Evaluation of High-Slump Concrete For Bridge Deck Overlays

Final Report for
Iowa Highway Research Board
Project TR-427

October 2005

Highway Division

Iowa Department
Of Transportation

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TECHNICAL REPORT TITLE PAGE

1. REPORT NO.

TR-427

2. REPORT DATE

October 2005

3. TITLE AND SUBTITLE

Evaluation of High-Slump Concrete for Bridge Deck Overlays

4. TYPE OF REPORT & PERIOD COVERED

Final Report, 12-98 to 10-05

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7. ACKNOWLEDGMENT OF COOPERATING ORGANIZATIONS/INDIVIDUALS

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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, because not all contractors have the capability or equipment required.

If it is possible for a ready-mix supplier to manufacture and deliver a dense PCC to the grade, then any competent bridge deck contractor would be able to complete the job. However, Type O concrete mixes are very stiff and generally cannot be transported and placed with ready-mix type trucks. This is where a “super-plasticizer” comes in to use. Addition of this admixture provides a substantial increase in the workability of the concrete – to the extent that it can be delivered to the site and placed on the deck directly out of a ready-mix truck. The objective of this research was to determine the feasibility of placing a deck overly of this type on county bridges within the limits of county budgets and workforce/contractor availability.

9. KEY WORDS

Bridge Deck Overlay
Dense PCC
Super-Plasticizer
Iowa Method

10. NO. OF PAGES

19

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Disclaimer

Research Objectives

The objective of this research was to determine the feasibility of using high-slump, dense concrete for bridge deck overlays on county roads and to develop effective mix designs and placement techniques.

Introduction

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). If adequate cover (greater than two inches) of concrete is placed over the reinforcing steel, the overlay will provide enhanced structure and corrosion protection.

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, because not all contractors have the capability or equipment required.

If it is possible for a ready-mix supplier to manufacture and deliver a dense PCC to the grade, then any competent bridge deck contractor would be able to complete the job. However, Type O concrete mixes are very stiff and generally cannot be transported and placed with ready-mix type trucks. This is where a high range water reducer or "super-plasticizer" comes in to use. Addition of this admixture provides a substantial increase in the workability of the concrete - to the extent that it can be delivered to the site and placed on the deck directly out of a ready-mix truck. The objective of this research was to determine the feasibility of placing a deck overlay of this type on county bridges within the limits of county budgets and workforce/contractor availability.

Previous Research

The Office of Materials at the Iowa DOT investigated the use of a super-plasticizer on a bridge deck in 1977 (project HR-192). Although there were several differences between the 1977 project and this one, it does provide valuable background information. HR-192 involved a complete deck placement with a standard structural PCC (i.e. not a dense concrete). Addition of the super-plasticizer was made to increase strength and decrease permeability, not to increase workability. The conclusion of HR-192 was that this effort was successful. Ultimate strengths were approximately 25 percent higher and chloride contents at depth were significantly lower compared with the conventional PCC. This suggests that there will be an improvement in these qualities on the current project in addition to the main objective of workability. Additional research performed by the same office in cooperation with the Federal Highway Administration (HR-501) examined the long-term performance of bridge deck overlays using the Iowa Method. Researchers studied 14 bridges with Iowa Method overlays between 15 and 20 years old. The study concluded, in part, that the Iowa Method was an effective means to rehabilitate older bridges and provided significant long-term corrosion protection to reinforcing steel.

Project Locations and Descriptions

The Buchanan County Engineer selected two county bridges for this project: one located just north of Quasqueton on Highway W-35 (hereafter called the Quasqueton bridge), the second located just north of Independence on Wapsie Access Boulevard (hereafter called the Independence bridge). A description of each is in the table below.

Location	Type	Length	Width
Quasqueton	Steel Stringer	75 feet	24 feet
Independence	Steel Stringer Floor Beam	54 feet	20 feet

Materials

There were two water reducing agents used in this project: DARA-CEM 65, a mid-range water reducing agent; and ADVA Flow, a high-range water reducing agent or super-plasticizer; both from W.R. Grace Company. The air entraining agent was Euclid AEA 92. Mix designs and aggregate information are provided in Appendix A.

Construction[1]

Construction began with the removal of deteriorated concrete from both bridge decks in mid September 2000. The contractor used a chain drag to locate deteriorated portions on each deck. Concrete removal was accomplished using a milling attachment on a skid loader, jack hammers and high pressure air blast.

The Quasqueton bridge had extensive PCC deterioration with most of the top steel and much of the bottom steel being exposed completely after concrete removal. However, the reinforcing steel itself was in good condition with very little corrosion. Because of the extensive concrete removal, only one lane was milled and overlaid at a time on this bridge. In contrast, the Independence bridge was in relatively good condition, allowing both lanes to be milled prior to deck placement.

For each of these projects, concrete was delivered in a standard mixing truck and placed by chute. The deck surface had been cleaned with an air blast and coated with a sand and cement grout mixture as a bonding agent. A portable, vibrating screed riding on wood forms provided initial surface leveling.

On September 27, 2000, the contractor began the first concrete pour at the Quasqueton bridge in the south-bound lane. DARA-CEM 65 was added to the eight cubic yards of concrete in the truck at the site. This was a mid-range water reducer instead of the super-plasticizer that was initially requested. The change was made based on a recommendation from the concrete supplier. Unfortunately, this admixture did not provide the necessary workability to the concrete.

[1]Photographs taken during the construction are provided in Appendix B.

The slump of the mix on site was only 1.5 inches and workers had a difficult time even getting the concrete to move down the chute of the mix truck. The contractor added water to the mix attempting (unsuccessfully) to increase the slump. Finally, the county engineer halted construction and the remainder of the load was wasted. Approximately six lineal feet of the overlay had been placed at the time of the decision to halt. All parties agreed to delay the rest of the pours pending a discussion of alternatives. In the interim, the west-bound lane of the Independence bridge was prepared for concrete placement.

PCC placement resumed on October 2. The contractor placed the remainder of the south-bound lane of the Quasqueton bridge and the entire west-bound lane on the Independence bridge. The contractor first made up a two cubic yard test batch of PCC. Using super-plasticizer and air entraining agent, the slump was approximately 6.5 inches and the air content was approximately 11 percent. This air content was too high, so the air entraining agent was decreased.

For the actual pour, the super-plasticizer was added to the mix at the plant. The time between batching and pour was between 45 and 60 minutes. On-site, the air content had dropped to 5.4 percent, but the slump was also down to 3 inches. Both changes were attributed to the extended time from mix to placement. To increase the slump, additional super-plasticizer was added at the job site. This resulted in adequate flow and workability. Placement of this first lane was slow due to inexperience of some of the contractor personnel.

On the subsequent pours, the loads were divided in half (4 cubic yards each). Each of the pours proceeded smoothly and lanes were finished routinely in under an hour. Slump for the subsequent loads stayed at approximately 6.5 inches, but air content continued to be excessive. The air entraining agent was reduced with each pour to a final value of 4.5 ounces per 4 cubic yard load – which is negligible.

After the final pour on the east-bound lane of the Independence bridge, the concrete was covered with tarp for curing and barricades were placed on the lane. This left the bridge open for one lane of traffic. Approximately 40 minutes later, a motorist moved the barricades and drove across the bridge with a wide farm vehicle. This caused a minor wheel track indentation in the concrete of the east-bound lane near the centerline of the bridge (see photograph in Appendix B).

Evaluation

The bridge decks were evaluated regularly for signs of deterioration – both are performing well. Results of strength, air and slump tests are provided in Appendix C.

Discussion

This project was initially let allowing conventional overlay conditions. The final bids were $73,839, $74,620, and $99,608. With an engineering estimate of $52,400, all of the bids were considered to be too high. The contract was then let locally with consideration of using super-plasticizer in the mix. In addition, a different, longer bridge was substituted for one of the original bridges listed. The bid result for this combination was $50,000. At the completion of the project, the actual final cost was $51,353.

Additional savings could be realized potentially by using a standard class C PCC with a low water-to-cement ratio, super-plasticizer and a permeability reducer such as ground granulated blast furnace slag. This would provide all of the benefits of the dense overlay PCC with a smaller cement fraction – and (possibly) lower cost.

One concern expressed by participants was the possibility of adverse effects on long-term durability from using a super-plasticizer. While the Materials Laboratory does not have service records for the use of super-plasticizer with dense (Type O) PCC, its use with types C and D has been documented. None of those records have indicated problems since the first use in the late 1970s.

During the past five years, at least one other county has successfully placed bridge decks with this method. The Iowa DOT has used a similar method on several as well with good results (additional photographs provided in Appendix D).

Conclusions

The cost of placing a dense bridge deck overlay using a super-plasticizer was considerably lower than that of placing a conventional overlay. Once initial placement and composition difficulties were ironed out, placement of the deck was faster as well. Because of locally available contracting and supplies, the project timetable was very flexible.

Implementation

The results of this research will be communicated to the county engineers through the Iowa County Engineers Association Service Bureau and annual meeting. The Iowa DOT has a Developmental Specification in place: DS-01062, Developmental Specifications for High Performance Concrete Overlays of Bridge Floors (a copy is provided in Appendix E. This will provide encouragement for use of this process at the state level.

Acknowledgements

The research project was sponsored by the Iowa Highway Research Board. The board's funding and oversight is greatly appreciated.

The authors wish to extend appreciation to the Buchanan County Board of Supervisors for their part in approving and partially funding the construction process; to Todd Hanson, the PCC Materials Engineer, for providing excellent background and technical support; to Weaver Construction Inc. for the work on the bridges; to Manatt's Concrete for the PCC used in the project; and to Allen Johnson with W.R. Grace Company for technical support with admixtures.

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.

Appendix A

PCC Mix Design

***** ABSOLUTE VOLUMES *****

ABSOLUTE VOLUME CEMENT	0.156
ABSOLUTE VOLUME WATER	0.160
ABSOLUTE VOLUME AIR	0.060
ABSOLUTE VOLUME COARSE AGGREGATE	0.312
ABSOLUTE VOLUME FINE AGGREGATE	0.312

***** SPECIFIC GRAVITIES *****

SPECIFIC GRAVITY OF COARSE AGGREGATE	2.650
SPECIFIC GRAVITY FINE AGGREGATE	2.650
SPECIFIC GRAVITY OF CEMENT	3.140

***** DRY BATCH WEIGHTS PER CU. YD. *****

POUNDS OF CEMENT PER CU. YD	825
POUNDS WATER (BASIC) PER CU. YD	270
POUNDS COARSE AGGREGATE PER CU. YD.	1,393
POUNDS FINE AGGREGATE PER CU. YD.	1,393

PERCENT MOISTURE - COARSE AGGREGATE (WET WEIGHTS)

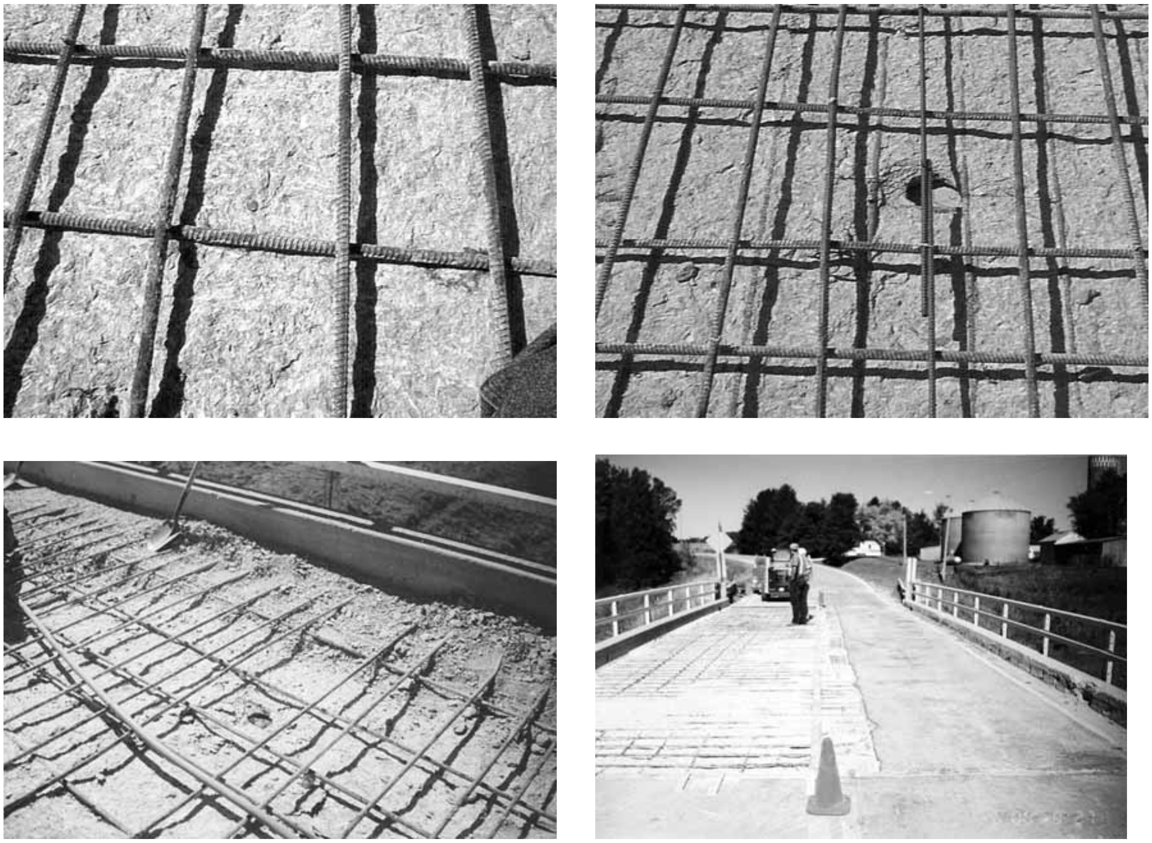
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	1393	1394	1396	1397	1399	1400	1401	1403	1404	1406
1	1407	1408	1410	1411	1413	1414	1416	1417	1419	1420
2	1421	1423	1424	1426	1427	1429	1430	1432	1433	1435
3	1436	1438	1439	1441	1442	1444	1445	1447	1448	1450
4	1451	1453	1454	1456	1457	1459	1460	1462	1463	1465
5	1466	1468	1469	1471	1473	1474	1476	1477	1479	1480
6	1482	1483	1485	1487	1488	1490	1491	1493	1495	1496
7	1498	1499	1501	1503	1504	1506	1508	1509	1511	1512
8	1514	1516	1517	1519	1521	1522	1524	1526	1527	1529
9	1531	1532	1534	1536	1538	1539	1541	1543	1544	1546

PERCENT MOISTURE - FINE AGGREGATE (WET WEIGHTS)

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	1393	1394	1396	1397	1399	1400	1401	1403	1404	1406
1	1407	1408	1410	1411	1413	1414	1416	1417	1419	1420
2	1421	1423	1424	1426	1427	1429	1430	1432	1433	1435
3	1436	1438	1439	1441	1442	1444	1445	1447	1448	1450
4	1451	1453	1454	1456	1457	1459	1460	1462	1463	1465
5	1466	1468	1469	1471	1473	1474	1476	1477	1479	1480
6	1482	1483	1485	1487	1488	1490	1491	1493	1495	1496
7	1498	1499	1501	1503	1504	1506	1508	1509	1511	1512
8	1514	1516	1517	1519	1521	1522	1524	1526	1527	1529
9	1531	1532	1534	1536	1538	1539	1541	1543	1544	1546

Appendix B
Photographs

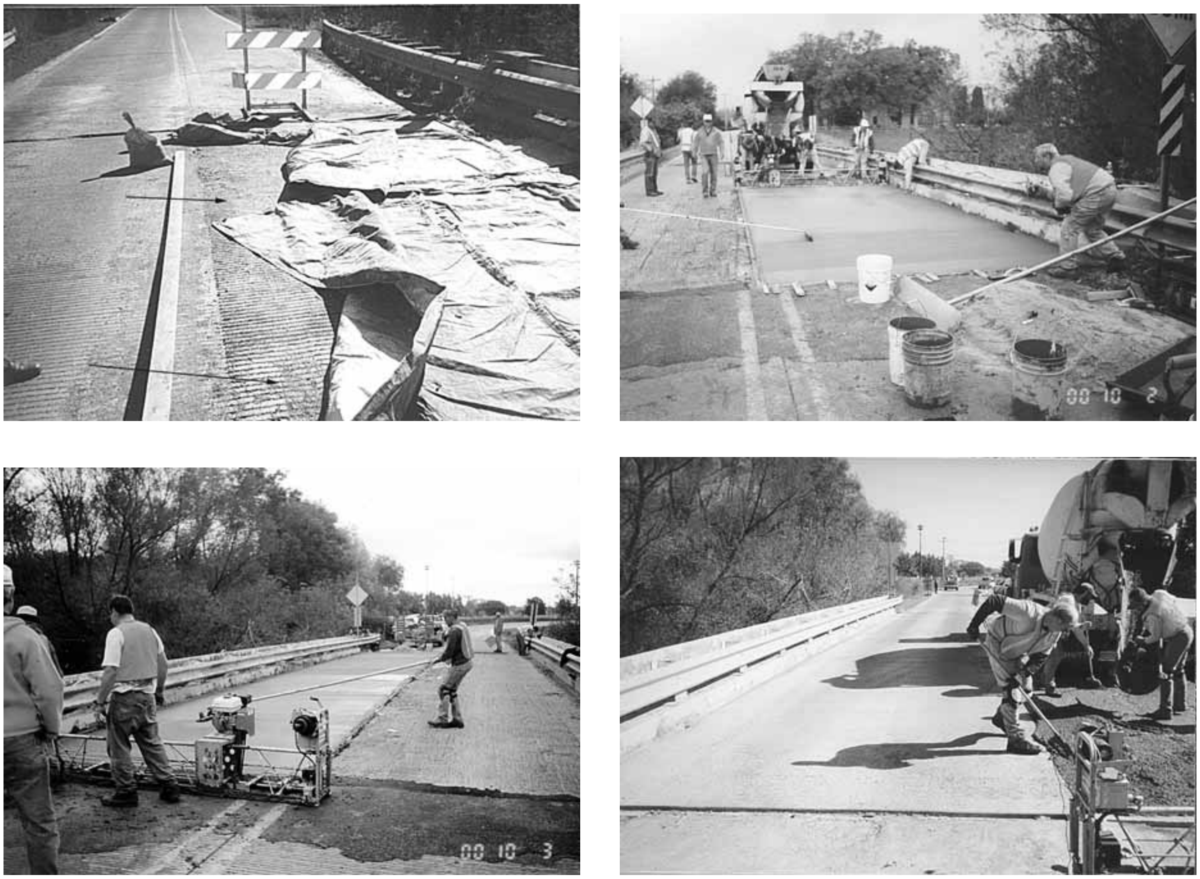
Use of milling, high-pressure air blast and jack hammers to remove deteriorated concrete from the bridge decks.



The Quasqueton bridge after removal of unsound concrete.
Note that both top and bottom steel are visible in some areas and there is at least one hole clear through the deck.

The Independence bridge after removal of unsound concrete from both lanes. Note that the majority of reinforcing steel remains covered with concrete.

PCC placement on the Quasqueton bridge



PCC Placement on the Independence Bridge.
East-bound lane of the Independence bridge, showing the wheel track (arrowed) from a farm vehicle that passed over it approximately 40 minutes after PCC placement.

Appendix C

Tensile Strength Test Data

Date	Location	Curing Time (Days)	Air (%)	Slump (inches)	Strength (psi)
10/2/2000	Quasqueton	2	5.4	3.0	738
10/3/2000	Independence	2	7.0-8.1	6.5	764
10/4/2000	Quasqueton	2	5.4	3.0	737
10/9/2000	Independence	3			712
10/9/2000	Independence	3			655
10/9/2000	Quasqueton	3			785
10/9/2000	Quasqueton	3			545

Appendix D

Photographs from Iowa DOT Projects

Bridge Deck overlay on IA-330 in Marshal county, summer of 2005.

Appendix E

Developmental Specification

DS-01062
(Replaces DS-01049)

Iowa Department of Transportation

DEVELOPMENTAL SPECIFICATIONS

FOR

HIGH PERFORMANCE CONCRETE FOR OVERLAYS OF BRIDGE FLOORS

Effective Date
April 19, 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.

Sections 2413 and Division 41 of the Standard Specifications shall apply with the following modifications:

01049.02 MATERIALS.
~~At the Contractor's option, a~~ A high performance concrete (HPC) with the following proportions ~~may~~ 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 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 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.

01049.03 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.

01049.06 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.

01049.07 PLACING AND FINISHING.
Placing and finishing of the concrete shall be done according to Article 2413.07 of the Standard Specifications, except that the requirement for consolidation to 100% of the rodded density is not required.