SCALING OF CONCRETE BRIDGE DECKS CONSTRUCTED WITH STAY-IN-PLACE FORMS

R. H. Merrill
J. E. Simonsen

Research Laboratory Division
Office of Testing and Research
Research Project R-62 B-61
Research Report No. R-458

Michigan State Highway Department
John C. Mackie, Commissioner
Lansing, April 1964

SCALING OF CONCRETE BRIDGE DECKS CONSTRUCTED WITH STAY-IN-PLACE FORMS

In 1962-63, the Research Laboratory Division conducted a laboratory study to determine the difference in scaling performance under freezing and thawing cycles of concrete specimens molded in porous and in watertight molds. The results of these laboratory tests, which were transmitted to C. J. Olsen by E. A. Finney's letter of April 17, 1963, indicated that for all three nominal air contents of 5, 7, and 10 percent, the specimens cast in porous molds exhibited less scaling after 120 cycles of freezing and thawing.

As a result of this laboratory study, which confirmed previously published observations by Grieb, Werner, and Woolf of the Bureau of Public Roads (HRB Bull. 323, 1962, p. 43), the Research Laboratory was asked in April 1963, to conduct a field survey of scaling of bridge decks constructed using stay-in-place forms. Shortly thereafter a meeting of Laboratory personnel concerned with this problem was held to discuss the procedure to be used in performing the survey. It was the consensus that the performance evaluation should be based on comparison of scaled deck areas of bridges constructed with conventional forms and with stay-in-place forms. It was also agreed that a preliminary study should be performed in order to determine a definition of scaling to be used, to select control bridges, to examine construction notes for pertinent information, and to develop a procedure for conducting the survey.

This report summarizes the results of this preliminary study and discusses the field evaluation of bridges in Districts 5, 7, and 8. Conclusions are included regarding the effect of stay-in-place forms with respect to surface scaling. Suggested further research to isolate the effect of watertight forms and to develop preventive measures to reduce scaling is discussed very briefly.

Preliminary Study

Definition of Scaling. Based on a review of previous survey reports and Laboratory test results it was concluded that for a field survey comprising numerous bridges, "scaling" should be categorized in three degrees of severity, illustrated in Fig. 1 and defined as follows:

1. Light scale. Areas where most of the surface is defaced by the mortar being removed as deep as the surface of the coarse aggregate.

2. Medium scale. Areas where all mortar has been removed to the top of the coarse aggregate, with about one-half the area showing deep spots where the mortar surface is below the upper surface of the coarse aggregate.

3. Heavy scale. Areas where all mortar has been removed well below the upper surface of the coarse aggregate with some of the coarse aggregate loose or removed.

Selection of Control Bridges. In selecting control bridges the influence of climate, traffic volume, and years of service were considered. To minimize the effect of these variables only bridges in the same general area, exposed to approximately equal traffic volumes, and of the same relative age as the bridges constructed with stay-in-place forms, were used as control.

Examination of Construction Notes. Construction notes on the bridges were studied and the factors selected for correlation with scaling were concrete slump, air content of concrete, type of curing, and type of finishing.

Survey Procedure. The procedure developed for inspecting the bridges consisted of sketching the location and area of scaled surface on a plan drawing of the bridge deck with each area coded as to type of scaling. This method of recording, in addition to giving the area and type of scaling, would indicate if scaling was confined to certain specific areas of the decks. Only the scaling of the clear roadway surface was recorded in this manner, whereas the condition of the remaining superstructure and cracking of the deck were described in qualitative statements.

Field Survey

The field survey was conducted during the late summer and fall of 1962 and included inspection of 18 bridges with stay-in-place forms and 10 bridges constructed with conventional forms. In addition, four bridges were inspected where the center span was constructed with stay-in-place forms and the end spans with conventional forms. Scaled areas were

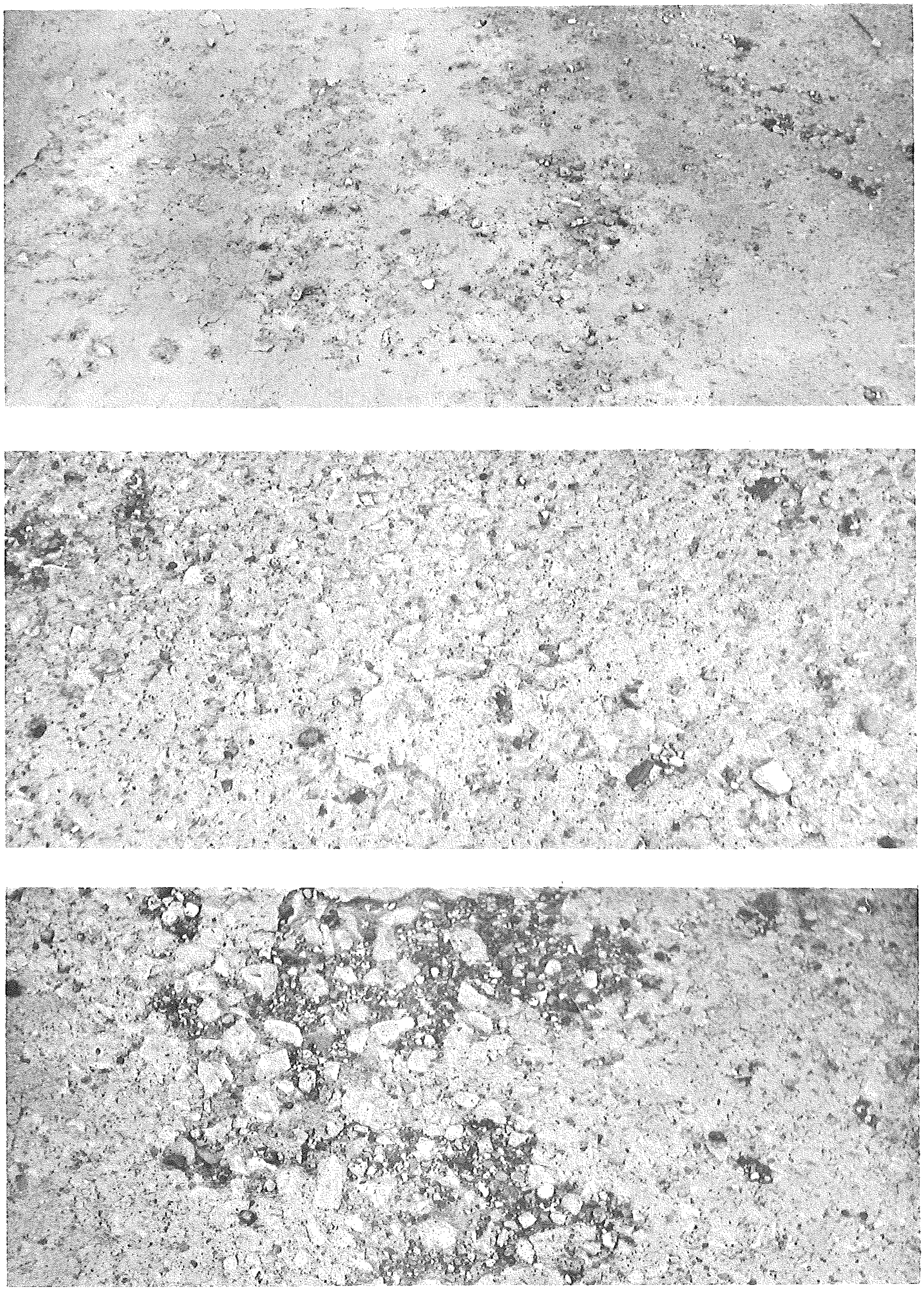

Figure 1. Categories of scaling: light (top), medium (center), and heavy (bottom).

measured and defined as to degree of scaling, and deck cracks, sidewalk conditions, and water seepage through the deck were also noted.

The project number, year built, location, and type of forming for each inspected bridge are shown in Table 1, along with the total deck area and extent of scaling. The last column of Table 1 gives the percent of total surface area scaled for each bridge, indicating that of the 18 bridges and 4 center spans built with stay-in-place forms, 11 bridges and the 4 center spans showed no scaling. Of the 10 bridges and 8 end spans built with conventional forms, 5 bridges and 6 end spans showed no scaling. The average percent surface scaled was 3.4 percent with the stay-in-place forming, as compared to 5.1 percent for conventional forming.

A statistical analysis of the means was conducted to test for a significant difference in average scaling between the two types of forming method. A significant difference would indicate that one type of form might be preferred over the other. A "t" test was performed to test the difference in means, and indicated no significant difference between the two forming methods. However, this result was not conclusive, because the assumptions required in performing the test were not entirely met.

A cursory examination of field construction notes gave no indication of poor concrete in the bridges where scaling was prevalent. The air contents were within the limits of 5.5 ± 1.5 percent, and the slump ranged from 2 to 4 in. with medium consistency. No correlation could be found between scaling and different methods of curing, such as wet burlap, polyethylene, or sprayed-on curing membrane, nor between scaling and various methods of surface finishing.

From the survey records it appears that scaling generally is confined to the gutters and individual deck pours or parts thereof. In many instances it was observed that concrete in a certain deck pour, or part of a pour, exhibited very different scaling properties than others, although concrete was from the same source, and was placed, finished, and cured in the same manner.

No distinct difference was noted in the crack pattern of decks formed using the two types of forms. In no case was there any evidence of water leaking through the deck cracks and seeping out between joints in the stay-in-place forms. Water seepage through cracks of conventionally formed decks was noted on only two structures. Aside from some slight pitting, the sidewalks were found to be in excellent condition regardless of form type.

TABLE 1
SUMMARY OF FIELD SURVEY DATA

District No.	Bridge No.	Const. Year	Route and Structure	Location	Type of Form	Deck Surface (sq ft)	Surface Scaled (sq ft)			Percent Surface Scaled
							Light	Medium	Heavy	
	S12 of 41131	1960	US 131 over Market Avenue	Grand Rapids	Stay-in-Place	9858				
5	B01 of 41024	1961	I 96 over Thornapple River (WB)	1.5 miles southeast of Cascade	Stay-in-Place	13200	1013		8	7.7
	B01 of 41024	1961	I 96 over Thornapple River (EB)	1.5 miles southeast of Cascade	Conventional	13200				
	B01 of 11016	1960	I 94 over St. Joseph River (EB)	2.5 miles south of Benton Harbor	Stay-in-Place	19320				
	B01 of 11016	1960	I 94 over St. Joseph River (WB)	2.5 miles south of Benton Harbor	Stay-in-Place	19320				
	S03 of 11016	1960	I 94 over Pipestone Road (EB)	1.5 miles southeast of Benton Harbor	Stay-in-Place	6713				
	S03 of 11016	1960	I 94 over Pipestone Road (WB)	1.5 miles southeast of Benton Harbor	Stay-in-Place	6713				
	X01 of 11015*	1960	I 94 over NYC RR (SB)	0.5 mile northeast of New Buffalo	Stay-in-Place	3049				
	X02 of 11015*	1960	I 94 over NYC RR (NB)	0.5 mile northeast of New Buffalo	Stay-in-Place	3049				
	X03 of 11015*	1960	I 94 over C & O RR (SB)	1.0 mile north of Harbert	Stay-in-Place	2366				
	X03 of 11015*	1960	I 94 over C & O RR (NB)	1.0 mile north of Harbert	Stay-in-Place	2366				
	B01 of 11015	1962	I 94 over Galien River (SB)	2.5 miles northeast of New Buffalo	Stay-in-Place	8190				
	B01 of 11015	1962	I 94 over Galien River (NB)	2.5 miles northeast of New Buffalo	Stay-in-Place	8190	436			5.3
	S01 of 11015	1962	I 94 over US 12 and M 60 (SB)	0.7 mile northeast of New Buffalo	Stay-in-Place	10080				
	S02 of 11015	1962	I 94 over US 12 and M 60 (NB)	0.7 mile northeast of New Buffalo	Stay-in-Place	10080	118	269		3.8
	S03 of 11015	1962	I 94 under Kruger Road	1.1 miles south of Union Pier	Stay-in-Place	6990	1047	72		16.0
7	S04 of 11015	1962	I 94 under Union Pier Road	0.9 mile east of Union Pier	Stay-in-Place	10981	120			1.1
	S05 of 11015	1962	I 94 under Lake Side Road	1.3 miles south of Lakeside	Stay-in-Place	8400	2236			26.6
	S06 of 11015	1962	I 94 under Warren Road	1.0 mile southeast of Lakeside	Stay-in-Place	9835				
	B02 of 11015	1960	I 94 over Keelo Creek (SB)	2.1 miles northeast of Stevensville	Conventional	3150				
	B02 of 11015	1960	I 94 over Keelo Creek (NB)	2.1 miles northeast of Stevensville	Conventional	3150				
	S08 of 11015	1960	I 94 under Three Oaks Road	1.5 miles southeast of Harbert	Conventional	6220	395			6.4
	S09 of 11015	1960	I 94 under Harbert Road	1.5 miles east of Harbert	Conventional	5240				
	X01 of 11015**	1960	I 94 over NYC RR (SB)	0.5 mile northeast of New Buffalo	Conventional	5407	40	60		1.9
	X02 of 11015**	1960	I 94 over NYC RR (NB)	0.5 mile northeast of New Buffalo	Conventional	5407				
	X03 of 11015**	1960	I 94 over C & O RR (SB)	1.0 mile north of Harbert	Conventional	4613				
	X03 of 11015**	1960	I 94 over C & O RR (NB)	1.0 mile north of Harbert	Conventional	4613				
	S07 of 11015	1961	I 94 under Easy Road	1.6 miles east of Lakeside	Conventional	8873				
	S10 of 11015	1961	I 94 over Sawyer Road (SB)	2.0 miles northeast of Harbert	Conventional	7679	1154			15.0
	S10 of 11015	1961	I 94 over Sawyer Road (NB)	2.0 miles northeast of Harbert	Conventional	7679	516			6.4
	S01 of 38103	1960	I 94 under Sargent Road	4.0 miles east of Jackson	Stay-in-Place	5525				
	S02 of 38103	1960	I 94 under Whipple Road	5.0 miles east of Jackson	Stay-in-Place	5736				
	S03 of 38103	1960	I 94 over Race Road (WB)	6.5 miles east of Jackson	Stay-in-Place	4694				
8	S04 of 38103	1960	I 94 over Race Road (EB)	6.5 miles east of Jackson	Stay-in-Place	4589	772			16.8
	S05 of 38103	1960	I 94 under Mt. Hope Road	8.5 miles east of Jackson	Conventional	5525	18			0.3
	S06 of 38103	1960	I 94 under Clear Lake Road	11.5 miles east of Jackson	Conventional	5447	2219			40.7

* Center span only
** End spans only

Conclusions

Laboratory information concerning scaling of slab models poured in watertight forms and on damp sand bases, due to de-icing chemicals, shows that more scaling occurs on slabs poured in watertight forms. This does not seem to establish any relation between scaling of concrete poured with stay-in-place forms and conventional forms, because it is felt that both types (as specified by the Department) resemble the watertight form model slab more than either resembles the porous base model slab. In order to determine if the specification methods of forming differ significantly with respect to scaling, it appears that somewhat larger scale, controlled, laboratory experiments would be more useful than inspection of existing structures.

However, on the basis of the factual evidence presented here, and disregarding other variables which contribute to scaling of concrete bridge decks, it appears that no significant difference in surface scaling can be attributed to the two forming methods.

Since scaling occurs on some bridges regardless of form type, it is evident that factors inherent in the material, its placement, its finishing, and curing methods have greater influence on scaling than type of form used. In other words, the factor under study is overshadowed by project variables. Therefore, if it is desired to reduce the scaling area below the average 3 to 5 percent now found on existing structures, it appears that tightening of test and inspection procedures during construction would be necessary.