TECH**BRIEF**

Structural Behavior of a Prototype UHPC Pi-Girder

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This document is a technical summary of the unpublished Federal Highway Administration report, *Structural Behavior of a Prototype Ultra-High Performance Concrete Pi-Girder*, available only through the National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 an ultra-high performance concrete (UHPC) pi-girder cross section prototype 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. When 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. Structural testing was completed on girders to investigate their flexural response, shear response, transverse flexural response, and lateral load distribution capabilities. Through this work, topics related to the design and 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 materials, namely UHPC. As a class, these concretes tend to contain

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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

UHPC Prototype 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. Topics such as creating longer lasting bridges through enhanced durability or 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.

The development of a decked girder prototype member which utilized UHPC as the primary structural component was initiated during the early stages of the Federal Highway Administration's (FHWA) UHPC research program. It is evident that UHPC's mechanical and durability properties allow for beneficial modifications to conventional concrete bridge component solutions. It also allows for the development of previously impractical components. Given the prior applications of conventional concrete decked girder members in infrastructure applications and the construction of the Peace Footbridge in Seoul, South Korea, a decked pretensioned girder with slender cross sectional dimensions was envisioned as a prototype solution.

The cross section dimensions of the UHPC pi-girder prototype were established through an analytical study completed at the Massachusetts Institute of Technology.[4,5] The models implemented in the design included one-, two-, and three-dimensional analyses of the predicted response of the girder to the loadings prescribed in the *AASHTO LRFD Bridge Design Specifications*.[6]

Figure 1. UHPC pi-girder cross section prototype.

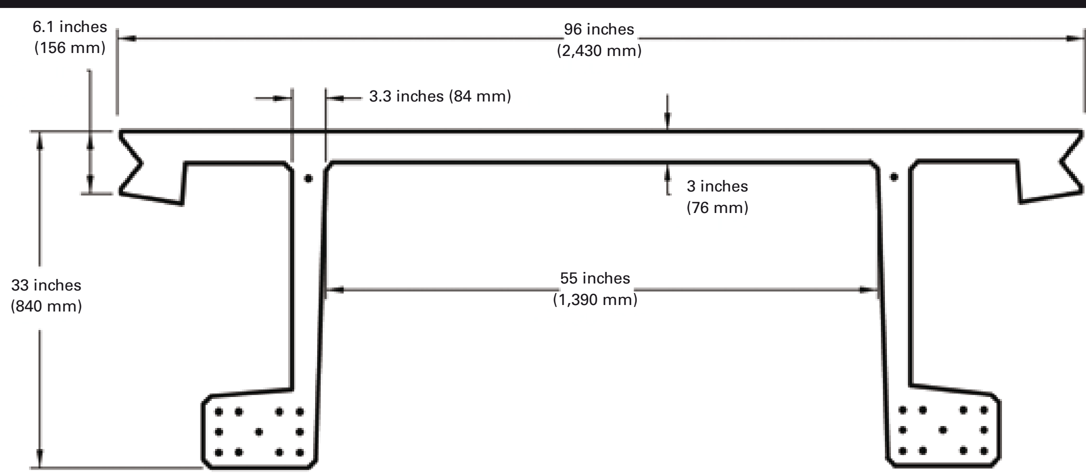

Figure 2. Full-scale shear test.

The girder prototype is a modular component designed to span 70 and 100 ft (21 and 30 m). Figure 1 shows a UHPC pi-girder cross section prototype, which is 96 inches (2.4 m) transversely and 33 inches (0.84 m) deep. It can also be prestressed by up to 15 strands in each bulb.

Test Program

This research program included two phases. The first phase focused on the fabrication of four UHPC pi-girders. These 70-ft (21.3-m)-long prestressed girders were fabricated at a conventional precast bridge girder production plant and then transported to FHWA's Turner-Fairbank Highway Research Center (TFHRC). The second phase of the research focused on the physical testing of these full-scale girders through the application of structural loads. Three tests including primary flexure and shear, transverse flexure, and load distribution were conducted. Figure 2 shows a full-scale shear test of the pi-girder prototype underway in the laboratory. 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 UHPC pi-girder prototype demonstrated that the concept of decked UHPC modular girders for bridge construction is viable. Girders of this type can be fabricated in existing prestressed girder production facilities. The structural response of the girder prototype exceeds design requirements in terms of ultimate shear capacity and meets flexural design requirements with the inclusion of appropriate prestress force. The load distribution capability of the girder is limited, so distribution of live loads beyond adjacent girder legs is not recommended. The transverse flexural capacity of the girder is insufficient to elastically resist service-level wheel loads.

Further Pi-Girder Development

The research results presented in the corresponding report have led to the further development of the pi-girder concept. A 2nd generation pi-girder has been designed, full-scale test girders have been fabricated, and testing has begun. The 2nd generation pi-girder retains the initial concept, but it has been modified to provide significantly increased transverse flexural capacity while also allowing for simplified fabrication. Results of this follow-up program will be published in the near future.

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Distribution—The unpublished report (PB2009-115495) 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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