OFFICE MEMORANDUM

MICHIGAN
STATE HIGHWAY DEPARTMENT
JOHN C. MACKIE, COMMISSIONER

October 16, 1963

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

From: G. R. Cudney and M. G. Brown

Subject: Investigation of Deck Cracking. EBI-96 Over the Grand River in Grand Rapids. B02 of 41027A, C2. Research Project 63 B-72. Research Report No. R-442.

The following is a summary of our study of the subject project. This is according to your assignment following a telephone request by R. L. Greenman on September 3, 1963. As stated in P. A. Nordgren's letter to W. W. McLaughlin of September 4, this study was to determine the causes of the high incidence of transverse cracking in the outer superstructure pours and to recommend possible changes of construction procedure to avert a similar occurrence on the westbound deck to be poured later.

A complete scale drawing of all deck cracking was transmitted by D. C. Bowen, Bridge Project Engineer, to J. V. Murray, Design Coordinator, on August 26. An inspection of the structure was made on September 16. The crack diagram as prepared by D. C. Bowen proved to be quite accurate except for a few additional short, fine, transverse cracks found between some of the larger full width cracks. This fine transverse cracking, see Fig. 1, is almost entirely confined in the outer deck pours of the 536 foot, five span continuous section between piers 1 and 6. Fig. 2, attached, shows a general view of the plate girder spans with a center 24 foot wide section and the outer pours producing a total deck width of 58 feet. The entire continuous deck section was poured on nine different days using machine finishing and retarded concrete. The center 24 feet was poured on the first three days followed by the six outer 16-1/2 and 17-1/2 foot wide pours. A brief tabulation of these nine pours with related weather and crack data is contained in the attached Table 1. All pours were cured by white curing compound spray applied later the same day after finishing, except DGK. This particular pour could not be sprayed until the following day due to faulty spray equipment. It can be noted in Table 1 that this pour has the highest total number of cracks. It was noted by the project engineer that the small garden tank sprayer was not applying curing compound heavy enough and some areas were re-sprayed.

The sequence and direction of pouring was as prescribed in the plans with the exception of pours PSV, NRU, and QTW. These sections of slab were poured from the construction joint east of Pier 4 toward the construction joint west of Pier 3. The plans called for concrete to be placed in both directions from the center of Span 4. We do not believe that the resulting crack pattern has any direct connection with the sequence of concrete placement which was utilized. Providing proper retarding of the concrete is attained, the method of pouring Span 4 should be of little consequence. However, to offset the possibility of cracking in the top surface in the negative moment areas over Piers 3 and 4, the original prescribed pour sequence should be followed on the westbound deck.

In all probability, the deck cracking is primarily due to plastic shrinkage caused by an excessive rapid evaporation of water from the concrete surface. Only one outside pour, FJM, had a low number of cracks and this was poured on the only cloudy and overcast day. Because the greatest amount of cracking occurred in the exterior lane pours, it is quite likely that a good deal of the cracking was also the result of induced tensile forces in the exterior lane pours brought about by an elongation of the structure as the temperature increased from early morning till late afternoon. The 24 foot central slab area which was poured first would greatly add to the heat absorption volume of the structure surface being heated, and the slab reinforcing would exert tensil forces on the freshly placed exterior segments as the structure elongated.

The critical rate of water evaporation from the concrete is primarily a function of the prevailing relative humidity, air temperature, and wind velocity. Any action which will reduce the rate of evaporation will reduce the chances of shrinkage cracks from occuring. Suggested construction practice for minimizing the detrimental effects of hot weather concreting can be found in the Proposed ACI Standard: Recommended Practice of Hot Weather Concreting, Journal of the American Concrete Institute, Nov. 1958, No. 5. Vol. 30.

These corrective measures would include the following:

1. Utilization of cold mixing water.

2. Keep the aggregate coll (?, cool) by intermittent sprinkling of the stockpile or sprinkling successive layers as the stockpile is built up.

3. Shading the aggregate stockpile from the direct rays of the sun.

4. Keep the forms and reinforcing steel protected from the direct rays of the sun and cool by sprinkling.

5. Start curing the concrete as soon as possible after placing and finishing. Particular attention should be paid to having all facilities ready for prompt initiation of curing.

6. After placing, and before application of curing compound, keep surface moist with fog sprays.

7. Erect wind breaks to reduce wind velocity over the concrete surface.

8. Provide sun shades to control surface temperatures.

In addition, all exterior pours should begin in mid-afternoon, so that the structure would be in the process of cooling off and contracting during the time interval these sections were being placed. This would tend to put the fresh concrete in compression rather than tension as it cured.

If the westbound deck, B01 of 41027A, is poured in hot weather or in clear, sunny and windy weather, as many of the above precautions as possible should be taken. A faster and heavier application of white curing compound would be advisable even prior to use of curing blankets if used for protection from cold night temperatures this fall.

OFFICE OF TESTING AND RESEARCH

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GRC:MGB:nl

Attachments

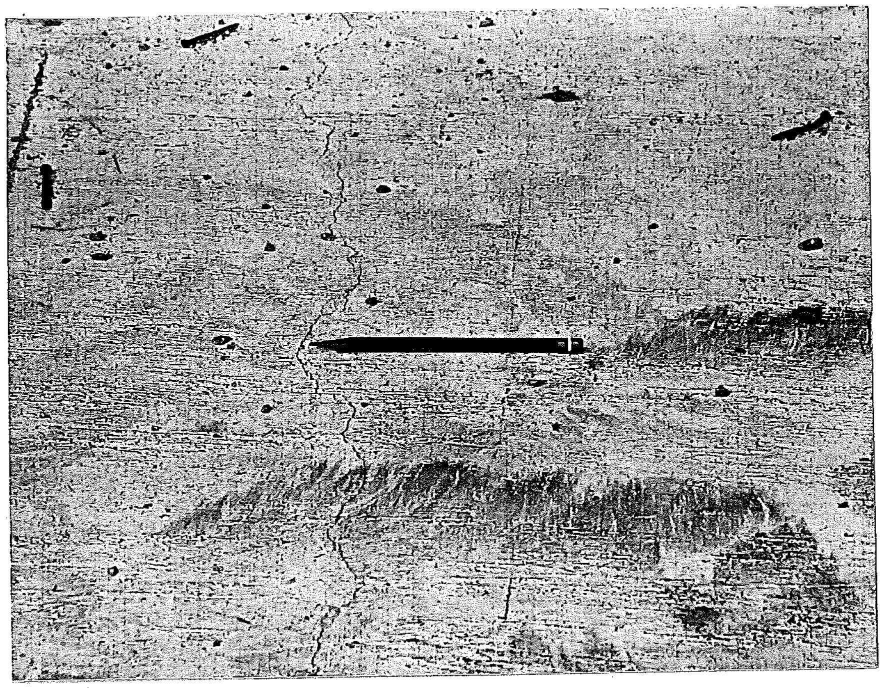

Figure 1. Typical fine transverse crack mainly in outer pours.

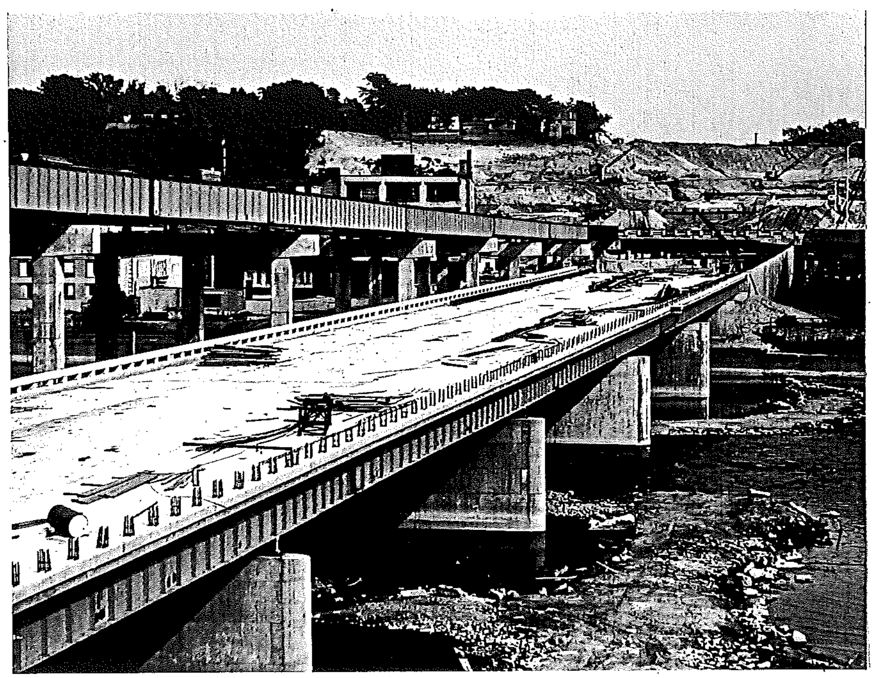

Figure 2. General view of eastbound deck looking east. Higher westbound deck in background.

TABLE 1
SUMMARY OF POUR DATA AND CRACK INCIDENCE
I 96 Eastbound over the Grand River (B02 of 41027A)

Date	Pour* Code	Dimensions, ft	Direction of Pour	Time[a]	Temperature, F[a]		Relative[a] Humidity, percent	Weather	Max. Wind Velocity, mph	Retarder, oz/sack	Cracks[b], full width
					Air	Concrete					
6-25-63	E, H, L	24 x 183	East	8:45- 4:30	75-90	76-83	42-21	Clear-warm	9E	3-4	0
6-27-63	Y, BB, EE	24 x 183	West	7:15- 1:30	71-91	81-87	72-31	Clear-hot	16W	3-4-3	2
6-28-63	P, S, V	24 x 170	West	8:10- 1:50	69-83	81-81	86-57	Cloudy, Clear-warm	17SE	4-3	3
7-17-63	F, J, M	17-1/2 x 183	East	9:40- 2:45	77-85	83	76-54	Part cloudy	25SW	2-1/2 -3- 2-1/2	3
7-22-63	D, G, K	16-1/2 x 183	East	8:00- 1:30	67-82	78-81	82-47	Cloudy, Clear-warm	18NE	2-1/2-3	17-1/2
7-23-63	Z, CC, FF	17-1/2 x 183	West	8:15- 1:45	66-84	85	93-46	Clear	14E	2-1/2-3	12
7-24-63	X, AA, DD	16-1/2 x 183	West	8:40- 2:25	77-87	82	59-45	Clear	10SE	2-1/2-3-1/2	11-1/2
7-25-63	N, R, U	16-1/2 x 170	West	8:05- 2:45	72-88	79-86	76-41	Clear	13S	2-1/2-3-1/2	8-1/2
7-26-63	Q, T, W	17-1/2 x 170	West	8:05-12:20	76-87	80-82	76-48	Clear-hot Part cloudy-hot	15S	2-1/2-3	10

(a) Time, temperatures, humidity from beginning to end of pouring operations.
(b) Full width crack count from D. C. Bowen's crack diagram.

* Same mix and materials on all pours

Cement	94 lbs	- Penn-Dixie, Type 1A
Sand	226.5	- Grand Rapids Gravel (No. 41-38)
6AA	286.5	- Grand Rapids Gravel
Water	45.4	