EVALUATION OF SILICA FUME HIGH DENSITY THIN BONDED OVERLAYS

Final Report
September 2002

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Microsilica fume, commonly called silica fume, is made up of particles which are 100 times smaller than those which make up cement. When silica fume is added to Portland Cement Concrete (PCC), its small size allows it to fill voids, producing a denser, less permeable, PCC.

In September, 1999, the Oklahoma Department of Transportation (ODOT) experimentally placed overlays of silica fume modified PCC on two bridge decks. The two bridges are located on I-35 in Carter County.

The overlays have been evaluated since placement. Surveys for the evaluation included collecting data from the following tests: Half-cell potentials, smoothness measurements, crack surveys, and general condition surveys.

In the three years since the overlays were placed, corrosion activity measured by half-cell potentials has remained low and smoothness measurements have indicated a good ride. Cracking has increased over three years, but cracks have not exceeded "hairline" width. The bridge deck had remained in good condition.

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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
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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FINAL REPORT

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September 2002

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INTRODUCTION

The two bridges used in this evaluation are located on I-35 in Carter County, 1.6 km (1 mi) north of S.H. 53. ADT at this location is 27,500, which includes 21 percent trucks.

Silica fume can be defined as a very fine noncrystalline silica produced in electric arc furnaces as a by product of the production of elemental silicon or alloy containing silicon; also known as condensed silica fume or microsilica. Microscopic sized silica fume particles are 100 times finer than those which make up cement, this allows it to physically fill voids between cement particles which produces a denser concrete.

The two bridges were built in 1979. By 1997, both bridges were showing considerable deterioration. Delamination and cracking, with spalling where cracks met, were widespread (1). Maintenance forces had patched both decks numerous times. These conditions combined to produce a rough ride on both bridges.

A rehabilitation project, which included full and partial depth patching, coldmilling, and placement of a silica fume modified PCC overlay (hereafter referred to as a "silica fume overlay") was completed in 1999.

This was the Oklahoma Department of Transportation's (ODOT) first use of the silica fume overlay. An evaluation was performed in cooperation with the Federal Highway Administration (FHWA). Some of ODOT's concerns regarding silica fume overlays were excessive and/or premature cracking and the ability of the overlay to resist penetration of chloride ions to the reinforcing steel.

OBJECTIVES

The objectives of this project are as follow:

- Evaluate conditions of each installation before overlaying.
- Document procedures for specification changes in the mix design proportions and other characteristics in the mix.
- Document preconstruction preparation.
- Monitor construction and document procedures.
- Record results of job control testing for each site.
- Evaluate bridge deck repair and overlay placement.
- Do an annual evaluation of the bridge deck installation.

OVERLAY CONSTRUCTION OPERATIONS

Before construction of the overlay began, 51 mm(2 in) of the existing surface was removed (by coldmilling) from each of the bridge decks. Areas where delamination of the concrete had been observed were jack-hammed out, and the corroded reinforcing steel was cleaned. Patches of Class A concrete, with silica fume were poured, and then placement of the silica fume overlay was completed, and the deck was covered with plastic.

When placement of the silica fume overlay began, grout was broomed onto the deck surface. Trucks backed onto the deck and discharged the silica fume concrete. Each load was tested for slump, air content and temperature by a contracted testing firm. See Appendix A of the construction report for Job Site Testing. The concrete was placed in 51 mm (2 in) lifts in front of the paver, one lane at a time. The concrete paver vibrated the mix as it rolled transversely across the lane. Then, dual augers on the paver leveled the material to the designated height. Concrete placed along the walls and the centerline was hand vibrated. A vibra-tamp roller, located on the paver, helped consolidate and smooth the surface. Dual steel rollers finished the mat in both directions as they passed. A fog bar, located above the rollers, misted a pre-cure evaporation prevention film on the concrete. Behind the rollers was a drag pan used for further finishing the surface. Small adjustments or corrections were made by hand finishing, while the Fresno float smoothed and finished the mat. A tine float formed grooves in the mat. The shoulders on the deck received a broom finish.

White curing compound was applied from a 208 L (55 gal) drum with a gasoline engine powered sprayer. A burlap cover was placed over the deck and saturated with water. Finally, the deck was covered with plastic for 78 hours before the cover was removed.

INVESTIGATION

The investigation activity prior to, during, and after construction, other than scheduled surveys (semi- annual, annual, etc.) are covered in the construction report for this project (1).

Investigation activity done after that (described in the construction report) included the following:

- Annual crack surveys, half cell testing, chain-drag testing, skid testing and profilograph testing. These tests were done in October, 2000.
- Annual crack survey and chain-drag test done in September, 2001

Data collected from each survey is summarized below:

The October 2000 survey showed hairline cracking as the major distress found on both bridge decks. Approximately 10% of the northbound bridge deck had random hairline size cracks while the southbound bridge deck had similar distress over approximately 25%. No delaminations were detected during chain-drag testing. All half cell readings were in the lowest potential class (ASTM C 876). The southbound bridge had only 7% and the northbound bridge had 2.9% class " A" range readings. Skid values were measured on the southbound right lane at 43 and 52, and the northbound right lane at 42 and 46, which indicates good skid resistance. See Figure 1 for a graph of the profilograph test results from 1999 to 2000.

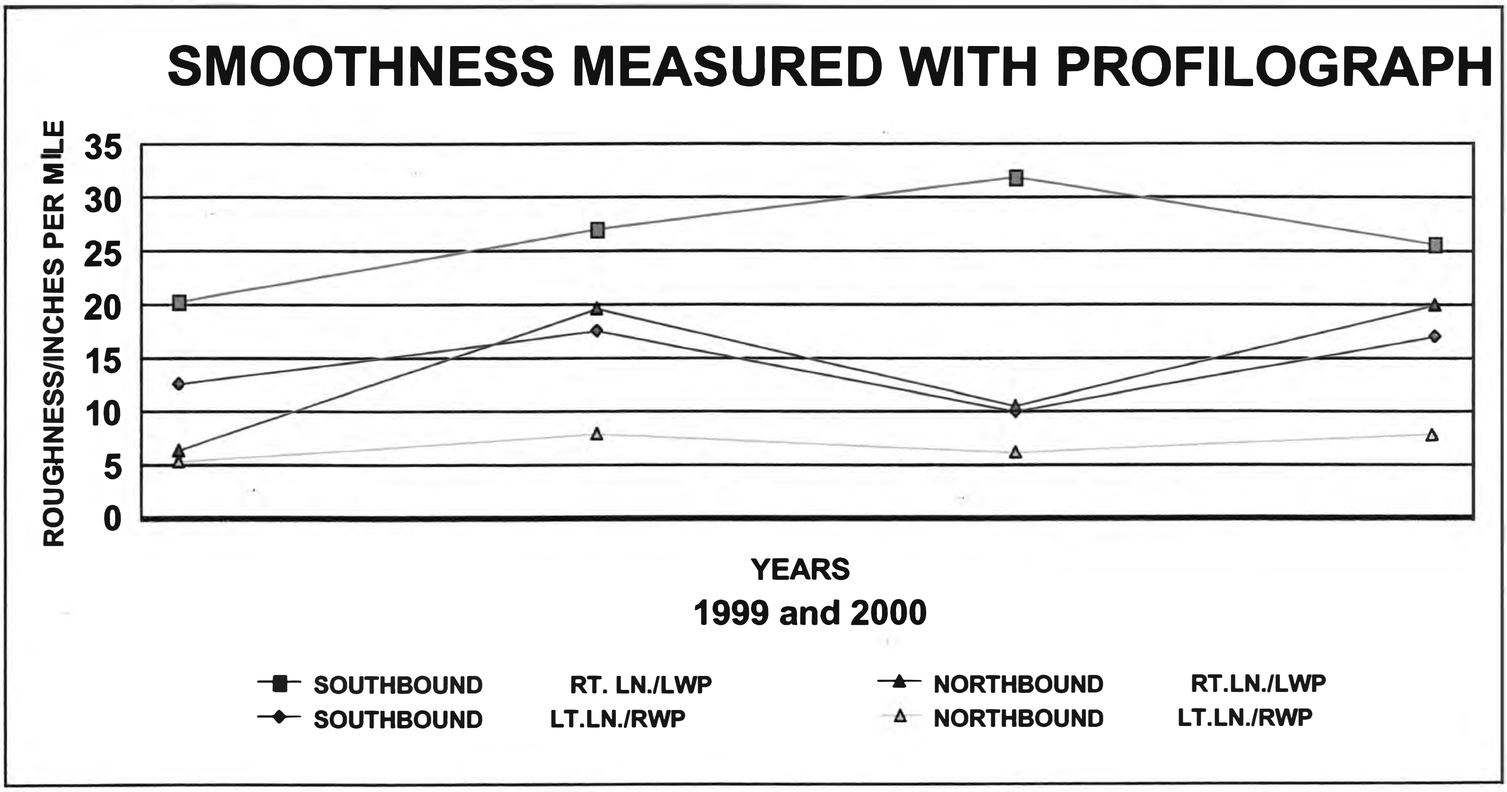

Figure 1. Profilograph testing of the total project which includes 200 ft (61 m) on each side of the bridge deck and on the bridge deck for the years 1999 and 2000. Locations 1 and 3 are results of testing on the bridge decks and locations 2 and 4 results of testing the length of the total project.

The southbound expressway bridge right lane in year 2000 had 751 ft (226 m)of cracking. Most of this was random cracking, but a construction joint crack of 148 ft (45 m) that runs the length of the bridge deck is included. Year 2001, 274 ft (84 m) of random cracks, in addition to those measured in 2000 were observed. The total amount of cracking for year 2000 and year 2001 is 1025 ft (312 m). Cracking in the left lane has the smallest amount. In the year 2000, the linear feet of cracking was 48 ft (15 m) and it increased to 138 ft (42 m) in the year 2001.

Cracking in the northbound lane has been less severe. In year 2000, the right lane cracking totaled 263 ft (80 m). Of that, 124 ft (38 m) was a longitudinal construction joint crack that runs the length of the bridge deck. Left lane cracking has been moderate. In year 2000, 86 ft (26 m) of random cracks were recorded. Two hundred and sixty three feet (80 m) of cracking was measured in 2001. Both construction joint cracks had a width opening of 1/4 in (6 mm) and the random cracks are still hairline size (2). The linear feet of cracking is graphed in figure 2. from the years 2000 and 2001, the graph shows the new cracking observed each year and a combined amount from both years. Each year, chain-drag testing was performed on both bridge decks and no deliminations were found.

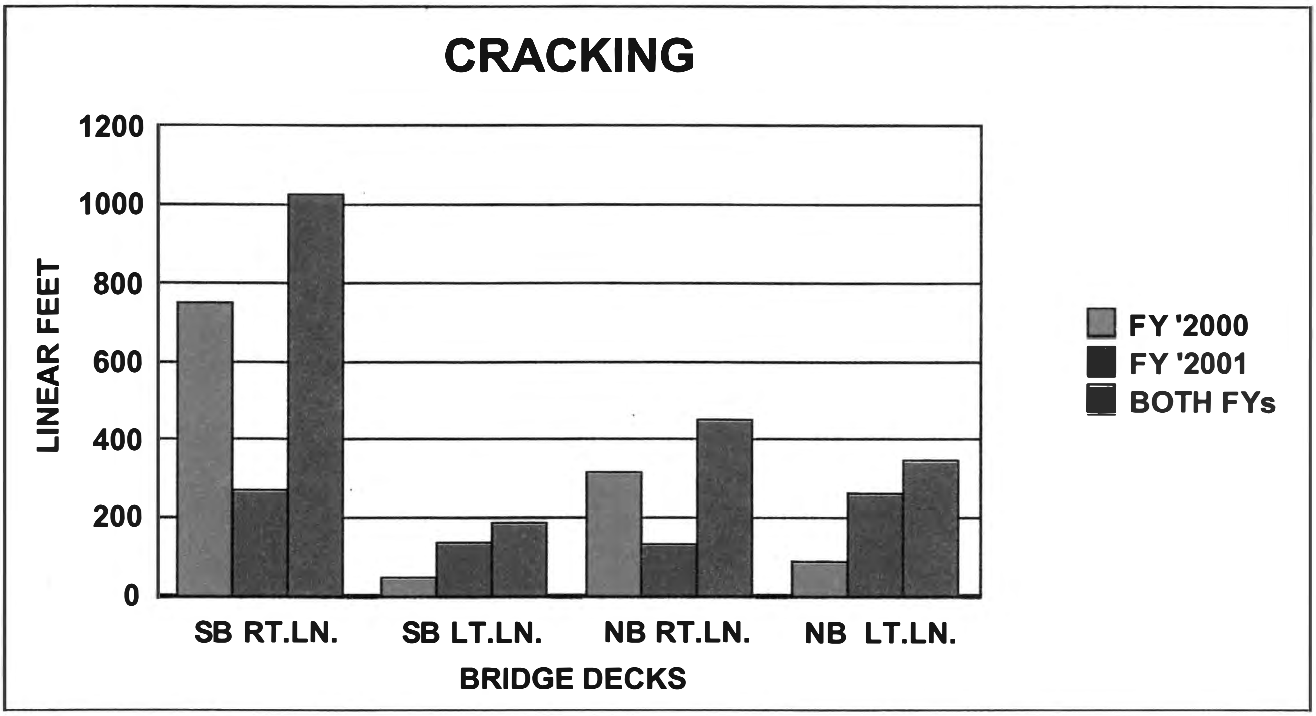

Figure 2. Bar graph of linear feet of cracking on the bridge decks in the years 2000 and 2001 in both lanes.

CONCLUSIONS

ODOT is testing silica fume to find alternate methods that will increase serviceability in a rehabilitated bridge. Durability and diffusivity are two major components that can be looked at. Durability of a bridge deck overlay can be related to strength, low amounts of corrosion in the deck's reinforcing steel, and the ability to resist cracking. The cylinders broke between 5,000 psi (34,475 kPs) and 9,000 psi (62,055 kPs) (1). These strengths were greater than required by specifications. Diffusivity is the rate of ingress of some deleterious species such as chloride of sulfate ions regulates the initiation of deterioration (6). The silica fume overlay has made the two bridge decks less permeable than the typical bridge deck. Therefore, the rate of deterioration from ion penetration should be greatly reduced. Half cell potentials indicate relatively low corrosion activity.

Cracking has an effect on the amount of ions passing to the reinforcement bars. The hairline size cracks have increased each year. The southbound right lane has more than double the amount of cracking as the northbound right lane. While the northbound left lane has more cracking than the southbound left lane. There is no pattern with regards to traffic which would account for the great difference in cracking. The cracking problem should be examined with a goal of determining any connection to air entrainment and curing during construction.

According to smoothness measurements shown on the line graph, three out of the four readings show the entire project being slightly rougher than the bridge deck and there was no noticeable increase in roughness for 1999 to 2000. Profilograph testing was not done in year 2001 but the ride quality felt approximately the same as previous years. Both bridges still have smooth riding surfaces.

RECOMMENDATION

Cracking continues to be a major concern which could affect the life of this project. It has increased each year and should continue to be observed and evaluated to determine its rate. Although the ride is currently smooth, and the overlays are performing well, an additional three years of investigation to observe cracking, ride quality and surface distress is recommended.

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APPENDIX A

PHOTOGRAPHS

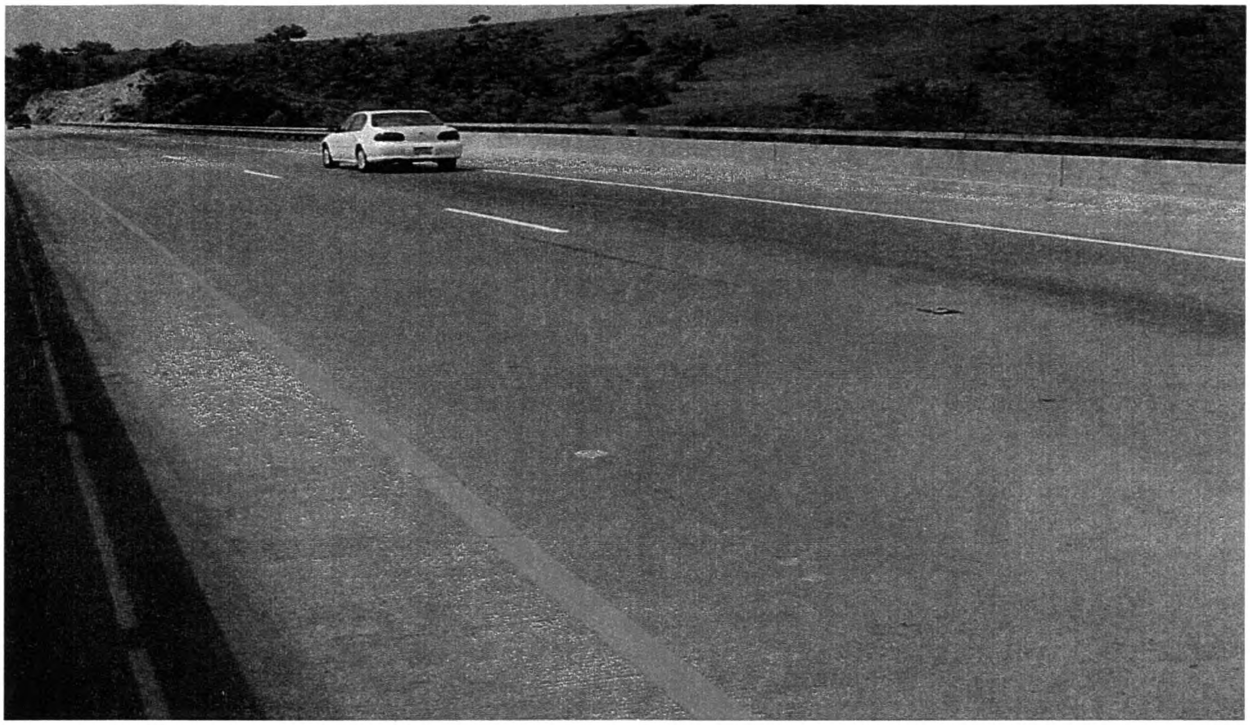

Figure 3. Photograph Of Entire Bridge, Showing Overlay 3 years After Placement.

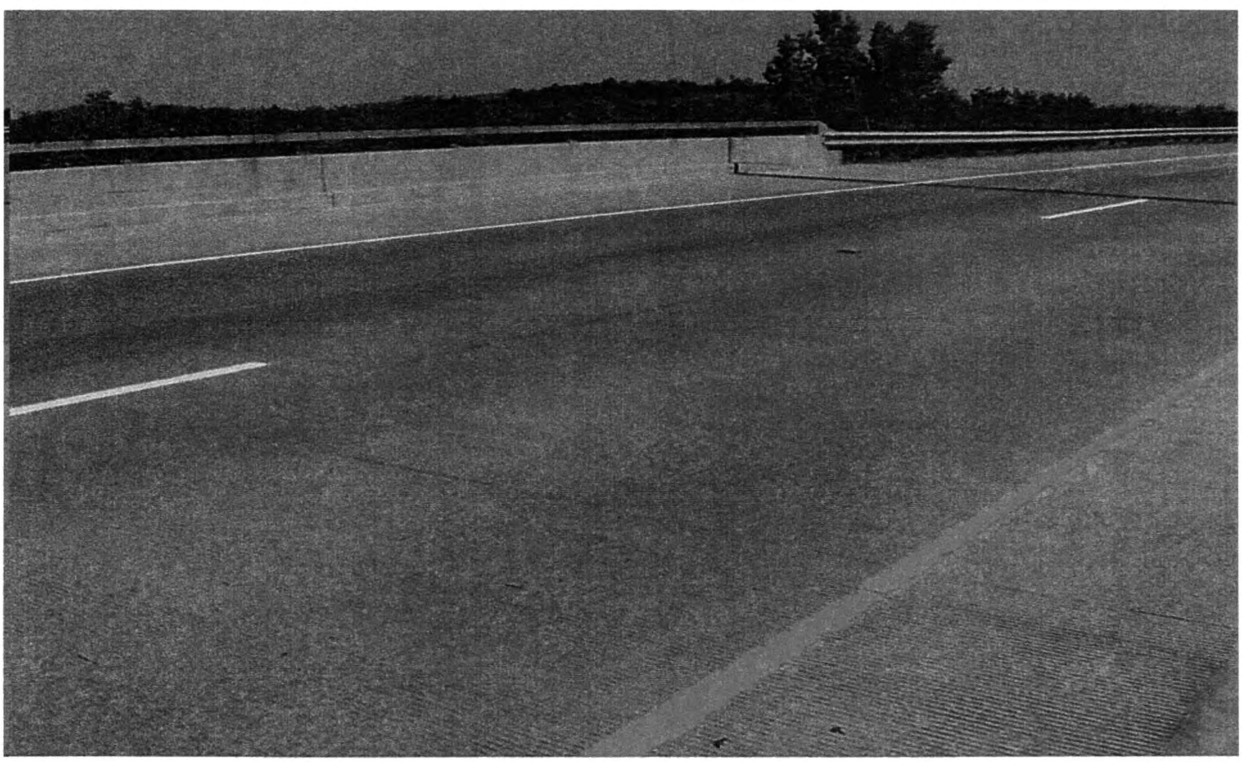

Figure 4. Overlaid Deck, No Distress Present Other Than Cracking.

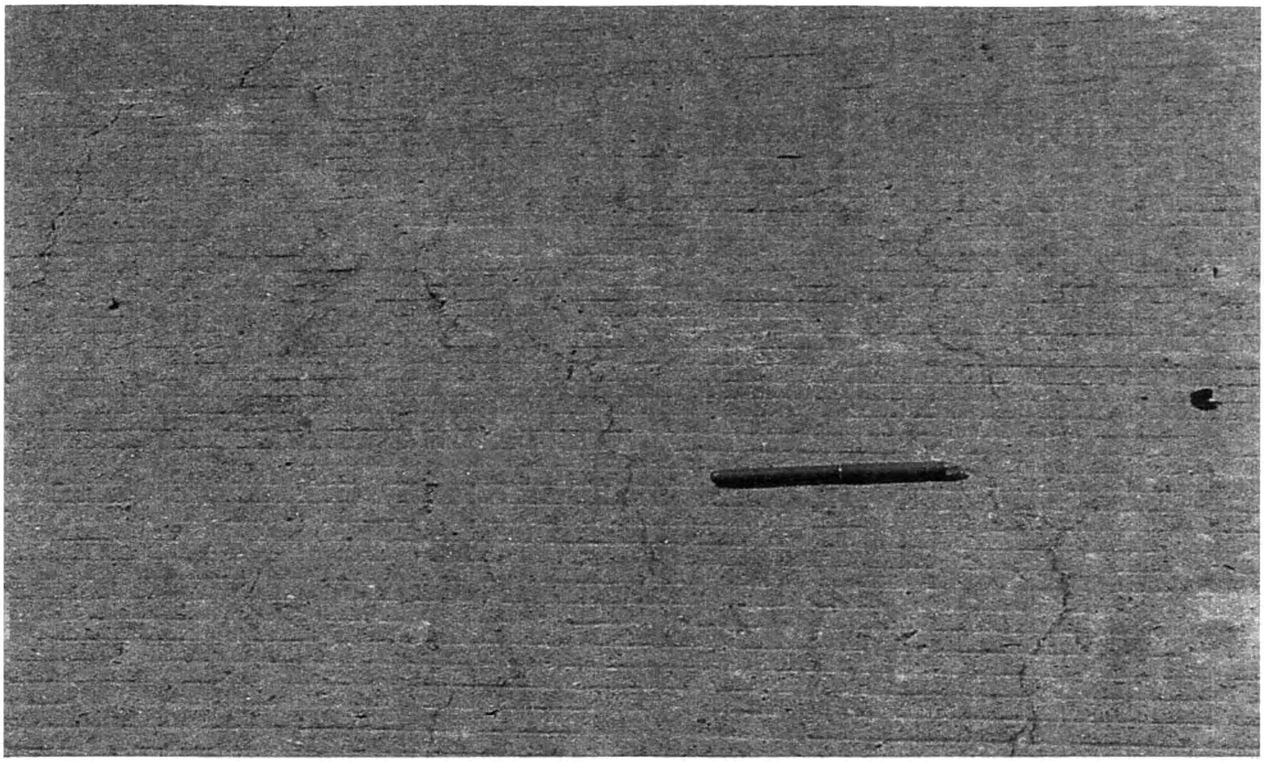

Figure 5. Hairline Size Random Cracks.

Figure 6. Longitudinal Construction Joint Crack.