R-441

OFFICE MEMORANDUM

MICHIGAN
STATE HIGHWAY DEPARTMENT
JOHN C. MACKIE, COMMISSIONER

October 18, 1963

To: E. A. Finney, Director
Research Laboratory Division

From: M. G. Brown

Subject: Concrete Durability on Bridge Deck Widening: I 94 - Edsel Ford Expressway Structure over DeQuindre Yards (EBBI X01 of 82024B, C5). Research Project R-63 B-70. Research Report No. R-441.

The following report summarizes the results of a study authorized by R. L. Greenman on March 12, 1963, and expanded in scope by W. W. McLaughlin on May 14, 1963. The study's subjects are scaling of concrete and adequacy of air entrainment on an eastbound lane added at the south side of the I 94 - Edsel Ford Expressway bridge over the DeQuindre Yards (Federal Project EBI 94-6 (47)222).

The south lane was placed late in 1962, as an improvement of the original 1957 structure (which already had been widened on the north in 1961). The construction involved 28 spans at the level of the existing deck, designated from west to east as Spans 7 through 34, and an additional three spans (designated as Spans 4 through 6) providing access from the northbound roadway of I 75 - Chrysler Expressway to the eastbound roadway of the DeQuindre Yard structure. I 75 and the access lane are not yet open to traffic, but the 28 spans at deck level on I 94 where opened shortly after construction, carried normal traffic during the 1962-63 winter, and received applications of winter maintenance chemicals.

The Bureau of Public Roads informed the Department during this first winter of service that areas of scaling of varying severity were developing. The Office of Testing and Research extracted 19 cores from Spans 4 through 32 (west to east), with initial air contents for the top 1/2-in. reported April 1, 1963. Considerable variation was apparent between these air contents and results obtained on fresh concrete within the same pours in the field. As a result, a more complete study was initiated, involving both examination of the project records and the hardened concrete.

In a memorandum to W. W. McLaughlin dated June 7, C. B. Laird requested that six cores be taken for comparison purposes from a structure not yet open to traffic in the same interchange area, S24 of 82251, where the deck was cast at the same time, with concrete from the same plant using the same materials as the DeQuindre widening.

Additional linear traverse measurements were made on the first 19 cores and also on the 6 comparison cores. The complete cores were also tested using a high pressure chamber at 5000 psi and the Illinois methods as described by Lindsay(1). These core data are summarized in Table 1.

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(1) Lindsay, J. D. "Illinois Develops High Pressure Air Meter for Determining Air-Content of Hardened Concrete." HRB Proceedings, Vo. 35 (1956), pp. 424-35.

A field survey was made by R. H. Merrill and D. DeLoach in July 1963, to determine the degree and extent of scaling. Construction records were obtained and Table 2 summarizes pertinent construction and survey data for the deck roadway widening pours from Spans 4 through 34. Figs. 1 through 4 show typical roadway scaling and sidewalk pitting as observed in various locations from Spans 7 through 32. Spans 4, 5, and 6 are on the northbound I 75 ramp entering eastbound I 94, which are not yet open to traffic. They received little or no salt applications last winter. Similarly, the four spans of the comparison structure also had no winter maintenance or scaling.

Summary of Inspection and Test Results

1. Air contents obtained for cores from the I 94 - DeQuindre deck widening indicate numerous areas definitely deficient in entrained air. The linear traverse results, as would be expected, generally ran lower than the high pressure results. These air contents are not consistent with the range of 5.6 to 8.5 percent obtained by rollometer on fresh concrete in the field and listed in Table 2. Air contents of the six comparison cores from S24 of 82251, generally were more uniform and slightly higher than the 19 DeQuindre cores. The high pressure results, on these last six, in particular, were quite high. In 1962, Erlin(2) found that high pressure chamber results can be expected to be as much as 3 percentage points higher than the linear traverse results and about 1 percentage point higher than low pressure results on fresh concrete.

2. The air content variation of the 19 DeQuindre Yard cores reflects the load-to-load variation frequently encountered in transit-mix concrete. If proper mixing is not obtained or if water is added at the job site, considerable variation in slump and air content can be expected even from beginning-to-end of an individual load. Even though adequate air entrainment was indicated on the loads of transit mix concrete checked, this does not guarantee that the greater number of unchecked loads will have the same level of air entrainment.

3. One additional factor was noted in the field inspection which may have reduced the air content of the fresh concrete, or more likely, increased the bleeding of water and fines to the surface during finishing. Considerable vibration was noticed in Spans 7 through 34 from traffic movement on the adjoining three lanes, particularly in suspended Spans 9 and 14. This same traffic and vibration might have an undetermined effect on the fresh concrete during placement.

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(2) Erlin, Bernard. "Air Content of Hardened Concrete by a High Pressure Method." Journal of the PCA Research and Development Laboratories, Vol. 4, No. 3 (Sept. 1963), pp. 24-9.

4. The three factors just listed would produce scale-prone concrete, particularly when the surface was subjected to early applications of winter maintenance chemicals, as was true in this particular case. The roadway pours were placed from September 6 through December 4, 1962, and, undoubtedly received salt applications directly or from the adjoining lanes soon thereafter. This is confirmed by the fact that no scaling occurred on Spans 4, 5, and 6 (which have not been in use), and the scaling pattern is most pronounced at the west or low end of Spans 7 through 14 and the east or low end of Spans 15 through 32. The drainage pattern splits at Spans 14 and 15 and the resulting movement of salt-laden slush is clear in the scaling pattern.

Recommendations

The roadway and refuge walk pours might have been given added resistance to scaling if a double application of a linseed oil-naphtha mixture or penetration epoxy could have been applied prior to early salt applications. It is recommended that the more severely scaled roadway areas be restored with a thin, bonded mortar coating, and that the entire roadway and walk pours be coated with a penetrating epoxy to give the air-deficient areas added protection against de-icing salts this coming winter.

OFFICE OF TESTING AND RESEARCH

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TABLE 1
SUMMARY OF CONCRETE CORE AIR CONTENTS

"Area A": Access Pavement, I 75 Northbound to I 94 Eastbound (not open to traffic)
"Area B": I 94 DeQuindre Yard Bridge Widening Pavement (open to traffic)
"Area C": Access Pavement, I 94 Westbound to I 75 Southbound (not open to traffic)

	Sample No.	Core No.	Core Location	Pour Date	Degree of Surface Scaling	Air Content, Percent			
						Linear Traverse			High Pressure(c)
						(a)	(b)	Avg.	
"Area A"	63 CR- 7	S- 1	Span 4E	9-7-62	None	2.5		2.5	4.6
	- 8	S- 2	Span 5E	9-7-62	None	4.3	2.9	3.6	3.0
"Area B"	- 9	S- 3	Span 32E	10-12-62	Very light	4.0	2.8	3.4	5.0
	-10	S- 4	Span 31E	10-10-62	None	4.2	3.0	3.6	5.8
	-11	S- 5	Span 31E	10-10-62	Medium	2.7	2.9	2.8	4.0
	-12	S- 6	Span 29E	10-10-62	Very light	5.8	4.2	5.0	6.4
	-13	S- 7	Span 29E	10-10-62	Light	4.9	3.8	4.4	7.4
	-14	S- 8	Span 28E	10-5-62	Heavy	0.7	1.6	1.2	2.5
	-15	S- 9	Span 28E	10-5-62	Heavy	2.9	2.6	2.8	
	-16	S-10	Span 25E	10-4-62	Heavy	2.3	1.5	1.9	2.6
	-17	S-11	Span 25E	10-4-62	Very light	5.5	2.6	4.1	5.9
	-18	S-12	Span 22E	10-4-62	Very light	4.6	3.6	4.1	5.2
	-19	S-13	Span 22E	10-4-62	Very light	4.9	3.9	4.4	6.2
	-20	S-14	Span 15E	12-4-62	Medium	4.1	3.4	3.8	4.2
	-21	S-15	Span 15E	12-4-62	Very light	3.5	1.2	2.4	2.9
	-22	S-16	Span 9E	11-9-62	Medium	2.5	2.9	2.7	
	-23	S-17	Span 9E	11-9-62	Very light	4.0	3.6	3.8	
	-24	S-18	Span 7E	9-13-62	Medium	2.5	1.7	2.1	4.2
	-25	S-19	Span 7E	9-13-62	Light	3.0	1.4	2.2	
"Area C"	**West Side of Deck**								
	63 CR-31	S-28	Span 1	10-20-62	None	5.2			9.0
	-32	S-29	Span 2	10-20-62	None	3.2			8.9
	-33	S-30	Span 4	10-20-62	None	3.5			6.7
	East Side of Deck								
	-34	S-31	Span 3	10-19-62	None	4.1			6.9
	-35	S-32	Span 2	10-19-62	None	4.9			8.5
	-36	S-33	Span 1	10-19-62	None	4.8			8.9

(a) Polished section 1/2-in. from core top.
(b) Polished section 3 to 4 in. from core top.
(c) High pressure method at 5000 psi (corrected for air in aggregate and volume of steel).

TABLE 2
SUMMARY OF CONSTRUCTION AND INSPECTION DATA

"Area A": Access Pavement, I 75 Northbound to I 94 Eastbound (not open to traffic)
"Area B": I 94 DeQuindre Yard Bridge Widening Pavement (open to traffic)
"Area C": Access Pavement, I 94 Westbound to I 75 Southbound (not open to traffic)

	Span	Pour	Pour Date	Volume Poured, cu yd(a)	Cement Overrun, percent	Temp. During Pour, F		Air Checks, percent by volume(b)	Visual Inspection (July '63)			
									Pour Area, sq ft	Surface Scaling		
						Air	Concrete			Area, sq ft	Percent	Type
"Area A"	4E	E	9-6-62	19.5	1.6	64-63	78-76	8.0 C				
	4E	A	9-7-62	52.5	4.3	67-69	76-80	6.0	1805	0	0	
	5E	E	9-7-62									
	5E	A	9-11-62	49.8	4.1	62-69	74-78	6.2	1830	0	0	
	6E	E	9-11-62									
	6E	A	9-12-62	35.5 P	8.2	76-82	83-86	7.2	2145	0	0	
"Area B"	7E	A	9-13-62	40.0 P	10.6	83-63 (rain)	87	6.5	1464	110	7.5	Light scale (east end)
	8E	A	11-12-62	73.0 P	9.0	40-42	64-66	5.6, 7.0, 6.0C, 7.0C	1615	0	0	
	10E	A	11-12-62						1196	0	0	Scattered pitting
	9E	A	11-9-62	41.7	6.8	47	70	7.0	1687	400	23.7	Light to medium scale (west end)
	11E	A	11-14-62	25.5	11.0	43-46	62-74	6.2	1068	0	0	
	12E	A	11-20-62	25.25	15.6	36-43	68-65	7.2	1000	0	0	Pitting along curb
	13E	A	12-3-62	73.5	2.9	39-58	68-78	8.5C, 7.5C, 8.0C, 6.0	1598	0	0	
	14E	A	12-3-62						1532	283	18.5	Light & medium scale (west end)
	15E	A	12-4-62	36.3	3.7	40-54	72-76	6.4	1595	0	0	
	16E	A	11-19-62	14.1	25.9	31-38	72-67	7.3	489	0	0	
	17E	A	9-18-62	34.8 P	16.8	57-62	73-74	7.5, 7.6	795	285	35.8	Light & medium scale (east end)
	18E	A	9-18-62						795	300	37.7	Light scale (east end)
	19E	A	9-19-62	49.5 P	13.4	57	73	7.5	795	0	0	Light pitting
	20E	A	9-19-62						661	0	0	Light pitting
	21E	A	9-19-62						535	0	0	Light pitting
	22E	A	10-4-62	101.75	16.8	64-66	72-70	7.5 C	1384	668	48.2	Light scale
	23E	A	10-4-62						1030	171	16.6	Light scale
	24E	A	10-4-62						760	464	61.0	Light & medium scale
	25E	A	10-4-62						795	224	28.2	Light, medium & heavy scale
	26E	A	10-5-62	60.5	14.5	52-68	72-74	8.0 C	795	0	0	Light pitting
	27E	A	10-5-62						795	180	22.6	Light scale
	28E	A	10-5-62						795	530	66.7	Light to heavy scale
	29E	A	10-10-62	51.0	16.4	53-68	74-72	8.0C, 8.5	805	531	66.0	Light scale
	30E	A	10-10-62						780	0	0	Light pitting
	31E	A	10-10-62						462	64	13.8	Medium scale
	32E	A	10-12-62	25.0 P	24.0	71-65	80-76	5.9, 7.3, 7.0, 7.5C	394	260	66.0	Light scale
	33E	A	10-12-62	13.0	Grade XX Black Concrete				364	0	0	
	34E	A	10-12-62						225	0	0	
"Area C"	1,2,3,4 (east side)		10-19-62	157.0	-1.0	60-70	72-73	7.5, 7.0, 7.3, 7.0C, 7.1C	4760	0	0	
	1,2,3,4 (west side)		10-20-62	244.0 P	-1.3		70-72	7.3, 7.2, 7.2, 7.5C	4550	0	0	

(a) "P" indicates pours using 2-oz Plastiment per sack of cement.
(b) "C" indicates air check with Chacemeter; all others measured by Rollometer.

Figure 1. Variable scaling pattern at east end of Span 24 (cores 10 and 11).

Figure 2. Heavy scaling at east end of Span 28 (cores 8 and 9). Lightly scaled surface of Span 29 in background.

Figure 3. Typical pitting or light scale found on portions of refuge sidewalk pours.

Figure 4. Typical light scale found in some roadway surface areas.