ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

ABC-UTC GUIDE FOR:

MULTI-SPAN LATERAL SLIDE PROJECTS – PHASE I

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ABSTRACT

This document summarizes the work activities undertaken in this Phase I study and presents the results of those activities toward development of this ABC-UTC Guide for Multi-Span Lateral Slide projects. The information will be of interest to designers, agencies, and contractors engaged on accelerated bridge construction slide-in projects.

ACKNOWLEDGMENTS

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1. BACKGROUND AND INTRODUCTION

Lateral slide-in bridge construction (SIBC) has gained increasing attention as a viable accelerated bridge construction (ABC) approach. 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 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 other considerations.

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

2. PROBLEM STATEMENT

While single-span lateral slides have been adopted by many states and are a common ABC method when short closure durations are needed, multi-span lateral slides are far less common. A multi-span lateral slide incorporates additional construction complexities that must be considered by the designer, agency, and contractor.

While many departments of transportation (DOTs) have constructed single-span bridges using lateral slide and have common connection details already established, these details do not apply directly to multi-span slides. 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. In addition, the fact that the multi-span bridge needs to slide on abutments plus piers (as opposed to just abutments with a single-span bridge) creates possible uplift and overturning scenarios.

3. SIBC PROCEDURE

SIBC offers a cost-effective technique to rapidly replace an existing bridge while reducing impacts to mobility and safety. Usually, implementation of SIBC involves the procedure outlined in Table 1.

Table 1. Typical SIBC implementation procedure

Step	Description
1	Construct a temporary substructure next to the existing bridge as the support for the superstructure of the new bridge.
2	Construct the superstructure on top of the temporary substructure while maintaining traffic on the existing bridge.
3	Construct the substructure under the existing bridge without disturbing traffic.
4	Detour traffic to the new bridge superstructure built on the temporary support and demolish the existing bridge. (The construction of the new substructure sometimes continues during this step.)
5	Slide the new bridge superstructure onto the new substructure. The road closure for the sliding usually takes a few hours to several days.

4. MULTI-SPAN LATERAL SIBC APPLICATIONS

The researchers identified more than 40 projects that have used the slide-in method for single- or multi-span bridges from online webpages, research project reports, and technical articles.

Since the objective of the research focus was on multi-span bridges, with an emphasis on the pier region, only the 10 projects that used SIBC on multi-span bridges were investigated further. The very brief summary that follows only includes the research team's overall observations for these 10 multi-span SIBC applications, while a comprehensive Literature Review of the SIBC applications is included in the final report for this project.

- Most of the bridges had two to six spans and the whole bridge was built continuously over the piers and slid simultaneously onto the permanent structure.
- For the bridges with tens of spans and usually constructed over a river, the superstructure was usually divided into units of up to three spans, and each unit was slid into final position using the SIBC approach (sometimes in conjunction with the float-in method).
- By comparing the lengths of the new bridges to that of their original bridges, the researchers found that the total length of the new bridges was usually shorter than that of the original bridge. This observation shows good agreement with the findings from the Utah DOT (UDOT) and Michael Baker Corporation (2013), where it was shown that the SIBC method required the construction of the substructure for the new bridge under the original bridge without disturbing the traffic on the old bridge. The common practice to achieve that was to build the new abutment in front of the original one. The new bridge was usually wider than the original bridge due to increased traffic volume.
- The beam-column frame pier was the most frequently used pier type for construction of the multi-span bridge utilizing the SIBC approach, and no special consideration seemed to be given to the pier design. In addition, no issues have been reported for the use of the beam column frame associated with the SIBC method.
- With respect to the foundation type, the limited information indicated that both spread footings and drilled shafts were used.
- The selection of the material for the diaphragm was mostly based on the type of girder. Both steel and concrete diaphragms were used with the SIBC approach without reports of an issue.
- For the selection of the sliding system, it appears when the superstructure in each slide exceeds approximately 300 ft in length or 50 ft in width, the roller support was commonly used, since a large heavier superstructure requires a low coefficient of friction on the sliding track to reduce the lateral sliding force demand.
- The researchers found that both steel plate girders and prestressed concrete beams were used for multi-span SIBC.

5. SIBC EQUIPMENT AND TECHNIQUES

Compared to conventional construction methods, SIBC requires the use of additional equipment to move the new superstructure from the temporary supports to the permanent ones. The special equipment used for SIBC usually includes a sliding system with rollers or bearing pads as the contact between the substructure and the superstructure, an actuating system (sometimes used with a movement control mechanism) to provide the power for the movement, and one or two temporary structures used to support the new or old superstructure.

The Literature Review in the final report for this project comprehensively discusses the different types of equipment used during the slide-in procedure and with respect to their effect on the substructure of the multi-span bridge. It includes detailed information about what is summarized in Table 2.

Table 2. Typical SIBC equipment and effects on the multi-span bridge substructure

Equipment, etc.	Considerations
Sliding systems	Sliding systems provide and maintain a path for the superstructure during the lateral slide. Polytetrafluoroethylene (commonly known as Teflon) pads and rollers are most commonly used for the slide systems in SIBC.
Actuating devices	Actuating systems are used to provide force to initiate and maintain the slide. Sliding can be completed by pushing, pulling, or the combination of both. Most commonly used actuating systems include hydraulic rams, mechanical pulling devices, and prestressing jacks. To provide enough force for the slide, multiple actuating devices placed at different locations are usually required.
Movement control mechanisms	Two approaches are used to control movement during the slide: pressure-regulated systems and servo-controlled systems. Pressure-regulated systems are used more commonly than servo-controlled ones.
Force application locations	Most of the bridges constructed in the US utilizing the SIBC approach have been single-span bridges. However, the SIBC approach has been successfully used to move up to six-span superstructures. The superstructure of bridges with more than six spans are usually divided and pre-fabricated as six-span units and slid in individually. For single-span bridges, it is a common practice to place an actuating device at each abutment. For bridges with more than one span, the actuating devices have usually been placed at both the abutment and the pier diaphragms. However, coordination of separate mechanical systems is required at each push/pull location to perform a smooth slide-in.
Temporary structures	To slide a multi-span superstructure using the SIBC method, temporary support structures are required at the pier location before and during the lateral slide. Temporary structures include a foundation, a frame system, and a sliding track. Loads transferred to temporary supports by friction forces need to be considered as well as gravity loads, such as weight, traffic, and equipment, in the design. Another consideration to take into account with temporary structures is their use is not only limited to the bent for the new superstructure but can serve as a bent for the old superstructure.

6. DESIGN CONSIDERATIONS FOR PERMANENT SUBSTRUCTURES

The slide-in process in the SIBC approach has special requirements on the design and construction of the substructure near the pier. The most commonly experienced challenges for the selection and construction of substructures include the large horizontal loading induced by the slide-in process, influence of the new foundation on the existing substructure, and limited headroom.

The first challenge to overcome is the large horizontal loading during the slide-in process. The magnitude of the force required to initiate and maintain the movement of the superstructure depends on the weight of the superstructure and the coefficient of friction between the superstructure and the substructure.

The second challenge to overcome is the influence of the new foundation on the existing foundation since, most of the time, the SIBC approach requires construction of the new foundation next to the original foundation, and the fill must be excavated and retained against the existing foundation.

Finally, the SIBC approach usually requires the construction of the substructure underneath the existing structure when traffic remains open on the existing structure. The headroom limits the construction of the foundation and use of various equipment. This challenge can be overcome by both design and the construction method.

The final report for this project includes additional information on design considerations, including foundation solutions and diaphragm types.

7. LITERATURE AND STATE DOT SURVEY GUIDANCE RESULTS

Based on the results from the literature review and a state DOT and private industry survey, the following conclusions can be made with regard to the practical and usable design guidance:

- For most of the bridges with two to five spans, the whole superstructure was usually built continuously over the piers and slid simultaneously onto the permanent structure. For bridges with more than six spans, the superstructure was usually divided into units of up to a few spans, and then slid into final position using the SIBC approach. The investigation indicates that the maximum number of spans in each slide that has been performed is six.
- The length of the bridge superstructure that was built utilizing the SIBC method could be as long as 2,165 ft. It was found that the total length of the new bridge was usually shorter than the original bridge since the SIBC method required the construction of the substructure for the new bridge under the original bridge without disturbing traffic on the original bridge. The common practice to achieve that is to build the new abutment in front of the original one. The new bridge is usually wider than the original bridge due to the increase in traffic volume.
- Both spread footings and drilled shafts were commonly used for the foundation. The most frequently used substructure type is the beam-column frame pier with a spread footing foundation, although drilled shafts and driven piles were also used. The most commonly experienced challenges for the selection and construction of substructures include limited headroom, influence of the existing substructure, and the large horizontal loading induced by the slide-in process. During foundation installation, the existing bridge response needs to be monitored to assure its stability.
- With respect to the bridge girders, both pre-stressed concrete beam and steel plate girders have been used with SIBC. However, no special consideration for the lateral flexural stress level in continuous girders has been given to the design of the girders in the past.
- Both steel and concrete diaphragms were used with the SIBC approach without report of an issue. In general, the lateral forces were applied at all of the diaphragms over the abutment and pier. The diaphragms are expected to be designed as a large, rigid member to jack up the bridge; transfer the lateral load to the deck and girders, and place the rollers and sliding shoes in multiple locations to prevent load concentrations.
- Both Teflon pad and roller systems have been used with multi-span bridges. For selection of the sliding system, it appears that, when the superstructure for each slide exceeds about 300 ft in

length or 50 ft in width, the roller support was commonly used, since a large, heavier superstructure requires a low coefficient of friction on the sliding track to reduce the lateral slide-in force demand. The researchers found that the coefficient of friction for the Teflon pads were usually assumed from 7% to 20%, while, for the roller system, the friction usually assumed was less than 5%.

- Both steel and concrete temporary structures have been used with inline setup. No outline setup had been used for a multi-span bridge. The inline setup slides the superstructure from the temporary structure directly to the permanent structure. Hence, the connection between the temporary and permanent structure is critical. The different settlement between the permanent and temporary structure during the slide-in of the superstructure is usually a concern. A common practice to capture it is to perform a trial slide before the full slide-in to measure the different settlement. It was suggested that the settlement and deflection of the system subject to the full bridge load should be calculated to determine the initial elevation for the temporary support setup. It is also recommended that a moving load analysis should be performed for the temporary support system considering forces developed in the direction of gravity, the slide, and the transverse of the slide.
- Usually, the design of bridge foundations does not consider the large horizontal forces induced by SIBC due to pull or push mechanisms. Hence, it is essential to evaluate the capacity of the substructure and foundation before the slide-in. The substructure should be evaluated for the effect of the uplifting force in the pier column and the overturning of the pier structure, the effect of the transverse forces (transverse to the sliding direction), especially for the unguided sliding system, etc.
- It was found that the difference between the applied force and resistance is not constant throughout the slide-in, which may result in binding and uncontrollable drifting. To allow accurate and rapid force control during the move operation, a servo controller is required. Laboratory tests associated with appropriate monitoring are one of the approaches that could be used to measure the difference between applied force and resistance to provide information for both bridge design and construction planning.

8. ANALYTICAL INVESTIGATION RESULTS AND FUTURE WORK

Little field monitoring and analytical simulation has been conducted to investigate pier structure response during the slide-in, creating a large demand for research to fill this gap. Although the literature search was productive and provided a significant amount of valuable information, many questions were left unanswered. To address these questions, the researchers performed preliminary modeling.

The objectives of conducting the analytical simulation were to investigate the structural behavior of the bridge piers during the bridge slide-in and evaluate the drawbacks and advantages of two- and four-point pushing. The research plan with respect to the analytical simulation included two steps: 1) full-scale model and 2) parametric study.

The modeling of the full-scale bridge provided insight regarding bridge behavior due to the lateral sliding load. The full-scale model was developed based on the onsite monitored bridge and was calibrated utilizing the field collected data. The parametric study investigated the effect of two- and four-point sliding on permanent bridge piers.

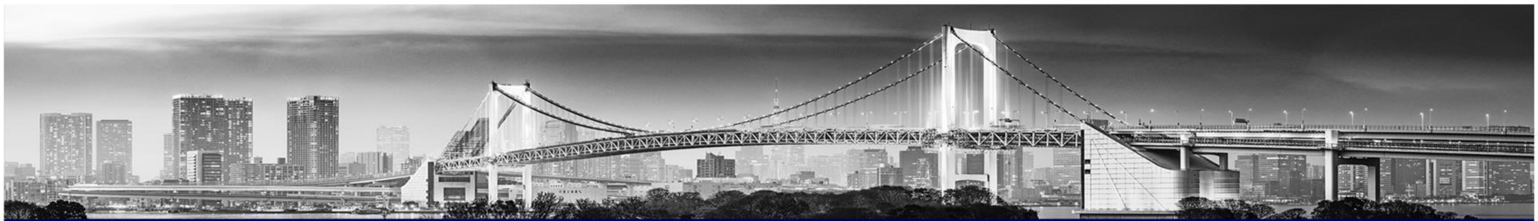
The results indicated that two-point pushing increased the loading on the pier diaphragms by 36%. Because of this, the pier response with respect to the tilt about the x and z directions increased; however, this increase was not significant. By analyzing the field and analytical solution results, the researchers also found that the bridge pier experienced a greater rotation about the bridge transverse direction than about the longitudinal direction.

Additional details on the analytical investigation are included in the final report for this Phase I project. This phase of the research included only preliminary modeling efforts, while future work is needed to address other variables of interest as detailed and outlined at the end of the final report for this project, including the following:

- Drawbacks and advantages of pushing and pulling
- Drawbacks and advantages of two- and four-point pushing/pulling
- Efficiency of steering control during the slide to prevent binding with four support points
- Lateral flexural stress level of continuous girders at 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
- Behavior of steel and concrete diaphragms
- In-depth study of lap-splice strength development for closure pour applications

REFERENCE

UDOT and Michael Baker Corporation. 2013. *Slide-In Bridge Construction Implementation Guide: Planning and Executing Projects with Lateral Slide Method*. Federal Highway Administration, Washington, DC.



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