Lateral Slide of Multi-Span Bridges: Investigation of Connections and Other Details–Phase I

tech transfer summary

This project advanced work on the design and construction of multi-span bridges using lateral slide-in construction to end up with bridges that are strong, durable, economical, and constructible.

June 2021

RESEARCH PROJECT TITLE

Lateral Slide of Multi-Span Bridges: Investigation of Connections and Other Details–Phase I

SPONSORS

Iowa Department of Transportation (InTrans Project 19-691)

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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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19-SPR2-001

Research Objective and Goals

The objective of this project was to develop economical and durable design details to be used with the lateral slide concept for a multi-span bridge. The ultimate goals with this research and the design/construction of the multi-span bridge were to end up with a bridge that is strong, durable, and economical and can be constructed utilizing the lateral slide method and to provide modifications to the Iowa Department of Transportation's (DOT's) three-span standards.

Problem Statement

The addition of more spans creates a more complex system that requires connections (and other details) that were previously not needed in a single-span slide. Furthermore, the fact that the multi-span bridge would need to slide on abutments plus piers (as opposed to just abutments in a single-span case) created possible uplift and overturning scenarios.

Background

Lateral slide-in bridge construction, also referred to as slide-in bridge construction (SIBC), has gained increasing attention as a viable accelerated bridge construction (ABC) approach. The use of SIBC is one of several ABC methods being promoted through the Federal Highway Administration (FHWA) Every Day Counts (EDC) program.

With lateral slide construction, the majority of the bridge superstructure is constructed off alignment, typically parallel to the final position, and usually on a system of temporary works. The construction of this portion of the bridge is often completed while the original bridge is still open to traffic.

In some states, such as Iowa, the use of ABC has been strategically deployed at locations where traffic volume, access, and other factors drive the need for a very short disruption to the traveling public.

Construction of IA 1 Bridge over Old Man's Creek southwest of Iowa City

In some instances, portions of the substructure are also constructed while the original bridge is still open to traffic—a technique designed to further reduce traffic impacts. Common techniques for accomplishing this include building substructure elements outside of the original bridge footprint as well as using innovative techniques to complete construction under the bridge with consideration of clearance limitations, stability of the underlying soil, and others.

Once the construction of the superstructure is essentially complete, the original bridge is demolished, and new substructure construction is completed. Then, usually over a relatively short period of time (commonly hours to a day), the new bridge superstructure is slid laterally from the temporary works onto the in-place substructure.

The DOT completed its first lateral slide-in bridge project in the fall of 2013 during the replacement of a single-span bridge on IA 92 over a small stream just west of Massena in southwest Iowa.

After successfully completing this and other ABC projects, the Iowa DOT planned to construct a multi-span bridge using slide-in construction techniques, which raised many questions. As such, it was vitally important that the Iowa DOT design engineers have the best information regarding the performance of various critical details.

Research Description

To achieve the goal, four tasks were completed. In the Task 1 work, relevant information was collected and evaluated by conducting a literature review on various details and construction approaches for previously completed lateral slide projects. Although a good amount of general information related to the use of lateral slide as an ABC method was available, very little literature has been published specifically related to such construction for multi-span bridges.

In Task 2, a survey was conducted among state DOTs that may have related experience on using the SIBC method on multi-span bridges. The goal of this task was to collect the information on the methods and practices that have never been documented with published details.

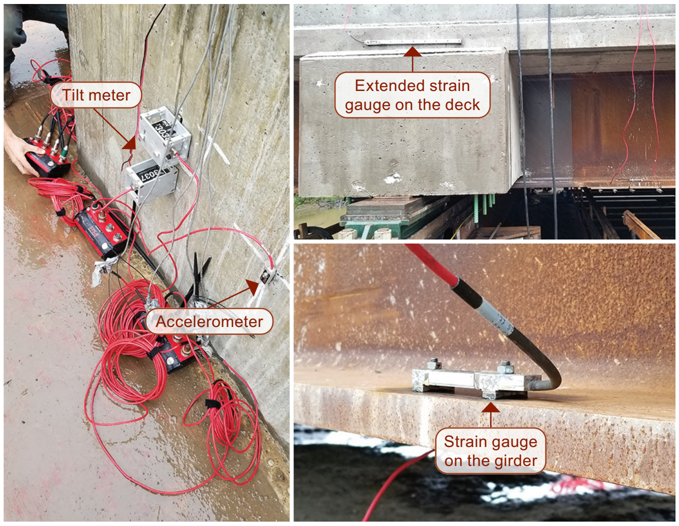
A significant amount of valuable information was collected from the literature review and survey, and the successful design and construction details were identified and discussed.

In Task 3, the successfully implemented design details were evaluated and summarized based on the findings from the previous tasks. Based on the results, additional research needs were identified and recommended for future work.

In Task 4, the researchers monitored a three-span, 300-ft-long, steel girder bridge over Old Man's Creek on IA 1 southwest of Iowa City that was constructed utilizing the SIBC method using gauges during the slide-in. The goal of this task was to monitor the lateral slide effects on the bridge and its associated structural elements to gain useful insights.

Sliding track on the permanent pier for the IA 1 Bridge over Old Man's Creek

Slide-in equipment for the IA 1 Bridge over Old Man's Creek



Instrumentation of the multi-span bridge slide-in for field monitoring

Data collection station used for multi-span bridge slide-in field monitoring

Key Findings

- The slide-in procedure worked well for the multi-span bridge with respect to the steel girder superstructure and the piers. No noteworthy response from the substructure was observed during the slide-in, and no visible signs of distress (e.g., cracking) were observed on the concrete deck or piers. No indications of significant binding or restrictions were observed during the slide-in process.
- The field monitoring results indicate that flexural bending (about the Z direction) of the superstructure on the horizontal plane occurred during the slide-in. However, the deck strain data were minimal, and the resulting forces were inconsequential to the structure. The superstructure consisting of the steel girders and concrete diaphragms performed well during the slide-in.
- Greater strains were measured at the pile strain gauge locations. Even so, the resulting forces were well below the maximum allowable forces. The residual axial and moment forces were low in comparison to capacity. An uplifting action was captured on Pier 1.
- A rough calculation indicates that the greatest forces in the z direction induced by the impulse pushing load experienced at the top of the pier was about 400 kips, with approximately 80 kips of residual force after the slide.
- In general, Pier 1 had larger responses than Pier 2 in both the longitudinal (z) and transverse (x) directions of the bridge. This could be explained by multiple reasons, such as the different embedment heights, different coefficients of friction, or uneven distribution of the weight, etc. A further investigation using analytical methods, such as finite element modeling, is needed to quantify the effect from each parameter.

Implementation Readiness and Benefits

The results of this work should provide confident validations of the details proposed for the slide-in of a multi-span bridge as was used for the bridge project monitored in the field for this work.

The general finding from the field monitoring work was that the current slide-in practice works well with the multi-span steel girder superstructure. No significant response from the substructure was visually observed during the slide-in, and no cracking occurred on the concrete deck or piers. This indicated that the superstructure with steel girders and concrete diaphragms can be built with the lateral slide-in method.

Although a significant amount of valuable information was collected through the literature review and the state DOT survey, many questions remain unanswered. Based on the results from the work conducted in the four tasks, further research, including laboratory tests and analytical simulation, is proposed as additional Phase II work.

Recommendations for Phase II Research

Further evaluation of structural performance, particularly on the pier and foundation components subject to the slide-in process should be conducted—experimentally and analytically—as a continuation of the project, as was mentioned in the original project proposal.

The objectives of the additional work proposed for Phase II are to investigate the performance of the substructure on the multi-span bridge during lateral slide-in construction and come up with design guidance to provide ideas and solutions for the various questions related to the performance of the substructure and other superstructure connection details. Questions that remain unanswered include those surrounding the following topics:

- Drawbacks and advantages of pushing and pulling
- Drawbacks and advantages of two- vs four-point pushing/pulling (i.e., pushing only at the abutments vs. pushing at all abutment and pier locations)
- Lateral flexural stress levels of continuous girders at the piers
- Performance of different types of piers (including T-piers, beam-column frames, etc.) during the slide-in process
- Effect of the uplifting force in the pier column and in overturning of the pier structure
- Effect of transverse forces (transverse to the slide-in direction)
- Behavior of steel and concrete diaphragms
- Efficiency of steering control during the slide to prevent binding with four support points
- In-depth study of lap-splice strength development for closure pour applications

The following tasks are recommended for Phase II research work:

- Laboratory evaluation
- Finite element analysis/simulation
- Development of recommendations for design and construction