High Performance Concrete Bridge Deck Overlays for County Bridges

Operations Research Project Number HR-2107

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DISCLAIMER

The contents of this report reflect the views of the author and do not necessarily reflect the official views of the Iowa Department of Transportation. This report does not constitute any standard, specification or regulation.

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8. ABSTRACT

The Iowa Method for bridge deck overlays has been very successful in Iowa since its adoption in the 1970s. This method involves removal of deteriorated portions of a bridge deck followed by placement of a layer of dense (Type O) Portland Cement Concrete (PCC). The challenge encountered with this type of bridge deck overlay is that the PCC must be mixed on-site, brought to the placement area and placed with specialized equipment. This adds considerably to the cost and limits contractor selection.

A previous study (TR-427) showed that a dense PCC with high-range water reducers could successfully be used for bridge deck overlays using conventional equipment and methods. This current study evaluated the use of high performance PCC in place of a dense PCC for work on county bridges. High performance PCC uses fly ash and slag to replace some of the cement in the mix. This results in a workable PCC mix that cures to form a very low permeability overlay.

9. KEY WORDS

structures, bridges, PCC, Portland cement concrete, repair, patch, de-icing salts, corrosion overlays, Iowa Method, High Performance Concrete

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23

Research Objective

The objective of this research was to demonstrate the feasibility of placing high-performance concrete bridge deck overlays on low-traffic-volume bridges - applying the Iowa DOT specification DS-01069[1] to city and county bridges.

Introduction

County engineers are constantly looking for better, less expensive ways to maintain the important infrastructure in their counties, especially bridges. Bridge construction and maintenance are major challenges for county engineers.

The Iowa Method (HR-502) for bridge deck overlays has been successful in Iowa since its adoption in the 1970s. This method involves removal of deteriorated portions of a bridge deck followed by placement of a layer of dense (Type O) Portland cement concrete (PCC). If adequate cover (the thickness of concrete above the steel) is placed over the reinforcing steel, the overlay will provide enhanced structure and corrosion protection.

The challenge for this type of deck overlay placement has been that the PCC must be mixed on-site, brought to the placement area and placed with specialized equipment. This adds considerably to the cost and limits contractor selection, because not all contractors have the capability or equipment required.

Previous studies by the Iowa DOT (HR-192 and TR-427) showed successful results from using high-range water reducers (super-plasticizers) to make the concrete more workable in the field. Buchanan county was able to place two bridge deck overlays in a short period of time and at low cost. They were able to bring the dense concrete to the job site with a standard ready-mix truck.

Since that time, the Iowa DOT has developed a specification for using high-performance PCC instead of a dense O-mix for bridge deck overlays. High performance PCC is a mix containing standard cement plus fly-ash, slag, and a medium-range water reducer. The additives ensure a mix that is readily workable and has low permeability.

The Iowa DOT has now used this specification to place overlays on more than a dozen bridges. It is hoped that the success of the project described in this report will allow cities and counties to use this method on their bridges.

[1] The full developmental specification is included in Appendix A.

Project Location/Description

The Dubuque County Engineer selected two concrete-slab bridges near the town of Durango in Dubuque county (see map below), both crossing the Little Maquoketa river. The overlays were placed across the full width of the bridges requiring bridge closure. Detours for local traffic were a maximum of four and six miles long respectively.

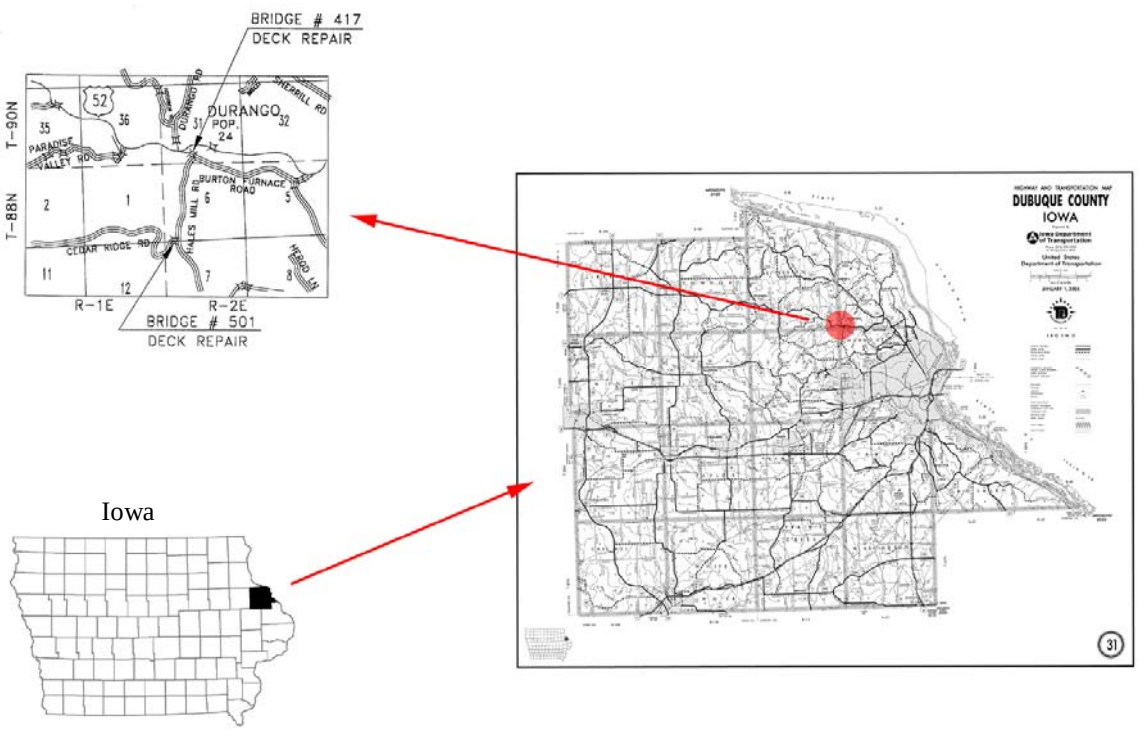

Figure 1
Location of the project bridges in Dubuque County.

Both bridges were built in the early 1980s. At the time of repair, the decks of both were exhibiting significant deterioration. The south bridge (bridge 501) had little visible distress on the surface of the deck, but had large areas of delamination. The north bridge (bridge 417) showed both surface deterioration and large areas of delamination (see below).

Much of the deterioration seemed to be related to the drains along the sides of the bridge—radiating outward from the drains toward the center of the bridge. The areas near the drains were probably hand-worked to ensure proper drainage. It is possible that this resulted overworking of the concrete and thinner cover in these areas.

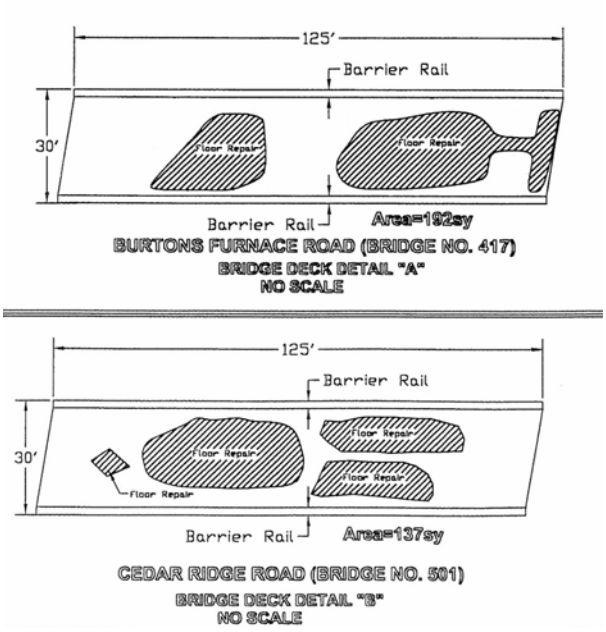

Figure 2
Deterioration estimates from the plans.

Figure 3
Surface distress and patching visible on the north bridge prior to repair work.

Figure 4
The deck of the south bridge after milling and chipping, showing areas that had delaminated.

Materials

The bridge deck overlays that were done for TR-427 were placed using a standard, dense O-mix concrete and high-range water reducers. The overlays in the current project were placed under the requirements of DS-01069. The specification and actual mix design are provided in Appendices A and B. The important differences between this mix and the O-mix used previously is the addition of fly ash and ground granulated blast furnace slag (hereafter called slag) in place of a portion of the cement. These two additives substantially decrease the permeability of the concrete. In addition, the slag and medium range water reducer significantly improve the workability of the plastic concrete.

Slag or blended cements already containing slag are now widely available in Iowa. Fly ash has been readily available in Iowa for many years. As a result, the use of slag and fly ash should not have an adverse impact on cost in future projects.

Construction

The project was let on 21 May, 2007 with Taylor Construction, Inc. of New Vienna, Iowa awarded the contract. The contractor began work on the south bridge in August and had finished and opened both bridges by early September.

There were two parts to the construction: Removing concrete from the surface of the bridge deck and placing a new concrete overlay. These tasks were performed under DS-01069 and Sections 2413 and Division 41 of the Standard Specifications.

Concrete Removal

Approximately ¼-inch of the surface of each bridge deck was milled using a rotary milling machine attached to a skid loader. As part of the Class A repair, any damaged or deteriorated concrete was removed at this time. Some came loose with the milling and the remainder was removed using jack hammers and high pressure water jets. Although there were extensive areas of delamination in both decks, the damage was limited in depth to the level of the top of the upper reinforcing steel. After scarification, a second chain drag was performed to locate any remaining delaminated areas; which were removed.

Figure 5
Milling the bridge deck surface.

Once the deck had been scarified and cleaned, the corroded areas on and around the reinforcing steel were sandblasted and the contractor applied epoxy coating to the exposed and cleaned reinforcing steel.

Overlay Placement

The overlays on these bridges were place full-width, in contrast to the Buchanan county bridges which were staged one lane at a time. This has both benefits and drawbacks.

Pouring full width allows the use of the barrier rail as a foundation for the screeding equipment (see below). The project can be completed more quickly compared to staging one lane at a time. Also, placing one lane at a time can introduce roughness because of vibrations from vehicles in the traveled lane. However, full width placement requires complete closure of the bridge for the duration of the project including demolition, placement and curing. In this case, the detours required were manageable.

Figure 6
Spreading grout.

Just prior to placing the overlay, a thin grout mixture was sprayed on the deck to aid adhesion. Then the concrete mix was placed using an ordinary ready-mix truck and a rolling screed. The concrete supplier for this project was Flynn Ready Mix Concrete Co.

There was some discussion about the requirements for curing, texturing and tining. To minimize the occurrence of shrinkage cracking, the contractor is required to place and maintain wet burlap on the surface starting within 30 minutes of placement. For Iowa DOT projects this time is minimized to 15 minutes or less. However, this early placement of burlap can cause problems with smoothness and the texturing and tining. The Iowa DOT's solution is to do grinding afterward. But this is not always an economical solution for local projects. After consultation with personnel in the offices of Construction and Materials at the Iowa DOT, it was decided that the burlap placement could wait until after texturing/tining but no more than 30 minutes after concrete placement.

Figure 7
Placing the overlay.

Discussion

Cover

These bridges are reinforced with black steel which is common for county bridges. Adequate concrete cover is essential to preventing deterioration due to corrosion of the reinforcing steel from deicing salts.

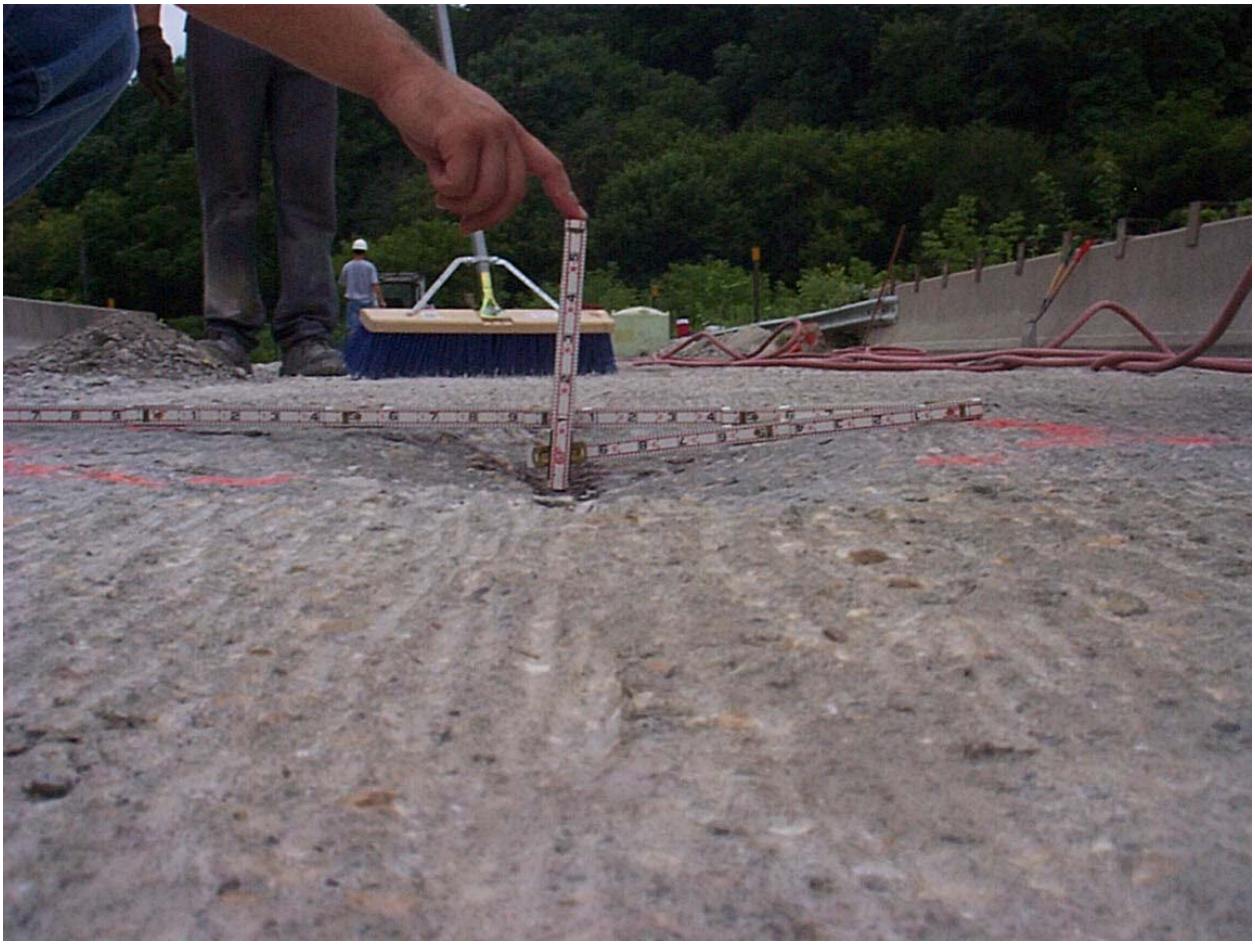

Figure 8
Spall depth on south bridge deck.

Figure 8 is a photograph of the deck on the south bridge after the demolition phase of the project. This particular spall extends down to the top of the reinforcing bar. Measurements such as this and examination of cores indicate that the amount of cover on these decks was about two inches, which is the bare minimum needed. Apparently, it was not adequate for the environment these bridges are in.

The overlay process involves removing ¼-inch of concrete (plus any deteriorated concrete) and adding one inch of concrete above the nominal surface. This should result in close to three inches of cover over the steel. In addition the high performance concrete has very low permeability. So the steel should be well protected into the future.

Barrier Railing

One concern that the contractor had was the effective heights of the safety barriers on the sides of the bridge. Adding height to the bridge deck removes some effective height from the rail. Inspection after the end of the project showed the height of the rails above the deck was 34 inches, which is well above the minimum required for a bridge on a low volume road.

The Iowa DOT has been planning ahead by adding two inches to the nominal heights of barriers during design to allow for future overlays as necessary. This may or may not be feasible at the local level, but this type of safety barrier is not often used on county bridges. However, it is an important point. Counties will want to look at the impact of an overlay on barrier rails of all types.

Figure 9
Barrier rail on the finished north bridge.

Conclusions/Recommendations

The bridges are shown below just a few days after being reopened to traffic. Both appeared to be in excellent shape with no cracking or smoothness issues evident.

Figure 10
The finished bridges, open for traffic.

High performance concrete is an excellent option for counties that plan to perform bridge deck overlays. The high performance mix does not require special mixing or placement equipment and is widely available in Iowa. It provides very low permeability without the need for high cement percentages in the mix. The developmental specification that was used for this project (DS-01069) will be added to the Specification Book in October, 2007. So it will be available for use statewide.

References

HR-192, Evaluation of Dense Bridge Floor Concrete Using High Range Water Reducer (Super-plasticizer), Iowa Highway Research Board, May 1983, Richard D. Smith.

HR-501, Performance of Concrete Bridge Deck Overlays, Iowa DOT and Federal Highway Administration, November 1990, Chris Anderson

TR-427, Evaluation of High-Slump Concrete for Bridge Deck Overlays, Iowa Highway Research Board, October 2005, Brian Keierleber, Edward Engle

Appendix A
DS-01069

DS-01069
(Replaces DS-01062)

Iowa Department of Transportation

DEVELOPMENTAL SPECIFICATIONS

FOR

HIGH PERFORMANCE CONCRETE FOR OVERLAYS OF BRIDGE FLOORS

Effective Date
November 15, 2005

THE STANDARD SPECIFICATIONS, SERIES 2001, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

Section~~s~~ 2413 and Division 41 of the Standard Specifications shall apply with the following modifications:

01069.02 MATERIALS.
A high performance concrete (HPC) with the following proportions shall be used in place of a Class O concrete or latex modified concrete:

- **A.** Basic w/c ratio of 0.40, with a maximum w/c ratio of 0.42
- **B.** A mid-range water reducing admixture meeting the requirements of Materials I.M. 403, Appendix C, shall be used. Other admixtures may be approved by the Engineer.
- **C**. Air content shall be in accordance with Article 2413.02, A, of the Standard Specifications, except the target shall be 6.5%, with a maximum variation of plus 2.0% and minus 1.0%

The slump, measured in accordance with Materials I.M. 317 shall be between 1 inch (25 mm) and 3 inches (75 mm) with a maximum of 4 inch (100 mm). Testing for slump from a continuous mixer shall commence within 2 to 4 minutes after the concrete is discharged.

The HPC mix shall have the following characteristics and absolute volumes per unit volume:

- **A.** Cement 0.134
- **B.** Fly ash (Class C) 15% replacement by weight maximum (mass)
- **C.** GGBFS 25% replacement by weight (mass)
- **D.** Water 0.168 (w/c ratio of 0.40)
- **E.** Coarse aggregate 0.317
- **F.** Fine aggregate 0.316
- **G.** Air 0.065

When blended cement (Type IP, IS, or I(SM)) is used, the GGBFS listed in C above shall ~~will~~ be eliminated from the mix. Other mix combinations may be approved by the Engineer.

Grout for bonding shall meet the requirements of Article 2413.02, A, of the Standard Specifications.

01069.03 EQUIPMENT.
Equipment shall meet the requirements of Article 2413.03 of the Standard Specifications, with the following exceptions:

When volumetric proportioning equipment is used, the cement, fly ash, and GGBFS shall be pre-blended by the producer or by using equipment capable of thoroughly mixing the materials to the tolerances in ASTM C 685.

The finishing machine shall meet the additional requirements of either Article 2413.03, C, 1 or 2413.03, C, 2 of the Standard Specifications, except that the screed may be cable winched with approval by the Engineer.

01069.06 PROPORTIONING AND MIXING.
Proportioning and mixing shall meet the requirements of Article 2413.06 of the Standard Specifications, except that ready mixed concrete equipment meeting the requirements of Article 2001.20 and 2001.21 of the Standard Specifications, will be allowed.

01069.07 PLACING AND FINISHING.
Placing and finishing of the concrete shall be done according to Article 2413.07 of the Standard Specifications and the equipment modifications in Article 01069.03 above, except that the requirement for consolidation to 100% of the rodded density is not required.

Placing concrete overlay will not be allowed if the theoretical rate of evaporation for the pour exceeds 0.2 lbs. per square foot per hour (1 kg/m^2 per hour). The theoretical rate of evaporation shall be calculated using the procedure in Article 2412.05 of the Standard Specifications.

Appendix B
PCC Overlay Mix Design

Mix Number:	1	2	3	4	5
Mix Type:	HPC-S	HPC-S			
Date:	8/27/2007	8/31/2007			
Cement Type:	I	I			
Cement Specific Gravity:	3.14	3.14			
% Fly Ash:	15	15			
Fly Ash Type:	C	C			
Fly Ash Specific Gravity:	2.64	2.64			
% GGBFS:	25	25			
GGBFS Specific Gravity:	2.87	2.87			
T-203 Fine Agg. Specific Gravity:	2.66	2.66			
Intermediate Agg. Specific Gravity:					
T-203 Coarse Agg. Specific Gravity:	2.68	2.68			
Fine Agg. % Moisture:	2.6	1.9			
Intermediate Agg. % Moisture:					
Coarse Agg. % Moisture:	1.8	1.8			
Starting Time (Paving):	13:30				
Stop Time (Paving):	16:00				
Cubic Yards Batched:	42.00	51.00			
% Of Estimated Used:					
Plant Water Added Lbs/CY:	228.0	223.0			
Grade Water Added Lbs/CY:	9.0				
w/c, enter if lower than basic w/c					

Enter Agg. Percentages for BR, QMC, HPC-D Mixes When (ENTER) displays

% Coarse	50.0
%Intermediate	
% Fine	50.0
Total	100.0

Enter Required Fields for QMC, BR, HPC-D Mixes When (ENTER) displays

Target Gradation

1 1/2"	100
1"	
3/4"	
1/2"	
3/8"	
#4	
#8	
#16	
#30	
#50	
#100	
#200 Max	1.0