DESIGN OF LINK SLABS: A SHORT COURSE MODULE

Quarterly Progress Report
For the period ending August 31st, 2020

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Submitted to:
ABC-UTC
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Miami, FL

1. Background and Introduction

One of common techniques in Accelerated Bridge Construction (ABC) is using Prefabricated Bridge Elements and Systems (PBES). The bridge components are built outside of the construction area, transported to the site, and then rapidly installed. This helps significantly reduce the time lost due to concrete placement, curing in the construction zone, and formwork erection/removal. Another benefit to using the PBES is the improved quality control. Damaging effects due to weather is minimized because elements are built in a controlled environment. However, there is a standing question on how the long-term performance and durability concerns associated with the joints that connect high-quality bridge elements can be addressed. One approach that has gained significant attention is to eliminate the joints through revised design strategies. While such strategies have been successfully developed for integral abutments used for ABC applications, no systematic approach is available on removing the expansion joints between bridge girders. To address this issue, the current project builds on the findings from a former ABC UTC-sponsored research project on link slabs and develops a short course module to provide the design guidelines and practical recommendations necessary to properly implement a link slab in jointless bridges.

2. Problem Statement

Application of ABC techniques has been significantly increased owing to the unique advantages of the bridges built with ABC, including short duration of construction and high quality of prefabricated bridge elements. By decreasing the construction time from months to days, the ABC techniques contribute to the safety of work zones by minimizing the on-site activities that can cause accidents for construction workers and motorists. On the other hand, with improved product quality, which can be achieved in prefabricated bridge elements built under controlled environmental conditions, the durability and performance of bridges are enhanced during the design life. Despite major advances in the design and construction of the main bridge elements for ABC applications, the joints that connect the bridge spans are still in need of attention. The expansion joints play a critical role in accommodating unrestrained deformations of adjacent spans due to thermal expansion and traffic loads. The existing joints, however, deteriorate rapidly and require major maintenance efforts. To address this issue, the idea of using link slabs to eliminate the joints has been explored through a set of experimental tests and numerical simulations performed through a former ABC UTC-sponsored research project. In the absence of any established design methodology, the proposed educational project aims to explain various fundamental and practical aspects of using link slabs in bridges.

3. Objectives and Research Approach

This project will follow a systematic plan to develop a short course module that will cover the basics, material considerations, and structural aspects of design and configuration of link slabs. This is expected to create a unique learning opportunity for a wide group of practicing bridge engineers and graduate students.

4. Description of Research Project Tasks

This project benefits from the outcome of experimental tests and numerical simulations performed on link slabs to explain their structural performance under various loading conditions. A design guideline will then be presented for the implementation of link slabs in appropriate bridges. This will cover a range of practical aspects, including crack criteria, bonding/debonding requirements, and rebar details.

This course module is envisioned to consist of the following parts, which will be developed one by one through the task listed below:

Task 1 - Development of course outline

Description of work performed up to this period: The outline has been expanded and developed for this course module. The tentative outline developed for this course is presented below.

1. **Introduction to link slabs**
    - Problems associated with expansion joints
    - Introduction to link slabs
        - Defining different sections of link slabs
        - Examples of link slabs in real bridge projects
2. **Materials and their Promises**
    - Discussion on the field implemented link slabs and the issues observed by field monitoring

- Expected material performance requirements – Mix design/selection objectives
- ECC as link slab material
- UHPC as link slab material
- FRC as link slab material

3. <u>Design Considerations</u>

- Design assumptions
- Design Methodology
    - Detail of the experiment performed by Caner and Zia (1998)
    - Design equations and their explanation
- Modifications and Improvements
- Discussion on recommended debonded length
- Issues in bonded region and design practices
- Rebar spacing
- Support condition

4. <u>Structural Configuration of Link Slabs</u>

- Effects of rebar spacing on the strains in the rebar and surface of link slab
- Effects of support conditions on link slab behavior
- Effects of adding a link slab on bridge substructure, including a case study bridge

5. <u>Design Examples</u>

- Example 1
- Example 2

6. <u>Final Conclusions and Recommendations</u>

- Practical aspects/considerations at the material level
- Practical aspects/considerations for structural analysis
- Practical aspects/considerations for structural design and configuration

Task 2 - An introduction to link slab

Description of work performed up to this period: A preliminary literature review has been completed and the necessary information has been collected to form this part. Additional figures have been generated to demonstrate the necessary concepts.

This part of course module starts with discussion on the problems associated with expansion joints. The associated problems are further shown by images obtained from literature and different DOT reports as shown in the slide from course module presentation in Figure 1. The material in this portion then moves on to introduce link slab as potential solution for replacement of expansion joints and then further defines the different parts of link slab as shown in the slide in Figure 2.

Figure 1 The slide explaining problems associated with expansion joints

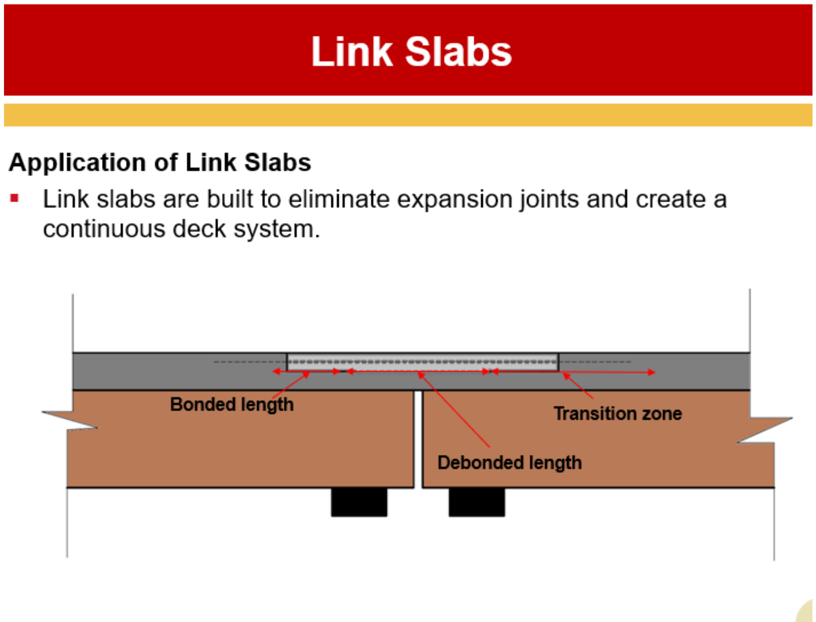

Figure 2 Link slabs and different parts of link slab shown in a slide

Task 3 - Material considerations and structural aspects

Description of work performed up to this period: The content of the course module is being prepared based on the available literature and the studies performed at ISU. This portion of the course module starts by discussing the problems highlighted by field monitoring of link slab made with concrete. The observations from field showed that the link slab requires a highly ductile material with crack width controlling capacity [1]. The presentation in this stage further looks into three different types of materials, i.e., Engineered Cementitious Composites (ECC), Ultra High Performance Concrete (UHPC), and Fiber-Reinforced Concrete (FRC) as link slab material alternatives (see an example in Figure 3).

Figure 3 FRC developed in the ISU for link slab applications

Task 4 - Design guidelines and practical notes

<u>*Description of work performed up to this period*</u>: This portion of the link slab course module will discuss the available design procedures and recommendations and moves onto the findings obtained through the experimental work and finite element simulations carried out at Iowa State University as part of a previously ABC-UTC funded project on link slabs. Additional simulations have also been performed to investigate the design features. The simulations have considered a combination of dead, live, and thermal loads. This portion of the course module will be updated after processing the results from ongoing simulations.

This part will have two main components: design considerations (item #3 in the outline) and structural configuration of link slab (item #4 in the outline). The first component on design consideration starts with the explanation of the earliest experimental work and design equations (Figure 4) developed by Caner and Zia [2] for link slab design. This portion further discusses alternative approaches to the analysis and design of link slab by other researchers [3,4]. The design recommendation component is completed by providing a summary of recommendations on different design aspects, such as debonded length, bonded length, rebar spacing, and support conditions of the link slab.

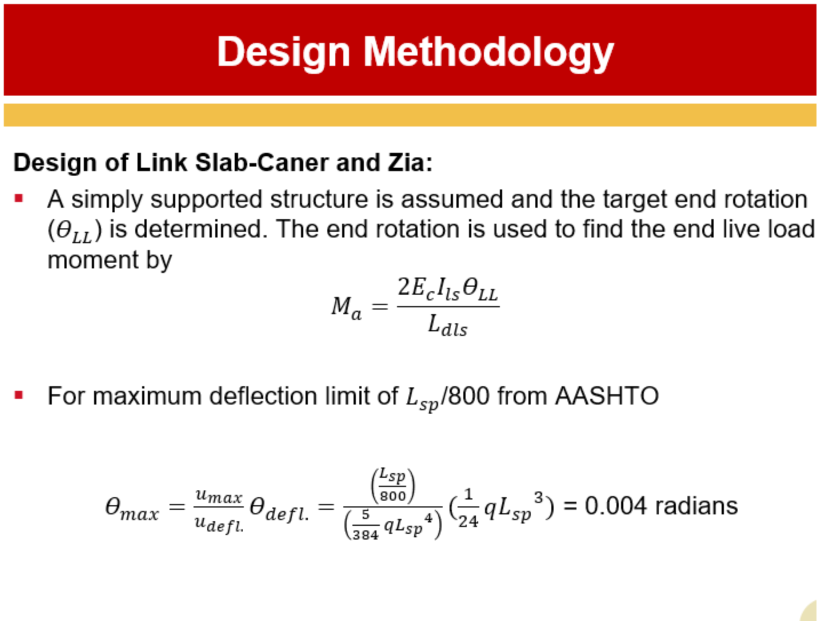

Figure 4 Design equations developed by Caner and Zia (1998).

In the second part, the findings from the experimental works are extended to a full-scale case study bridge located in Iowa (Figure 5). The finite element models answer important questions such as how the addition of a link slab to an existing bridge structure will affect the super and substructure response. Furthermore, the effect of different support configurations under link slab will be discussed for this full-scale bridge model. The results for reaction moments are shown in the Figure 6. This part of the course, thus, covers both design and analysis aspects of link slabs in bridge structures.

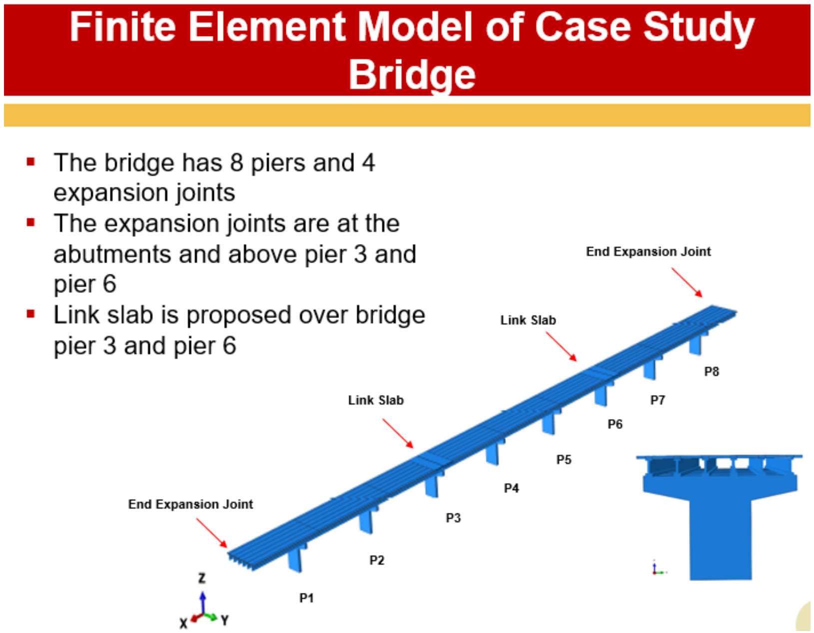

Figure 5 Finite-element model of the case study bridge

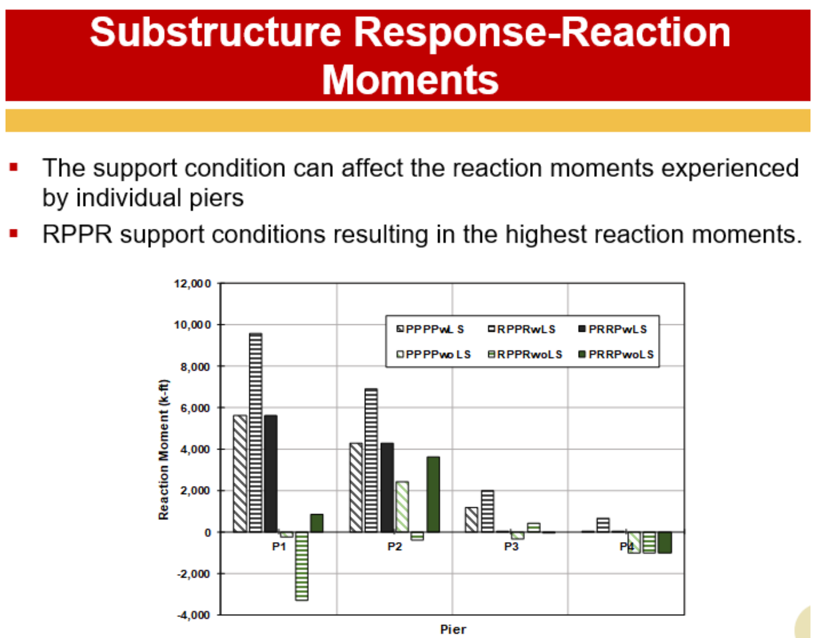

Figure 6 Reaction moments on bridge pier before and after addition of link slab

Task 5 - Solved example(s)

Description of work performed up to this period: This portion will present two solved examples. This is an ongoing activity and still needs some work.

5. Expected Results and Specific Deliverables

The primary deliverable resulting from this project will be a two-hour course for practicing bridge engineers and graduate students. The course will be offered through a set of slides supplemented with necessary handouts.

6. Schedule

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

Item	**% Completed**
Percentage of Completion of this project to Date	80%

Tasks	**Q1**	**Q2**	**Q3**	**Q4**
Task 1				
Task 2				
Task 3				
Task 4				
Task 5				

References

1. Wing, K. M., and Kowalsky, M. J. (2005). *Behavior, Analysis, and Design of an Instrumented Link Slab Bridge*. Journal of Bridge Engineering, 10(3), 331-344.
2. Caner, A., and Zia, P. (1998). *Behavior and Design of Link Slabs for Jointless Bridge Decks*. Math. Intell., 43(3), 68-80.
3. Okeil, A.M., and ElSafty, A. (2005). *Partial Continuity in Bridge Girders with Jointless Decks*. Practice Periodical on Structural Design and Construction, ASCE.
4. Au, A., Lam,C.,Au, J., and Tharmabala, B. (2013). *Eliminating Deck Joints Using Debonded Link Slabs*. Research and Field Tests in Ontario. Journal of Bridge Engineering, Vol. 18, No. 8, pp. 768-778.