OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

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To: L. T. Oehler
Engineer of Research

From: C. J. Arnold

Subject: Experimental Shoring to Reduce Vibration During Bridge Deck Widening. Research Project 65 F-84. Research Report No. R-780.

This report covers an evaluation of the performance of deck widening on 110 spans of 19 structures, on I 94 in Berrien County.

Background Information

During the 1965 construction season, work was begun on widening the I 94 structures in Berrien County. The Department specified that traffic be maintained during widening on all except the St. Joseph River bridges, where traffic was diverted to the opposite roadway. Early in the construction program it became obvious that traffic on the bridges would subject the new deck sections to considerable vibration during placement and curing of the concrete. The Construction Division made arrangements to place temporary shoring on some of the structures, and requested that the Research Laboratory make measurements to determine the effectiveness of the shoring in reducing vibration of the newly placed deck sections.

Based on the results of initial experimentation, it was decided that temporary shoring should be placed on 44 of 94 spans to be widened under traffic. The Federal Highway Adminstration agreed to participate in the cost of shoring as an experimental construction procedure.

Evaluation

Research Laboratory representatives were on-site to observe placement of most of the decks. Initial condition surveys were made on all structures after construction was completed, and yearly surveys have been made since that time. Cracking, rust staining, and spalling or fracture plane separation, have been recorded each year. The most recent survey, conducted during June 1971, included soundings for hollow areas. Deterioration was noted on scaled sketches of the decks so that progressive failure could be observed. Estimated crack lengths and square footage of spalled and hollow areas were also included.

Results of the June, 1971 survey, indicating the deck condition six years after placement, are shown in Table 1. While the recorded amounts of deterioration are somewhat subjective, they do give a general indication of the condition of the widened portions of the decks. Based on the recorded data, field observations, and notes on construction, there appears to be no significant relationship between the amount and type of deterioration, and the presence or absence of shoring. It is evident that other variables, such as concrete quality, cover over the bars, and location and detail of the splice, have more effect on deck performance than does the use of shoring.

Discussion

Several problems arise and special considerations are required when widening structures, especially when traffic is not diverted. The following points were noted on the Berrien County jobs, and are included here for future reference.

1) The existing sidewalk, rail, and a portion of the deck must be removed from above the existing fascia beam. Since the fascia may have more camber than the other beams, and in general is not low enough to blend well with the new deck section, a thin slab can result and the reinforcement can extend too near the finished surface in this area. This can result in premature deterioration of the deck. Therefore, the existing fascia should be removed and used as the fascia for the widened section, or reseated lower to avoid the problem.

2) When widening is done on an old structure, the new bridge rail will generally be required to meet current specifications. This results in a strange appearance unless the opposite rail is reconstructed to match. Also, on widening the highway, there is good justification for bringing the opposite rail up to par. If this is done in the usual way, it requires careful demolition of the sidewalk to avoid damage to the reinforcement and the deck underneath. This is a very expensive process. Several of the Berrien County structures were fitted with new parapet rail without the removal of the sidewalk. Epoxy grouts in drilled holes were used to anchor reinforcement into the existing sidewalk and deck. The process gave good results, and reportedly saved about $30,000 on the two projects.

3) Traffic-induced vibration causes rippling of the new deck concrete. This condition is further complicated by grade or superelevation of a structure, and by close proximity of traffic to the freshly placed mix. In some cases it will be necessary to refloat the deck surface several times while the concrete is obtaining its initial set. The Berrien County structures show no ill effects from such refinishing.

4) The face or edge of the existing slab should be coated with epoxy grout immediately prior to placement of the new concrete, to aid in bonding and sealing the construction joint.

5) Steel reinforcement should be tied tightly in place. Steel for the Berrien County structures was tied at every intersection; and the mat was supported at many more locations than would be normal for bridge construction.

6) Depth of steel at the longitudinal construction joint is fixed by the location of the existing deck steel. Since many older decks have less cover than presently is specified, and low cover is a major factor in deck deterioration, the steel depth should be increased as quickly as possible, near the construction joint.

7) The side-by-side bar splice detail has proven to be a problem in bridge deck performance throughout the state. If other factors are equal, the first location to spall away is directly above the splice. Once this concrete is gone, the net effect is about equivalent to a broken bar. Therefore, it is obvious that special care should be taken to provide extra cover in the region of the splice. Also, a vertical arrangement of the lapped bars should be used instead of the horizontal or side-by-side configuration. Since the splice is important to the structural integrity of the deck, and can also be a deleterious factor in performance of the deck, careful attention to this detail is of utmost importance.

8) If other factors are equal, and bar splice areas are excluded, spalling generally occurs first where cover is least. Since there are plus and minus tolerances on both the beam seat elevations and the camber of beams, it would be wise to design the widened section with beam seats slightly lower than usual. This will help insure adequate cover over the reinforcement, while maintaining proper slope for drainage of the deck. Construction personnel should set steel toward the lower end of tolerance to increase cover over the bars, expecially at the splice.

9) Since ease of placement is important to construction, and low water-cement ratio is required for durability, it would seem reasonable to specify a seven-sack mix with water reducing admixtures for future projects.

Conclusions

Based on the six-year performance of the Berrien County structures, shoring of the stringers during placement of deck widening does not seem to be warranted. Concrete quality, cover over the reinforcement, and splice details appear to have more bearing on deck performance than does shoring.

Recommendations

It is recommended that future widening projects be designed and constructed in accordance with the nine points discussed above, and that shoring not be required unless some unusual circumstances indicate that it would be beneficial. Note that none of the bridges evaluated was of continuous design. Widening such a structure may present additional problems. It is not the intent here to recommend prohibition of shoring on all future projects, but instead to indicate that shoring as a general practice is not warranted by the performance to date of the Berrien County structures.

TESTING AND RESEARCH DIVISION

C. J. Arnold

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CJA:bf

TABLE 1

RESULTS OF JUNE 1971 SURVEY OF BERRIEN COUNTY STRUCTURES

(Tabulated values of crack length, fracture plane separation, and hollow areas are estimates made by the inspector)

Structure Number	Roadway	Supported	Dimensions and Deterioration																				Lineal Feet of Cracks[1]	Fracture Plane Separation and Hollow Areas[1]
			Span 1					Span 2					Span 3					Span 4						
			Length (ft)	Area (ft²)	Cracks (lin ft)	F. P. S. (ft²)	H. A. (ft²)	Length (ft)	Area (ft²)	Cracks (lin ft)	F. P. S. (ft²)	H. A. (ft²)	Length (ft)	Area (ft²)	Cracks (lin ft)	F. P. S. (ft²)	H. A. (ft²)	Length (ft)	Area (ft²)	Cracks (lin ft)	F. P. S. (ft²)	H. A. (ft²)		
S01 of 11015	EB	yes	40	600	50	0	0	78	1170	115	10	34	78	1170	65	16	12	43	645	65	0	0	8.2	2.0
S02 of 11015	WB	yes	38	494	25	0	0	78	1014	65	12	9	78	1014	55	8	1	45	585	30	1	0	5.6	1.0
X02 of 11015	EB	no	50	400	10	0	0	56	448	1	0	0	50	400	0	0	0	----	----	----	----	----	0.9	0
X01 of 11015	WB	no	51	867	20	0	0	56	952	10	0	0	50	850	5	0	0	----	----	----	----	----	1.3	0
B01 of 11015	EB	no	65	650	0	0	0	64	640	10	0	0	64	640	10	0	0	----	----	----	----	----	1.0	0
B01 of 11015	WB	no	65	650	0	0	0	65	650	5	0	0	65	650	5	0	0	----	----	----	----	----	0.5	0
X03 of 11015	EB	no	54	540	45	0	0	56	560	25	0	2	55	550	0	0	7	----	----	----	----	----	4.2	0.1
X03 of 11015	WB	no	55	550	10	0	4	55	550	35	0	16	55	550	50	5	45	----	----	----	----	----	5.8	4.2
S10 of 11015	EB	yes	42	420	0	1	0	65	650	0	4	9	41	410	5	2	3	----	----	----	----	----	0.3	1.3
S10 of 11015	WB	yes	42	420	10	0	0	64	640	10	1	1	41	410	0	0	0	----	----	----	----	----	1.4	0.1
S12 of 11015	EB	yes	55	715	80	1	3	78	1020	55	1	13	78	1020	30	1	11	51	663	75	0	0	7.1	0.9
S12 of 11015	WB	yes	55	715	15	1	2	78	1020	70	1	2	78	1020	80	1	3	51	663	85	0	0	7.3	0.3
S13 of 11015	EB	no	57	570	5	0	0	57	570	5	0	1	57	570	20	0	0	----	----	----	----	----	1.8	0.1
S13 of 11015	WB	no	57	570	0	0	0	57	570	0	1	1	57	570	0	0	0	----	----	----	----	----	0	0.1
X04 of 11015	EB	no	31	403	0	0	0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0	0
X04 of 11015	WB	no	31	403	30	0	0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	7.4	0
S16 of 11015	EB	yes	47	470	50	3	15	50	500	10	0	1	56	560	0	0	0	----	----	----	----	----	3.9	1.2
S16 of 11015	WB	yes	48	480	20	1	3	50	500	5	1	7	56	560	10	0	3	----	----	----	----	----	2.3	1.0
S17 of 11015[2]	EB	yes	43	430	70	22	14	101	1010	110	10	40	47	470	95	0	8	----	----	----	----	----	14.4	4.9
S17 of 11015[2]	WB	yes	43	430	55	2	8	100	1000	70	1	8	48	480	45	14	9	----	----	----	----	----	8.9	2.2
X05 of 11015	EB	no	66	990	30	0	0	65	975	0	0	0	65	975	0	0	0	----	----	----	----	----	1.0	0
X05 of 11015	WB	no	65	975	80	1	0	65	975	15	1	6	65	975	10	1	9	----	----	----	----	----	3.6	0.6
B02 of 11015	EB	no	73	803	35	1	0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	4.4	0.1
B02 of 11015	WB	no	73	876	40	0	0	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	4.6	0
S21 of 11015	EB	no	36	360	15	0	0	46	460	35	0	0	36	360	30	0	0	----	----	----	----	----	6.8	0
S21 of 11015	WB	no	36	324	10	0	1	46	414	20	0	0	36	324	15	0	0	----	----	----	----	----	4.2	0.1
S01 of 11016	EB	yes	56	728	0	0	0	57	741	0	0	2	56	728	0	0	7	48	624	30	0	0	1.1	0.3
S01 of 11016	WB	yes	56	728	0	1	1	57	741	0	0	0	57	741	0	0	0	49	637	0	0	1	0	0.1
S03 of 11016	EB	yes	56	728	0	0	0	102	1326	10	0	0	64	832	15	0	0	----	----	----	----	----	0.9	0
S03 of 11016	WB	yes	58	754	20	0	0	104	1352	45	0	0	64	832	5	1	0	----	----	----	----	----	2.4	0
X01 of 11016[3]	EB	no	58	580	----	----	----	58	580	----	----	----	58	580	----	----	----	----	----	----	----	----	----	----
X01 of 11016[3]	WB	no	58	580	----	----	----	58	580	----	----	----	58	580	----	----	----	----	----	----	----	----	----	----
B01 of 11016[4]	EB	no	70	910	0	0	0	84	1092	10	0	10	84	1092	20	0	0	84	1092	5	0	10	----	
B01 of 11016[4]	WB	no	70	910	35	0	0	84	1092	80	2	4	84	1092	40	0	0	84	1092	75	0	4	----	----

Structure Number	Roadway	Supported	Dimensions and Deterioration																				Lineal Feet of Cracks[1]	Fracture Plane Separation and Hollow Areas[1]
			Span 5					Span 6					Span 7					Span 8						
			Length (ft)	Area (ft²)	Cracks (lin ft)	F. P. S. (ft²)	H. A. (ft²)	Length (ft)	Area (ft²)	Cracks (lin ft)	F. P. S. (ft²)	H. A. (ft²)	Length (ft)	Area (ft²)	Cracks (lin ft)	F. P. S. (ft²)	H. A. (ft²)	Length (ft)	Area (ft²)	Cracks (lin ft)	F. P. S. (ft²)	H. A. (ft²)		
B01 of 11016[4]	EB		84	1092	0	0	0	84	1092	40	0	6	84	1092	70	0	0	70	910	25	0	0	2.0	0.3
B01 of 11016[4]	WB		84	1092	25	0	0	84	1092	0	0	5	84	1092	85	0	0	70	910	35	0	0	4.5	0.2

(1) Per 100 sq ft of deck area.
(2) Support under center span only.
(3) Deck covered with epoxy surface treatment.
(4) No traffic allowed during curing.