

Applications of Ultra High Performance Concrete to Bridge Construction in Georgia

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Abstract:

Due to its high compressive strength, higher tensile capacity, and ultralow permeability ultra high performance concrete (UHPC) can find broad applications in bridge construction and repair. The growing utilization of UHPC across the US, including locally produced materials, creates new opportunities for sharing material design and processing methods, structural and repair design considerations, and construction methods. This paper reviews recent UHPC bridge projects in Georgia by presenting case studies on Georgia's use of UHPC in the construction of the state's bridges. Additionally, details are given about recent research projects on UHPC funded by the Georgia Department of Transportation.

Keywords: Georgia, GDOT, UHPC, Accelerated Bridge Construction, SR 211 / Beech Creek Bridge, Research, UHPC Bridge Joints

Introduction

Ultra high performance concrete (UHPC) is noteworthy for its improved mechanical properties over conventional concrete. Due to its high compressive strength, higher tensile capacity, and ultralow permeability UHPC can find broad applications in bridge construction. Although the suitability of UHPC for transportation structures had been studied for many years by researchers in the state, the first use of UHPC in construction in Georgia occurred in 2016. The Georgia Department of Transportation (GDOT) used UHPC to repair moderate spalling in precast girders in 2017.

Currently, UHPC in Georgia is primarily in accelerated bridge construction as a connection material for precast deck joints and shear connections. In this application, UHPC is used to fill the transverse and longitudinal joints of precast bridge deck panels, fastening them into one composite member. UHPC is then also used to join the deck panels to the shear connections along the beams supporting the deck.

This type of UHPC connection has been used on projects across North America [1-3]. UHPC is an attractive option for these joints because it allows very short reinforcement development. Typical designs for such joints can be seen in Figure 1 and Figure 2. Since 2014, detailing for these joints has been determined by guidelines set forth by the Federal Highway Administration in document FHWA-HRT-14-084 “Design and Construction of Field-Cast UHPC Connections” [4]. The work done by GDOT to date has followed these guidelines.

This paper will discuss past and present work involving UHPC in the state of Georgia, both in industry and academia. The State Road 211 bridge and County Road 131 bridge will serve as examples of how UHPC is being used in construction. Additionally, the details of two completed research projects and one in-progress project will be given as an example of the research progress in the state.

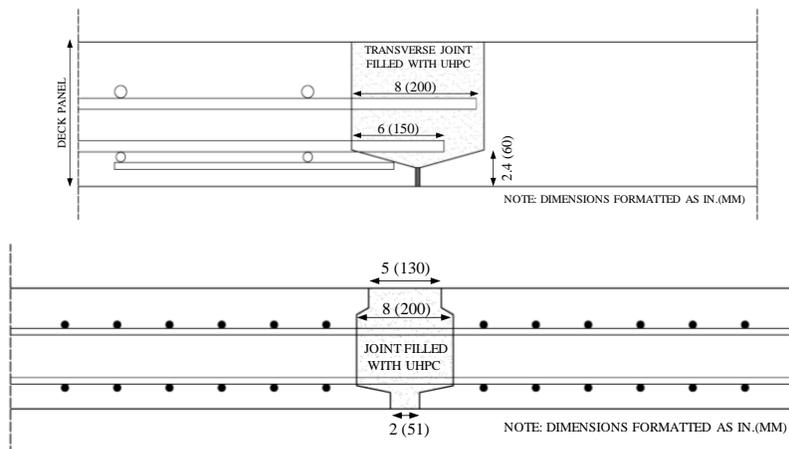


Figure 1: Examples of transverse joint details from Toronto, Canada (Modified from [2], top) and Chicago, Illinois (Modified from [1], bottom)

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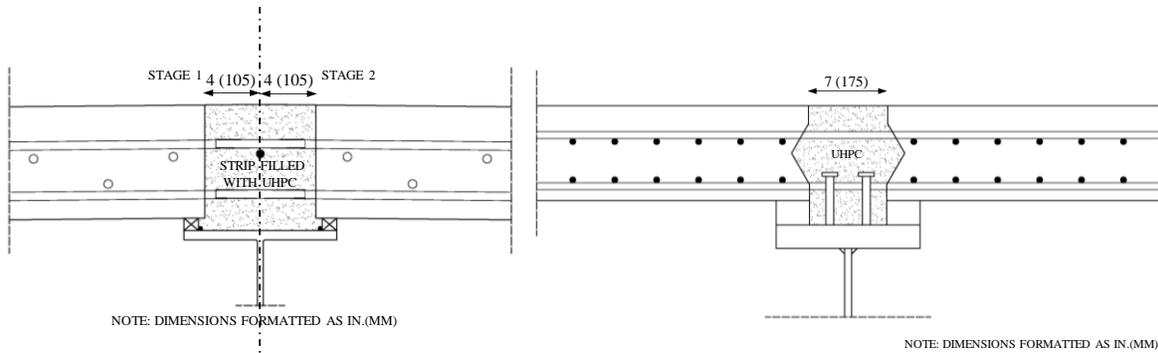


Figure 2: Examples of longitudinal joint details from Toronto, Canada (Modified from [2], left) and Chicago, Illinois (Modified from [1], right)

Construction Incorporating UHPC in Georgia

2.1 Completed Construction: State Road 211 / Beech Creek Bridge

To date, there has only been one structure in Georgia built using UHPC - a bridge on State Road 211 over Beech Creek near Athens, GA. This bridge was built by E.R. Snell Contractor for GDOT. It consists of a single 148 foot (45.1m) span, with a 40 foot (12.2m) gutter-to-gutter width. Full-depth precast deck panels 8.75 inches (22.2 cm) thick were used to accelerate the construction time of the bridge [5]. As seen in Figure 3, the rebar overlap in the transverse and longitudinal joints was 5 inches (12.7cm). The bottom of the transverse joint was designed to fit snugly to reduce the amount of necessary formwork, while the top was given a 2 inch (5cm) gap to allow for UHPC placement. Additionally, UHPC was utilized in the shear connections, as seen in Figure 4 [6].

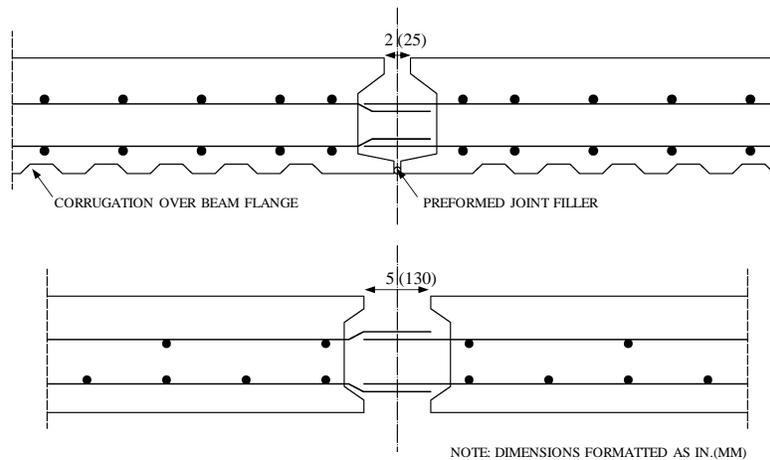


Figure 3: Typical transverse [top] and longitudinal [bottom] joint details from SR 211 Bridge [6]

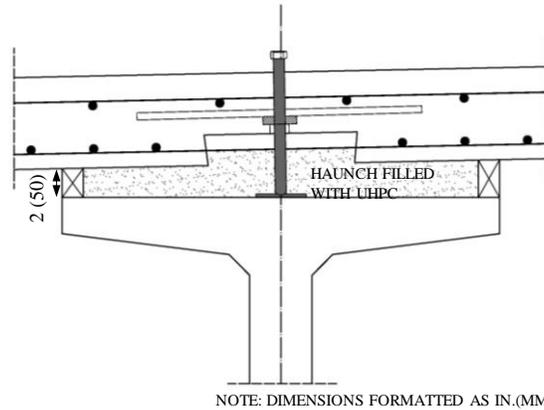


Figure 4: Typical shear connection details from SR 211 Bridge (GDOT 2014)

The UHPC used on the project was Ductal UHPC provided by Lafarge. Aside from the first placement day, pours were done in the night in order to avoid hot placement temperatures during the day.

The UHPC was mixed on-site in one of two large shear pan mixers, provided by the producer. After, the UHPC was loaded into a crane bucket for placement. Placement into tight joints from the bucket presented a challenge and is identified as an area for improvement in constructability with UHPC produced on-site. Once the joints had been filled, short “chimneys” were constructed over the ends of the joints and connected to buckets. One bucket was partially filled with remaining UHPC. The hydraulic pressure head between these bucket reservoirs ensured that the UHPC flowed into the whole joint [5]. The usage of UHPC in this project allowed for accelerated bridge construction, with the bridge opening back up to traffic after only 60 days of construction.

2.2 Construction in Progress

Currently, another bridge incorporating UHPC is being constructed in Henry County, Georgia on County Road 131. As with the State Road 211 bridge, UHPC will be used as a connection material for precast deck panels and shear connections. As a result of placement difficulties with the 2 inch (5cm) joint width on the State Road 211 project, transverse joint widths for the Henry County bridge have been expanded to 5 inches (12.7cm) as seen in Figure 5. Current construction planning is ongoing, but construction is anticipated to proceed in much the same way as the State Road 211 bridge.

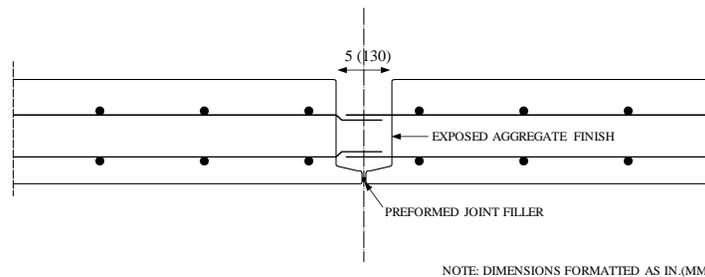


Figure 5: Henry County / County Road 131 transverse joint details [7]

Research in Georgia on UHPC

3.1 Multi-scale Investigation of Tensile Creep of Ultra High Performance Concrete for Bridge Applications

The likelihood of UHPC precast members being produced for use in the field creates a need to understand how UHPC members will perform under service loads. In 2009 GDOT Research Project 2043 investigated the tensile creep behavior of UHPC, a necessary consideration when designing pre-stressed, precast girders. Over the course of the project the effects of thermal conditions, fiber content, and varying loading conditions were evaluated to see what effect they had on tensile creep in UHPC.

It was found by Garas et al. that while the maximum difference in tensile strength of all specimens tested only varied by 8% the tensile strain varied by up to 70%, confirming that creep is an important design consideration [8]. Thermal treatments showed great promise in reducing creep. A 48-hour 90°C heat (194°F) treatment was found to reduce tensile strain by 63%, while a 72-hour 60°C (140°F) reduced tensile strain by 57%. Additionally, a porous fiber-cement matrix interface was observed in non-heat-treated specimens, while specimens that had been heat treated lacked such an interface. Garas et al. also suggested using a maximum design stress less than 60% of the ultimate tensile strength of the material in order to avoid the deleterious effects of creep in the field [9].

3.2 Shear and Shear Friction of Ultra High Performance Concrete Bridge Girders

Because UHPC is cast without standard reinforcing bars, all shear forces must be borne by the concrete and reinforcing fibers themselves. To further study how effective these fibers are in resisting shear, the 2010 GDOT Research Project 07-05 investigated the performance of UHPC bridge girders under shear loading conditions. The team coordinated with a local precaster to make the UHPC girders used in this project. Each girder was 120 inches (3.05 m) long with a 114-inch (2.9 m) span. The beams with cast in place decks had a reduced deck length of 88 inches (2.2 m) in order to force a shear failure [10]. Standard girder designs are shown in Figures 6 and 7. Note that 1 inch is 25.4 mm, a #3 bar is equivalent to a 10M bar, and a #9 bar is equivalent to a 29M bar.

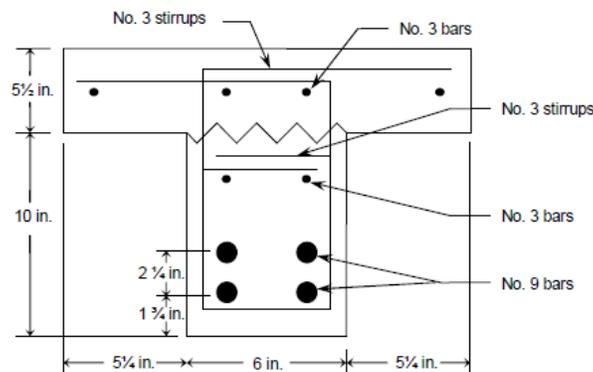


Figure 6: Typical T-beam cross section [10]

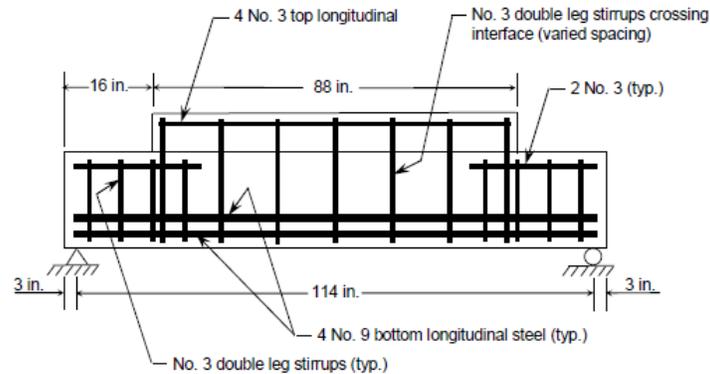


Figure 7: Typical reinforcement for all beams [10]

Through testing, Crane et al. [11] found that smooth UHPC cold joints provided low interface shear and were not recommended for use in shear systems. However, using form liners to produce a fluted effect on shear surfaces was found to provide a surface finish comparable to the AASHTO recommendation for surface roughness. Shear joints incorporating this fluted finish were found to make both ACI and AASHTO equations conservative in their analysis. Crane et al. also observed that using tensile test data and Mohr's circle a simple and conservative estimate of the shear strength could be calculated. [11]

3.3 Development of GDOT Ultra High Performance Concrete for Bridge Deck Closure Pours

A major factor inhibiting UHPC from more widespread use in Georgia is the high price of the material relative to more standard concrete options. The only UHPC provider in Georgia at this time is Lafarge, whose Ductal UHPC mix is proprietary. On-site UHPC batching also requires rental of proprietary mixing equipment. In the currently-ongoing GDOT Research Project 18-01, researchers from Georgia Tech are developing a non-proprietary UHPC mix design from local materials. Many of the materials required to make UHPC are abundant in Georgia. Both Class C and Class F fly ash, as well as finely divided and relatively pure calcined clays, are widely available. Dolomitic sands and coarse aggregate are also readily available. The goal of this project is the development of a non-proprietary mix that can serve as a more economical option that can be produced state-wide, while meeting the performance requirements for closure pours.

Looking Forward

In conclusion, UHPC use in Georgia is expected to grow. The construction of the State Road 211 / Beech Creek Bridge provided GDOT with experience working with UHPC- experience that is being applied towards the construction of a second bridge. Because of GDOT's funding, the state also has been conducting research into UHPC for more than a decade. As more companies enter the UHPC marketplace and GDOT acquires their own UHPC mix designs, the increased accessibility to UHPC should lead to even more advancement in UHPC construction.

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