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STATE HIGHWAY DEPARTMENT
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INVESTIGATION OF BRIDGE DECK DETERIORATION

B1 OF 81-1-13 ON US-23 OVER HURON RIVER

by

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Research Laboratory
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At the request of Mr. W. W. McLaughlin and in accordance with a letter from District Engineer, N. E. MacDougall, Bureau of Public Roads, to C. A. Weber, Deputy Commissioner, Chief Engineer, dated June 27, 1956, the Research Laboratory has made a survey of Bridge B1 of 81-1-13 on US-23 over the Huron River and has carried out an investigation to determine the reasons for the unusual deterioration of the concrete deck surface on this structure. This is a report of that investigation.

The bridge deck was poured in the summer of 1955 and only the northbound roadway was open to traffic during the winter of 1955-56. Deep progressive scale has developed to date in the northbound roadway and chiefly within four feet of the curb in the outside lane. The northbound lane adjacent to the median strip also has a good deal of pitting and some slight scale. The lane in the southbound roadway closest to the median has a good deal of pitting next to the median strip. The evidence of pitting on this lane appears to substantiate the conclusion that when the southbound lanes are opened to traffic and eventually subjected to chlorides for snow and ice removal, the same type of serious surface deterioration may result in varying degrees.

GENERAL CONDITION OF DECK

M. G. Brown and L. T. Oehler inspected the deck of this structure on June 27, 1956. A general idea of the extent of scaling and other deterioration may be obtained from Figure 1, which is a plan view of the deck showing the condition of the surface of that date.

A detailed view of the extent of deterioration may be obtained from the photographs which are arranged in sequence from south to north starting with Span 1. Figure 2 shows the scaling off of laitance on Span 1 which suggests the concrete mix in this area must have had an excess of water, lack of the proper air content, or both. Figures 3, 4 and 5 show pitting and cracking of concrete on Span 2. Similar cracking was observed on other spans (see Figure 1). Spans 3 and 4 are two of the most badly scaled. Figures 6, 7, 8, and 10 illustrate the deeply scaled areas of these spans while Figure 9 shows fine shrinkage cracks which occurred in one small area of Span 3. The pitting and light scale which has already occurred on the southbound lane closest to

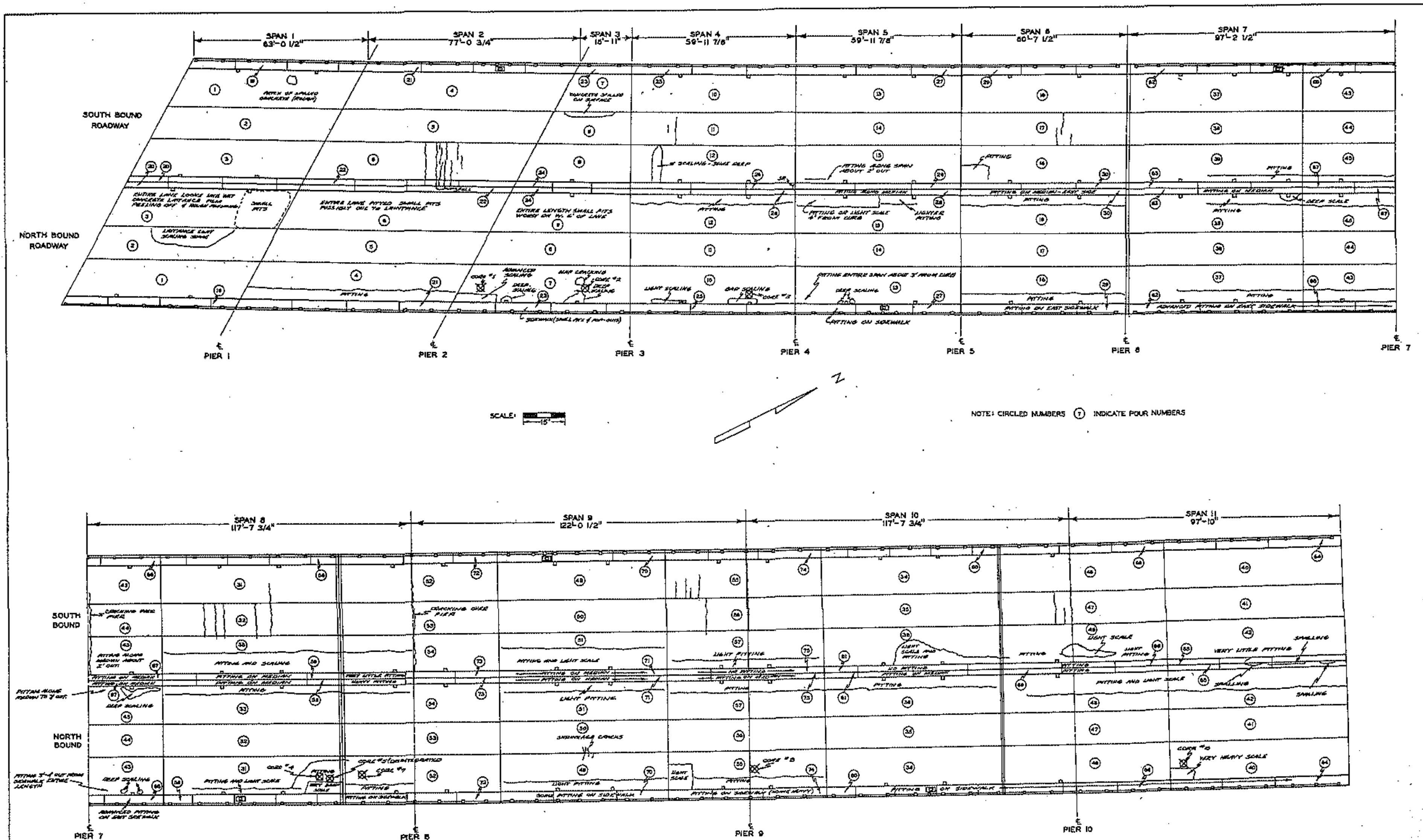

FIGURE 1
CONDITION OF BRIDGE DECK AND CORE LOCATION

the median strip is shown in Figure 11. Because this condition was observed to be general throughout the southbound lane next to the median, it may be assumed that this has occurred only as a result of chlorides being thrown over the median strip from the northbound lanes which were subjected to winter traffic and maintenance. Figures 12, 13, and 15 illustrate two areas of very serious scaling on Spans 8 and 11, and Figure 14 illustrates small hair-line cracks and pitting on the east sidewalk of Span 9. The pitting along the east sidewalk and the median strip is more or less general throughout the length of the bridge and appears to be due to a large amount of shale particles in the fine aggregate and in some of the coarse aggregate.

CONCRETE

A series of Swiss Hammer readings were made on various portions of the bridge deck to determine any possible differences in concrete compressive strength. Fifteen readings were made at each location and the average result with the corresponding strength is given in Table 1.

TABLE 1

SWISS HAMMER TESTS ON BRIDGE DECK

Location Span	Roadway	Pour	Condition of Concrete	Average Hammer Reading	Compressive Strength (psi)
1	N. B.	Center of 3	Light Scale	26.0	3,400
1	N. B.	Center of 1	Good	35.0	5,800
2	S. B.	Center of 6	Cracked Area	36.9	6,300
	N. B.	North end of 5	Good	35.8	6,000
3	N. B.	South end of 7	Heavy Scale	34.4	5,600
4	N. B.	Center of 10	Heavy Scale	35.5	5,900
5	N. B.	Center of 15	Good	35.4	5,900
8	S. B.	Center of 33	Light Scale	35.6	6,000
9	S. B.	Center of 57	Good	36.2	6,100
11	N. B.	South end of 40	Heavy Scale	36.8	6,300
				Average	5,700

As shown in Table 1, all of the areas tested indicate a good compressive strength for one year old concrete, except the first area which was flaking off as shown in Figure 2. This surface defect probably caused the low compressive strength indication by the Swiss Hammer.

The Field Engineer's Reports on this project were studied for pertinent data which might explain the damaged areas present on the deck. There is an indication of a lack of control over the consistency and homogeneity of the transit mixed concrete. This was mentioned in Field Engineer's Reports of June 3 and June 14, 1955. Most of the air checks listed below are in areas other than the ones showing deterioration and are within specification limits. In general, throughout the pouring of the deck it was necessary to add Darex in varying amounts to obtain the required air content in the concrete mixture.

TABLE 2

AIR CHECKS ON DECK CONCRETE

Date of Pour	Pour Numbers	Percent Air (Pressure Method)*
Southbound Roadway		
6- 2-55	34 and 40	3.8 and 6.0
6- 3-55	36 and 42	3.6 and 5.6
6-14-55	6 and 7	6.2
6-30-55	33	4.8
7- 1-55	32, 49 and 57	4.8
7-14-55	13, 15 and 17	6.8 and 4.1
Northbound Roadway		
8-19-55	7 and 9	4.6
8-31-55	42, 46, 55 and 57	4.6

*Each figure shown in this column is the average of at least two air checks.

Eight cores were removed from the roadway portion of the bridge deck for laboratory examination. The locations where these cores were drilled are shown in Figure 1. The top half-inch was cut from these cores and the sawed surface polished for running the air content of the concrete by the linear traverse technique. The result of these measurements are given in Table 3.

TABLE 3

AIR CONTENT OF CORE SPECIMENS

Core No.	Date Received	Location in Northbound Outer Lane	Concrete Condition	Air Content, Percent
1	7-10-56	Pour 7, Span 3, near south end	Badly scaled area	3.85
2	7-10-56	Pour 7, Span 3, near north end	Badly scaled area	2.12
3	7-10-56	Pour 10, Span 4, near north end	Heavy scale	1.68
4	7-10-56	Pour 31, Span 8, near north end	Very deep scale	2.38
5	7-10-56	Pour 31, Span 8, near north end	Disintegrated	----
6	7-10-56	Pour 40, Span 11, near south end	Very heavy scale	1.57
7	8- 7-56	Pour 52, Span 8 just north of pour 31	Good area	6.92
8	8- 7-56	Pour 55, Span 10, near middle	Good area	4.30

Only cores 7 and 8 exhibited the numerous dispersed, minute air voids characteristic of good air entrained concrete. Among the bad cores, Core 1 had a highest air content, due to many larger voids some of which were probably caused by trapped mix water. A distinct clay odor and tan coloration were noted in Cores 1, 3, 4, and 6, when moistened with water. Core 5 disintegrated as it was removed from the roadway, and no air content check could be run.

The following materials were used in the concrete for the deck of this bridge:

Cement	- Peerless AE, Detroit
Fine Aggregate	- Haas Pit No. 2 (Inventory No. 81-51)
Coarse Aggregate	- American Aggregates, Green Oak, 6B - Beneficiated by heavy medium process.

MATERIALS

An investigation of the sand used on this project was begun by the Research Laboratory at the request of Ray Durfee, May 21, 1956. This sand, from the Haas No. 2 Pit, (81-51), had been used on another bridge project B1 of 81-1-8 over US-12, southwest of Ann Arbor and in both cases high sulfate soundness losses were reported by the Ann Arbor Testing Laboratory. This fine aggregate was examined in the Research Laboratory and was found to contain a high amount of shale. The percentage of this rock type was determined on the three largest sieve fractions by floating the shale off with a heavy medium liquid of acetylene tretrabromide adjusted to a specific gravity of 2.50 with carbon tetrachloride. The magnesium sulfate soundness test was run on this material and also on a sample of concrete sand from the Boichot pit north of Lansing for a comparison. Boichot sand has been used as a reference, since several years of concrete work has shown this sand to be reliable and uniform from year to year. The relative durability of the Haas and Boichot fine aggregates in air entrained concrete exposed to rapid freeze in air and thaw in water was also determined. Each sand was used in a mix of 5-1/2 sacks of cement per cubic yard, 3.6 percent air, 2 - 3 inch slump, and crushed dolomite coarse aggregate, 1 inch maximum size. Beams made from these mixes were cured in the moist room for fourteen days prior to the freeze-thaw test. The results of all these tests comparing the Haas material and the Boichot sand are presented in Table 4.

An unusual amount of shale in the fine aggregate from the Haas pit was the main cause for a greater-than-specification loss in the magnesium sulfate soundness test. This type of rock has a high absorption as is evidenced in the 2.75 percent value, and tends to expand and break along its laminations under moist freezing and thawing. The numerous small pop-outs in the median strip and sidewalk on the bridge deck, Figure 14, show the effects of this material. The freeze-thaw beams in the laboratory exhibited none of this surface defect and have remained sound for over 220 cycles with practically no loss in strength or weight. The effect of the shale in these beams has not been evident, due to a good air content in the concrete and also because the beams were frozen in air rather than the water or brine which would have resulted in a more destructive surface effect on the beams.

TABLE 4

TEST RESULTS ON FINE AGGREGATE FROM HAAS PIT. NO. 2 (81-51)

Specific gravity, bulk dry	2.55
Absorption, 24 hour	2.75%
Material lighter than 2.50 specific gravity (shale)	
No. 4 - 8 fraction	22.0%
No. 8 - 16 fraction	21.4%
No. 16 - 30 fraction	15.4%

Magnesium sulfate soundness, 5 cycles

Sieve fraction tested	Percent loss on finer sieve Boichot sand	Haas sand
No. 4 - 8 sieve	13.0	32.0
No. 8 -16 sieve	13.0	29.0
No. 16 -30 sieve	11.0	26.0
No. 30 -50 sieve	4.5	16.5
Percent loss on original sand grading	7.5	20.8
Maximum allowable loss, MSHD Specs.		16.0

Durability in fast freeze in air thaw in water

Eight cycles per day, 0^{o} to 40^{o} F.

	Air content %	Percent* of Original Dynamic Modulus after: 0 cycles	85 cycles	170 cycles	220 cycles
Boichot sand	3.6	100	96.7	98.0	**
Haas sand	3.6	100	96.0	99.5	99.6

Note: *All percents are averages of 4 beams each.
**Boichot sand specimens have not yet received 220 cycles.

Cracking in Southbound Roadway

The condition survey as shown in Figure 1 revealed considerable transverse cracking in the southbound roadway and none of this type in the northbound roadway. The physical condition of the cracking is shown in Figures 4 and 5.

A brief study was made of flexural strength values and construction operations in order to determine possible causes for this phenomena. A summary of flexural strength data for 7 days and 28 days are presented in Table 5.

We are informed that the deck on the northbound roadway was constructed using transit mix equipment operating from the southbound roadway. During earth moving operations the LeTourneau earth moving equipment was permitted to return empty over the southbound roadway to borrow pit located south of the bridge. Loaded cement trucks used the southbound roadway in hauling cement from Detroit to the plant located at the north end of the bridge. There is a good possibility that the three load conditions mentioned above imposed on the southbound roadway in areas of indicated low early flexural strengths might have caused the transverse cracking noted in the condition survey.

SUMMARY

The factual evidence presented in this report indicates that the principle cause for the advanced deterioration of the concrete in certain localized areas of the bridge deck was the lack of proper amounts of entrained air in the areas affected. It is also indicated that in certain instances nonuniform concrete might have contributed to this deterioration.

It is to be expected that higher general air content would have probably counteracted most of the bad pitting effects of the fine aggregate material. On the other hand however, materials with high shale content can be expected to produce general surface pitting such as encountered on this project.

There is a good possibility that the transverse cracking appearing only in the southbound roadway may be associated with construction load conditions imposed in areas of indicated low early flexural strengths.

TABLE 5

SUMMARY OF FIELD BEAM FLEXURE TESTS

Series	Pour Date	Deck Pour No.	Modulus of Rupture*(psi.) 7 Day	28 Day
Southbound Roadway				
36	6- 8-55	48	542	683
37	6-14-55	6 & 7	475 **	692
38	6-16-55	8 & 12	567	700
40	6-30-55	33	588	750
41	7- 5-55	51, 54, & 56	517	683
42	7-14-55	17	700	833
43	7-20-55	43 & 45	509	700
Northbound Roadway				
44	8- 2-55	15	516	667
45	8- 5-55	38	517	667
46	8- 9-55	54	534	717
47	8-17-55	10 & 12	525	700
48	8-29-55	35, 40, & 50	525	707
49	8-31-55	55 & 57	534	667
50	9-16-55	2, 4, & 6	500	667

*Each figure is the average of two breaks on one test beam only, for each age.

** Field Report indicated poor curing conditions.

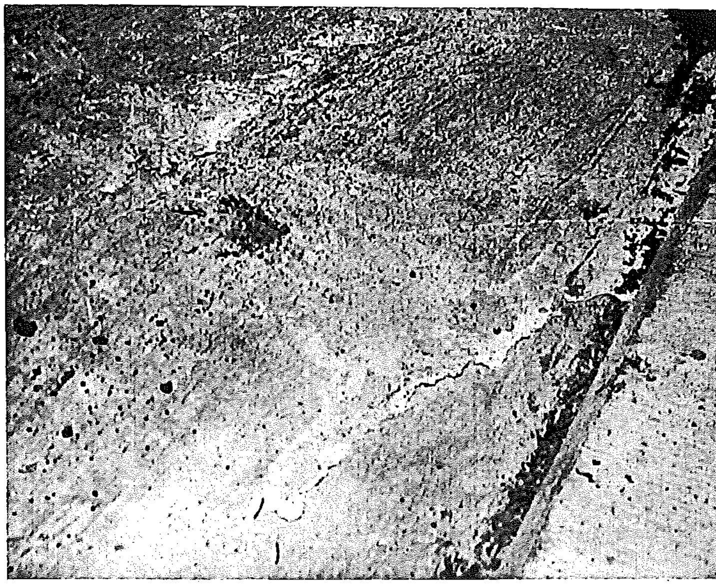

FIGURE 2. LAITANCE SCALING OFF FROM SPAN 1 ON NORTHBOUND LANE CLOSEST TO MEDIAN STRIP.

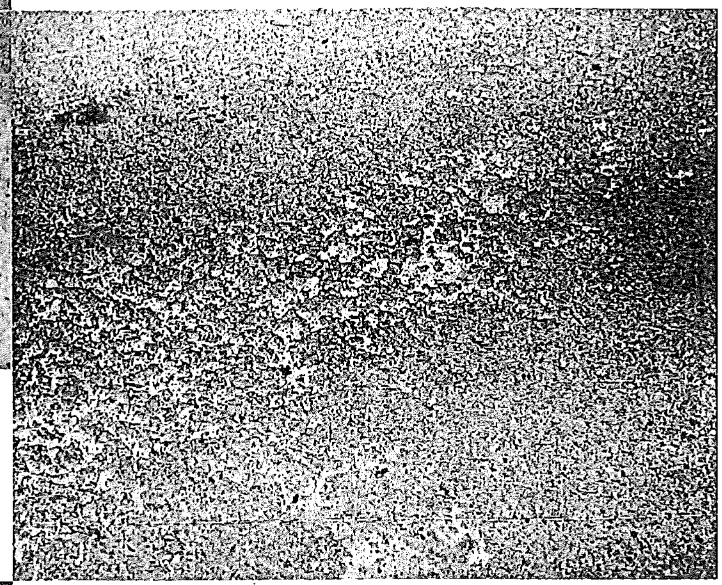

FIGURE 3. TYPICAL VIEW OF PITTING ON SPAN 2 ON NORTHBOUND LANE CLOSEST TO MEDIAN.

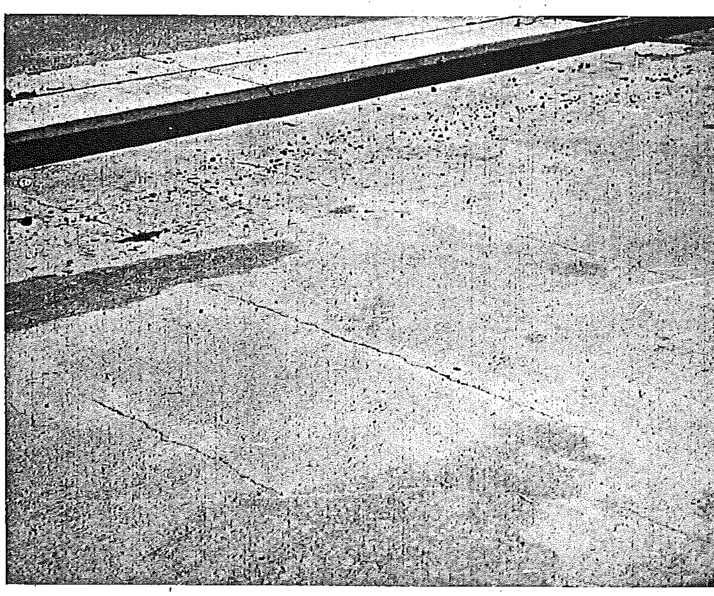

FIGURE 4. CLOSELY SPACED CRACKS AT MID-SPAN OF SPAN 2 ON SOUTHBOUND LANE CLOSEST TO MEDIAN.

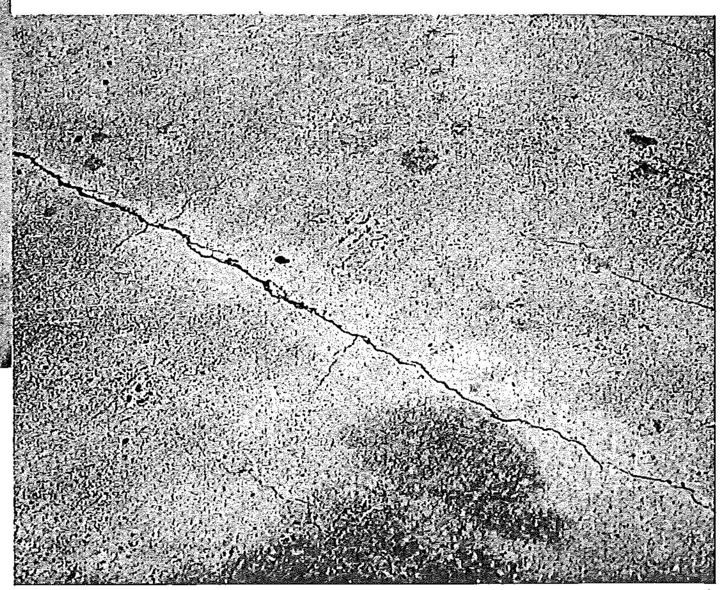

FIGURE 5. DETAILED VIEW OF MOST PROMINENT CRACK SHOWN IN FIGURE 4.

FIGURE 6. OVERALL VIEW OF PROGRESSIVE SCALING ON SPAN 3 AND 4 ON OUTSIDE NORTHBOUND LANE.

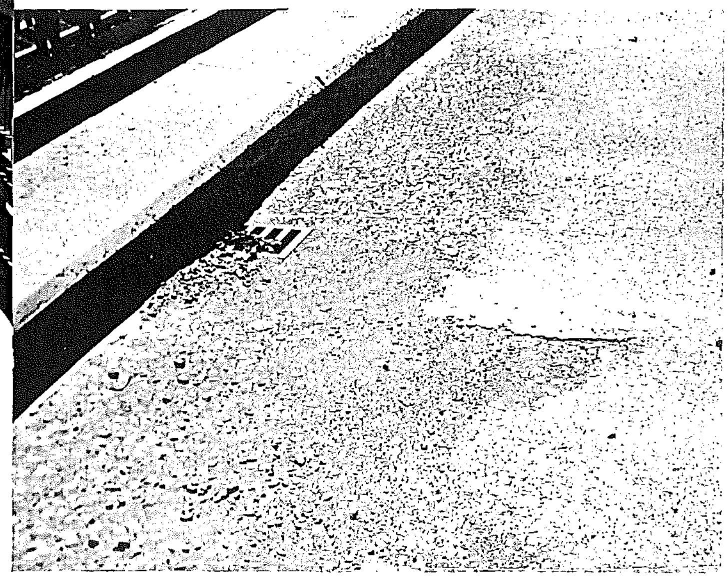

FIGURE 7. DEEP AND PROGRESSIVE SCALING AROUND CATCH BASIN ON SPAN 3, OUTSIDE NORTHBOUND LANE.

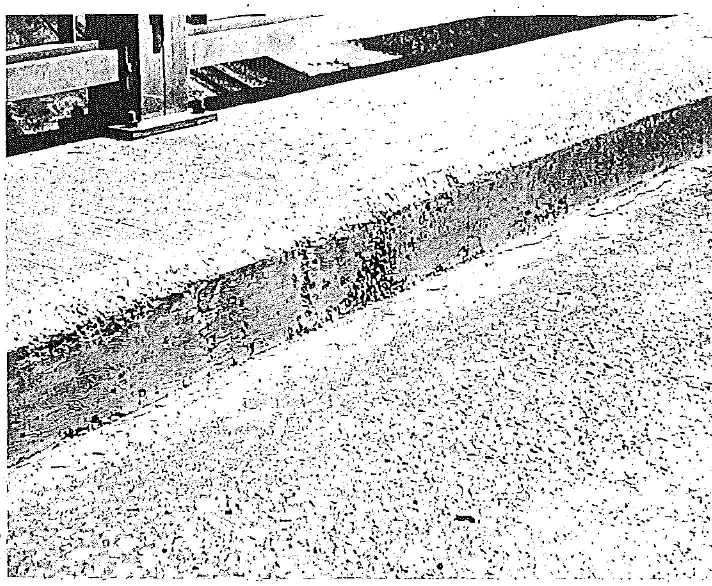

FIGURE 8. SCALING OF BRIDGE DECK AND WHEEL GUARD AND PITTING ON SIDEWALK SPAN 3.

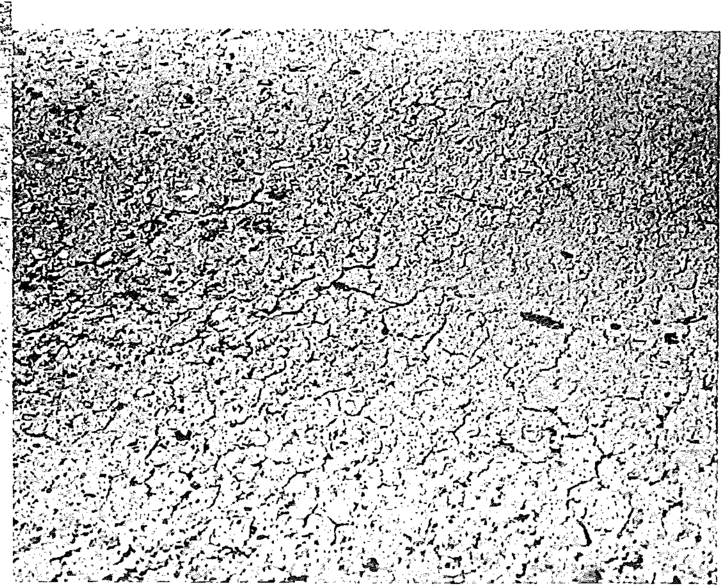

FIGURE 9. DETAILED VIEW OF "MAP" CRACKING, SPAN 3 ON OUTSIDE NORTHBOUND LANE.

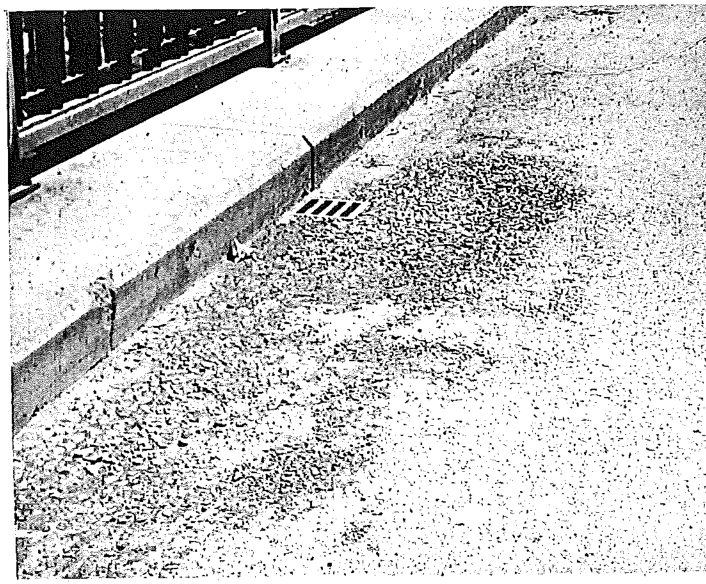

FIGURE 10. DEEP AND PROGRESSIVE SCALING AROUND CATCH BASIN ON SPAN 4, OUTSIDE NORTHBOUND LANE.

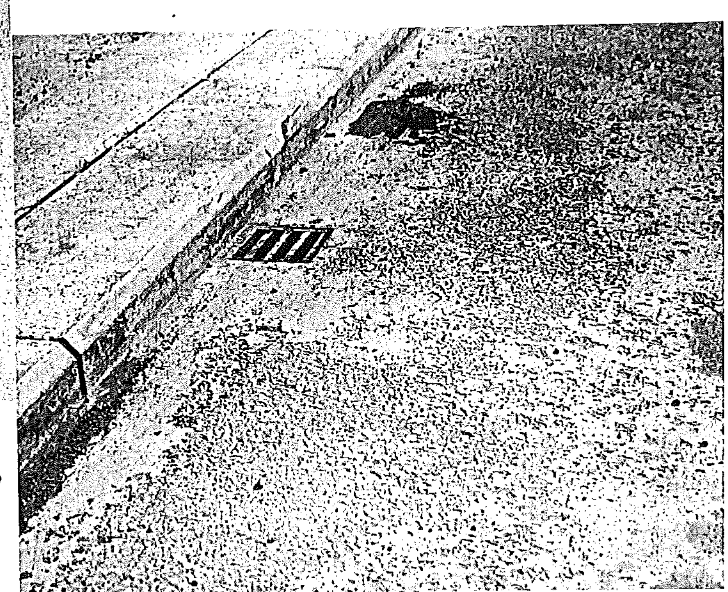

FIGURE 11. PITTING AND LIGHT SCALING ON SPAN 8, SOUTHBOUND LANE CLOSEST TO MEDIAN.

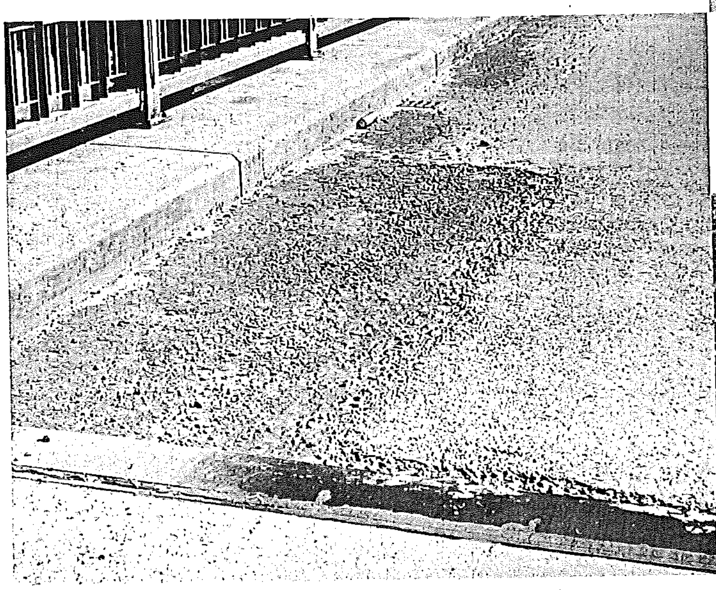

FIGURE 12. VERY DEEPLY SCALED AREA ON NORTH END OF SPAN 8 ON OUTSIDE NORTHBOUND LANE.

FIGURE 13. DETAILED VIEW OF SCALING SHOWN IN FIGURE 12.

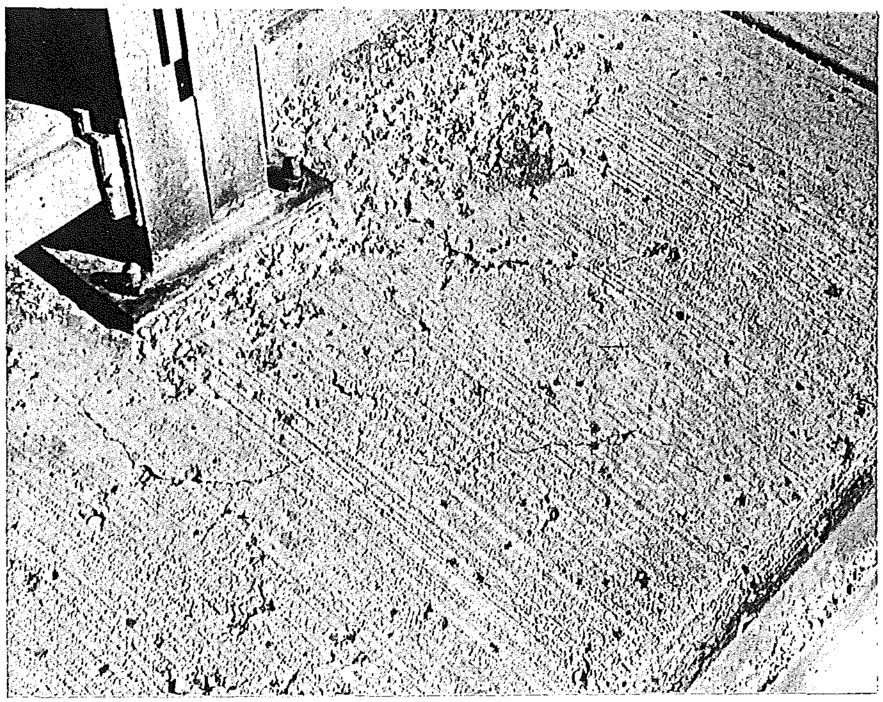

FIGURE 14. DETAILED VIEW OF SMALL CRACKS AND PITTING ON EAST SIDEWALK, SPAN 9.

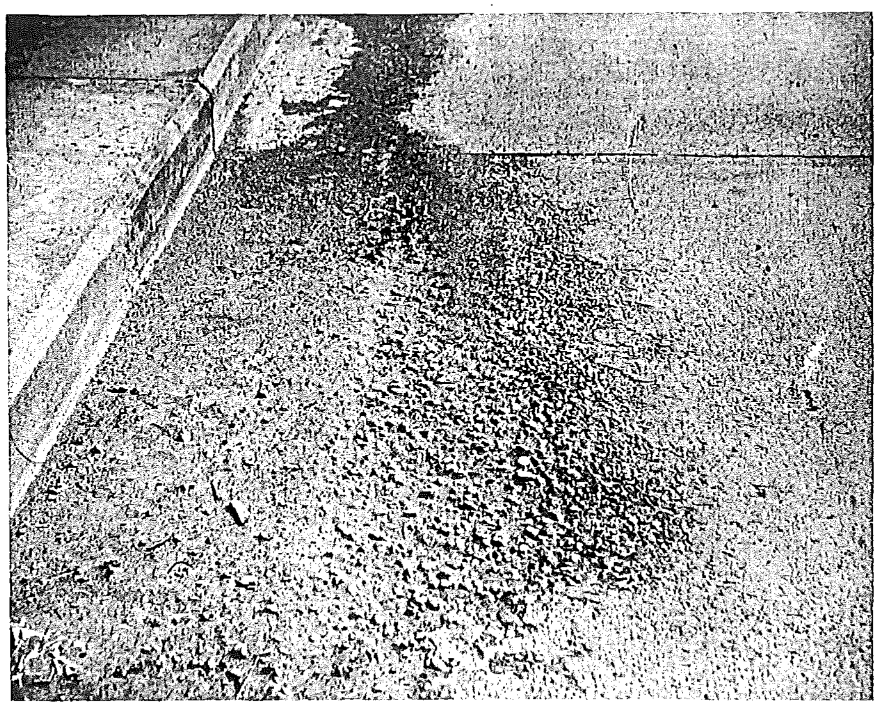

FIGURE 15. VERY DEEP SCALING ON SPAN 11 ON OUTSIDE NORTHBOUND LANE.