Evaluation of High-Slump Concrete For Bridge Deck Overlays Construction Report

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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 is 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.

9. KEY WORDS

Bridge Deck Overlay
Dense PCC
Super-Plasticizer

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13

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Research Objectives

The objective of this research is 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 "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 is 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

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

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. 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 will be evaluated on an annual basis for any signs of deterioration. Cores will be obtained for permeability testing of the overlay. The results of these evaluations will be presented in the final report. Strength tests were performed on beams cast from each bridge project. The results 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.

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.

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References

HR-192, Evaluation of Dense Bridge Floor Concrete Using High Range Water Reducer (Superplasticizer), 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 CEME	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)

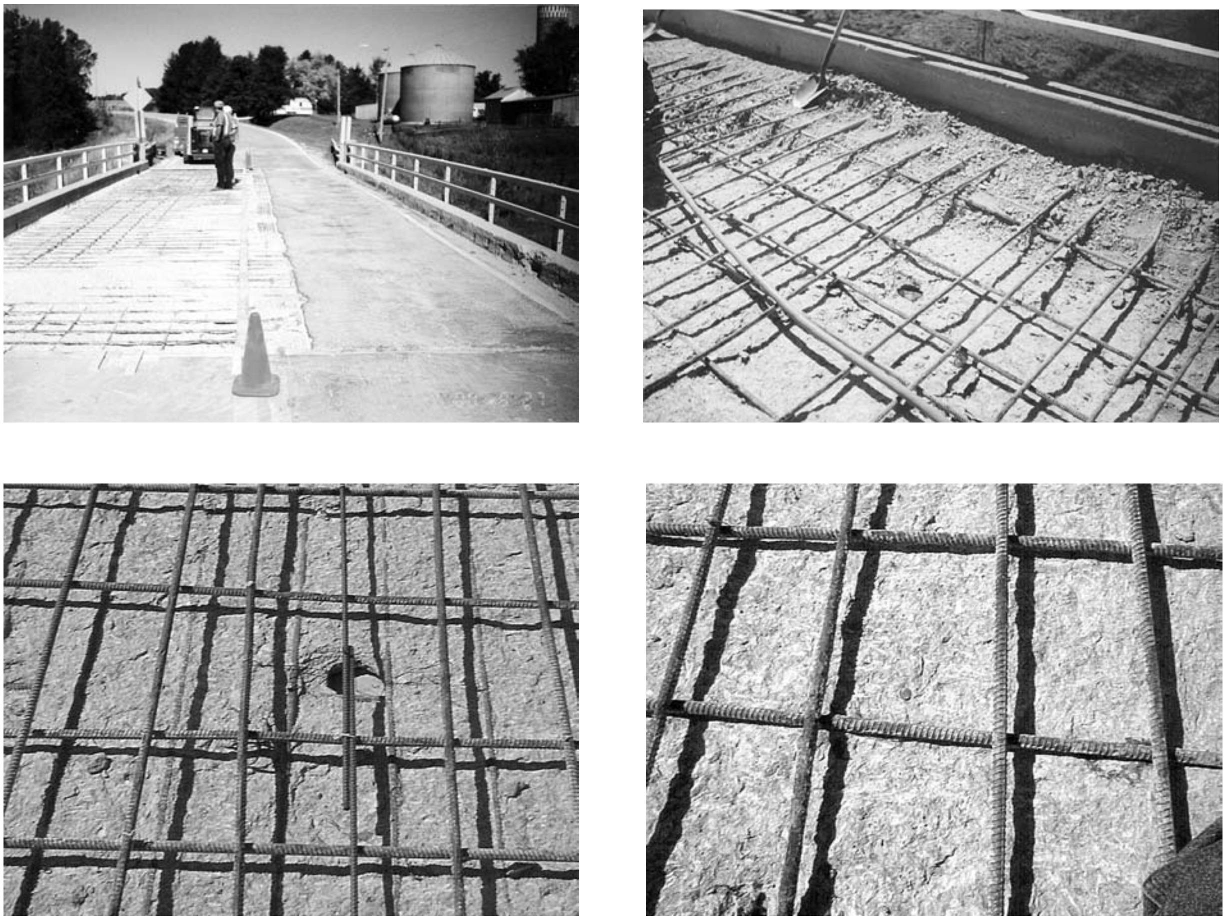
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	1393	1394	1396	1397	1399	1400	1401	1403	1404	1406
1	1407	1408	1410	1411	1413	1414	1416	1417	1419	1420
2	1421	1423	1424	1426	1427	1429	1430	1432	1433	1435
3	1436	1438	1439	1441	1442	1444	1445	1447	1448	1450
4	1451	1453	1454	1456	1457	1459	1460	1462	1463	1465
5	1466	1468	1469	1471	1473	1474	1476	1477	1479	1480
6	1482	1483	148S	1487	1488	1490	1491	1493	1495	1496
7	1498	1499	1501	1503	1504	1506	1508	1509	1511	1512
9	1514	1516	1517	1519	1521	1522	IS24	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	1486	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	IS38	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