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RESEARCH PROJECT TITLE

Investigation of Techniques for Accelerating the Construction of Bridge Deck Overlays

SPONSORS

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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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IOWA STATE UNIVERSITY
Institute for Transportation

Investigation of Techniques for Accelerating the Construction of Bridge Deck Overlays

tech transfer summary

Overlay construction is a vital part of bridge preservation and accelerating overlay construction is important in re-opening bridges to traffic as quickly as possible.

Background

Today's environment is increasingly hostile to bridge decks with exposure to deicing salts and environmental factors such as large temperature swings and polluting chemicals. Being subjected to the most severe loading of all the bridge components, decks undergo deterioration and cracking, which usually results in the deck service life being shorter than that of the other major bridge components.

Overlays can replace the deteriorated part of the deck, thus extending the bridge life. Many states including Iowa have been using overlays to replace the damaged deck concrete.

Problem Statement

Even though overlay construction avoids the construction of a whole new bridge deck, construction still requires significant time in re-opening the bridge to traffic.

Project Objective

The objective of this project was to investigate various ways to accelerate the construction of bridge deck overlays.



Covering freshly finished overlay concrete with wet burlap for three-day curing time to reach 400 psi flexural strength

Project Description

This investigation included three activities:

- Collect information on the latest fast-curing concrete mixes that can be used for overlays
- Observe an ongoing overlay construction project to suggest time-saving changes
- Test deck overlay specimens in the laboratory to evaluate the required depth for removal of substrate concrete



Use of milling machine to remove top layer of bridge deck



Area marked for additional substrate concrete removal after milling and cleaning top of the deck (left) and an area marked for more in-depth concrete removal (right)



Concrete removed past the bottom of the embedded reinforcing steel (left side of image) and removal of concrete along barrier rail using jackhammer (right)



Overlay construction site showing extent of in-depth substrate concrete removal

Investigation into Fast-Curing Concrete Mixes

Generally, the Iowa Department of Transportation (DOT) uses high-performance concrete (HPC) Class HPC-O or Class O concrete mix for overlay construction, which takes at least three days after overlay placement to re-open the bridge to traffic. For the first task, literature on the latest fast-curing concrete mixes were studied and several concrete mixes were found that can reduce the curing time to as short as four hours.

Observation of Ongoing Overlay Construction Project

During the second task, the researchers observed and documented an ongoing overlay construction project.

According to current Iowa DOT practice, during the removal of unsound concrete, if the unsound concrete is found to be present above half the diameter of the top reinforcing steel bar, there is no need for extra removal of any sound concrete. If the unsound concrete is present below half the diameter of the reinforcing steel bar, in addition to the unsound concrete, extra sound concrete needs to be removed until one-half to one inch below the reinforcing steel bar. This extra removal of the sound substrate concrete leads to additional construction time.

Through observation, several opportunities were noted where small modifications in the process could lead to significant savings in time. Suggestions were made for better management of time, labor, machinery, and material.

Laboratory Testing of Specimens

A major part of this project was the third task, which was comprised of four different laboratory tests with different loading conditions to determine the depth of sound concrete removal necessary for the required bond strength between the substrate concrete and the new overlay concrete.

Laboratory Testing Methodology

The bond strength between the substrate concrete and the new overlay concrete was tested for four different concrete removal depths:

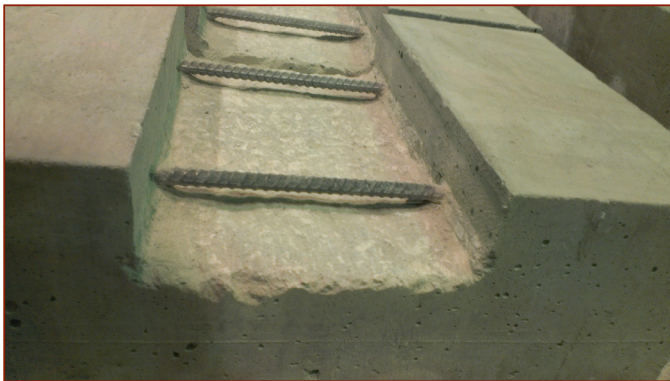
- Case 1– Down to the upper surface of the reinforcing steel
- Case 2– Down to half the diameter of the reinforcing steel
- Case 3– Down to the full diameter of the reinforcing steel
- Case 4– Down to the full diameter of the reinforcing steel plus an additional 0.5 to 1 in. below it

For these four different cases of removal depth, the bond between the substrate concrete and the new overlay concrete was evaluated using four different tests:

- Pull-off test
- Push-out test
- Positive bending flexural test
- Negative bending flexural test



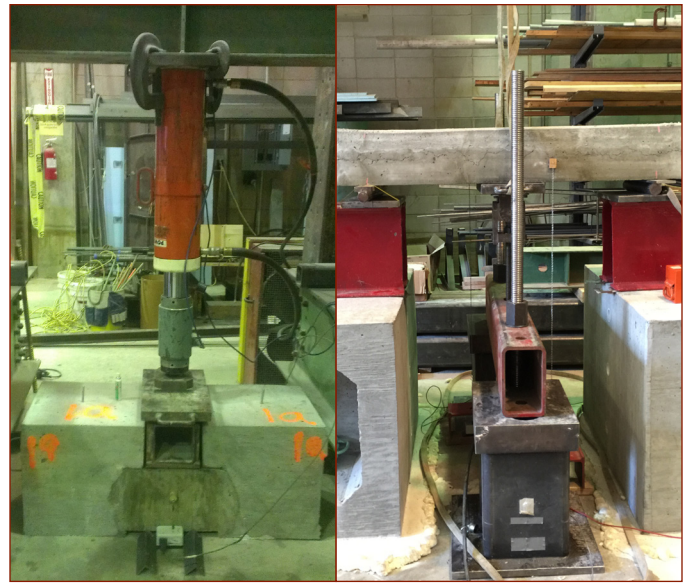
Positive bending flexural test formwork for substrate concrete with steel plate under the reinforcing steel bars



Pull-off test specimen with substrate concrete removed using a jackhammer to below the reinforcing steel before building the overlay formwork and placing the overlay concrete



Pull-off test specimens in overlay formwork with studded steel plates pushed into overlay concrete on top



Push-out test (left) with specimen on bottom and positive bending flexural test (right) with specimen on top



Negative bending flexural test specimen with substrate concrete on top and overlay concrete on the bottom

Factors that were taken into consideration for comparing the bond strength were load at stiffness changes, maximum load, shear stresses at stiffness change and at failure, and stiffnesses.

Two types of concrete mixes were used for all of the tests. For the substrate concrete, Class C4 was used; and, for new overlay concrete, Class HPC-O was used.

Key Findings and Conclusions

The literature review of fast-curing concrete mixes led to a conclusion that CTS Rapid Set Low-P cement mixes, 4x4 concrete mix, polyester polymer concrete, and very-early-strength latex-modified concrete (LMC) are possible substitutes for Class HPC-O and O mixes, and, therefore, could be used for overlays to reduce curing time without any loss in the necessary strength requirements.

Observation of the ongoing overlay construction project concluded that additional machinery like sandblasting equipment, jackhammers (and the number of workers using them), and dump trucks could be used at times when it would lead to time savings.

Based on the laboratory testing to determine the required concrete removal depth level, the following results were found.

- For the pull-off test, the load at failure and the tensile bond stress at failure showed slight variation with respect to the concrete removal depth. This suggests that the removal of the additional sound concrete beyond half the diameter of the reinforcing steel bar would not have a significant effect on the bond strength.
- Push-out test results showed that the concrete removal depth Case 1 showed significantly lower bond strength than the other removal depths. The load and the shear stress values at the stiffness change for the concrete removal depths Case 2 through 4 showed insignificant variation. The stiffness values for all cases showed very small variation. The load and the shear stress at a stiffness change (i.e., crack development) are important parameters when it comes to ensuring long-lasting structural performance of a bridge deck. The push-out test indicates that the removal of the additional sound concrete below half the diameter of the reinforcing steel bar would not result in a significant difference in the bond strength.
- Results from flexural tests with positive bending showed that the maximum load, stiffness, and elastic shear stress at the bond interface were slightly different for different concrete removal depths. The results show that Case 2 provides sufficient bond strength and no additional bond strength is achieved with additional sound concrete removal.
- For the flexural tests with negative bending, the load at stiffness change, maximum load, and elastic shear stresses showed relatively small change in values with changes in concrete removal depths. This shows that the removal of sound concrete below half the diameter of the reinforcing steel bar would not lead to a significant increase in bond strength.

Overall, from all of the laboratory tests, it can be concluded that the removal of the substrate concrete to half the diameter of the reinforcing steel bar provides as much bond strength as removing additional sound concrete. If unsound concrete exists below half the diameter of the reinforcing steel bar, removing only the unsound concrete would likely be sufficient. The test results indicated that removing the additional sound concrete half the diameter of the reinforcing steel bar would not result in a significant difference in the bond strength.



Pull-off test specimen failure at the concrete bond interface showing the failure planes on the substrate concrete surface in the center and the overlay concrete surface on the right

Implementation Benefits and Readiness

- CTS Rapid Set Low-P cement mixes, 4x4 concrete mix, polyester polymer concrete, and very-early-strength LMC should be further evaluated for use as overlay materials.
- Contractors could possibly look at potential means and methods to help minimize closure time.
- During the removal of the unsound concrete on an actual bridge, a trial attempt should be made with the following removal conditions:
 - If unsound concrete exists to or above half the diameter of the reinforcing steel bar, all concrete should be removed to half the diameter of the reinforcing steel bar.
 - If unsound concrete exists below half the diameter of the reinforcing steel bar, all the unsound concrete should be removed until the depth to which it exists, but no additional sound concrete should be removed.
- The performance of overlays should be evaluated over a period of years following installation.

One of the major concerns about the construction of an overlay is the time it takes to open the bridge to traffic. As with other construction activities, attempts to minimize construction time must not compromise the structural soundness or longevity of the bridge.

However, reducing the time required for overlay construction could have a significant impact on reducing the socioeconomic costs associated with bridge deck rehabilitation, including those for agriculture, business, and industry, as well as the inconvenience caused to the traveling public.