Beam End Repair for Prestressed Concrete Beams

tech transfer summary

September 2020

RESEARCH PROJECT TITLE
Beam End Repair for Prestressed Concrete Beams

SPONSORS
Iowa Highway Research Board
(IHRB Project TR-715)
Iowa Department of Transportation
(InTrans Project 17-598)

PRINCIPAL INVESTIGATOR
Behrouz Shafei, Associate Professor
Bridge Engineering Center
Iowa State University
shafei@iastate.edu / 515-294-4058
(orcid.org/0000-0001-5677-6324)

CO-PRINCIPAL INVESTIGATOR
Brent Phares, Research Associate Professor
Bridge Engineering Center
Iowa State University
(orcid.org/0000-0001-5894-4774)

MORE INFORMATION
intrans.iastate.edu

Bridge Engineering Center
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103
www.bec.iastate.edu

IOWA STATE UNIVERSITY
Institute for Transportation

Alternative patching materials including ultra-high performance concrete and high early strength concrete may help improve water and chloride resistance, as well as the load-carrying capacity, of prestressed concrete beam ends.

Objective

The objective of this project was to investigate innovative repair and retrofit solutions for restoring the capacity of prestressed concrete beam ends experiencing deterioration.

Background

A primary concern with the use of precast prestressed concrete beam (PPCB) bridges is the frequent occurrence of cracking and spalling of the concrete towards the ends of the prestressed concrete beams.

This deterioration allows water and chlorides to penetrate into the beam ends, causing exposure and corrosion of the beams' steel reinforcement and prestressing strands. Chloride ingress is particularly problematic in areas with colder climates, such as Iowa, where deicing salts are used on roadways.

If allowed to progress, this corrosion will compromise the load-carrying capacity of the beams, which can affect the integrity of the entire bridge and raise safety and durability concerns.

Problem Statement

Patching spalled concrete restores damaged beam sections and covers any exposed steel. While patches of mortar or normal concrete meet these needs, additional measures are often required to enhance chloride resistance and restore the damaged beam's structural capacity.

Alternative patching materials such as ultra-high performance concrete (UHPC) and high early strength concrete (HESC) may bond more strongly to the substrate concrete, more effectively resist water and chloride infiltration, and restore the capacity of a damaged beam.

Severely deteriorated prestressed concrete beam ends in Minnesota

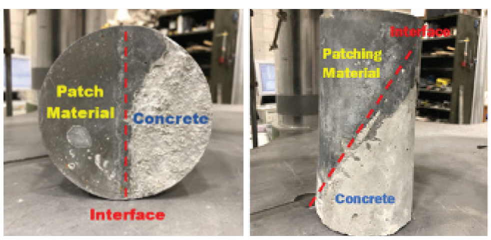
Research Description

Current repair strategies were reviewed and evaluated to determine the key qualities of effective repair methods and identify potential alternative patching materials.

Small-scale laboratory testing was conducted to evaluate the bond strength of four potential patching materials and their suitability for use in patch repairs. The materials included proprietary and nonproprietary UHPC, HESC, and shrinkage compensating cement concrete (SCC-C). Each material was evaluated under tensile and shear stresses using the splitting tensile strength test and the slant shear strength test, respectively.

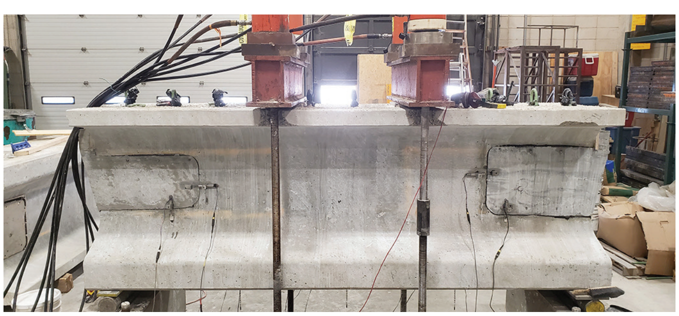
Full-scale laboratory testing was conducted to determine the properties and performance of UHPC and HESC as beam patching materials. Six prestressed concrete beams 11 ft in length were cut from a full-size bulb-tee C-shaped beam and artificially damaged at the ends. Two segments were left unrepaired, two were repaired with UHPC, and two were repaired with HESC.

The beams segments were instrumented with various strain and displacement gauges, and structural response was measured using four-point bending tests.



Specimens for splitting tensile strength test (left) and slant shear strength test (right)

Beam specimen with artificial damage on both ends



Patched beam specimen instrumented for the four-point bending test

Key Findings

Small-Scale Testing

- All material types demonstrated good tensile bond strength. Both the HESC and SCC-C bonded samples exhibited a tensile bond strength exceeding that of the plain unbonded samples tested. Both types of UHPC samples resulted in higher peak loads resisted.
- All material types demonstrated good shear bond strength. No bond failures were observed during slant shear testing.
- In the HESC and SCC-C samples, failure initiated in the substrate concrete and cracking propagated as vertical splitting cracks in nearly all specimens.
- Pure substrate failure occurred for the UHPC samples. Some cracks penetrated into the UHPC but were mitigated by the steel fibers in the mix.
- The results of the small-scale testing suggest that all materials provide adequate bond strength and are suitable for use as patch repair materials.

Full-Scale Testing

- All four repaired specimens maintained their integrity and performance with no failure after loading. No significant differences in behavior were observed under loading between the four patch-repaired girders and the two unpatched girders.
- Failure of one of the unrepaired beams due to confinement failure demonstrated an important consequence of the loss of concrete cover caused by corrosion damage.
- Both the UHPC and HESC patches demonstrated good bonding to the beam substrate during full-scale testing.
- The four patch-repaired girders experienced lower maximum strains and deflections despite being subject to a greater maximum load, indicating that the patching was satisfactory during loading and unloading.

Implementation Readiness and Benefits

Effective repair and retrofit solutions for the damaged ends of prestressed concrete beams can extend the service life of PPCB bridges. While patching has traditionally been combined with other repair techniques to enhance chloride resistance and restore load-carrying capacity, alternative patching materials such as UHPC or HESC can help meet these needs.

Further research is needed to characterize the strength-enhancing capabilities of UHPC and HESC for beam-end repair in the field.