MULTI-SPAN LATERAL SLIDE LABORATORY INVESTIGATION: PHASE 1

Quarterly Progress Report
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1. Background and Introduction

While single span lateral slides have been adopted by many states and are a common ABC method for construction of bridges 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.

2. Problem Statement

Lateral slide-in bridge construction (sometimes referred to as slide-in bridge construction) 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 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 time (hours to a day commonly), the new bridge superstructure is slid laterally from the temporary worksite onto the in-place substructure.

While many DOTs have completed lateral slide construction of single span bridges and have common connection details already established, these details do not directly apply to multi-span slides. The addition of more spans creates a more complex system that will require connections (and other details) that were previously not needed in a single span slide. Further, the fact that the multi-span bridge will need to slide on abutments plus piers (as opposed to just abutments in a single span case) creates possible uplift and overturning scenarios.

3. Research Approach and Methods

The objectives of this project will be achieved via these three tasks:

1. Literature Review
2. Analytical Investigation and Establish Testing Plan
3. Summary and Recommendations for Phase 2

4. Description of Research Project Tasks

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

Task 1 – Literature Review

To prepare the current proposal, the research team has conducted a preliminary review of relevant information. For Task 1 of this project, the research team will compile all related information available in journals, conference proceedings, technical reports, and online resources in a concise and comprehensive summary. Note that match funds for this project are coming from an existing Iowa DOT project, so some of this work will be completed in conjunction with that project.

The literature review is largely complete. The following is a brief summary of the findings:

Based on the results from the literature review and 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 could be as long as 2,165 ft. The researchers 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 old 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 to 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 diagrams 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 concentration.*
- *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 do 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.*
- *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 a significant amount of valuable information was collected from the survey, it appears the performance of the substructure on multi-span bridges during the slide-in is still a new topic and that not a lot of research work has been conducted on it. The questions that could be answered through the survey were relatively basic, and many questions were left unanswered, including questions surrounding the following topics:

- *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*
- *T-pier performance during the slide-in process, etc.*

Task 2 – Analytical Investigation and Establish Testing Plan

Following the presentation of information collected in Task 1, the research team will be prepared to begin a preliminary analytical investigation of the variables impacting the performance of multi-span bridges constructed using slide in construction. To complete this preliminary analytical investigation, the team will develop various finite element models of a case study bridge and then complete a parametric study of the influence of various structural details. When the results are combined with the results of Task 1, the research team will be in a position to determine the need for additional work and recommend the most appropriate additional investigations to be completed in Phase 2 of this work. Although it is too early to make predictions as to the need for additional work, it is the team's opinion that additional work could be in the form of either greater analytical and/or experimental evaluations or both. In either case, it is likely that the additional work could consist of full scale evaluations or the evaluations of individual connections on small scale components.

Based on the findings from Task 1, knowledge gaps with respect to the construction of a multi-span lateral slide bridge will be identified. These areas which would benefit from further investigation will be addressed via proposed laboratory testing. This task will result in multiple suggested laboratory testing plans that will be proposed for further work in Phase 2 of the project.

A new graduate student has started on this project to complete the modeling work and wrap up the project next quarter. Included below are some details on the model to date:

Element type

- *Solid65 is selected for abutment and pier cap and encasement where extra displacement shapes (K1) were excluded and the linear (K5) and nonlinear (K6) solution will be calculated at the centroid.*
- *Beam188 is selected for piles with section properties of an I beam. Dimensions of HP10x57 and HP16x101 were taken from AISC- Steel construction manual.*

Dimensions of piles

	HP10x57 (abutment)	*HP16x101 (pier)*
Flange length (in)	*10.2*	*15.8*
Web length + (2xflange thickness) (in)	*10*	*15.5*
Web and flange thickness (in)	*0.565*	*0.625*

Material Properties

Material Properties	*Steel*	*Concrete*
f'c (ksi)	*Elastic*	*4*
Poisson's ratio	*0.3*	*0.18*
Young's modulus (ksi)	*29000*	*3865*
Coeff. Of thermal expansion	$6.5x10^{-6}$	$5.5x10^{-6}$

Geometry

West abutment with piles modeling and meshing done. Fig. 1 shows the isometric view of the abutment and Fig. 2 shows the zoomed in image of the bottom of the abutment.

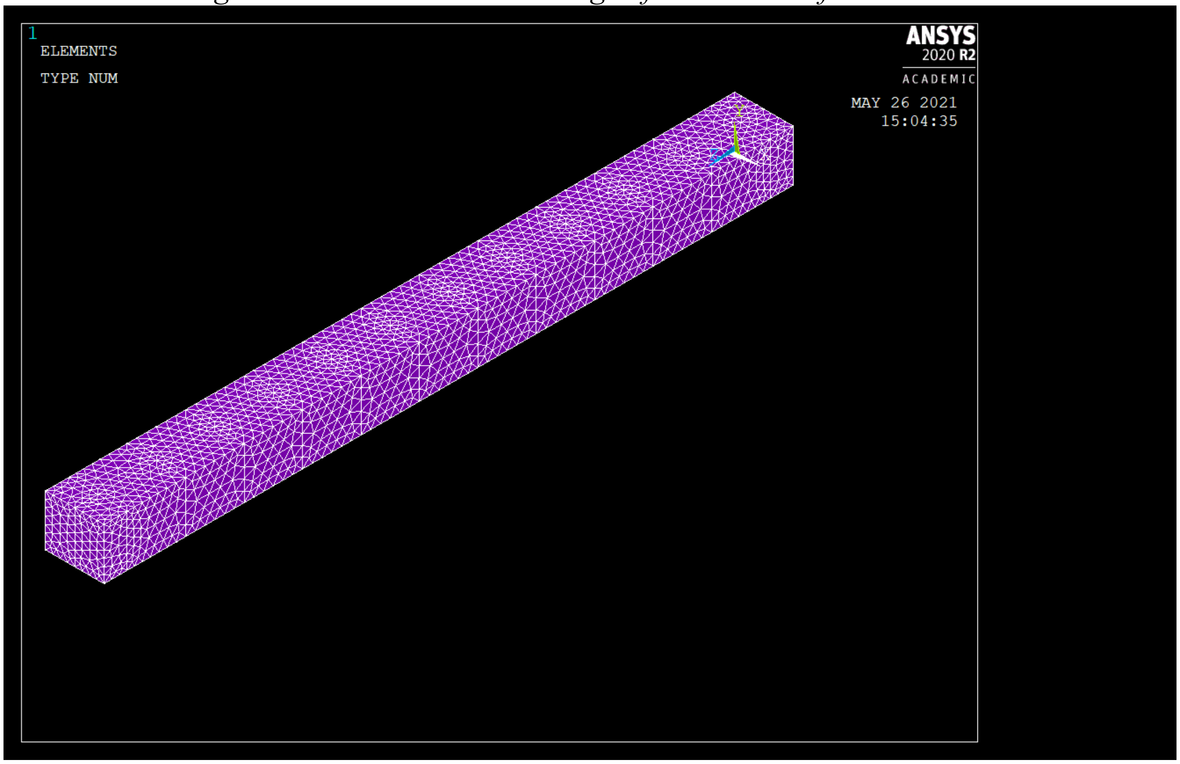

Fig1. Isometric view of west abutment.

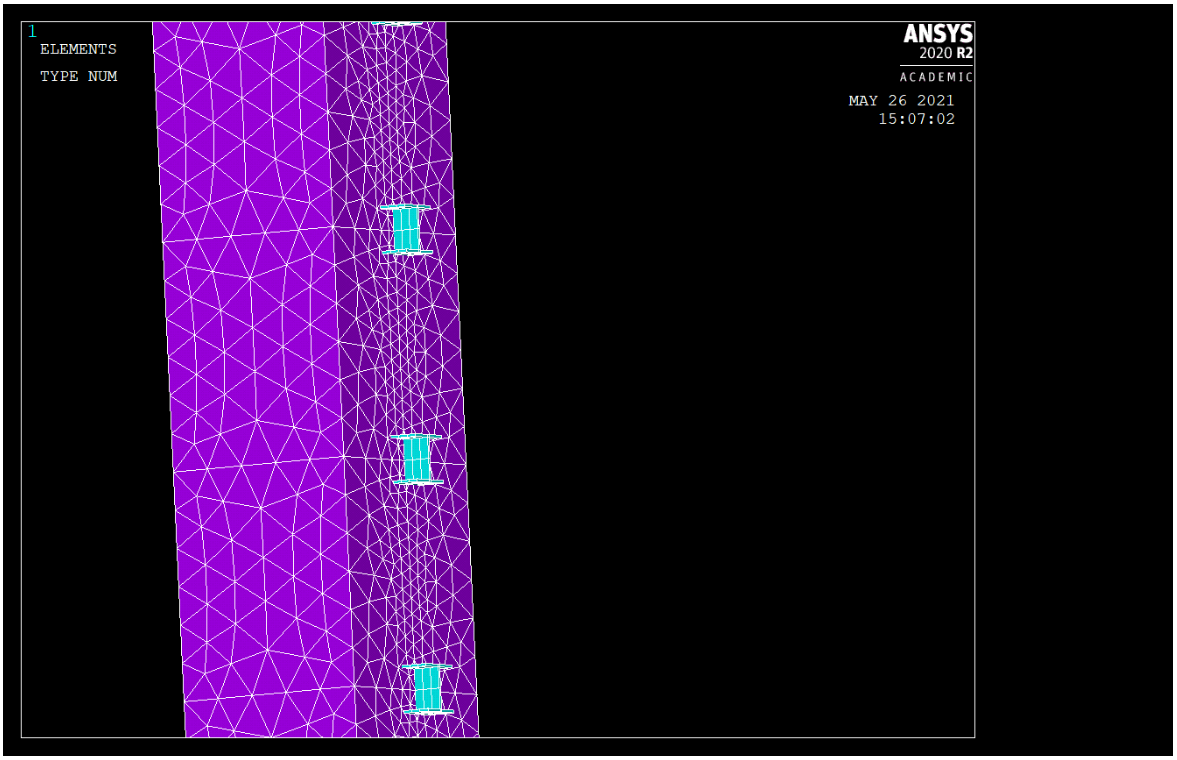

Fig. 2 Bottom of abutment footing

Task 3 – Summary and Recommendations for Phase 2
The efforts associated with Tasks 1 and 2 will be summarized and areas for future work will be identified. This will mainly consist of proposed laboratory testing that would be beneficial for agencies looking to proceed with a multi-span lateral bridge slide.

5. Expected Results and Specific Deliverables

A comprehensive literature review on the use of multi-span lateral slides for ABC construction will be compiled, along with proposed laboratory and/or analytical testing to investigate any knowledge gaps that are seen. This work will be beneficial for establishing the work to be proposed in Phase 2, which will directly benefit agencies by means of details and component performance during multi-span lateral slide construction projects.

6. Schedule

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

Item	% Completed
Task 1: Literature Review	100%
Task 2: Analytical Investigation and Establish Testing Plan	50%
Task 3: Summary and Recommendations for Phase 2	0%

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Task 1: Literature Review	X	X	X	X	X	X						
Task 2: Analytical Investigation and Establish Testing Plan						X	X	X	X	X		
Task 3: Summary and Recommendations for Phase 2										X	X	X