Development of a Precast UHPC Hollow Stem Abutment for Accelerated Bridge Construction

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Abstract

Various Accelerated Bridge Construction (ABC) techniques, such as structural precast elements or complete modular bridge systems, are being developed and implemented throughout the United States to reduce on-site construction time and improve mobility. One of the major constraints of ABC is that precast elements can be very large and need to be broken into transportable pieces. In addition, larger cranes are required for assembly on-site. In this work, bridge components fabricated using ultra-high-performance concrete (UHPC) are investigated to overcome these challenges. The ordinary standard bridge seat type abutment, typical of the Caltrans inventory, is used as a prototype. By using UHPC, the sectional sizes have been reduced, making it possible for the abutment to be transported as a single piece. Two different concepts have been explored. The first one uses stay-in form shells while the second concept relies on a hollow section with a wall thickness of 6 inches and corbels to provide a seat width of 36 inches which exceeds the Caltrans Seismic Design Criteria (SDC) requirement. The precast abutment cap will be designed with corrugated metal pipe sockets, which shall be filled with in-situ closure pours to ensure fixed connections with steel H piles. The investigation evaluates the performance of the new abutment under service, strength, and extreme loads. The performance of the new system and its components will be validated by a half-scale experimental test unit. It is anticipated that Caltrans will implement this detail in constructing two-lane standard ordinary bridges of two or three spans.

Keywords: accelerated bridge construction, seat-type abutment, UHPC abutment components, ordinary standard bridge, pile to pile-cap connection, corbels, seismic

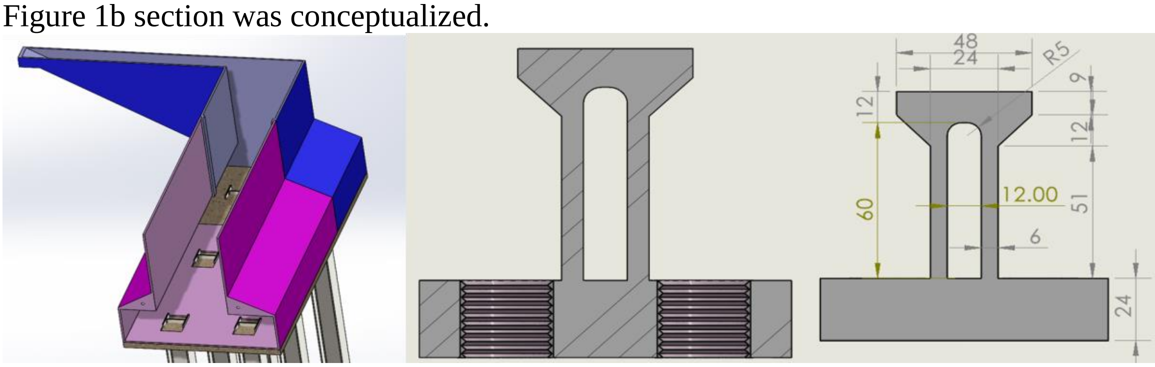
1. Introduction

The 2016 American Society of Civil Engineers report highlights that more than 40 percent of the nation's bridges have been around for 50 years or longer, and 7.5% are structurally deficient. While such bridges must be rehabilitated or replaced to meet structural and safety requirements, reducing traffic impact is imperative, thus warranting novel ABC techniques. To achieve efficient ABC techniques, it is essential to have lightweight and easily producible modules that can be swiftly transported and assembled using commonly available tools at the construction site. Additionally, the system's connections must be appropriately designed and described to simplify assembly and ensure that the overall structure performs as well as, if not better than, a similarly constructed cast-in-place (CIP) system. Cheng et al. (2021) verified the performance of the preformed socket connection using corrugated metal pipes between the steel H-pile group and precast pile cap. To facilitate the practical application of ABC methods, numerous State Departments of Transportation (DOTs) have allocated resources to develop structural connection specifications.

2. Materials and Methods

Ordinary standard bridge (OSB1) drawing details from Caltrans was used as a prototype bridge, representing a typical ordinary bridge in California. OSB1 is a two-span concrete bridge whose superstructure consists of a five-cell continuous CIP post-tensioned concrete box girder with a total width of 47.5 ft (14.478m) and a depth of 6 ft (1.83m). Fourteen 24 in. (61cm) diameter CIDH pile group and a pile cap support the abutments. The main aim of this project is to create and confirm through experiments a process for ABC of seat type abutment that employs easily handled, lightweight prefabricated modules and properly designed connections suitable for construction. UHPC will be used as the choice of material to achieve the project objective.

The LPile model of a CIDH pile was created to analyze the pile's behavior under the nominal and service loading and to replace it with an equivalent steel H-pile. The behavior of the replaced steel H pile was analyzed further to meet the lateral stiffness as per Seismic Design Criteria (SDC 2.0) and Memo to Designers 5-1. To construct the pile cap and stem wall, stay-in-place (SIP) UHPC shells were first explored (Fig. 1a). Even though the transportation of big pieces of SIP UHPC formwork was promising, assembling them and incorporating reinforcement in the field were perceived to be challenging. Hence, a novel UHPC abutment with a hollow stem shown in Figure 1b section was conceptualized.



(a) **(b)** **(c)**

Figure 1: (a) SIP UHPC Formwork (Initial Proposal), (b) Novel UHPC Hollow Stem Abutment with CMP Pile to Pile Cap connection, (c) Dimensions (in inches) of the 40ft Long-Proposed Wall

3. Results and Future Works

The UHPC shells added tolerance and constructability issues and required horizontal and vertical maneuvering, as presented in figure 1a. However, the novel hollow UHPC stem could be transported to the field as a single unit even when the abutment is 50 ft. (15.24m) long. It is lightweight and reduces the unit's total weight for transportation to about 150 kips (667.2 KN).

As shown in Figure 1b, the pile to pile-cap connection in the new section will be maintained by providing socket connections. Corrugated Metal Pipe (CMP) will be used to connect piles and pile-cap, which will be filled with high-strength concrete or UHPC. The pile cap can be designed with high-strength concrete instead of UHPC which can result in a cost reduction of up to 40%. The stem's dimensions are chosen to meet the seating width requirement of 36 in (91.44cm) as per the plans for OSB1. This required for the provision of corbels on two sides of the stem at the top (Figure 1c) to accommodate seat width and a 12 in (30.48cm) CIP back wall, which will be designed using a strut and tie model. Our preliminary analysis shows a hollow sectioned wall of 6 in (15.24cm) thickness at the front and back (Figure 1c), and a single layer or two layers of reinforcement could be used in the stem walls.

Upon moment-curvature analysis (Figure 2) of the CIDH pile section under nominal and service loading conditions for replacement with steel pile, HP section 14x89 aligned along its strong axis was found to be most suitable for a full-scale unskewed bridge like OSB1. Soil models in LPiles were chosen based on Standard Penetration Test (SPT) data of the soil profile primarily consisting of alternating layers of stiff clays and sand. The lateral stiffness of HP 14x89 for the given soil site was found to be 60.8Kips/in (10647.6 KN/m), which satisfies the Caltrans design requirement.

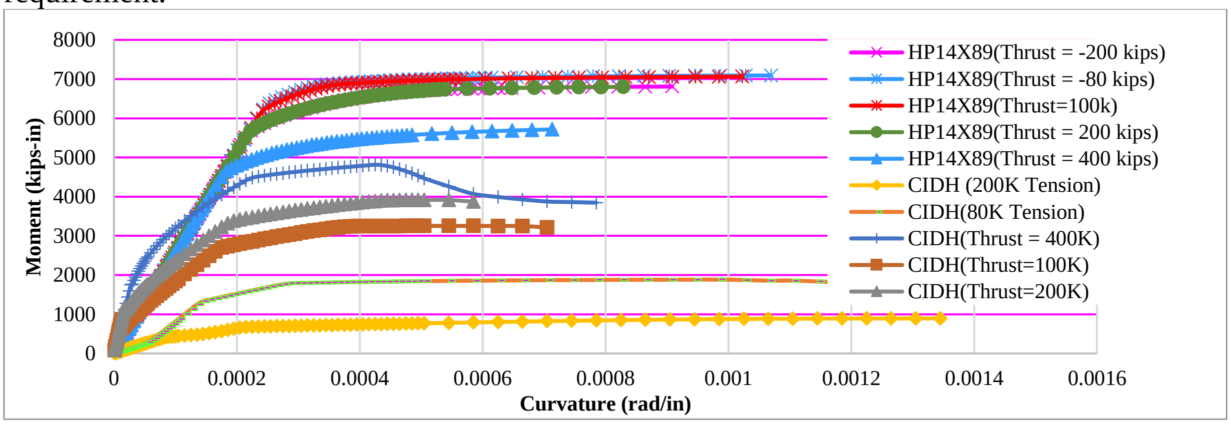


Figure 2: Moment Curvature Curves for CIDH pile and HP 14x89 under nominal and service thrust values

A thorough experimental program is planned for the near future to validate the functionality of this hollow UHPC stem section and to develop criteria for Caltrans.

4. Acknowledgement

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5. References

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