber contents were used with both the 1" and the 2-1/2" fibers. A comparison of the overlay sections where the only intended major variable was the fiber content is given in Table 5. There are two sets of sections where all three fiber contents were used. When averaging these two, the grand average shows that the 160 pounds per yard is superior to both the 100 pound and the 60 pound with

TABLE 4

PERFORMANCE RATINGS AND FLEXURAL STRENGTHS OF FIBROUS CONCRETE OVERLAY SECTIONS WHERE CEMENT CONTENT WAS THE ONLY MAJOR VARIABLE

COMPARATIVE OVERLAY SECTIONS			FLEXURAL STRENGTH, PSI			AVERAGE 10 YEAR PERFORMANCE RATING		
500 lb/yd^3 +234 lb F.A.	750 lb/yd^3	600 lb/yd^3	500 lb/yd^3 +234 lb F.A.	750 lb/yd^3	600 lb/yd^3	500 lb/yd^3 +234 lb F.A.	750 lb/yd^3	600 lb/yd^3
14, 40	10, 12	9, 24	643	745	624	42	59	70
	30, 34	33		821	664		58	62
	8	37, 16		730	665		60	56
	17	7, 13		769	647		50	53
	28, 29, 32	27, 31		741	646		48	55
	20	18, 19		809	758		73	79
	Grand Average			753	667		58	62
15	11,21		615	757		43	63	
	Grand Average		629	751		42	61	

ratings of 76, 65 and 52 for the 160, 100 and 60 pound contents respectively. The comparitive sections would show that the 100 pound fiber content yields a rating number approximately 10 points higher than that of the 60 and the 160 pound fiber content yields a rating number approximately 10 points better than the 100 pound fiber content. It would appear that the fiber content is one of the more important major variables as two of the 160 pound per cubic yard fibrous sections compared favorably with the 4" and 5" nonfibrous sections. Unfortunately, however, the 160 pounds of fiber per cubic yard increases the cost of the overlay sections substantially.

Fiber Type

Two different fiber types were used in this research as noted earlier. There are six sets of comparitive sections (Table 6) where fiber type is the only major variable. In all six cases, the 2-1/2" long fibers exhibited a performance superior to that of the 1" fiber in the comparitive section. The grand average yields a rating six numbers better for the 2-1/2" fibers than for the 1" fiber.

TABLE 5

PERFORMANCE RATINGS OF
FIBROUS CONCRETE OVERLAY SECTIONS
WHERE FIBER CONTENT WAS THE ONLY MAJOR VARIABLE

COMPARATIVE OVERLAY SECTIONS			AVERAGE 10 YEAR PERFORMANCE RATING		
60 lb/yd^3	100 lb/yd^3	160 lb/yd^3	60 lb/yd^3	100 lb/yd^3	160 lb/yd^3
7, 13	9, 24	18, 19	53	70	79
17	10, 12	20	50	59	73
		Grand Average	52	65	76
	27, 31	33		55	62
	28, 29, 32	30, 34		48	58
	35, 36	26		45	64
		Grand Average		55	67
8	11, 21		60	63	
		Grand Average	54	64	

TABLE 6

PERFORMANCE RATINGS OF

FIBROUS CONCRETE OVERLAY SECTIONS

WHERE FIBER TYPE WAS THE ONLY MAJOR VARIABLE

COMPARATIVE OVERLAY SECTIONS		AVERAGE 10 YEAR PERFORMANCE RATING	
0. 010 x 0.022 X1" Fiber	0.025 x 2.5" Fiber	0.010 x 0.022 x 1" Fiber	0.025 x 2.5" Fiber
7, 13	16, 37	53	56
17	8	50	60
10, 12	11, 21	59	63
14, 40	15	42	43
30, 34	26	58	64
28, 29, 32	35, 36	48	64
	Grand Average	52	58

Overlay Thickness

The thickness of the overlay was intended to be either 2" or 3" except for transition sections. This 2" or 3" thickness was to be a nominal thickness and due to the irregular rough surface of the underlying original concrete, there was substantial variation in the thickness. Some thicknesses of only 1" were sited. There were five sets of sections where the only intended major variable was overlay thickness (Table 7). In all five comparitive sets the 3" overlays provide substantially better performance ratings than do those of their comparitive 2" sections. The grand average is 69 for the 3" vs. 54 for the 2" or a 15 point superiority for the 3" overlays.

TABLE 7

PERFORMANCE RATING OF

FIBROUS CONCRETE OVERLAY SECTIONS

WHERE OVERLAY THICKNESS WAS THE ONLY MAJOR VARIABLE

COMPARATIVE OVERLAY SECTIONS		AVERAGE 10 YEAR PERFORMANCE RATING	
3 inches	2 inches	3 inches	2 inches
18, 19	33	78	62
11, 21	35, 36	63	45
9, 24	27, 31	70	55
10, 12	28, 29, 32	59	48
20	30, 34	73	58
	Grand Average	69	54

TABLE 8

PERFORMANCE RATINGS OF

FIBROUS CONCRETE OVERLAY SECTIONS

WHERE THE ONLY INTENDED VARIABLE WAS THE TYPE OF BONDING

COMPARATIVE OVERLAY SECTIONS			AVERAGE 10 YEAR PERFORMANCE RATING		
Bonded	Unbonded	Partially Bonded	Bonded	Unbonded	Partially Bonded
12		10	62		55
21	11		59	66	
36	35		52	37	
29		28, 32	50		47

Type of Bonding

There are a few sections where the type of intended bonding is the only variable. These are presented in Table 8. 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 identify delaminations in bridge decks. This device was capable of indicating delaminated relatively thin layers. In October, 1978, the entire length of the project was tested in the outside wheel track 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 the "partial" or "unbonded" sections. Experience has shown that overlays are either "bonded" or "unbonded" as a "partial bond" yields an unbonded overlay. Research has shown that a cement grout squeegeed onto a properly prepared dry concrete surface prior to placing the new concrete mix results in a well bonded overlay. For this reason, the type of bonding was not considered as a major variable in this evaluation.

There are, however, four sets of comparitive sections where the type of bonding is the only intended variable. Because of the limited number and the variation among the rating numbers on those comparitive sections, no conclusions can be reached.

Pavement on Grade

The two sections which were placed on grade contained 160 pounds of fiber per cubic yard and were 3" thick. These two sections had performed quite well through five years (ratings of 69 and 76) but have shown substantial deterioration in the period from five through ten years and now exhibit ratings of 55 and 51.

CONCLUSIONS

Based upon the results of the current survey utilizing the rating numbers of the panel as the relative performance of the experimental overlay sections after ten years of service, it can be concluded that:

1. The 4" thick nonfibrous mesh continuous reinforced concrete pavement provided the best performance in this research project. A nonfibrous 5" thick number 4 deformed bar reinforced concrete section performed almost as well.

2. The best performance of fibrous reinforced concrete was by those sections containing 160 pounds of fiber per cubic yard.

3. In general, the fibrous concrete overlays have provided a 10-year performance superior to that expected at the 5-year evaluation.

4. The performance ratings of the fibrous concrete overlays containing 600 pounds of cement per cubic yard were somewhat better than those of the overlays with 750 pounds of cement per cubic yard. It is obvious that in this project increasing the cement content from 600 to 750 pounds per cubic yard with its increase in cost, did not significantly improve overlay performance.

5. The performance of the overlays was directly related to the fiber content of the concrete mix with the 160 pounds of fibers per cubic yard mixes providing the best performance, followed by those containing 100 pounds of fibers per cubic yard, with the poorest performance exhibited by the mixes containing only 60 pounds of fibers per cubic yard.

6. The higher aspect ratio fiber (0.025 x 2.5" fiber with an aspect ratio of 100) produced a higher performance rating than the 0.010 x 0.022 x 1.0" fiber with an aspect ratio of about 63.

7. The 3" thick fibrous concrete overlays yielded substantially better performance than the 2" fibrous overlays.

8. Substantial bonding was not achieved on any of the fibrous concrete overlay sections and, therefore, no conclusions can be reached in regard to type of bonding.

9. The additional cost of the fibrous reinforcement cannot be justified based upon the 10-year comparitive performance of the fibrous and 4" and 5" thick nonfibrous sections.

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APPENDIX

GREENE COUNTY
EVALUATION FORM

The purpose of this sheet is to evaluate independently the 42 different test sections on E-53 Greene County Road from the east corporation limits of Jefferson west 3.0 miles. We ask that each evaluator be objective in their rating and pay particular attention 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 or removal of the entire test section.
4. Overall condition relative to the other sections on the project.

The following rating system will be used:

0-25	25-50	50-75	75-100
Poor Condition Major repairs are needed. (Please comment if the section should be replaced.)	Below Average Repairs are needed.	Above Average Average maintenance is needed.	Good Only minor or no maintenance is is needed.

Number	Bond Type P Partial Bonded U Unbonded B Bonded	Section	Overlay Thickness	Rating	Comments
1	P	Type "A" Plain Concrete 1/2" x 12' Tie Bars	5"		
2	P	Type "A" Plain Concrete Mesh Rein. 6" x 6"	4"		
3	B	CRC 3" x 16" Steel	4"		
4	U	CRC 8' Crack In. 3" x 16" Steel	4" - 4 3" - 4A		

AVERAGE COST OF OVERLAYS

Thickness	Cement lbs./cu.yd.	Fiber lbs./cu.yd.	Cost Sq. Yd.
2"	600	100	$3.40
2"	600	160	$4.10
2"	750	100	$3.52
2"	750	160	$4.22
3"	500 + 234 fly ash	100	$4.94
3"	500 + 234 fly ash	160	$5.61
3"	750	160	$6.64
3"	750	100	$4.56
3"	750	60	$3.86
3"	600	160	$5.42
3"	600	100	$4.30
3"	600	60	$3.61

SPECIAL SECTIONS

Description	Cost per square yard
5" plain concrete	$3.57
4" type A concrete with mesh	$3.58
4" CRCP with elastic joints	$4.41
3" CRCP with elastic joints	$3.48