TECHBRIEF

Structural Behavior of a 2nd Generation UHPC Pi-Girder

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FHWA Contact: Ben Graybeal, HRDI-06, 202-493-3122, benjamin.graybeal@dot.gov

This document is a technical summary of the unpublished Federal Highway Administration report, *Structural Behavior of a 2nd Generation Ultra-High Performance Concrete Pi-Girder*, available only through the National Technical Information Service (NTIS).

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Objective

This TechBrief highlights the results of a research program that evaluated a 2nd generation ultra-high performance concrete (UHPC) pi-girder cross section developed for use in short- and medium-span highway bridge applications.

Introduction

UHPC is an advanced cementitious composite material which has been developed in recent decades. Compared to more conventional concrete materials, UHPC tends to exhibit superior properties such as exceptional durability, high compressive strength, usable tensile strength, and long-term stability.[1,2]

This experimental investigation focused on the structural behavior of a newly developed highway bridge girder cross section, the pi-girder. This girder was developed and optimized to exploit the advanced mechanical and durability properties of UHPC. Full-scale prestressed girders were fabricated, and structural testing was completed on these girders to investigate critical structural behaviors. Through this work, topics related to the design and the fabrication of the pi-girder were also addressed.

UHPC

Advances in the science of concrete materials led to the development of the next generation of cementitious

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

www.tfhrc.gov

materials, namely UHPC. As a class, these concretes tend to contain high cementitious material contents, low water-to-cementitious material ratios, compressive strengths above 21.7 ksi (150 MPa), and sustained tensile strength resulting from internal fiber reinforcement. Table 1 presents a select set of material properties for the type of UHPC investigated in this study.(1)

Table 1. UHPC material properties.

Property	Value
Unit weight	156 lb/ft^3 (2,500 kg/m^3)
Modulus of elasticity	7,600 ksi (52,400 MPa)
Compressive strength	28.0 ksi (193 MPa)
Post-cracking tensile strength	1.0 to 1.5 ksi (6.9 to 10.3 MPa)
Chloride ion penetrability (ASTM C1202)(3)	Negligible

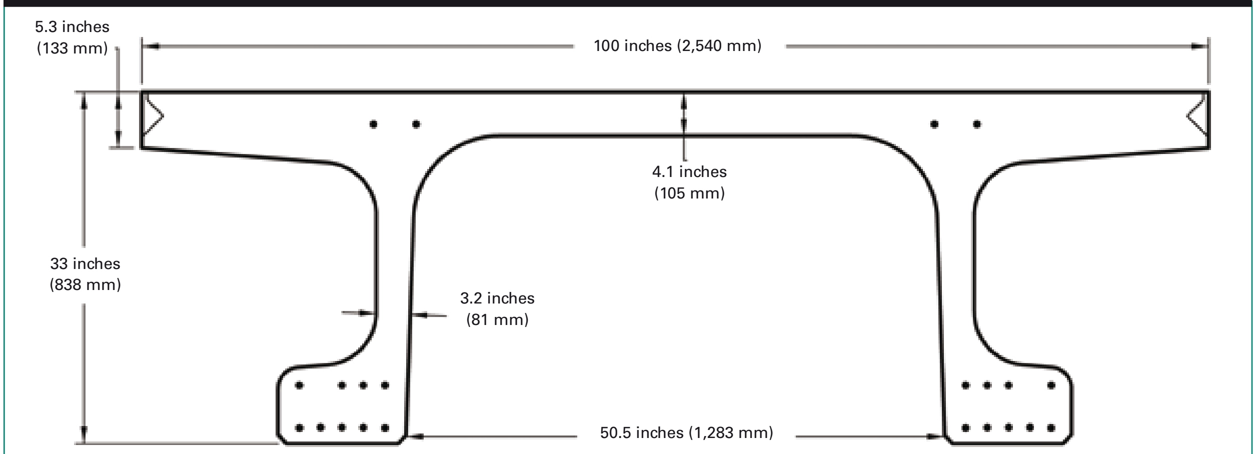
2nd Generation UHPC Pi-Girder

The advanced properties of UHPC provide opportunities for the development of new structural forms focused on addressing any number of important transportation infrastructure issues. Straightforward topics such as creating longer lasting bridges through enhanced durability and allowing for the spanning of longer distances with shallower superstructures can be addressed through the use of UHPC. In a systematic sense, UHPC also presents the opportunity to create new structural forms which facilitate accelerated construction and rapid renewal of the highway infrastructure.

Development of a UHPC decked girder member prototype was initiated during the early stages of the Federal Highway Administration's (FHWA) UHPC research program. Results from the full scale fabrication and testing of this prototype girder are presented in *Structural Behavior of a Prototype Ultra-High Performance Concrete Pi-Girder*.(4) These results led to the refinement of the pi-girder solution and the development of a 2nd generation pi-girder component.

The basic cross sectional shape of this 2nd generation UHPC pi-girder is similar to the prototype; however, modifications to ease fabrication, simplify construction, and add structural capacity have been implemented. The cross section modifications include increased deck thickness and width, increased web thickness, decreased web spacing, and rounded reentrant corners (see figure 1). Overall, this girder is a modular component designed to span up to 87 ft (26.5 m). Each

Figure 1. A 2nd generation UHPC pi-girder cross section.



girder is 100 inches (2.54 m) transverse to traffic and 33 inches (0.84 m) deep. It can also be prestressed by up to 16 strands in each bulb.

Test Program

Testing the pi-girder prototype demonstrates that the primary flexure and shear behaviors of this girder are consistent with a line girder analysis and can be predicted through the use of basic engineering principles. As such, these behaviors were not explicitly investigated in the testing of the 2nd generation component. The structural testing completed for this study focused on the transverse flexural response of the girder when subjected to monotonically increasing simulated wheel loads.

Two 25-ft (7.6-m)-long prestressed girders were fabricated at a conventional precast girder production plant and then shipped to FHWA's Turner-Fairbank Highway Research Center. The transverse flexural capacity of the girder deck between the webs, as well as the longitudinal connection detail between adjacent girders were then investigated. Figure 2 shows a photograph of a transverse flexure test. Observations from the girder fabrication and results of the structural tests are discussed in detail within the corresponding main report.

Conclusions

The design, fabrication, and testing of a 2nd generation UHPC pi-girder modular bridge component has been completed. The research program has demonstrated the viability of the decked UHPC modular girders concept for use in conventional and accelerated bridge construction. Girders of this type can be fabricated in existing prestressed girder production facilities. The girder cross section on which the research focused is capable of meeting the requirements of the *AASHTO LRFD Bridge Design Specifications* with a span length up to 87 ft (26.5 m).[5] The transverse flexural capacity of the girder is sufficient, and the capacity of the longitudinal joint exceeded that of the prefabricated deck.

Figure 2. Transverse flexure test.

Initial Pi-Girder Deployment

The initial deployment of the UHPC pi-girder concept was completed in Buchanan County, IA. The Jakway Park Bridge opened to traffic in late 2008. This bridge includes three adjacent 2nd generation UHPC pi-girders.

Further Pi-Girder Development

The research completed in this study has led to the initiation of a number of related studies. A family of pi-girders is under development with the intention of developing components for accelerated construction of medium span bridges. Optimal connection details between girders and for barrier rails are also being investigated. Finally, finite element computer modeling is being used to better understand the structural behavior of UHPC components and to facilitate the development of new components.

References

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Researchers—This study was completed by Ben Graybeal of the Federal Highway Administration's (FHWA) Turner-Fairbank Highway Research Center. Additional information can be gained by contacting him at 202-493-3122 or in the FHWA Office of Infrastructure Research and Development located at 6300 Georgetown Pike, McLean, VA, 22101.

Distribution—The unpublished report (PB2009-115496) covered in this TechBrief is being distributed through the National Technical Information Service, www.ntis.gov.

Availability—The report will be available in November 2009, and it can be obtained from the National Technical Information Service, www.ntis.gov.

Key Words—Ultra-high performance concrete, UHPC, Fiber-reinforced concrete, Bridges, Precast concrete, Prestressed concrete, Bridge design, Accelerated construction, and Durable infrastructure systems.

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