FY 16/17 Research Initial Scope of Work

I. Project Title:

ABC Bridge Column Seismic Anchorage Performance

II. Project Problem Statement:

Caltrans has made great strides in researching seismic Accelerated Bridge Construction (ABC) connection details and implementing the results into practice. A multi-span ABC pilot program is currently under way in an effort to vet design, specification, and construction concerns for mainstreaming ABC in California. The General Earthquake Committee has been involved in evaluating connection details for ABC and has approved a non-coupled 'plunged' (PNC) detail for column-to-footing and column-to-cap connections. Though past research has proven the seismic performance of this connection, the cementitious material used is roughly 9 times as expensive as standard grout, and is a proprietary product posing challenges for specification writers. This presents an obstacle for the adoption of ABC by California bridge engineers.

III. Objective:

The objective of this research is to evaluate standard cementitious material or combinations of materials that could be used to provide anchorage in the Caltrans approved PNC detail such that a less expensive alternative for ABC column connections in California can be established. This would also alleviate the sole-source specification currently required for ongoing ABC pilot projects.

IV. Description of Work and Expected Deliverables:

The research is expected to focus on investigating the performance of various types of ductile concrete/grout in the Caltrans approved PNC grouted duct ABC column connection. This is expected to take the form of casting multiple specimens with varying mix designs for testing that follows the PNC research protocol. However, shake table testing is not expected; the researcher should design a cyclic axial load scenario that mimics the prior results at the duct level. Researchers are encouraged to create ***non-proprietary*** mix designs that deliver results comparable to the original connection's seismic performance. The work is to document mix design, compressive and tensile concrete capacity, bar strain levels, and expected cost for each alternative. Bar sizes are expected to be for non-scaled specimens based on typical well confined Caltrans seismic column designs having 1% to 2% longitudinal

reinforcement. The work is expected to include bundled bar configurations. High early strengths are also expected from each mix due to the ABC aspect of this research.

Deliverables include –

1. Literature search for standardized high early, high performance mix designs and previous grout duct tests.
2. Material and performance results for each proposed mix and specimen, including comparison to a PNC type specimen.
3. Cost comparison for all specimens.
4. Design, detailing, specification, and construction recommendations.

V. Background:

Caltrans has completed various single span ABC projects, most notably the Fort Goff Creek Bridge which was awarded an honorable mention in the 2015 PCI Bridge Design category:

http://www.pci.org/Project_Resources/Project_Profiles/Profile_Pages/Fort_Goff_Creek_Bridge/

As Caltrans expands the use of ABC where practical to do so, multi-span bridges come into view. These feature seismically vulnerable plastic hinge regions in the same locations where columns are connected to other ABC components.

Prior research has helped Caltrans establish a preferred column connection detail to be used for ABC in California. The connection follows the current Caltrans Seismic Design Criteria in not using mechanical or grouted couplers in the plastic hinge zone. It instead uses a debonded bar plunging detail in combination with grouted ducts. Though the detail (referred to as PNC) is simple to construct and has exceptional seismic performance, it involves use of Ultra High Performance Concrete (UHPC) in its most compact state.

The exceptional properties of UHPC make it a promising material for bridge construction. The FHWA has shown UHPC specimen tests to produce over 25,000 psi in compressive strength [3]. Over 20 bridges in the US have been built with UHPC, mostly in the Northeast and Midwest. Studies show that UHPC can accelerate bridge construction, reduce traffic disruption, extend service life, lower maintenance costs, and improve structural performance. Recent studies [1-2] have shown the higher energy absorption and damping characteristics of UHPC, as compared to conventional concrete, leading to significant improvement in seismic performance of columns with UHPC particularly within their plastic hinges.

Though this material is exceptional, it also carries an exceptional price tag, and is considered proprietary. As Caltrans considers a more widespread deployment of ABC projects, it would be advantageous to find a non-proprietary alternative material for use in the PNC joint. This would both lower the cost and alleviate the cumbersome sole-source requirement in current ABC specifications. The proposed research will investigate and assess the material properties and performance of suggested alternatives to UHPC as applies to the PNC connection.

VI. Estimate of Duration:

18 months

VII. Related Research:

1. Zohrevand and Mirmiran, “Effect of Column Parameters on Cyclic Behavior of Ultra High Performance Concrete-Filled FRP Tubes,” Structural Journal, ACI, 110(5), 823-832, 2013.
2. Zohrevand and Mirmiran, “Seismic Response of Ultra-High Performance Concrete-Filled FRP Tube Columns,” Journal of Earthquake Engineering, Taylor & Francis, 17(1), 155-170, 2013.
3. Graybeal, Benjamin A., “Compressive Behavior of Ultra-High-Performance Fiber-Reinforced Concrete”, ACI Materials Journal, Title 104-M17, March-April 2007
4. Caltrans contract 65A0372 “Seismic Performance of Next Generation Bridge (NGB) Components for Accelerated Bridge Construction (ABC)”
5. Caltrans contract 59A0641 “Rapid Construction of Bridge Piers with Improved Seismic Performance”
6. NCHRP 12-74 "Development of Precast Bent Cap Systems for Seismic Regions", Matsumoto, Restrepo, Tobolski, 2010
7. Graybeal, Benjamin and Yuan, Jiqui, “Bond of Reinforcement in Ultra-Hight-Performance Concrete”, ACI Structural Journal, Title No. 112-S70, November-December 2012

VIII. Support of California Bridges & Structure Strategic Direction:

Twelve objectives are outlined in the Structures Strategic Direction which can be found at the site below.

http://onramp.dot.ca.gov/hq/des/spi/docs/Final_California_Bridges_Structures_Strategic_Direction_9-11-14.pdf

The proposed ABC research helps fulfill many of these objectives as follows:

#1	Minimize Accidents	Use of ABC helps minimize accidents by reducing traffic impacted construction exposure. This improved safety benefits the contractor, state forces, and the public.
#2	Minimize Traffic Delays	Internal estimates have shown that over 40 days of traffic impacted construction time can be reduced from a typical two-span overcrossing using ABC. This translates to reduced delays.
#3	Ensure Reliability and Structure Integrity	The proposed research focuses on the reliability and integrity of structural seismic joints. Joint materials in ABC connections must meet stringent performance objectives.
#8	Balance Performance/ life cycle/ Optimize Value	Life cycle costs can be reduced by discovering alternatives to more expensive ABC connections. This optimization spreads to all such ABC projects.
#9	Preserve Environment and Minimize Impacts	ABC reduces environmental impact by reducing construction time and simplifying methods. This is especially true for stream crossings where work can be reduced to a single season.
#12	Encourage Innovative Solutions	The proposed ABC connection research requires innovation on the part of both Caltrans and the researcher. Non-proprietary solutions are the goal.

IX. Deployment Potential:

ABC at Caltrans is already being deployed but has experienced roadblocks due to the seismic requirements of California. This research focuses on making ABC more cost effective while not sacrificing the previously gained seismic achievements. Reducing the cost and complexity of implementing ABC will greatly enhance its deployment in California. This results in reduced construction zone traffic delays, improved work zone safety, and mitigation assistance for environmental impacts when building bridges.

X. Sponsor: Office of Earthquake Engineering and Research