
ABC-UTC | RESEARCH GUIDELINE

ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

ABC-UTC GUIDE FOR:

Multi-Span Lateral Slide Laboratory Investigation: Phase II

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ABSTRACT

This document summarizes the work activities undertaken in this Phase II study and presents the results of those activities toward development of this ABC-UTC guide for closure joints on multi-span lateral slide projects. Recommendations are presented regarding the closure joint materials and configurations evaluated in this study. The information will be of interest to designers, agencies, and contractors engaged in 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. In this approach, the majority of the bridge superstructure is constructed off alignment, typically parallel to the final position and usually on a system of temporary works, often while the original bridge is still open to traffic.

Once construction of the superstructure is essentially finished, the original bridge is demolished and construction of the new substructure is completed. Then, and usually in less than a day, the new bridge superstructure is slid laterally from the temporary worksite onto the in-place substructure. Once the sliding is complete, closure joints between the bridge superstructure and substructure are cast to establish continuity.

Closure joints can be constructed using various cementitious materials and reinforcement designs. A common reinforcement design for closure joints is the use of noncontact lap-spliced reinforcement bars grouted with cementitious material. This type of connection can create a strong joint sufficient to connect the precast elements and maintain overall structural integrity. Various parameters, including lapped length, the ratio of lapped bars, bar diameter, concrete mechanical properties, and concrete cover, have been shown to impact the performance of lap splices.

A commonly used cementitious material for closure joints is ultra-high performance concrete (UHPC). The high-strength properties of UHPC have led to many successful applications in connections on bridge structures, including closure pour connections in prefabricated deck systems and connections between pier columns and cap beams. Another candidate material for closure joints is hybrid composite synthetic concrete (HCSC), a polymer-based basalt fiber-reinforced structural concrete offering several advantageous properties at a lower cost than UHPC.

2. PROBLEM STATEMENT

In Phase I of this research (Liu et al. 2021), a three-span, 300 ft long, steel girder superstructure was observed being placed onto concrete piers using the lateral slide-in method. The closure joints between the bridge pier diaphragms and the pier caps were constructed using UHPC and noncontact lap-spliced rebar.

Although the slide-in method worked well, a question remained regarding when the bridge could be subjected to construction loads or vehicular loads without compromising the strength and performance of the UHPC closure joints. A secondary question was whether an alternative joint closure material such as HCSC could provide sufficient early-age capacity at a lower overall cost.

The closure pours are the last major step to completing the lateral slide, and identifying how soon the joints achieve the necessary strength could allow for additional time savings.

3. LABORATORY INVESTIGATION OF CLOSURE JOINT CONFIGURATIONS

Time-dependent laboratory tests were undertaken to determine when UHPC and HCSC closure joints reinforced with noncontact lap-spliced rebar achieved sufficient strength to either open a bridge or expose it to construction loading.

Direct tension pull-out tests were conducted on specimens in four design configurations (Design 1 through Design 4). Each specimen was made by casting UHPC or HCSC blocks atop a precast concrete base slab. Two protruding No. 6 rebars extended from the base slab, and one No. 7 rebar was cast into the top layer material for load application, with a 4 in. spacing (*S*) between the rebars.

Design 1 aimed to mimic the closure joints used to connect the bridge pier diaphragms to the pier caps on the steel girder bridge observed in Phase I (Liu et al. 2021). The development length (l_d) was 9 in., the rebar overlap length (l_s) was 8 in., and the grouting material used was UHPC. Design 4 was identical to Design 2, except the grouting material was changed to HCSC.

Designs 2 and 3 were designed following Federal Highway Administration (FHWA) guidance (Graybeal 2014) and using UHPC as the grouting material. Design 2 had a shorter l_d of 7 in. and a shorter l_s of 6 in. For Design 3, round-headed bar instead of the deformed rebar used in the other designs was embedded in the UHPC, which reduced the l_d to 5 in. and the l_s to 4 in.

The design specifications are summarized in Table 1.

Table 1. Pull-out specimen design specifications

Design ID	Sample Geometry (in.)			Design Parameters (in.)			Grouting Material	Rebar Type
	L	W	D	l_d	l_s	S		
Design 1	12	8.25	10	9	8	4	UHPC	Straight deformed
Design 2	12	8.25	8	7	6	4	UHPC	Straight deformed
Design 3	12	8.25	6	5	4	4	UHPC	Round-headed
Design 4	12	8.25	8	7	6	4	HCSC	Straight deformed

In addition, compression tests were conducted to evaluate the material properties of the UHPC and HCSC at times corresponding to the pull-out tests. Alongside each group of pull-out test samples, a set of three test cylinders was prepared to test the compressive strength at each point in time.

The laboratory investigation yielded the following key findings:

- The UHPC material strength at an age of 12 hours was insufficient to fully develop the reinforcement bars. At that time, the pull-out force for all three UHPC lap splice designs (Designs 1 through 3) was less than 10% of the ultimate capacity at full strength. When the UHPC reached one day in age, Design 1 had a greater capacity than Design 2 or 3, and the rebar stress at failure for Design 1 exceeded the bar yield strength of 60 ksi. At 1.5 days, all UHPC connection designs reached the bar yield strength before failure.

- The compressive strength of the HCSC quickly increased to near full strength within the first 12 hours. In fact, the pull-out force (40 kips) required to fail the HCSC connection (Design 4) exceeded the force at which the reinforcement bar yields (36 kips) at 6 hours.

- The HCSC samples showed better performance than the UHPC samples with respect to the ultimate pull-out capacity during the earliest stages of material curing (before 1.5 days). HCSC gains strength more quickly than UHPC and could provide a solution for joint fill material if a very accelerated timeline is required (e.g., the bridge must be opened to traffic or construction loading in less than 24 hours).

- Considering the cost of both materials and their similar minimum durability and strength properties, HCSC presents a viable alternative to UHPC for short lap-spliced construction joints with SIBC. HCSC thus contributes to making SIBC cost competitive to staged construction.

- The confinement condition adjacent to the lap-spliced connection could affect the ultimate capacity. That is, when the splitting failure mode is restrained due to continuous joint material adjacent to the point of interest, the ultimate capacity trends higher than the alternative. Hence, prediction equations with respect to one- and two-sided restraint situations were established to estimate the time-dependent ultimate capacities for each design (see below).

4. RECOMMENDATIONS FOR CLOSURE JOINT CONFIGURATIONS

The following recommendations are offered regarding the connection designs and materials evaluated in this study:

- **When the development of bar yield strength is used as the minimum threshold for lap-spliced connection capacity, the connection can be considered sufficient for traffic or construction loading 24 hours after the connection is placed if Design 1 is used, 36 hours after placement when Designs 2 and 3 are used, and 6 hours after placement when Design 4 is used.** See Table 1 above for the depth of connection, total lap length, bar configuration, and cementitious material used in each design. Note that the capacities are presented without factors of safety, the magnitude of which are left to be decided by the engineer.

- **Earlier age load application can be considered when two-sided restraint is taken into account.** The pull-out capacities in this research were affected by the presence of continuous joint material (UHPC or HCSC) and reinforcement adjacent to the bar being evaluated. The capacity requirement for the connection between the bridge superstructure and substructure is uniquely calculated for each bridge structure. It is recommended that the prediction equations in Figure 1 and Figure 2 be used to assess when the required capacity is met.

- **For the greatest capacity using UHPC, Design 1 is recommended over Designs 2 and 3.** The ultimate capacities of the Design 1 samples tested at each point in time were always higher than those for Designs 2 and 3. Design 1 does require greater quantities of UHPC, however, which is likely to increase placement time and material costs.

- **For connections requiring very high early strength, HCSC is recommended over UHPC.** It is further recommended that the builder work closely with the material supplier to attempt to increase the flowability of the material without affecting its strength and durability attributes.

- **When reduction of the total height of the closure pour connection is necessary, it is recommended that headed bars be considered because they offer capacities similar to straight rebar in connections of greater height**. Both Designs 2 and 3 were based on FHWA guidance (Graybeal 2014), and the pull-out test results showed similar ultimate capacities for each design at each point in time during the tests.

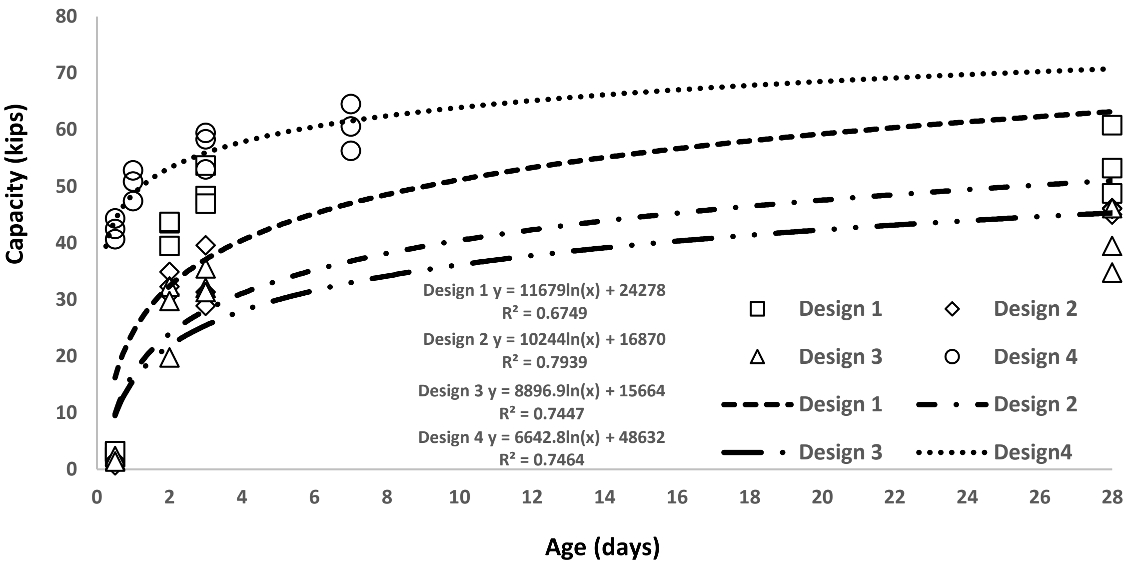

Figure 1. One-sided restraint effect for all designs

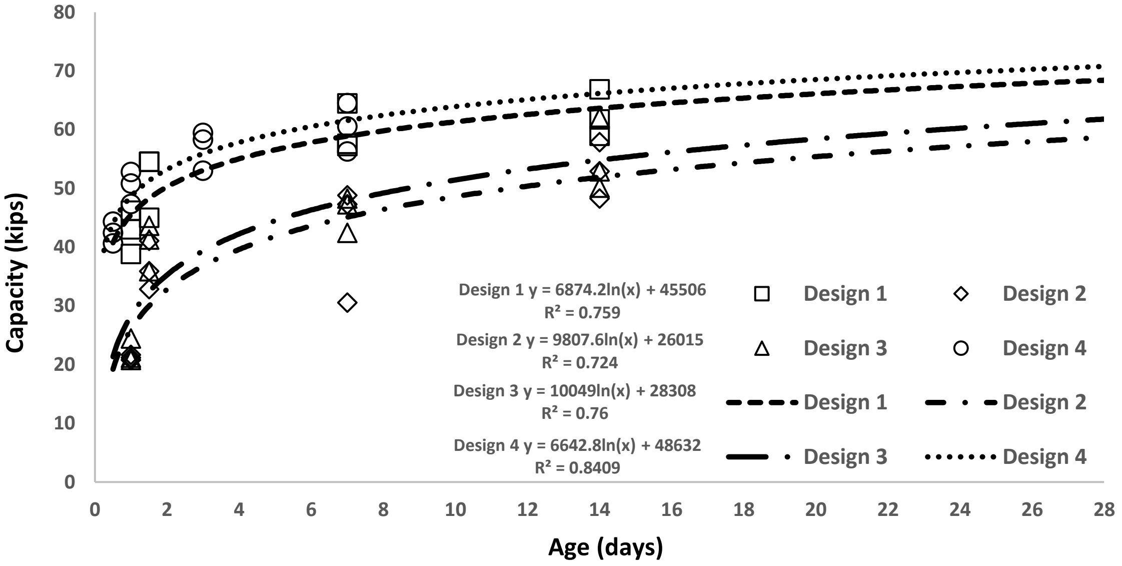

Figure 2. Two-sided restraint effect for all designs

5. REFERENCES

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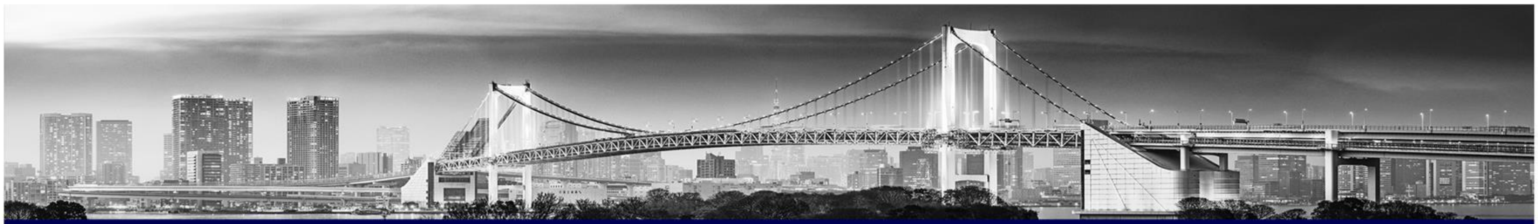

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