EVALUATION OF SILICA FUME HIGH DENSITY THIN BONDED OVERLAYS

Interim Report
February 2001

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15. SUPPLEMENTARY NOTES
Silica fume concrete is performed well the first year under traffic.

16. ABSTRACT

In September 1999, Bridges "A" and "B" of contract TBOI-0035-1(110)044 were overlaid with a silica fume concrete surface. ODOT has been exploring ways to stop or slow chloride-induced corrosion of uncoated reinforcing steel in bridge decks. Silica fume concrete additive has demonstrated success in reducing chloride intrusion.

After one year of testing, the ride quality decreased slightly, skid test results show an adequate amount of friction characteristics. and both bridges in good condition base on based on reinforcing steel corrosion activity. Overall, silica fume modified PCC overlay is performing well.

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SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.40	millimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.9144	meters	m
mi	miles	1.609	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.0929	square meters	m^2
yd^2	square yards	0.8361	square meters	m^2
ac	acres	0.4047	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0283	cubic meters	m^3
yd^3	cubic yards	0.7645	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.4536	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.448	Newtons	N
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa

Approximate Conversions from SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.0394	inches	in
m	meters	3.281	feet	ft
m	meters	1.094	yards	yd
km	kilometers	0.6214	miles	mi
		AREA		
mm^2	square millimeters	0.00155	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.196	square yards	yd^2
ha	hectares	2.471	acres	ac
km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME		
mL	milliliters	0.0338	fluid ounces	fl oz
L	liters	0.2642	gallons	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
		MASS		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	degrees Celsius	9/5+32	degrees Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	Newtons	0.2248	poundforce	lbf
kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

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INTRODUCTION

In September 1999, the Oklahoma Department of Transportation (ODOT) placed silica fume modified PCC overlays on two bridges on I-35 in Carter County. The first year of testing was completed in October 2000.

ODOT has been exploring ways to stop or slow chloride-induced corrosion of uncoated reinforcing steel in bridge decks. One method widely used to prevent chloride intrusion is placement of thin, low permeability PCC overlays on the existing decks. Silica fume is a commonly used PCC additive where high density and low permeability is desired. Added benefits of overlays are improved smoothness and friction characteristics. Other agencies have reported that silica fume modified PCC overlays have demonstrated success in reducing chloride intrusion and restoring driving surfaces of bridge decks(2).

INVESTIGATION

Various researchers have expressed concern that the difficulty of curing silica fume mixes might lead to cracking, which in turn, can be a cause of delamination(1). Cracking of the overlay was measured and mapped. The following observations regarding cracking were made.

The south bound bridge has a longitudinal construction joint which travels the length of the project. The joint is located on the inside half of the outside (west) lane. A crack formed over this joint which has a maximum width of 6 mm ($^1/_4$ inch). All other cracks were randomly spaced over approximately 10 percent of the bridge deck of the southbound bridge. These are "hairline" cracks size in accordance with SHRP-3-338 manual, a fracture that is very narrow in width, less than 3mm ($^1/_8$ inch).

The north bound bridge also had a construction joint in the corresponding location (inside half of the outside, or east, lane). Maximum width of the crack over this joint was 3 mm ($^1/_8$ inch). Hairline cracks were randomly located over approximately 25 percent of the northbound bridge. Crack maps of each of the two bridges are included in Appendix A.

All four lanes of the two bridge decks were chain-dragged tested to detect the presence of delamination or debonding. Deck areas where the deck has a horizontal fracture plane give a hollow sound when a chain is dragged on their surface. Generally, it is not possible to distinguish between delamination and debonding using manual sounding techniques (3). The longitudual construction joints on both bridges gave the hollow sound during chain drag testing. These were the only locations, on either bridge, where delamination or debonding was indicated. No debonding was noted at these locations during the testing done after completion of the overlays (September 1998), indicating that any delamination or debonding present has occurred since then.

Half-cell testing (ASTM C - 876 - 80) was done on both bridges to detect electrical potentials associated with corrosion. Locations where the individual half-cell potentials were measured, and the amounts of the readings, are shown in Appendix A. Half-cell readings are divided into three classes, based on the measured potential. These are listed below:

Class	Potential(v)
• Class "A"	- .250 to - .350
• Class "B".	-360 to - .400
• Class "C"	-.410 and more negative.

Seven percent of the readings on the southbound bridge and 2.9 percent of the readings done on the northbound bridge were in the Class "A" range. No readings were classified as Class "B" or "C".

Smoothness of the bridge was measured with an Ames 4000 - B profilograph and a K. J. Law T-6400 Lightweight Profilometer. Each lane of each bridge deck was measured with each of the instruments. Measurements from both the profilograph and the profilometer are listed in Appendix

B. On the southbound bridge, the profile index for the outside lane was 25.71 in/mi. and 17.41 in/mi. for the inside lane. The average profile index (both lanes) was 21.56 in/mi. The northbound bridge had a profile index of 20.00 in/mi in the outside lane and 7.92 in/mi in the inside lane. The average of both lanes on this bridge was 13.96 in/mi.

Skid trailer measurements were also taken. The skid trailer was able to get one measurement for each lane of each bridge. Skid trailer measurements are expressed as skid numbers (SN). Measured values were 43, 52, 42, 46. Skid data sheets are included in Appendix B.

The ODOT interstate maintenance yard for the area containing the two bridges used 5:1 sand to salt mixture for deicing bridge and highway surfaces. Thirty light applications of sand/salt mixture has been placed on each bridge since completion of the silica fume modified overlay. The mixture was applied at a rate of less than 20 lb per square yard.

CONCLUSION

One year of test data has been summarized in this report. Regarding chloride ion transport through concrete, the presence of interconnected pores, cracks, hairline cracks, and aggregate particles will affect the ability of the chloride ions to migrate into the concrete(4).

Hairline cracking was the major distress found on the bridge decks. The 1999 half-cell readings on the southbound bridge had 2.9 percent in the Class "A" category. By 2000, Class "A" readings had increased to 7.0 percent. Locations with hairline cracking and relatively high half-cell readings tend to occur in the same general areas, indicating that chloride intrusion through the hairline cracking is the likely cause of the higher readings.

The ride quality decreased slightly, skid test results show an adequate amount of friction

characteristics. Carter county had a mild winter during the last evaluation period (less freeze-thaw cycle then the rest of Oklahoma). Results of half-cell testing indicates that both bridges are in good condition, based on reinforcing steel corrosion activity. Overall, the two silica fume modified PCC overlays are in good condition and performing well.

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2. Wilson B. Brewer, Jr. and Gary Williams, "Evaluation Of Silica Fume High Density Thin Bonded Overlays-Construction Report". Research & Development Division, Oklahoma Department of Transportation, Oklahoma City, OK, March 2000.

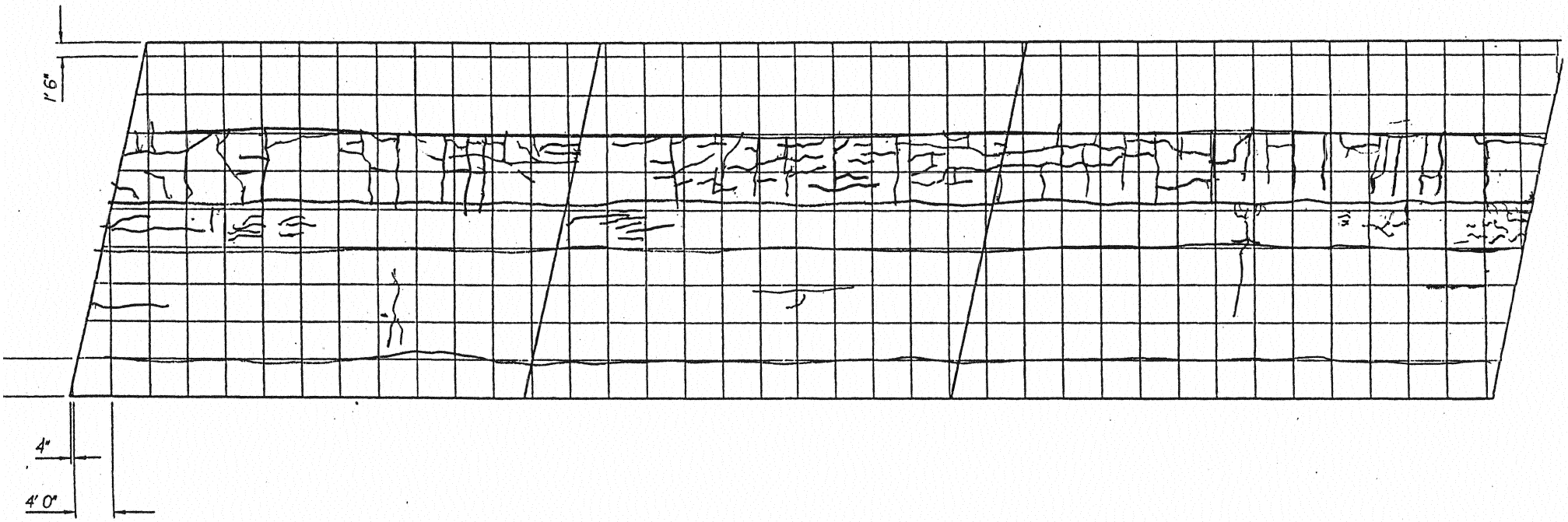
3. Osama A. Abdulshafi and Micheal G. Fitch, "Field and Laboratory Evaluation of Silica Fume Modified Concrete Bridge Deck Overlays in Ohio", CTL Engineering, Inc, Ohio Department of Transportation, Columbus, OH, July 1995.

4. D. Whiting and R. Detwiler, "Silica Fume Concrete for Bridge Decks, National Cooperative Highway Research Program, Transportation Research Council, Washington D.C.. 1998.

APPENDIX A

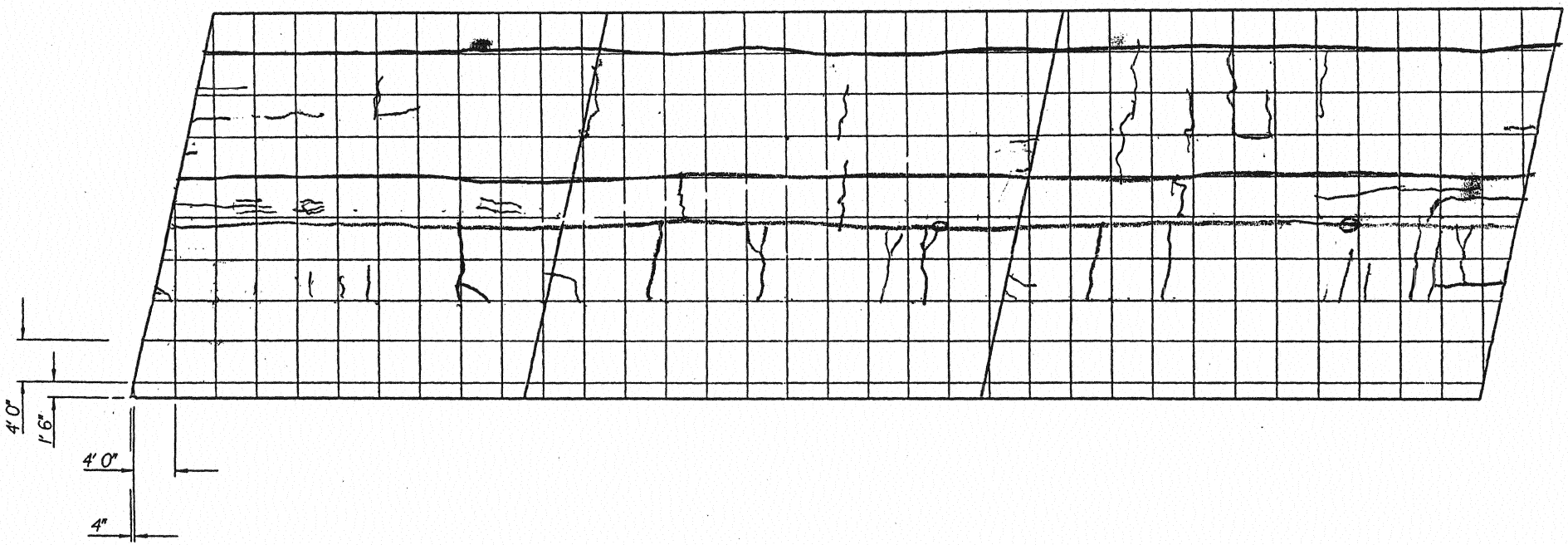
CRACK MAPS

CRACK MAP OF SOUTH BOUND BRIDGE



SB

CRACK MAP OF NORTH BOUND BRIDGE



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APPENDIX B
HALF CELL TESTING

Oklahoma Department of Transportation

Research and Development Division

Date October 6,2000

To Wilson Brewer

From Bryan W. Cooper

Subject Half Cell testing and deck analysis on Silica Fume bridge project in Carter County Item No. 2132

I have analyzed the results of the half-cell testing that was conducted on October 3, 2000. I have concluded from the results of this testing that there is very little corrosion in the reinforcing steel of these particular bridge decks.

Half-cell test readings are divided into three classes. They are Class "A", Class "B", and Class "C".The classification of these readings are specified within these following ranges:

Class "A": .250 - .350

Class "B": .360 - .400

Class "C": .410 and greater

A plan view of these bridge decks has been provided and displays the grid layout that was used in this testing and the readings that were gathered at each point.

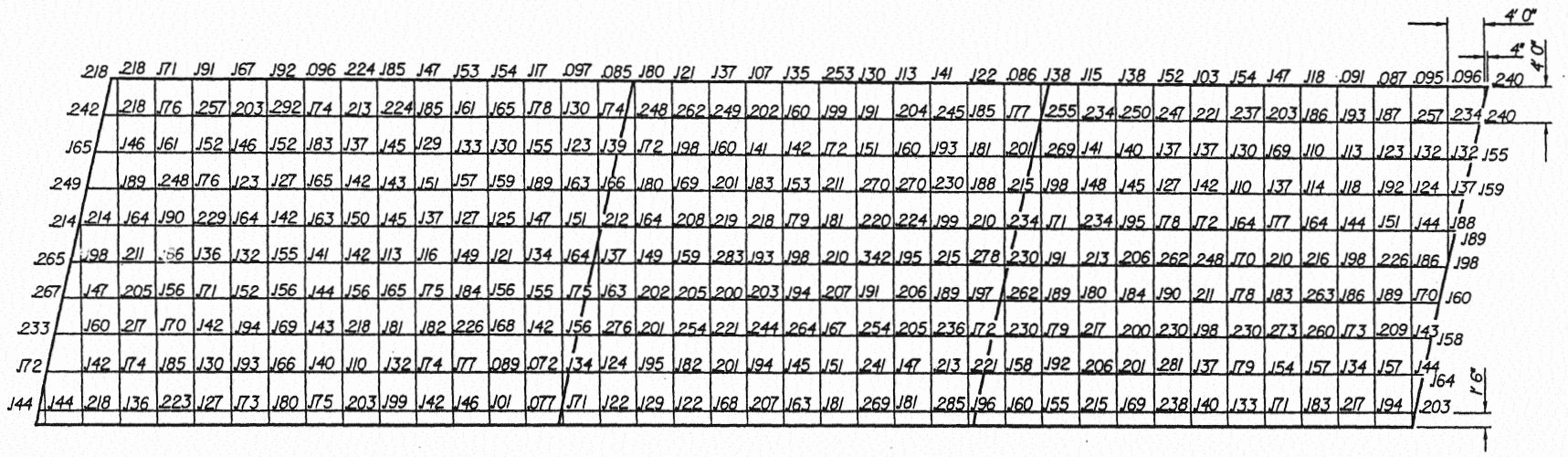
The results of this analysis shows that there was only 2.9% Class "A" readings on the Northbound bridge and no Class "B" or "C" data. The testing on the Southbound bridge indicated 7.0% of Class "A" readings and no Class "B" or "C" indications, Class "C" being the most critical. The 1999 results indicated 2.6% for the Northbound and 4.2% for the Southbound.

It is my belief that your crack mapping results will indicate that the cracking in the southbound bridge, is a major contributor to the increase of the percentage of Class "A" readings on this bridge.

The results seem to indicate that we still have two bridges in good shape in reference to the corrosion of the reinforcing steel.

Cc: Gary Williams

CLASS "A" % :7.0%
CLASS "B" % :0%
CLASS "C" % :0%

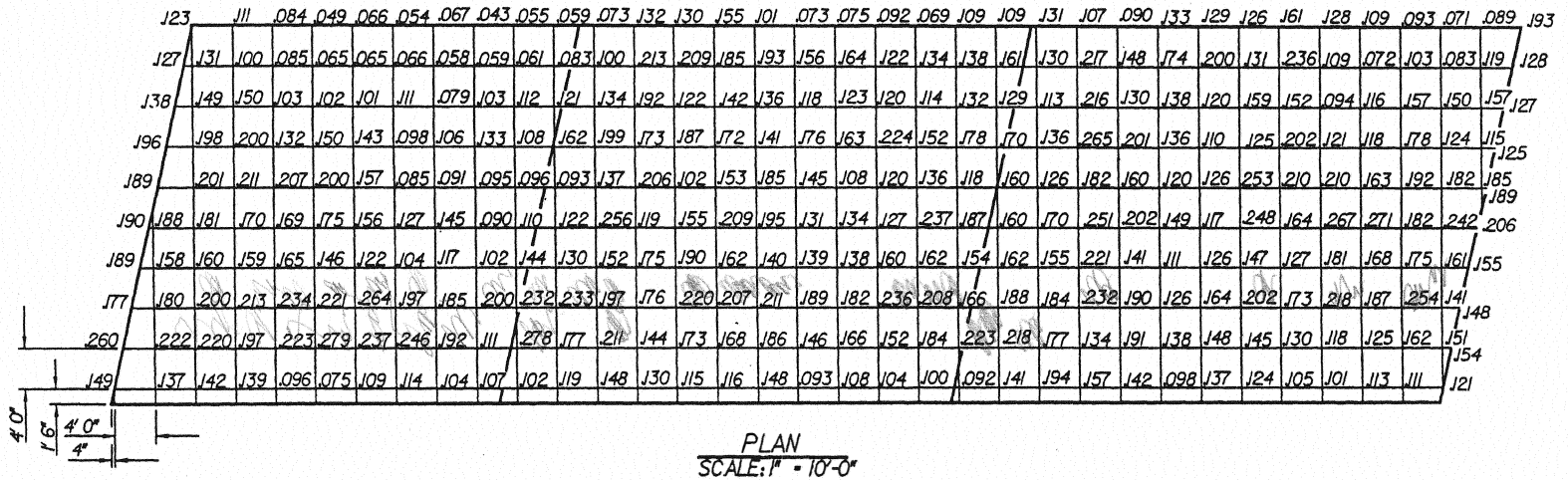


PLAN
SCALE: 1" = 10'-0"

I-35 Southbound Carter County
SILICA FUME
DECK ANALYSIS
STATE OF OKLAHOMA DEPARTMENT OF TRANSPORT

CLASS "A" % : 29%
CLASS "B" % : 0 %
CLASS "C" % : 0 %

CLASS "A" : .25 - .35
CLASS "B" : .36 - .40
CLASS "C" : .41 and Above



PLAN
SCALE: 1" = 10'-0"

I-35 Northbound Carter County
SILICA FUME
DECK ANALYSIS
STATE OF OKLAHOMA DEPARTMENT OF TRANSPORT

APPENDIX C
PROFILE RESULTS

Oklahoma Department of Transportation
Materials and Research Division

Date October 31, 2000

To Gary Williams

From Bryan K. Hurst BKH

Subject 2000 Silica Fume Overlay Bridge Profiles
Item 2132

On Wednesday, October 25, 2000, profilograph and KJ-Law Profilometer testing was performed on the Silica Fume Overlay Bridges on I-35 near Ardmore, Ok. The two southbound lanes were tested first that morning and the two northbound lanes were tested that afternoon. New software has been installed on the KJ-Law Profilometer since the 1999 testing on these bridges, and with it comes a change in the filter wavelength setting from 300 to 100. This setting slightly changes roughness results making them appear smoother. The 1999 results were amended with the new software and were included in the "1999 Silica Fume Overlay Bridge Field Report."

Roughness figures were obtained from both the Ames Profilograph and the KJ-Law Profilometer, for 2000. The table below contains the project results for the 1999 testing and the results from the 2000 testing:

LOCATION	ROUGHNESS / INCHES PER MILE							
	1999				2000			
	Ames Profilograph		KJ-Law Profilometer		Ames Profilograph		KJ-Law Profilometer	
	TOTAL PROJECT	BRIDGE DECK	TOTAL PROJECT	BRIDGE DECK	TOTAL PROJECT	BRIDGE DECK	TOTAL PROJECT	BRIDGE DECK
SOUTHBOUND RT. LN. / LWP	20.43	**27.14**	25.27	**32.93**	31.90	**25.71**	21.83	**31.91**
SOUTHBOUND LT. LN. / RWP	12.49	**17.5**	11.79	**18.44**	10.00	**17.14**	8.61	**16.31**
NORTHBOUND RT. LN. / LWP	6.33	**19.58**	7.5	N/A	10.52	**20.00**	12.15	**18.15**
NORTHBOUND LT. LN. / RWP	5.21	**7.92**	6.02	**7.57**	6.13	**7.92**	5.00	**4.76**

APPENDIX D
SKID TEST DATA

SITE: 035-10-36 Carter
LANE: NBOL
DATE: 11/09/2000
TIME: 15:29:11
DRIVER: RMB
OPERATOR: JAL

REF POST	SN	WHEEL	SN PEAK	AIR TEMP	TEST TIME	CYCLE NUMBER	EVENT
20.327	49.4	Left	86.9	49.4	15:28:57	510036068	
20.366	42.8	Right	84.8	49.1	15:29:00	510036069	Bridge
20.409	45.0	Left	79.1	49.1	15:29:04	510036070	

Left Wheel	N =	2	M =	47.2	SD =	3.11	H =	49.4	L =	45.0
Right Wheel	N =	1	M =	42.8	SD =	0.00	H =	42.8	L =	42.8
Total	N =	3	M =	45.7	SD =	3.37	H =	49.4	L =	42.8

SITE: 035-10-36 Carter
LANE: NBIL
DATE: 11/09/2000
TIME: 15:32:20
DRIVER: RMB
OPERATOR: JAL

REF POST	SN	WHEEL	SN PEAK	AIR TEMP	TEST TIME	CYCLE NUMBER	EVENT
20.294	53.7	Left	86.0	49.1	15:32:03	510036074	
20.253	46.1	Right	100.5	49.1	15:32:06	510036075	Bridge
20.213	52.0	Left	84.7	49.1	15:32:10	510036076	

Left Wheel	N	=	2	M	= 52.8	SD =	1.16	H	=	53.7	L	= 52.0
Right Wheel	N	=	1	M	= 46.1	SD =	0.00	H	=	46.1	L	= 46.1
Total	N	=	3	M	= 50.6	SD =	3.99	H	=	53.7	L	= 46.1

SITE: 035-10-36 Carter
LANE: SBOL
DATE: 11/09/2000
TIME: 15:27:26
DRIVER: RMB
OPERATOR: JAL

REF POST	SN	WHEEL	SN PEAK	AIR TEMP	TEST TIME	CYCLE NUMBER	EVENT
20.410	50.7	Left	86.7	48.2	15:26:36	510036065	
20.357	43.4	Right	91.1	48.2	15:26:41	510036066	Bridge
20.316	41.0	Left	77.4	48.2	15:26:44	510036067	

Left Wheel	N	=	2	M	= 45.9	SD =	6.88	H	= 50.7	L	= 41.0
Right Wheel	N	=	1	M	= 43.4	SD =	0.00	H	= 43.4	L	= 43.4
Total	N	=	3	M	= 45.1	SD =	5.07	H	= 50.7	L	= 41.0

SITE: 035-10-36 Carter
LANE: SBIL
DATE: 11/09/2000
TIME: 15:30:54
DRIVER: RMB
OPERATOR: JAL

REF POST	SN	WHEEL	SN PEAK	AIR TEMP	TEST TIME	CYCLE NUMBER	EVENT
20.393	51.5	Left	87.1	48.2	15:30:39	510036071	
20.352	52.2	Right	81.0	48.2	15:30:43	510036072	Bridge
20.315	50.5	Left	81.6	48.2	15:30:46	510036073	

Left Wheel	N =	2	M =	51.0	SD =	0.76	H =	51.5	L =	50.5
Right Wheel	N =	1	M =	52.2	SD =	0.00	H =	52.2	L =	52.2
Total	N =	3	M =	51.4	SD =	0.89	H =	52.2	L =	50.5