

MPC-511

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Project Title:

Mechanical Bar Splices for Accelerated Bridge Construction of Columns

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Research Needs:

Accelerated bridge construction (ABC) is a new paradigm in the USA mainly to expedite construction using new techniques, advanced planning, and novel detailing. ABC heavily relies on prefabricated bridge elements and systems. Pilot studies indicated that the application of precast columns in the USA is limited due to uncertainties related to the performance of precast column connections (Marsh et al., 2011; Kapur et al., 2013).

One method to connect precast columns to adjoining members is through the use of mechanical bar splices commonly referred to as couplers. Even though current codes prohibit the application of couplers in the critical area of columns (e.g. AASHTO Guide Specifications, Article 8.8.3), recent studies have revealed the feasibility of precast columns utilizing couplers in the plastic hinge regions helping expanding ABC in high seismic zones. The seismic performance is not a concern for none- or low-seismic states. Nevertheless, the application of bar couplers in precast bridge columns located in these states is also scarce probably because of the uncertainty pertaining to the coupler performance, column connection performance, and an engineering precaution. Utah, Florida, Colorado, and Washington have incorporated grouted sleeve bar couplers for bridge columns.

There are several types of couplers in the market and new coupler types are emerging. Their prime role is to shorten the splice length and to reduce bar congestion in connections. Since

bridge columns are the focus of the present study, couplers that transfer both tensile and compressive forces are investigated. Five suitable coupler types are (Fig. 1): shear screw couplers, (2) headed bar couplers, (3) grouted sleeve couplers, (4) threaded couplers, and (5) swaged couplers.

The PI recently conducted a research funded by the US Department of Transportation through the University Transportation Center - Accelerated Bridge Construction (ABC-UTC). A state-of-the-art literature review was conducted in this study to investigate the coupler performance as well as the performance of mechanically spliced columns. It was found that the available test data is not sufficient to conclusively comment on the suitability of couplers for precast column construction. A comprehensive testing schedule was recommended to investigate the coupler performance for ABC applications (Tazarv and Saiidi, 2015).



Figure 1. Mechanical Reinforcing Bar Splices

Due to a lack of test data, the PI developed an analytical method to include the effect of mechanical bar couplers on the performance of precast bridge columns. A generic material model was proposed (Fig. 2) for all coupler types assuming that a portion of the coupler is rigid (βL_{sp}) and does not contribute to the splice overall elongation. β is defined as the coupler rigid length factor. Therefore, for the same tensile force, the coupler region axial deformation will be lower resulting in a lower strain in the coupler region (ε_{sp}) compared to the strain of the connecting reinforcing bar (ε_s):

$$\varepsilon_{sp}/\varepsilon_s = (L_{cr} - \beta L_{sp})/L_{cr} \quad (\text{Eq. 1})$$

where L_{cr} is the length of the coupler region and L_{sp} is the coupler length. Overall, the stress-strain relationship for any type of mechanical bar splices can be determined by knowing only the coupler rigid length factor (β).

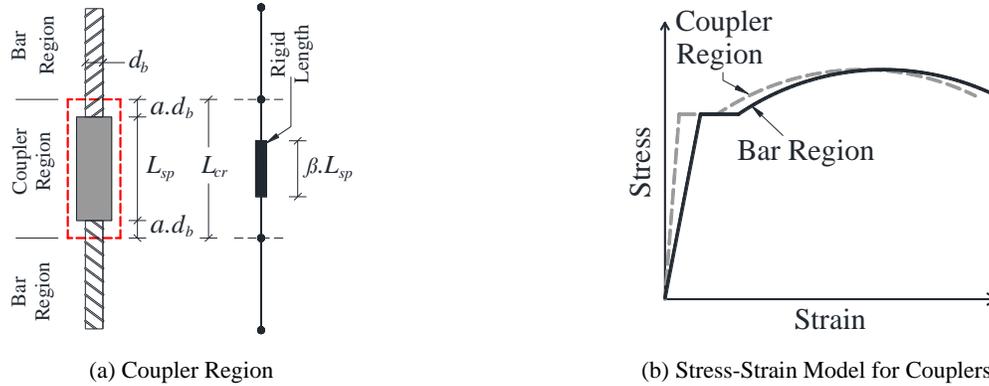


Figure 2. Stress-Strain Model for Mechanical Bar Splices

A comprehensive parametric study was carried out to investigate the coupler effect on the mechanically spliced bridge column displacement capacity. It was found that stiffer couplers closer to the column ends can reduce the column displacement capacity by 40% compared to the non-spliced conventional columns. Subsequently, a simple design equation was proposed to further aid the designers.

Even though the study by Tazarv and Saiedi (2015) provided a better understanding of the coupler behavior and their effects on column performance, a comprehensive testing schedule is needed to establish the coupler behavior and to develop design guidelines for the field deployment of mechanically spliced precast bridge columns.

Research Objectives:

- 1) Obtain properties and investigate the performance of mechanical bar splices
- 2) Perform an extensive tensile testing of all mechanical bar splice types available in the US
- 3) Generate a comprehensive database for mechanical bar splices and recommend reliable coupler for ABC column connections

Research Methods:

The Lohr Structures Laboratory of South Dakota State University is currently equipped with a 55-*kip* Universal Testing Machine (UTM), which can apply either static or dynamic loads to No. 6 or smaller reinforcing steel bars. Since bridge columns are usually reinforced with No. 9 or larger bars, a large-capacity UTM is needed. A justification for acquiring a 135-*kip* UTM is attached (Attachment 1). All UTM manufacturers located in the US were contacted to obtain the price for a 135-*kip* UTM (Attachment 2). Subsequently, all coupler manufacturers will be contacted to collect tensile-compressive coupler samples. Note that couplers for column should resist both tensile and compressive forces thus tension-only or compression-only couplers are not suitable for this project. It is expected that for each product of a manufacturer at least five samples per bar size (#5, #8, #10) resulting in a total of 15 samples per product will be tested. All coupler samples will be instrumented before testing. Force-deformation and stress-strain relationships for each coupler will be measured. The coupler mechanical properties such as the couple rigid length factor will be measured for each coupler. A comprehensive database will be generated for couplers. Post-processing and statistical analyses of the test data will provide sufficient information to conclude the suitability of each coupler for precast column construction. An example of unsatisfactory performance is when a coupler fails before the fracture of the bars or the anchoring bars prematurely fracture due to a stress concentration in the coupler region.

Expected Outcomes:

Data regarding the performance of mechanical bar couplers is inconclusive especially when couplers are used in precast bridge column construction. This research provides a comprehensive database on the mechanical properties of bar couplers with a recommendation on the suitability of each coupler for ABC column connections. The information generated under this project will benefit all 50 states since ABC is gaining a substantial momentum in the US due to significantly lower onsite construction time and potentially lower cost that it offers over the conventional construction. Tazarv and Saiidi (2015) showed that bridge bents with coupler connections at column ends can be built three times faster than bents built cast-in-place.

Relevance to Strategic Goals:

The expected outcomes of this project are directly related to the following goals: State of Good Repair and Economic Competitiveness.

Educational Benefits:

This project will provide a valuable learning experience to both graduate and undergraduate students. An MSc graduate student will be hired to work on this project which will provide the material for a master thesis. An undergraduate student hired for this project will benefit from the experimental exposure and will learn the research process. Results from the study will be incorporated into courses such as Advanced Reinforced Concrete and Bridge Design.

Work Plan:

- 1) Prepare test matrix and test setup
- 2) Contact all the US mechanical bar coupler manufacturers to provide test samples
- 3) Develop a loading protocol and testing standard for couplers
- 4) Instrument all the samples then perform monotonic and cyclic tensile testing
- 5) Develop a comprehensive database for bar couplers
- 6) Develop a guideline including constructability, performance, and feasibility of each coupler type for ABC column construction
- 7) Prepare a final report including an executive summary, measured test data in the form of figures and tables, and recommendations.

Project Cost:

Total Project Costs:	\$285,146	(Attachment 3)
MPC Funds Requested:	\$142,509	
Matching Funds:	\$142,637	Source of Matching Funds: SDSU and NCHRP

TRB Keywords:

Mechanical Bar Splices, Accelerated Bridge Construction, Precast Bridge Columns

References:

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