

# MPC-595

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## **Project Title**

Mechanically Spliced Precast Bridge Columns

## **University**

South Dakota State University

## **Principal Investigators**

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## **Research Needs**

Mechanical bar splices, which are commonly referred to as bar couplers, have been utilized mainly in laboratories to connect precast columns to footings or cap beams. Nevertheless, bar couplers are currently banned in seismic bridge design codes for the incorporating in the plastic hinge regions of either cast-in-place or precast columns. This is mainly because the coupler behavior and the seismic performance of mechanically spliced columns are largely unknown.

A recent study at South Dakota State University (SDSU) attacked the first problem by testing more than 160 bar couplers including nine products from six manufacturers, and established a comprehensive database of the coupler behavior (Dahal et al., 2018). Furthermore, they proposed standard test methods to systematically quantify the coupler performance, and also proposed acceptance criteria for couplers to be incorporated in bridge columns. The acceptable mechanical bar splices were categorized as “seismic couplers”. Nevertheless, test data regarding the performance of mechanically spliced bridge columns is scarce (Tazarv and Saiidi, 2016), and the available data is for columns with different geometries, confinement levels, and testing procedures.

Analytical studies performed by the PI showed that couplers can reduce the displacement ductility capacity of bridge columns up to 40% and may increase the column lateral strength by 10% (Tazarv and Saiidi, 2016; Dahal et al., 2018). Tazarv and Saiidi (2016) proposed a coupler

material model, and developed design methods for mechanically spliced bridge columns. One method, which was verified against three test data available at that time, modifies the AASHTO analytical plastic hinge length equation to include the coupler effect:

$$L_p^{sp} = L_p - \left(1 - \frac{H_{sp}}{L_p}\right)\beta L_{sp} \leq L_p \quad (\text{Eq. 1})$$

where  $L_p^{sp}$  is the modified plastic hinge length for mechanically spliced bridge columns,  $L_p$  is the non-spliced conventional column plastic hinge length according to the AASHTO SGS (Eq. T5.2.8-1),  $H_{sp}$  is the distance from the column end to the nearest face of the coupler embedded either inside the column or inside the column adjoining member,  $L_{sp}$  is the coupler length, and  $\beta$  is the “coupler rigid length factor” obtained from coupler monotonic tensile tests (refer to Dahal et al., 2018 for recommended Beta factors for No. 5, 8, and 10 couplers). In this method, the spliced column design is the same as the conventional cast-in-place column design but with the modified plastic hinge length.

To better understand the seismic performance of mechanically spliced bridge columns, testing of large-scale precast columns spliced with different bar couplers is proposed. Establishing a comprehensive precast column experimental database will allow to verify or further modify the proposed design methods and might provide a justification to relax current coupler ban for bridge columns. Furthermore, the experimental study will identify new and feasible detailing for mechanically spliced precast columns to promote accelerated bridge construction (ABC) for bents.

### Research Objectives

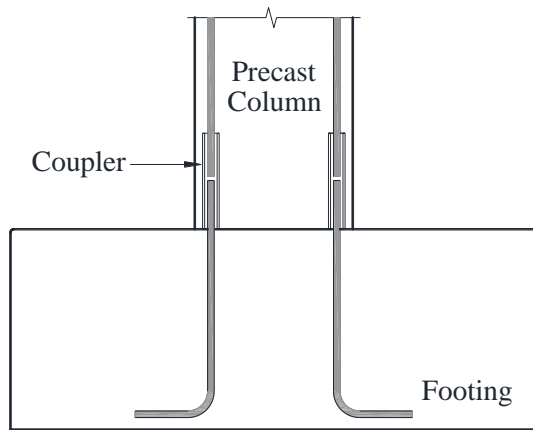
1. Establish a comprehensive performance database for mechanically spliced precast bridge columns through large-scale testing,
2. Verify or update current state-of-the-art design methods for mechanically spliced precast bridge columns.

### Research Methods

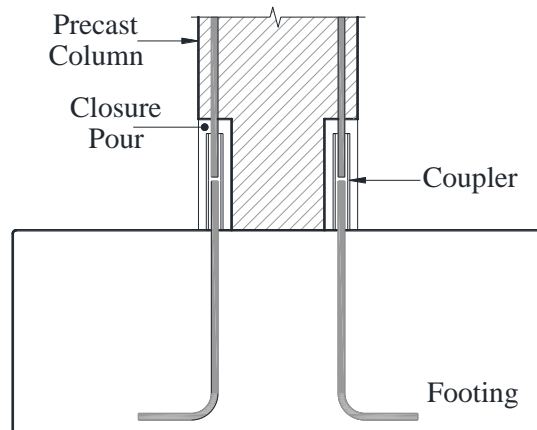
Nine “seismic couplers” (**Fig. 1**) produced by six manufactures have been identified in the previous phase of the project (Dahal et al., 2018) as potential candidates for incorporation in the plastic hinge region of bridge columns. All of these and other manufacturers will be invited to collaborate in this research project. **Figure 2** shows four feasible connection details in which couplers are used to connect precast columns to the adjoining member. The research team will work with each manufacturer to select the best detailing for each product or to develop a new detailing.



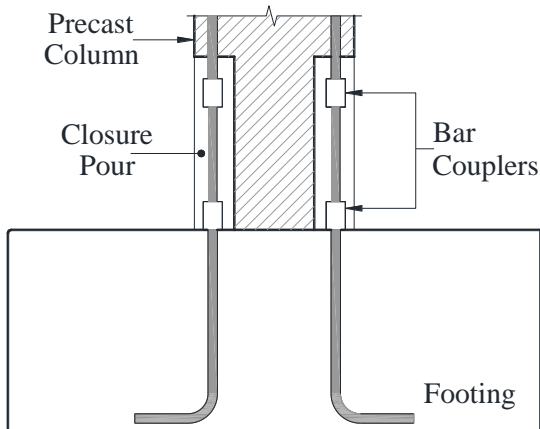
**Figure 1. Seismic Couplers Suitable for Incorporation in Precast Columns**



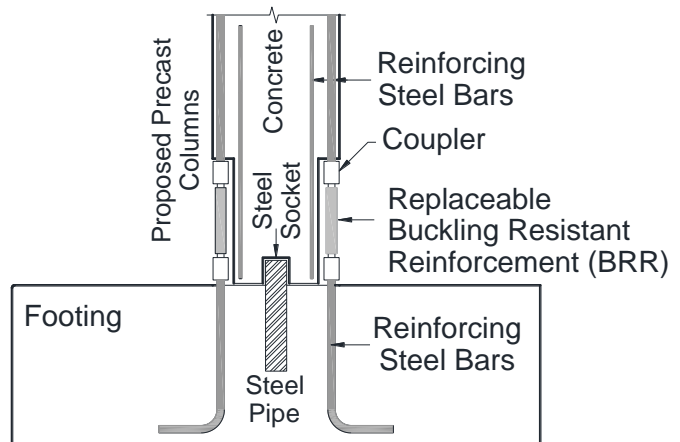
(a) Alt 1 – Couplers Embedded in Precast Column (or Adjoining Member)



(b) Alt 2 – Exposed Couplers in Precast Column (Cast-in-Place Closure Pour)



(c) Alt 3 – Exposed Two-Level Couplers in Precast Column (Cast-in-Place Closure Pour)



(d) Alt 4 – Repairable Precast Columns

**Figure 2. Feasible Connection Details for Mechanically Spliced Precast Columns**

Subsequently, one large-scale (40 to 50%) precast bridge column per coupler product will be constructed and tested using a lateral reversed cyclic loading protocol (e.g. ACI 374.2R-13, 2013) to failure. A cast-in-place conventional column will be included in the test matrix to serve as the benchmark model. Overall, seven to nine columns are expected to be constructed and tested in this project.

The columns are expected to be either circular or square with an approximate height of 9 ft and an approximate diameter/side of 24 in. The final column geometry will be selected based on pretest analyses and the SDSU test setup limitations. For each column, test data including force-deformation relationship, strain profiles, curvatures, rotations, photographs, and videos will be collected and processed. The data allows to generate a comprehensive and the first-of-its-kind database of mechanically spliced precast column seismic performance. Furthermore, post-test analyses will be performed to better understand the column performance and to verify/update the existing design methods (e.g. Tazarv and Saiidi, 2016) for mechanically spliced bridge columns.

### **Expected Outcomes**

Even though bridge bents consisting of precast columns with mechanical bar splice connections could be constructed three times faster than cast-in-place bents (Tazarv and Saiidi, 2015), the current bridge design codes prohibit the use of couplers at the end of columns in high seismic regions. This is mainly because test data on the structural performance of mechanically spliced bridge columns is rare. Successful execution of the proposed study will result in a comprehensive experimental database for mechanically spliced precast bridge columns, which will then be used to further verify or modify the current design methods for this type of precast column and potentially lift the current ban on the coupler use.

### **Relevance to Strategic Goals**

The expected outcomes of this project are directly related to the following goals: “State of Good Repair” and “Economic Competiveness”. The proposed repairable precast joint (**Fig. 2d**) offers a quick and cost-effective repair method for RC bridge columns, which can be done in a few hours after a severe event (e.g. earthquake) by simply replacing the exposed bars (BRR). In-depth discussion of the proposed repairable column performance can be found in Boudaqa et al. (2017). Since the proposed precast details (**Fig. 2**) will significantly accelerate the bridge bent construction compared to conventional cast-in-place methods, the bridge overall cost is expected to be lower. Furthermore, ABC bents will offer several other advantages such as improved member quality, reduction of onsite activities, and reduction of the project overall time.

### **Educational Benefits**

This project will provide a valuable learning experience to both graduate and undergraduate students. Two MS students will be hired to work on this project which will provide the material for two master thesis. Two undergraduate students 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”.

## Technology Transfer

Upon approval of this proposal, a project webpage will be designed under the PI's current website (<https://sites.google.com/people.unr.edu/mostafa-tazarv>) in which the sponsors, personnel, project goals, and findings will be presented. The reports and the test data will be publically available in this and the SDSU data repository websites. The US major bar splice manufacturers will be contacted to participate in this research project. This academia-industry collaboration is beneficial to achieve the project goals and also to directly transfer the technology to the coupler providers. The proof-tested precast column details and verified/updated design methods will facilitate the use of mechanical bar splice connections as a viable precast column technology. Finally, the PI and the collaborators will present the work in regional and national conferences to further disseminate the project findings to other researchers, professionals, and practitioners.

## Work Plan

1. Perform a literature review on the performance of mechanically spliced bridge columns (1 month)
2. Identify couplers and the number of test specimens by contacting all the US mechanical bar coupler manufacturers (1 month, five manufacturers already agreed to participate),
3. Prepare test matrix, design column test specimens and setup, prepare test setup (3 months),
4. Construct and instrument all the specimens then perform cyclic testing (12 months),
5. Post-process the test data and develop a comprehensive database of seismic performance of mechanically spliced bridge columns (3 months),
6. Verify/update current design methods for mechanically spliced bridge columns (2 months),
7. Prepare a final report including an executive summary, measured test data in the form of figures and tables, and recommendations (2 months).

## Project Cost

Total Project Costs:	\$427,335
MPC Funds Requested:	\$190,062
Matching Funds:	\$237,273
Source of Matching Funds:	SDSU, J. Lohr COE, and Industry Partners

## References

1. AASHTO. (2014). "AASHTO Guide Specifications for LRFD Seismic Bridge Design," Washington, D.C., American Association of State Highway and Transportation Officials.
2. ACI 374.2R-13. (2013). "Guide for Testing Reinforced Concrete Structural Elements under Slowly Applied Simulated Seismic Loads," Farmington Hills, MI: American Concrete Institute, 18 pp.
3. Boudaqa, A., Tazarv, M., and Tuhin, I. (2017). "Ductility without Confinement - A New Design and Construction Approach for RC Bridge Columns," International Journal of Bridge Engineering, Special Issue, pp. 53-77, can be found at: <https://www.ijbe.net/issues/special-issues/itemlist/category/40-special-issue-2017>.

4. Dahal, P.K., Tazarv, M., and Wehbe, N. (2018). "Mechanical Bar Splices for Accelerated Construction of Bridge Columns," Mountain-Plains Consortium (MPC) – University Transportation Center (UTC), MPC Report No. 511, Draft Final, 138 pp, Student's Thesis can be found at <https://openprairie.sdstate.edu/etd/2634/>.
5. Tazarv, M. and Saiidi, M.S. (2015). "Design and Construction of Bridge Columns Incorporating Mechanical Bar Splices in Plastic Hinge Zones," Center For Civil Engineering Earthquake Research, Department Of Civil and Environmental Engineering, University of Nevada, Reno, Nevada, Report No. CCEER-15-07, 149 pp.
6. Tazarv, M. and Saiidi, M.S. (2016) "Seismic Design of Bridge Columns Incorporating Mechanical Bar Splices in Plastic Hinge Regions," *Engineering Structures*, DOI: 10.1016/j.engstruct.2016.06.041, Vol. 124, pp. 507-520.