# MPC-404
## January 1, 2012 – December 31, 2012

**Project Title:**
Seismic Performance of Concrete Filled Steel Tube (CFST) Bridge Columns For Accelerated Bridge Construction

**University:**
University of Utah

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**Research Needs:**
In this study we will evaluate the seismic performance of concrete filled steel tube (CFST) bridge columns for potential use in emergency or accelerated bridge construction (ABC) projects. The main goal of the study is to determine whether CFST columns can be designed to perform adequately under gravitational loads and seismic hazard before the concrete reaches its design strength. Then, we need to investigate the effect of reduced seismic loading for this temporary condition on the CSFT limit states of interest, such as serviceability and ultimate limit state.

Columns used for ABC are usually precast components that can be rapidly installed on-site. One of the main challenges with these columns is to keep their weight within a practical weight range for transporting and handling. Special care is also needed when designing splices to connect the foundation to precast piers in high seismic hazard zones. The use of CFST columns largely reduces these problems because the steel tubes are erected prior to pouring the concrete, and can be easily connected to the foundation. Composite columns may be advantageous for ABC because the steel components can be designed to withstand the gravitational deck loads and a reduced seismic hazard. The total seismic capacity of the component is obtained once the filled concrete reaches the design concrete strength. Thus, the bridge performance needs to be analyzed under a seismic hazard for temporary conditions.

Several studies have assessed the possibility of reducing seismic hazard for shorter system exposure times. For instance, Amin et al. (1999) developed a methodology for computing reduced seismic loads for nuclear power plant components subjected to temporary conditions. Olson et al. (1994) developed a quantitative procedure for using available site-specific annual seismic hazard curves to determine an acceleration level for evaluating temporary conditions. Application of this procedure for a sample site resulted in seismic accelerations for compliance periods of one month that were about 33% of the design basis. Boggs and Peterka (1992) developed a procedure for specifying the design recurrence interval for a temporary structure such that the probability of failure is the same than that of permanent structures. However, Hill (2004) considered that temporal structures should have the same ability to sustain loads than permanent systems, independently of the exposure time. Cornell and Bandyopadhyay (1996) identified several challenges when applying reduced seismic loads that will be considered in this study, such as the definition of temporal loads, and license renewal of systems exposed to temporal loading.

Regarding the performance of CFST columns, Marson and Bruneau (2004) tested composite columns under axial and lateral loads. The diameters of these columns were 324 and 406 mm, with a D/t ratio ranging from 34 to 64. The columns reached drifts of 7% before a significant loss in moment capacity. Strength deterioration after the maximum strength was reached was slow until fracture occurred during cycling at 7% drift. They indicated that CFST columns provide an effective mechanism to dissipate seismic energy, and can be effective for bridge columns in seismic regions, although they indicated that further research is needed for larger components. Han et al. (2011) also concluded that circular CSFT columns have excellent seismic resistance. They also confirmed that the lateral load-carrying capacity and ductility decreased as the axial load level in the column increased. Recent studies have performed limited tests to evaluate the effect of concrete strength on the ultimate capacity of CSFT columns. For instance, An et al. (2012) showed that the capacity of CFST columns can be more than twice that of hollow tubes. As expected, the tube's capacity increases as the concrete strength increases, and the concrete strength contribution to CSFT capacity is less significant for columns of large slenderness ratio.

**Research Objectives:**

The objective of this research is to evaluate the feasibility of using CFST columns for emergency or accelerated bridge construction projects. Thus, we will assess whether CFST columns can perform adequately under gravitational loads and reduced seismic loading before the concrete reaches its design compressive strength. This seismic loading scenario has not been previously investigated for CSFT columns.

The main hypothesis of this work is that CSFT columns will be able to withstand gravitational loads and reduced seismic loads for temporary conditions before the concrete reaches its design compressive strength. We will consider discrete variations on the capacity and ductility of CSFT columns, as the concrete compressive strength increases.

The first phase of the study will use available data on CSFT components tested under axial and/or cyclic loading. Given the limited experimental data that accounts for concrete strength variation, a future second phase may include experimental tests of CSFT columns considering concrete strength variations.

**Research Methods:**
The study comprises two areas: i) the development of reduced seismic loads for temporary conditions on CSFT columns, and ii) the numerical analysis of CSFT columns at several limit states, including cases where the design concrete strength has not been fully developed.

For the first area, a reduced seismic hazard for the first 28 days of the CFST components will be proposed based on several parameters, such as relative risk and probability of failure (Hill, 2004). The methodology may be similar to that implemented for reducing seismic loads on nuclear power plants under temporary conditions (Amin et al., 1999). The main challenges identified by Cornell and Bandyopadhyay (1996) will be taken into account. Some of these challenges are easily addressed for CSFTs because the temporal condition is well defined, and once the design concrete compressive strength is reached, the temporal conditions is no longer present.

For the numerical evaluation of CSFT columns for emergency and ABC, a prototype bridge will be evaluated at two different locations. The first location will be located in California in a zone where moderate and strong seismic events have return periods of years or decades. The second location will be close to the Wasatch Mountains in Utah, where large earthquakes are expected to occur, but they have return periods of hundreds or thousands of years. Evaluation of bridges in these two locations should provide insights into the challenges that arise when proposing reduced seismic loads for temporary conditions.

We will perform the numerical evaluation in the Open Sees platform (2010) to take advantage of hysteretic models that can better reproduce the response of CSFT columns. We will also develop approximate evaluations in the computer program SAP2000. After the numerical models are completed, we will carry out a limited parametric study to identify the main parameters affecting the bridges seismic performance.

**Expected Outcomes:**
CFST columns have excellent properties, such as high strength and stiffness, high ductility, and large energy absorption capacity when full composite action of the steel tubes and filled concrete is developed. This study will provide a quantitative evaluation of the performance of CSFT columns for ABC, including limit states where the concrete has not reached the design compressive strength. The results of the investigation may suggest that CSFT columns may be used as an alternative to precast columns in ABC. A final report will summarize the main findings of this investigation.

**Relevance to Strategic Goals:**

The project and its outcomes are related to the state of good repair.  The study may provide a viable alternative to ABC, a construction method that minimizes the disruption of community activities. This alternative could also be used for emergency bridge construction.

**Educational Benefits:**
This project will support the research work of a graduate student who will evaluated reduced seismic loads for temporary conditions, and will develop the bridges numerical models.

**Work Plan:**
The activities of this research can be completed in one year. The following table presents the proposed schedule.

| | | Months | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Task** | **Description** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
| 1 | Literature survey on seismic performance of CFSTs | ■ | ■ | | | | | | | | | | |
| 2 | Development of reduced seismic hazard loads | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | |
| 3 | Modeling of a hypothetical bridge at two locations | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| 4 | Development of numerical models | | | | | | ■ | ■ | ■ | ■ | ■ | | |
| 5 | Parametric study | | | | | | | | ■ | ■ | ■ | ■ | |
| 6 | Final report | | | | | | | | | | | ■ | ■ |
| 7 | Documentation of results | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

**Project Cost:**
Total Project Costs:   $ 35,124
MPC Funds Requested:  $ 17,732
Matching Funds:  $ 17,393              Source of Matching Funds:  U of Utah (University of Utah Faculty Start-up Funds)

**TRB Keywords:**
Seismic, CSFT, accelerated bridge construction

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