

# **ACCELERATED REPAIR AND REPLACEMENT OF EXPANSION JOINTS**

**Quarterly Progress Report  
For the period ending September 1, 2019**

Submitted by:

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**ACCELERATED BRIDGE CONSTRUCTION  
UNIVERSITY TRANSPORTATION CENTER**

Submitted to:

ABC-UTC  
Florida International University  
Miami, FL

# **1. Background and Introduction**

Accelerated Bridge Construction (ABC) initiative is changing the way that bridges are built across the country. Accounting for an ever-increasing number of vehicles traveling over the nation's roads, reducing lane closure times has been identified as an integral part of ABC techniques and practices. In recent years, extensive research has been conducted on ABC. However, less attention has been devoted to accelerated repair and replacement of bridge deck expansion joints.

Many of the aging multiple span bridges utilize some form of expansion joint to properly counteract thermal movement and prevent stress buildup. The majority of these expansion joints require frequent repair and multiple replacements during the normal service life of a bridge. Typical deck expansion joint replacement involves traffic interference and lane closure ranging from a few days to multiple weeks. Over the years, extensive research has been done to improve the longevity of these joints, but oftentimes has been met with limited success. Eliminating deck joints instead of replacing them is a suitable option for bridges with moderate length and can be done in an accelerated fashion and minimize traffic interruption. However, for bridges requiring expansion joints, there is a dire need for accelerated replacement options/techniques, especially in areas with high AADT and limited time for lane closures.

To address this issue, this project will develop methods for accelerated replacement and elimination of bridge deck expansion joints. The constructability of these methods will be evaluated based on experimental testing. A cost analysis will be conducted, and a guide/manual for bridge engineers will be developed.

## **2. Problem Statement**

Bridge deck expansion joints are used to allow for the movement of the bridge deck due to thermal expansion and dynamic loading. They can also prevent the passage of winter de-icing chemicals and other corrosives applied to bridge decks from penetrating and damaging substructure components of the bridge. Expansion joints are often one of the first components of a bridge deck to fail. Therefore, repairing or replacing expansion joints is essential to extending the life of any bridge. Extensive research has been conducted and several expansion joint replacement options have been studied (e.g., Baker Engineering, 2006; Palle et al., 2011). However, these options typically involve extensive traffic interference and lane closure. Therefore, there is a need for accelerated replacement options and techniques, especially in areas with high AADT and limited time for lane closures.

## **3. Research Approach and Methods**

The objectives of this research are to: (1) conduct a literature review on replacement and elimination of bridge deck expansion joints; (2) develop methods for accelerated bridge expansion joint replacement and elimination; and (3) promote ABC for bridge deck expansion joint repair.

## **4. Description of Research Project Tasks**

The following is a description of tasks carried out to date.

## **Task 1 – Literature Review**

### Proposed task description

The research team has conducted literature reviews on current means and methods of expansion joint maintenance, replacement, and elimination in Iowa and other states. In this task, the research team will conduct a more in-depth review, with the focus on accelerated repair and replacement of bridge deck expansion joints. Documents that will be reviewed include published literature including academic journals, international journals, trade publications, product literature and Internet web pages. The content of articles related to the research will be summarized for use in the final report and a reference list will be developed.

### Description of work performed up to this period

The literature review is complete. The review focused on failure modes of commonly used expansion joints, repair methods of expansion joints, and replacement of expansion joints. Different concrete removal methods were studied, such as conventional mechanical methods (saw cutting/pneumatic hammering) and hydrodemolition. Additionally, concrete mixes with high-early-strength properties, such as UHPC, elastomeric concrete, and magnesium phosphate cement, were reviewed.

The review found that many states are using hydrodemolition techniques instead of, or often times in addition to, conventional mechanical methods. When looking at concrete mix types, some DOTs are looking towards elastomeric concrete. In one particular example, Virginia DOT has designed an elastomeric concrete plug joint, allowing construction to be completed lane by lane in an efficient manner. After the first summer/winter cycle, VDOT has experienced good performance results. DOTs are also starting to use UHPC connections. Although normally used for precast bridge elements to connect modular panels, the panels with the connection emulate the performance of a typical cast-in-place concrete bridge deck. New York State DOT has used both longitudinal and transverse field-cast UHPC connections. Magnesium Phosphate Cement (MPC) has been used by Alaska, Maryland, and Virginia DOTs for bridge deck patching and overlays, as well as for precast panel connections. These DOTs have experienced good performance with MPC in these capacities.

## **Task 2 – Develop methods for accelerated expansion joint replacement**

### Proposed task description

In this task, bottlenecks in the expansion joint replacement process will be identified. Different methods and options for accelerated expansion joint replacement for common types of expansion joints, such as strip seal, finger joint, modular, etc., will be developed by addressing the identified bottlenecks. Different demolition methods, including hydrodemolition, handheld pneumatic breakers, etc. will be evaluated. After evaluating the properties of different materials and demolition methods, methods for accelerated expansion joint replacement will be developed.

### Description of work performed up to this period

Evaluation of the various methods is complete. The largest bottleneck points in the expansion joint replacement process are demolition and curing of concrete. Evaluation of the various types of demolition methods and concrete mixes were completed. For demolition methods, saw cutting, pneumatic breakers, and hydrodemolition were evaluated. Of these three,

hydrodemolition is the recommended method for accelerated expansion joint replacement. It is much faster than the other methods and leaves a very good surface and remaining concrete for the new concrete. One difficulty that hydrodemolition has is the high mobilization costs and controlling the depth of removal. Contractors will need to “buy in” to the use of hydrodemolition in order for it to be effective over a long period of time. For concrete mixes, magnesium phosphate cement, elastomeric concrete, ultra-high-performance concrete, and fiber-reinforced concrete were evaluated. Magnesium phosphate cement was eliminated as an option due to its poor durability and water resistance. Of the three remaining options, ultra-high-performance concrete is the recommended material to use. Its high strength will allow the time between full joint replacements to be extended and its early strength and set time will allow construction to still be complete within one weekend. One difficulty that ultra-high-performance concrete has is its high initial cost of material. However, over time, as this material becomes more common, this initial price should be reduced.

### **Task 3 – Perform experimental studies to confirm constructability**

#### Proposed task description

To confirm the constructability of the methods developed from Task 2, experimental studies will be conducted. First, expansion joints mimicking the real condition will be constructed. The testing specimens will include bridge decks connected by an expansion joint, which are supported by steel girders. Next, the joint will be replaced following the methods developed from Task 2. Loading tests will be conducted on both old and new joints, and the responses from these tests will be compared. In this way, the constructability and the effectiveness of the methods developed from Task 2 can be evaluated.

#### Description of work performed up to this period

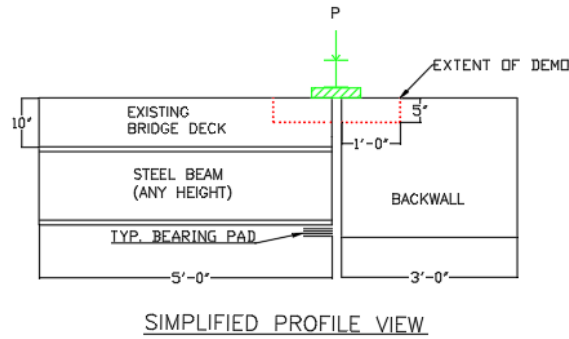
Work on this task is in progress.

#### General Procedure:

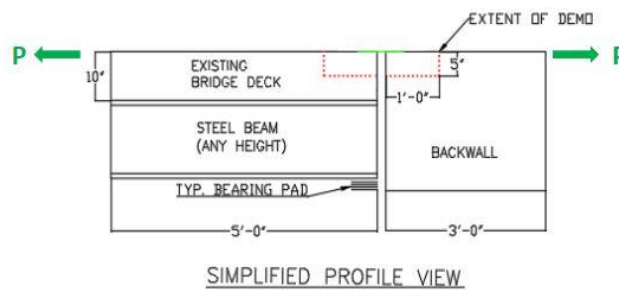
Both an existing specimen and replaced expansion joint specimen will undergo testing. The test itself will have four steps. Step one will consist of the initial pour of the specimen meeting DOT standards and a 28 day curing period. This specimen will then be tested. Step two will consist of the proposed replacement procedure. Hydrodemolition will be used to remove a one foot strip of concrete on either side of expansion joint to a depth of five inches. This will be done by CLC Hydro Services. The new D.S. Brown strip seal will then be cast in UHPC. The UHPC will then be allowed to cure for 12 hours. At this time, a compression test will be performed on a cylinder to evaluate if the UHPC has reached the required 14 ksi strength to be opened to traffic. Step three consists of the testing of the new joint and UHPC specimen. This will be conducted when the UHPC reaches the required strength. Step four consists of the removal of the UHPC material. This is to confirm that UHPC will not be an issue to remove if future construction projects are required in the field after the joint replacement.

Many different tests will be conducted on both specimens.

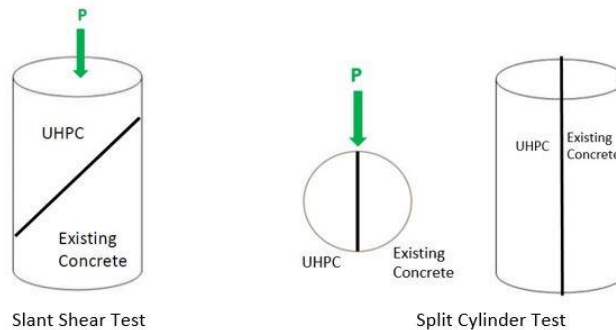
1. Direct loading that mimics performance under an HS-20-44 truck rear axle



2. End rotation will be measured during all tests
3. Lateral loads mimicking thermal expansion will be applied



4. The bond between UHPC and existing concrete will be evaluated using slant shear and split cylinder testing



5. Fatigue testing will be conducted on the final replacement specimen to evaluate the durability of the proposed joint under service level cyclic loading.

Testing of the existing specimen has been completed. As expected, no notable strain was recorded in the concrete or reinforcing along the expansion joint under performance loading. CLC Hydro Services are coming at the beginning of September to perform the hydrodemolition. The UHPC replacement joint will be poured and tested after that.

#### **Task 4 – Provide accelerated options where expansion joint elimination is feasible**

##### Proposed task description

Eliminating deck joints instead of replacement is a suitable option for bridges with moderate length. For joints at the abutment interface, they can be relocated into the approach slab. Accelerated methods for this option can be developed by using a precast concrete slab as a new approach slab. For joints at the piers, link slabs can be implemented to eliminate the joints. Other accelerated options include beam end encasements, closure joint/diaphragm, etc.

##### Description of work performed up to this period

Work on this task is completed. Link slabs, joint elimination, and moving the joint into the abutment were investigated. Link slabs are a common way to replace expansion joints over the pier supports in a bridge. The slab is debonded from the girder below to allow for rotation due to thermal movement of the bridge deck. UHPC has been used for link slabs previously, and can be adapted for accelerated construction using one of many fast-setting concrete mixes. Ductal's JS1212 mix of UHPC is one such option that would set quickly and have a long service life. Joint elimination was investigated by means of using an integral or semi-integral abutment. In an integral abutment, the bridge girders are encased in the backwall, and the abutment moves along with the thermal movement of the bridge deck. Semi-integral abutments function very similarly. The main difference is that semi-integral abutments still have the girders sit on a bearing pad. The girders are still encased in the backwall, but the bearing pads allow the foundation to be fixed instead of move with thermal effects. Both integral and semi-integral abutments can be constructed in an accelerated context when the main slabs are precast and sealed with a cast-in-place UHPC connector. These precast slabs with a cast-in-place UHPC connector can also be used if the joint is relocated into the approach slab. By moving the joint to approach slab, damage to the substructure can be avoided. The expansion joint would be situated over soil instead of these critical bridge elements.

#### **Task 5 – Cost analysis of the various options**

##### Proposed task description

With the methods for bridge deck expansion joint replacement and elimination developed in the previous tasks, the research team will conduct a comprehensive cost analysis on these options. Possible cost saving practices and materials can be identified in the process and incorporated in the guide/manual for bridge engineers.

##### Description of work performed up to this period

Work on this task is complete, and confirms the economic viability of the proposed replacement utilizing UHPC and stainless steel rails. Information on the service life, mobilization, traffic control, material costs, initial costs, operation & maintenance costs, user delay costs, and interest rate were gathered for the various options. Initial analysis showed that the proposed replacement would more cost effective than current practices. A Monte Carlo simulation was conducted to verify these findings. Bid information provided by the Iowa DOT was used to determine the cost distributions of the various items. Four scenarios were compared in this cost analysis. The first represents the current procedures/materials included in a typical joint replacement. It uses PCC, A36 rails, and pneumatic breaker demolition. The second utilized UHPC, stainless steel rails, and hydrodemolition in the replacement. The third represents if stainless steel rails are

unavailable. It uses UHPC, hydrodemolition, and a typical A36 rail. When the A36 rail fails, the use of EMSEAL BEJS is recommended to extend the time between full replacements. The fourth represents if UHPC is unavailable. This uses the typical PCC and pneumatic breaker demolition, but still uses stainless steel rails. The spalling of the PCC controls the time between replacements. The following table summarizes the average findings of each scenario for the various bridge service lives after the Monte Carlo simulation was complete. A bridge width of 30' was used in the analysis for the results below.

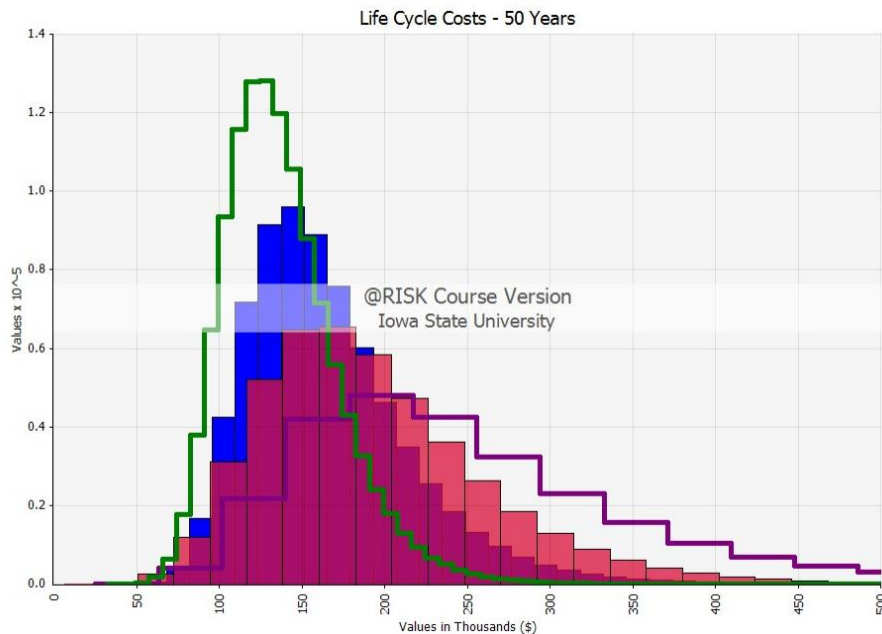
**Monte Carlo Simulation – Average Life Cycle Costs, 30' Bridge**

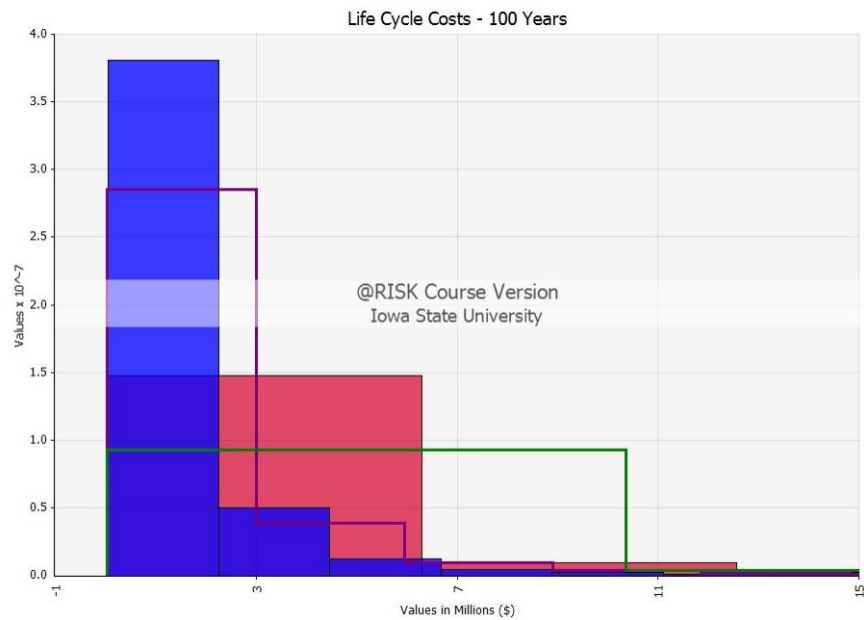
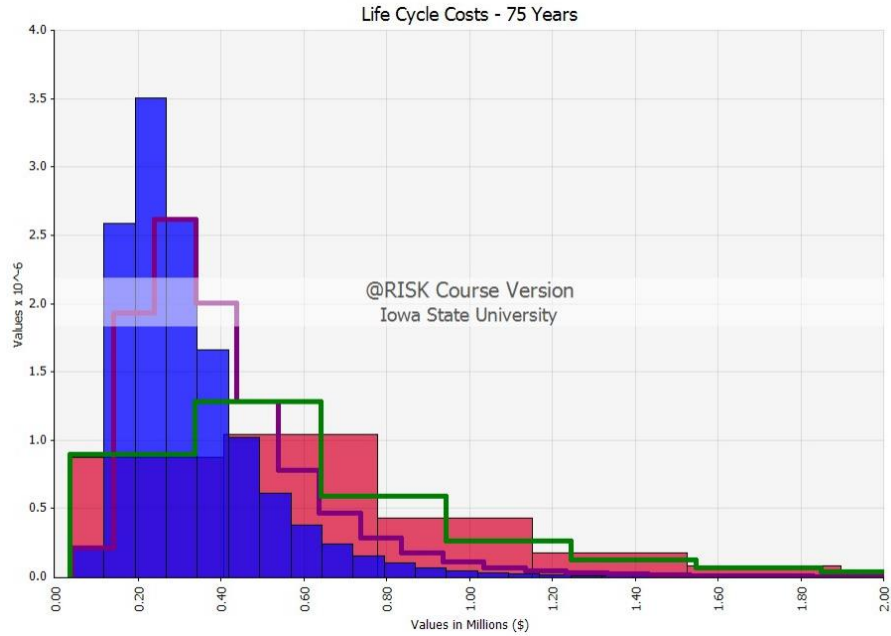
	50-yr Life	75-yr Life	100-yr Life
PCC/A36	\$ 193,973.00	\$ 680,665.60	\$ 2,498,755.00
UHPC/SS	\$ 165,960.30	\$ 321,316.30	\$ 1,409,298.00
UHPC/A36	\$ 137,669.50	\$ 625,669.40	\$ 2,918,989.00
PCC/SS	\$ 250,682.20	\$ 403,038.10	\$ 1,867,355.00

The Monte Carlo simulation also produced histograms for the various bridge service lives in the table above. The histograms show the probability distribution for the cost of each option over the life of the bridge.

**KEY:**

- Red – Pneumatic Hammer, PCC, A36 Steel Rail
- Blue – Hydrodemolition, UHPC, Stainless Steel Rail
- Green – Hydrodemolition, UHPC, A36 Steel Rail
- Purple –Pneumatic Hammer, PCC, Stainless Steel Rail





## Task 6 – Develop design guide/manual for bridge engineers

### Proposed task description

Based on the outcome of the first five tasks for this project, the research team will propose a guide/manual for bridge engineers. The draft guide/manual will be distributed to the Transportation Advisory Council (TAC) and several other identified potential users for review and comments. Once reviews and comments are received, the guide/manual document will be modified to its final form.

### Description of work performed up to this period



No work has been performed on this task up to this period.

**Task 7 – Final research report**

Proposed task description

A research report will be completed detailing the research process, including information regarding the literature review, the development of the expansion joint replacement and elimination options, the experimental studies, the comprehensive cost analysis, and the guide/manual for bridge engineers.

Description of work performed up to this period

No work has been performed on this task up to this period.

**5. Expected Results and Specific Deliverables**

**1. ABC-UTC guide/manual for bridge engineers**

A guide/manual for bridge engineers will be developed based on the options and methods developed. After distributing the guide/manual to the TAC and other identified potential users, revisions will be made, and a final form will be submitted.

**2. A five-minute video summarizing the project**

The research team will provide a five-minute video summarizing the findings from this project.

**3. Final research report**

A research report will be provided detailing the research processes and results.

**6. Schedule**

Progress of tasks in this project is shown in the table below.

Item	% Completed
Percentage of Completion of this project to Date	75%

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Anticipated	2018								2019											
	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Task																				
1: Literature Review																				
2: Method Development																				
3: Experimental Studies																				
4: Provide Options																				
5: Cost Analysis																				
6: Design Guide/Manual																				
7: Final Report																				
		Work performed																		
		Work to be performed																		

## 7. References

Baker Engineering. 2006. *Evaluation of Various Types of Bridge Deck Joints*. For Arizona Department of Transportation. Phoenix, AZ.

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