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Investigation of Precast Deck Panels Used in Spread Box Beam Bridges

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Introduction

During bridge deck construction, contractors often have limited access to the underside of the deck due to traffic control limitations or river crossing underclearance. Since many bridge decks today are undergoing replacement, we need to find a method that will eliminate the necessity to access the underside of the deck during construction.

This project was initiated due to the desire of contractors to use partial depth, precast concrete stay-in-place deck panels, eliminating the need to access the underside of the deck during construction. These types of panels have been used in other states, although they have not been widely used in Michigan. Initial guidance on the use of the precast deck panels was provided in FHWA's letter dated February 27, 1987, from Stanley Gordon. The Design Division anticipates an increased use of spread box beams and would like to use these precast deck panels; however, conflicting reports about the durability and longevity of bridge decks built with these precast panels have raised concern. Therefore, the Structural Research Unit performed an investigation into the performance of spread box beam bridge decks recently built with precast deck panels.

Two methods of incorporating precast panels into bridge deck forming have been used by the department, one that adds structural support to the deck and one that serves as form work only. To investigate the performance of bridge decks built with partial depth, stay-in-place precast deck panels, we selected three bridges, one of each form method for evaluation, along with a conventional formed deck for comparison. Refer to Figure 1 for a visual description of the forming methods. The first form type evaluated was the conventional plywood form method that requires access to the underside of the deck for form removal. The second form type investigated was a structural precast panel method that is left in place after the deck has been placed. The panels, supported by a foam backer rod or expanded polystyrene, are placed on the spread box beam and connected to the deck with steel ties as shown in Figure 2. This form acts monolithically with the deck, adding structural support. The third type of form analyzed was a form-only precast panel method that is seated into a preformed notch in the spread box beam, which is assumed not to add any structural support to the deck. Details of this method are shown in Figure 3.

Bridges selected for evaluation were as follows:

1. B02 of 13092 - Conventional Plywood Forms
2. S01 of 25031 - Structural Precast Panels
3. B01 of 10011 - Form-Only Precast Panels

Methodology

To evaluate the different form methods, we performed a crack survey of the top and bottom of each bridge deck, along with a detailed visual inspection. To create uniformity in the procedure, the same people mapped all three decks. Two different colors of paint were used to mark different crack widths (except B02 of 13092). Visible cracks on the dry deck were painted pink. After painting, we wetted the deck as shown in Figure 4. As the deck dried, hairline cracks appeared. These cracks were highlighted in keel and later painted orange. Once the cracks were painted, overhead pictures were taken from a bucket truck, as seen in Figure 5, and a video tape was made (except B02 of 13092). After developing the film, the paint marks were transferred to graph paper. To display the different crack widths, we used a solid line to represent visible cracks prior to wetting the deck (pink paint) and a dashed line to represent hairline cracks that were visible after wetting the deck (orange paint).

Since no cracks were evident in the deck of bridge B02 of 13092, we wetted the bridge deck to reveal the smaller cracks. These cracks were then mapped directly onto graph paper without the aid of photographs or video tapes. We used a solid line to represent the cracks in this deck.

All three structures were inspected in June through July 1996.

Description of Selected Bridges

<u>B02 of 13092 - Conventional Plywood Forms</u>

Structure B02 of 13092, M-99 over the Kalamazoo River, underwent a superstructure replacement in 1993 where conventional plywood forms were used. This structure is in downtown Albion with stop lights on either side. The posted speed limit is 48 kph (30 mph), but due to the traffic lights the speed of vehicles seemed less. The ADT, obtained from the 1992 plans, was 8600 with 2% commercial traffic. The bridge is composed of two spans, each 15.5 m (50'-10") in length with a clear roadway width of 19.3 m (63'-3"), for a total roadway area of 598 m^2 (6,430 ft^2), as shown in Figure 6. Beam spacing varies from 2,896 mm (9'-6") in the center of the bridge to 1,981 mm (6'-6") at the fascia beams. A 229-mm (9") reinforced concrete deck slab covers the thirteen 686 mm (27") prestressed concrete spread box beams. Traffic control during construction was handled by detouring traffic over existing roads.

<u>S01 of 25031 - Structural Precast Panel, Stay-in-Place Forms</u>

The second structure studied was S01 of 25031, Owen Road over US-23, which is between entrance and exit ramps located 1.6 km (1 mile) west of Fenton. Traffic lights are present on either side of the bridge and the posted speed limit is 64 kph (40 mph). The superstructure was replaced in 1994 and reconstructed using structural precast panels for the deck forming. These panels are integrated with the deck providing structural support. The ADT, obtained from the 1993 plans, was 12,000 with 3% commercial traffic. The superstructure, as shown in Figure 7, is composed of eleven 686 mm (27") prestressed concrete box beams spaced at 2,286 mm (7'-6") with a clear roadway width of 24.4 m (80'-0"). Four spans of 17.1 m (56'-0 3/8"), 21.0 m (68'-10 1/8"), 21.0 m (68'-10 1/8"), and 22.1 mm (72'-8 1/4") make the total bridge length 81.2 m (266'-4 7/8"). The total roadway area is 1981 m^2 (21,313 ft^2). This superstructure was replaced in four stages. Stage I and II involved shifting the traffic to the existing westbound lanes on the north portion of the bridge to reconstruct one and a half eastbound lanes. Stage III and IV involved shifting the traffic to the newly reconstructed south portion of the bridge to reconstruct the remaining lanes.

B01 of 10011 - Form-Only Precast Panel, Stay-in-Place Forms

The third superstructure evaluated was B01 of 10011, M-22 over the Betsie River, which is next to a sharp ninety-degree curve about 1.6 km (1 mile) south of Elberta. The speed limit is 64 kph (40 mph), but the advisory speed for the curve is 48 kph (30 mph). Therefore, vehicles were likely traveling slower than the posted limit. The superstructure was reconstructed in 1995. The ADT, obtained from the 1994 plans, was 4,300 with 3.5% commercial traffic. Form-only precast panels were used on this one span spread box beam structure. Refer to Figure 8 for the superstructure details. Nine 533-mm (21") prestressed concrete box beams are spaced between 1,194 mm (3'-11") and 1,499 mm (4'-11"). The total roadway area is 222 m^2 (2,396 ft^2) with a total length of 18.5 m (60'-7 3/4") and a clear roadway width of 12.0 m (39'-6"). The superstructure was replaced in two stages. The first stage shifted traffic to the westbound lane on the north portion of the bridge, while the eastbound lane was removed and rebuilt. The second stage involved shifting traffic to the newly constructed eastbound lane on the south side of the bridge to rebuild the westbound direction.

Findings

B02 of 13092 - Conventional Plywood Forms

After three years of service, this bridge is in good shape, though numerous tight cracks along with shrinkage cracks are present, as detailed in Figure 9. This bridge serves as a base line and the other two bridges will be compared with it. At least twenty cracks were found in the bottom of the deck as shown in Figure 10. Fifteen of the cracks might be full depth due to the similarity with the top deck crack pattern. The bottom deck cracks were outlined with a white powder residue, possibly calcium carbonate. Most of the top deck cracks were longitudinal cracks originating from the abutments and pier reference line. We also found some top deck cracks outlining the spread box beams. These were discovered by overlaying a transparency of the top of deck crack map onto the bottom of deck crack map. As previously stated, although the crack mapping revealed numerous cracks, they are mainly tight.

S01 of 25031 - Structural Precast Panel, Stay-in-Place Forms

After only two years of service this bridge deck is in fair condition based on the amount of cracking. Numerous, large cracks are visible in the top deck surface. Longitudinal and transverse cracks cover the deck. Figures 11 and 12 show the extent of cracking with solid lines representing cracks visible before water was applied to the deck and dashed lines representing cracks visible after the deck was wet. The eastbound lanes, constructed before the westbound, contained most of the cracks. This could be because the newly constructed eastbound lanes carried all of the traffic in a limited roadway width while the westbound lanes were constructed. The westbound lanes, did not contain as many longitudinal cracks, although they did contain more transverse cracks than the eastbound lanes. We also found that many cracks were outlining the box beams, especially in the eastbound lanes.

Structural precast panels performed poorly when compared with the baseline bridge and the third studied bridge, which follows. A detailed inspection of the deck underside, summarized in Figures 13 and 14, revealed three problems. The first problem was the transverse hairline cracks in the panels. Cracking generally occurred at the midpanel and quarter points. The second problem was the lack of concrete cover over the bottom mesh reinforcement. The mesh pattern reflected through the concrete exposing steel in random locations as shown in Figure 15. The third problem was the panel seat mortar placement. In numerous locations, the mortar placed on the box beams was not continuously in contact with the panel, since it had sloughed away from the precast panel, as noted in Figure 16.

B01 of 10011 - Form-Only Precast Panel, Stay-in-Place Forms

This bridge is out-performing both the baseline bridge and S01 of 25031-structural precast panel: however, the deck had been in service only one year. Form-only precast panels were used for the casting of the deck. Minor longitudinal and transverse cracking appeared in the deck and in the panels. The westbound lane appeared to have more hairline, longitudinal cracks occurring than the eastbound side. This may be the result of the westbound side being reconstructed first and carrying all the traffic during the reconstruction of the eastbound lane. Figure 17 shows the extent of cracking with solid lines representing cracks visible before water was applied to the deck and dashed lines representing cracks visible after the deck was wet. Figure 18 shows the results of the bottom of deck inspection. Most of the deck underside cracks appeared in Bay F, where the part-width deck construction was joined using cast-in-place concrete with plywood forms. We noticed that some precast panels were placed with minor gaps between the ends. So far these gaps do not appear to contribute to any structural deficiencies. One minor problem found with these panels was the finish. Some panels have rough aggregate showing on the outside, but the majority of the panels have a smooth finish. At this time, the rough finish does not appear to be a problem. The majority of the installed panels appeared in good condition.

Recommendations

The use of form-only precast panel (stay-in-place) concrete forms should be the only alternative method to the conventional plywood forms for bridge deck placement. Comparing all three forming methods, the structural precast panels are not performing satisfactorily compared with the conventional plywood forms and the form-only precast panels. Additional development of the structural precast panel is needed before further use. Therefore, we recommend that form-only precast panels seated into a preformed notch in prestressed spread box beams be the only alternative to our conventional plywood form work.

When designing precast panels, certain details must be considered:

1. The minimum thickness for the panel is 76 mm (3"), allowing 38 mm (1½") of reinforcement cover from the top and bottom to avoid reflective cracking in the panel due to limited concrete cover over the reinforcement mesh.

2. Use epoxy coated mesh reinforcement to limit future bottom of deck spalls.

3. One layer of reinforcing mesh is required for reinforcement.

4. Prepare a 64 mm (2½") deep notch detail that provides a 64 mm (2½") seat for setting the panel into the beam to assure a good bearing surface. Add a minimum of 13 mm (½") thick mortar bedding in the box beam notch before placing precast panels. Varying the depth of mortar a maximum of three quarters the depth of the notch can be used to adjust the haunch. The depth of the notch can also be decreased to 25 mm (1") minimum and varied along the beam length to accommodate variations in the haunch. Refer to Figure 19 for a typical notch detail. Consideration should be given to casting an adjustable leveling stud into the precast panel. A galvanized 13 mm (½") diameter stud spaced at 300 mm (12") would serve this purpose and would also anchor the mortar bedding. The mortar bedding would need to be overfilled to ensure a bearing surface for the precast panel.

5. As with any bridge, allow sufficient time for the newly constructed deck to cure before opening to traffic.

Future Work

1. Inspect B01 of 10011, M-22 over Betsie River, (form-only precast panels) in 1998 to determine 3 year deck performance.

2. Inspect several spread box beam bridges during construction in 1997 and 1998 as needed to verify preferred details.