



CONSTRUCTION MANAGEMENT  
AND TECHNOLOGY

# Rapid Bridge Deck Joint Repair Investigation – Phase III

tech transfer summary

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## RESEARCH PROJECT TITLE

Rapid Bridge Deck Joint Repair Investigation – Phase III

## SPONSORS

Federal Highway Administration  
Iowa Department of Transportation  
(InTrans Project 13-451)

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## CMAT

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The Construction Management and Technology (CMAT) program is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the CMAT program is to improve the efficiency and cost-effectiveness of planning, designing, constructing, and operating transportation facilities through innovative construction processes and technologies.

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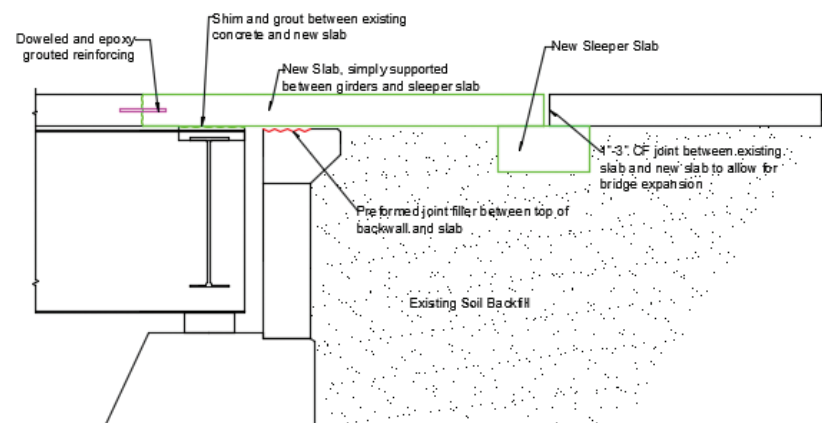
## Background

Many multiple-span bridges include an expansion joint to accommodate thermal movement and other behaviors; they also must be sealed to prevent winter deicing chemicals and other corrosives from leaking through the deck joints and damaging the bridge's substructure. Accommodating movement while providing a watertight seal is a challenging proposition, especially under the pounding of traffic.

Most expansion joints require frequent repair and multiple replacements during a bridge's normal service life, and efforts to improve the longevity of these joints have had limited success. A preferred option for some bridges may be to eliminate deck joints, which would also reduce concerns about the possible leakage of corrosives into the substructure and deterioration under traffic.

The Iowa Department of Transportation (DOT) funded a three-phase research project on rapid bridge deck joint repair. Phase I documented current methods of maintaining and replacing bridge expansion joints. In Phase II, workshops were held where representatives from industry, academia, and the Iowa DOT identified ways to improve traditional expansion joints.

The researchers and Iowa DOT engineers developed an alternative joint type, called the deck over backwall concept, which moved the expansion joint from the bridge deck to the approach slab. The concept would both minimize the concrete removal needed for rehabilitation and prevent corrosives from leaking onto the bridge's substructure.



Deck over backwall concept

## Problem Statement

Plans and details for the deck over backwall concept were developed to meet Iowa DOT standards and account for typical construction practices and preferences. However, this concept required structural analysis and experimental testing before it can be implemented.

## Objectives

Phase III of this research set the following objectives to further develop the deck over backwall concept initiated in Phase II:

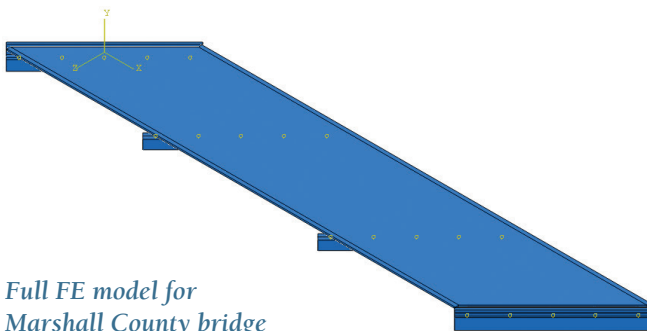
- Create finite element (FE) models of two existing bridges and study the impact of the concept on the existing bridge structures
- Conduct experimental testing to evaluate the performance of the deck over backwall concept
- Compare the costs of the deck over backwall concept to those of other types of joints
- Develop a plan for construction observation and post-construction testing so that the concept can be further studied after field implementation

## Research Description

### FE Models

Full-scale FE models of two existing bridges, a non-skewed bridge in Story County and a skewed bridge in Marshall County, were developed using the same process; both were validated using design data shown on the original drawing plans and American Association of State Highway and Transportation Officials (AASHTO) standard truck load configurations.

Additional models were developed based on the Marshall County bridge that incorporated the deck over backwall concept under various soil support conditions. Further versions of the Marshall County bridge with the deck over backwall concept were created to study the effect of various bridge skew angles ( $0^\circ$ ,  $30^\circ$ ,  $45^\circ$ , and  $60^\circ$ ) on the joint and approach slab.



Full FE model for Marshall County bridge

All models were analyzed with various loading conditions from dead loads, temperature loading, and live loads corresponding to various truck loading cases based on an HS-20-44 truck.

## Experimental Testing

Experimental testing was conducted on a single laboratory specimen to assess the performance of the deck over backwall concept in general and under various design decisions. The specimen was 10 ft wide and included sections representing a deck, diaphragm, and approach slab.

Two tests were performed on the specimen. In Test 1, both the top and bottom longitudinal reinforcing in the approach slab were continuous, and no hard support was used to represent a backwall. In Test 2, the top reinforcing was saw cut, and a hard support was used to simulate the presence of a backwall.

The specimen was instrumented to measure strain, displacement, and, for Test 2, the horizontal widening of the saw cut. Loading conditions for both tests corresponded to the rear axle of an HS-20-44 truck. The displacement, cracking patterns, and stress concentrations at various points on the specimen were analyzed.

## Cost Comparison

The installation and repair or replacement costs over the service life of a bridge were estimated for various types of joints, including the deck over backwall concept. In addition, the construction costs of the Iowa DOT's design for the deck over backwall concept were estimated.

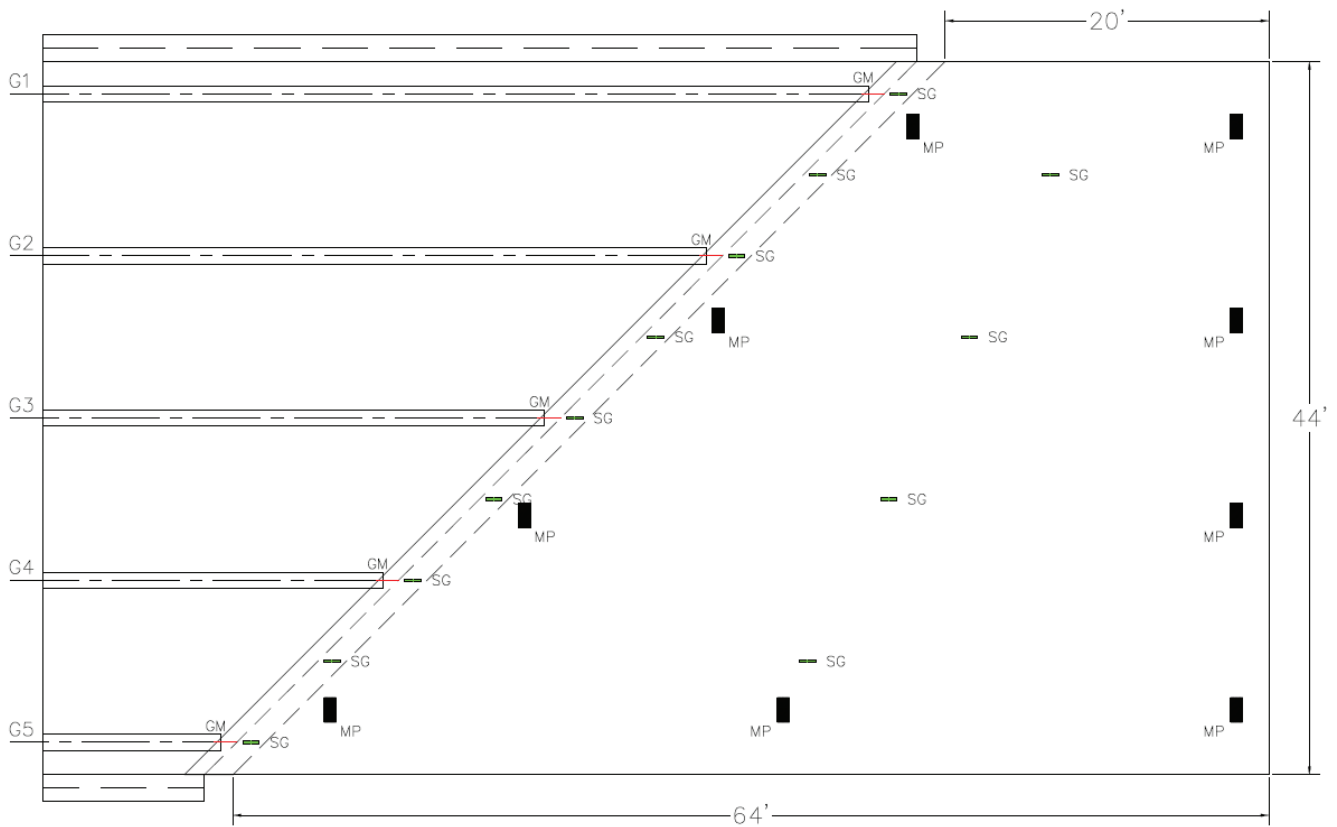
With these estimates, the lifetime costs of the bridge over backwall concept were compared to those of other joint types.

## Construction Observation and Post-Construction Testing Plans

A plan for construction observation and post-construction testing was developed that included an instrumentation plan and various truck loading cases that correlated with those used for the full-scale FE models.



Laboratory specimen showing approach slab and diaphragm sections



SG: strain gage (13 locations); MP: monitoring plate (8 locations); GM: gage meter (5 girders)

### Instrumentation plan for post-construction testing

## Key Findings

### FE Models

- The results from the FE models can help the Iowa DOT further develop the deck over backwall concept and possibly a detailed design for a test installation. Additionally, the model results may be able to be correlated with future laboratory and field measurements.
- The deck over backwall concept in the Marshall County bridge model increased bearing loads due to the additional dead load of the approach slab and increased live loads under the truck loading conditions.
- When the approach slab is modeled without soil support, an increase in the bridge skew angle generally increases the dead load abutment reactions and temperature deformation, the live load abutment reactions, and the deflection values and stress levels at the abutment interface and in the midspan of the approach slab.
- When the approach slab is modeled with soil support, the results show more variance and do not follow a general trend.

### Experimental Testing

- If the top longitudinal reinforcing in the approach slab is cut, the filler material in the saw cut will have to withstand considerable stretching and deformation and serve as a protective layer against any cracking that may form under the saw cut. Cracking and deformation may create a bump on the driving surface at the saw cut.
- Cracking under the saw cut could be mitigated by moving the cut to the edge of the backwall. When the saw cut is in the middle of the backwall, the rotation of the approach slab causes diagonal cracks to form from the contact point to the bottom of the saw cut.
- The far end of the approach slab experiences upward rotation. An engineer designing the connection between the roadway and approach slab should take this rotation into account.
- The presence of a backwall increases the moment capacity of the approach slab due to a decrease in the effective length. This, in turn, reduces the stresses in the midspan of the slab. Effective soil support under the approach slab can also reduce stresses.

## Cost Comparison

- For a bridge service life of 50 years, the deck over backwall concept is the lowest cost alternative among the nine joint types considered. For a bridge service life of 25 years, the deck over backwall concept costs more than most comparable joint types.
- The high initial cost of the deck over backwall concept accounts for most of its life cycle costs; the repair or replacement costs are the lowest among all types of joints by a considerable margin.
- A break-even point of 44 years was found at an interest rate of 2%, indicating that the deck over backwall concept is the lowest cost option when a bridge's service life is 44 years or more. The break-even point decreases as the interest rate increases. If road user delays are included in the analysis, the breakeven point decreases further in number of years.

## Recommendations for Future Research

Researchers should query other transportation agencies that have previously implemented concepts similar to the deck over backwall concept regarding recent performance of actual installations and use the results to improve the details of the Iowa DOT deck over backwall concept.

While the full-scale FE models serve to develop the deck over backwall concept, the models should be calibrated and modified after the deck over backwall concept is implemented in the field and post-construction field testing is conducted. Further modeling is recommended before details of end span beam concrete dimensions, reinforcing steel bar configuration, and longitudinal reinforcing design is finished.

In post-construction field testing, the Iowa DOT is expected to use trucks with loads and tire spacings that are different from than those of the HS-20-44 trucks used for the FE model analyses. The results of the field tests can be compared to those of an FE model analyses that is revised to use the configuration of test trucks, and correlations between both sets of results can help calibrate and improve the accuracy of the FE models.

In addition, the experimental testing can be supplemented with various truck loading cases and variations in soil support, and numerous factors and cost items could be incorporated into the cost analysis.

## Implementation Readiness and Benefits

The deck over backwall concept is a promising alternative to expansion joints that can both minimize the concrete removal needed for rehabilitation and prevent corrosives from penetrating the bridge's substructure. The concept can also be constructed relatively quickly and, in many cases, incur lower life-cycle costs in comparison to other joint types.

The deck over backwall concept, along with the post-construction testing plan, is expected to be implemented in a future Iowa DOT construction season. The results of this research can help the Iowa DOT continue to improve upon the design and confidently implement the concept in the field.

Given the high stresses and deflections and loads that were calculated when the bridge abutment was skewed and the far end of the approach slab and its supporting sleeper slab is not skewed, it is recommended that consideration be given to designing the far end of the approach slab and supporting sleeper slab so that it is always parallel to the abutment. This will reduce the length that the approach slab will have to span for much of the width of the roadway.

Further detailing should be developed regarding the deck over backwall concept. Several options remain to be resolved, such as selecting exactly where a joint or saw cut might be placed in relation to the abutment backwall and the possibility of moving the joint closer or keeping it parallel with the backwall. Other slab, subdrain, and joint options can also be incorporated into the concept.