Eliminating the Need for Formwork using UHPC Shells

Nerma Caluk, Florida International University (786) 208-1101, ncalu001@fiu.edu
Islam Mantawy, Ph.D., Florida International University, (775) 537-9019, imantawy@fiu.edu
Atorod Azizinamini, Ph.D., P.E., Florida International University, (402)770-6210, aazizina@fiu.edu

INTRODUCTION

Ultra-High Performance Concrete (UHPC), durable material used in constructing unique and innovative structural elements, is proven to be a perfect fit for accelerated bridge construction (ABC). This research utilizes UHPC to construct prefabricated shells that act as stay-in-place forms for bridge columns to eliminate traditional formwork and scaffolding. Incorporating these structural elements improves the structural performance of bridge columns; reduces the on-site construction time; and protects normal concrete and column reinforcement in aggressive environments such as coastal areas where steel corrosion and water intrusion are service life issues. After erecting and splicing column reinforcement onsite, prefabricated UHPC shell is placed around the column reinforcement which is followed by casting of column-to-footing connection with UHPC. This connection is designed to relocate the plastic hinge away from the protected elements (footing and cap beams). Once the UHPC hardens, the normal strength concrete is cast inside the shell, creating a permanent concrete-filled UHPC shell. This publication discusses briefly the development of this new concept along with experimental results for one column specimen which was constructed using an unreinforced UHPC shell. Another specimen is being constructed to enhance the bond between UHPC and concrete by sharing the longitudinal reinforcement between them.

DESING AND CONSTRUCTION

Design of the specimen

The main goal of incorporating stay-in-place prefabricated UHPC shells for bridge columns is to eliminate the use of formwork and scaffolding which enhances safety and mobility in addition to enhancing the column performance and serviceability. In this research, a column specimen was designed, constructed and tested at Florida International University. The column specimen consists of an unreinforced UHPC shell where the conventional steel cage is located inside shell cavity and is filled with normal strength concrete. The connection between the footing and the column was designed as a "step" made of UHPC, where the splice region is located. Before testing the specimen, moment-curvature analyses were conducted for three different sections (footing, UHPC step, and column sections). These analyses were used to assure that no damage should occur in the footing and that the plastic hinge is shifted away from the footing and UHPC step (1). **Figure 1** shows specimen details.

Construction of the specimen

The construction of the specimen started by placing the footing reinforcement inside traditional formwork, followed by casting of normal strength concrete. To shape the UHPC shell, a sonotube was used as the outer perimeter and Styrofoam was used to shape the inner diameter.

As mentioned before, no reinforcement was embedded in the shell element. However, the steel cage consisting of longitudinal reinforcement and transverse reinforcement (spiral) was placed inside the cavity in the UHPC shell. Due to height limitations in the laboratory, the steel cage had to be placed in the UHPC shell before placing them together on top of the footing. After the shell and the cage were spliced with the extended dowel bars from the footing, another sonotube was used to shape the UHPC step connection. Once the UHPC step has hardened, the column concrete was cast together with the loading cap. **Figure 2** shows the UHPC shell and the UHPC step connection.

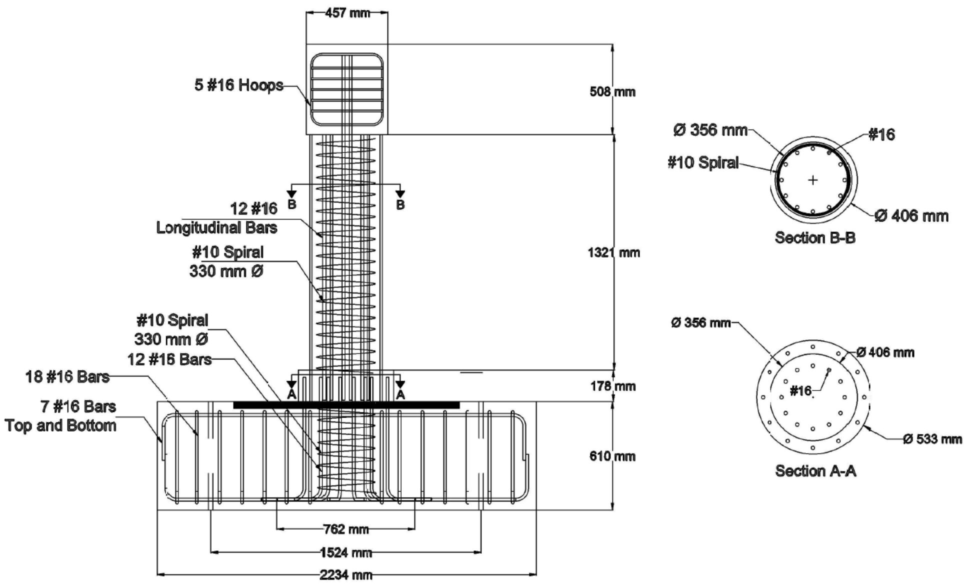

Figure 1. Detailing of the column.

Figure 2. Bridge column made of UHPC shell: Prefabricated UHPC shell (left), UHPC step connection between the column and the footing.

EXPERIMENTAL RESULTS

The column specimen was tested under a constant axial load of 534 kN and an incremental lateral load. The incremental lateral load was applied using displacement control as multiplications of yield displacement (Δ_y) of the specimen.

Twenty-six strain gauges, four displacement transducers, twelve strain potentiometers, and four cameras were instrumented to collect and measure specimen response in addition to tracing of the progression cracks and damage.

During the test, the UHPC shell cracked at the north side of the column at a drift ratio of 3%. However, even when the specimen has cracked in the plastic hinge zone, the column still had sufficient capacity and behaved similarly to a conventional reinforced column. The first bar raptured at a drift ratio of 7.5%. No damage was noticed at the UHPC step and footing, which proves that the design was appropriate for relocating the plastic hinge above the footing and UHPC step connection. **Figure 3** shows the hysteresis and envelope for the lateral force versus the lateral displacement for the tested specimen.

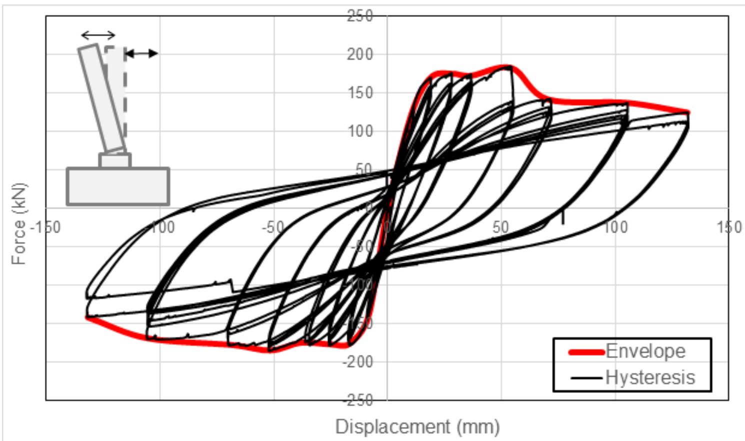

Figure 3. Force vs Displacement graph for the tested specimen

CONCLUSION

Based on the collected data, it was determined that the first bar fracture occurred at a drift of ratio 7.5% and that the designed UHPC step element is effective in shifting the plastic hinge away from the column-to-footing interface with no observed cracks. The first and main cracks were noticed at the north and south side of the column, at the connection between the column and the top of the UHPC step. Although the shell has cracked at the 3% drift ratio, the column still showed sufficient capacity and continued to act as a conventional reinforced concrete column until the first bar fracture. Prior to the testing, it was assumed that possible slippage might occur between the normal strength concrete and UHPC, however, after the test was conducted, no slippage between these two materials was noticed. Further investigation will be done to better understand the behavior of stay-in-place precast UHPC shell columns.

REFERENCES

1. Caluk, N.; Mantawy, I.; Azizinamini, A. Durable Bridge Columns using Stay-In-Place UHPC Shells for Accelerated Bridge Construction. *Infrastructures* **2019**, *4*, 25