LAMBERTS/BRAMBLETON VIADUCT
NORFOLK LIGHT RAIL TRANSIT PROJECT

by Jason R. Doughty, PB

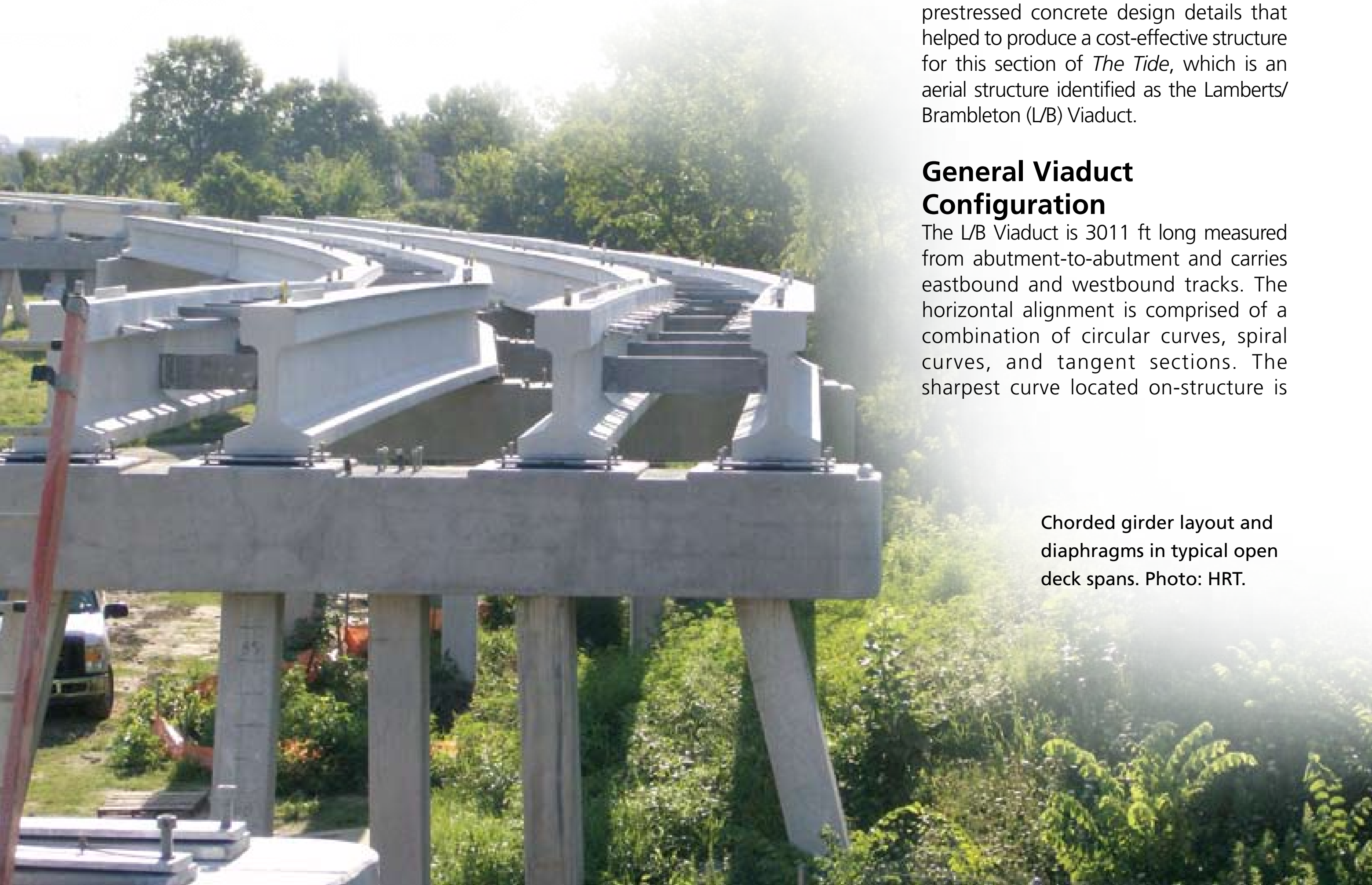
Hampton Roads Transit (HRT) in Hampton, Va., has been planning a new-start light rail system known as *The Tide* since the late 1990s. In late 2006, the General Engineering Consultant (GEC) contract was awarded to the team of Parsons Brinckerhoff (PB) and URS. The team proceeded with final design of track alignments, aerial structures, trackwork, stations, a yard-and-shop building, and a variety of other components comprising this multi-discipline project. In the fall of 2007, HRT executed a Full Funding Grant Agreement with the Federal Transit Administration, which provided necessary federal funds to begin construction activities. Construction began in late 2007 and passenger revenue operations are expected to begin in 2010. The estimated total cost for the project is $288 million and the estimated ridership is 6000 to 12,000 riders per day.

The Tide light rail line will extend 7.4 miles on a west-east alignment from the East Virginia Medical Center through downtown Norfolk, continuing along a former Norfolk Southern Railroad right-of-way, roughly parallel to I-264, to the city line at Newtown Road. Eleven stations will be constructed along the route with four park-and-ride locations that provide access to major areas such as Sentara Norfolk General Hospital, MacArthur Center, City Hall, Harbor Park, Tidewater Community College (Norfolk Campus), and Norfolk State University.

The 7.4-mile system was divided into several different construction contracts. The first contract was awarded in late 2007. This article focuses on the precast, prestressed concrete design details that helped to produce a cost-effective structure for this section of *The Tide*, which is an aerial structure identified as the Lamberts/Brambleton (L/B) Viaduct.

General Viaduct Configuration

The L/B Viaduct is 3011 ft long measured from abutment-to-abutment and carries eastbound and westbound tracks. The horizontal alignment is comprised of a combination of circular curves, spiral curves, and tangent sections. The sharpest curve located on-structure is



Chorded girder layout and diaphragms in typical open deck spans. Photo: HRT.

profile

LAMBERTS/BRAMBLETON VIADUCT / NORFOLK, VIRGINIA

BRIDGE DESIGN ENGINEER: PB Americas Inc., Norfolk, Va.

PILE-BENT DESIGNER FOR OPEN DECK SPANS: Simpson Engineers & Associates Inc., Cary, N.C.

PRIME CONTRACTOR: Bryant Contracting Inc., Toano, Va.

PRECASTER: Bayshore Concrete Products Corporation, Cape Charles, Va., a PCI-certified producer a circular curve with a radius of 166 ft. The distance between the track centers along the viaduct varies, requiring some sections of the viaduct to be a double-track structure and other sections to be separate eastbound and westbound single-track structures. The vertical alignment varies from level to grades up to 6% and the average height of the viaduct above the existing and finished ground is approximately 20 ft.

Structural Components of the Viaduct

Key objectives behind this aerial structure design were to produce a simple structure that would use repetitive details, could be constructed rapidly, would be as cost-effective as possible, and would be easily maintained in the future. Early preliminary engineering work had concluded that the sharply curved portion of the viaduct (Spans 1 through 11) was to be designed as a horizontally-curved steel plate girder superstructure with a direct-fixation (DF) deck. However, given the volatility of the structural steel market over the past few years, the high steel prices at the time of design, and the long lead times expected for these girders, a decision was made to use chorded, simple-span, precast, prestressed concrete girders with the same DF deck.

As a result of this early decision, simple-span, precast, prestressed concrete girders were used for all but two of the spans of the 43-span viaduct. Chorded span layouts were used throughout the viaduct and the girder layout was developed such that the centerlines of the girders remained aligned as close as possible with the track's running rails. The center-to-center bearing span lengths range from approximately 50 to 85 ft.

The girders are 4 ft 6 in. deep and are a modified bulb-tee section. The wide top flanges normally associated with bulb-tee sections were reduced to a width of 20 in. The girder cross section resembles a rail section, and the narrower top flange better accommodates the dapped timber ties used in the open deck spans. The compressive strength of the girder concrete at release was specified to be 6400 psi, and the 28-day compressive strength for the girder concrete was specified as 8000 psi.

Two different deck types, each with different systems of rail fixation, were used on the concrete girder spans. In the sharply curved portion of the viaduct, a direct-fixation (DF) deck was used. The reinforced concrete deck helps provide lateral stability and serves as the mechanism to distribute live load to the girders. On all other concrete girder spans, an open-deck track system with timber ties was used.

Key objectives were to use repetitive details, be constructed rapidly, be as cost-effective as possible, and be easily maintained in the future.

The girder bearings consist of a combination of steel fixed bearings, guided steel-reinforced elastomeric expansion bearings, and conventional fixed and expansion, steel-reinforced, elastomeric bearings. Constant pad and plate dimensions were used as much as possible in order to simplify fabrication and construction.

Another cost-effective, repetitive, and easy-to-build feature was the bridge piers. Pile bents, which represent one of the most economical substructure types, were used for nearly every substructure unit on the viaduct. The pile bents consisted of battered 20-in.-square precast, prestressed concrete piles and cast-in-place reinforced concrete bent caps. The end bents also are supported by the same 20-in.-square piles. The typical pile length at the pile bents was approximately 80 ft.

Lateral bracing and diaphragms in typical open deck span. Photo: PB Americas.

Open Deck with Precast, Prestressed Concrete Girders

In order to provide HRT with a cost-effective structure and to eliminate well over 1000 yd^3 of deck concrete that would have been required for a DF deck, it was decided to

PRECAST, PRESTRESSED CONCRETE LIGHT RAIL AERIAL STRUCTURE / HAMPTON ROADS TRANSIT, OWNER

BRIDGE DESCRIPTION: 3011-ft-long bridge with 43 spans ranging in length from 50 ft to 85 ft and using both direct fixation and open deck details, chorded geometry, and precast pile bents with cast-in-place concrete bent caps

STRUCTURAL COMPONENTS: 162 precast, prestressed concrete 54-in.-deep, modified bulb-tee girders, 268 20-in.-square precast, prestressed concrete piles

BRIDGE CONSTRUCTION COST: $11.7 million for bridge structures only; does not include track system

End diaphragm detail at typical open deck spans. Photo: PB Americas.

investigate the use of an open-deck system supported on precast, prestressed concrete girders. An open deck system consists of timber railroad ties spanning transversely between the longitudinal girders and represents one of the most economical deck options available for light rail or freight railroad bridges.

At the time of design, no examples of open deck bridges with concrete girders could be found in the literature in the United States. As a result, a detailed analysis ensued to investigate live load distribution, overall girder stability, and the distribution and transfer of lateral design forces such as centrifugal forces and wind loads.

The American Railway Engineering and Maintenance-of-Way Association (AREMA) requires that steel girder open deck freight railroad bridges be designed with intermediate diaphragms spaced not more than 18 ft apart, and requires that they be designed with both top and bottom flange lateral bracing. Although light rail vehicle (LRV) live loads are markedly less than the Cooper E80 freight railroad loading that AREMA employs, the AREMA philosophy related to diaphragms and top flange lateral bracing was conservatively applied to the open deck concrete girder spans. Analysis showed that this two-girder superstructure framing system comprised of diaphragms and lateral bracing with the precast concrete girders provides balanced distribution of the LRV loads, an overall stable two-girder system, and a system that can effectively transfer lateral loads to the bearings. Any contribution to girder stability from the timber ties was neglected in the analyses based on the assumption that, over time, the ties could become deteriorated and loose from the girders.

The L/B Viaduct is one of the first open deck light rail transit structures to be designed and built with precast, prestressed concrete girders in the United States.

The precast, prestressed concrete girders are spaced at 6 ft 6 in. on center in the open deck spans. Galvanized steel channel sections were used as intermediate diaphragms and were positioned approximately at the span quarter points. A top flange lateral X-bracing system was designed using galvanized steel angles. This bracing was used along the full-length of every open deck span. Due to the chorded girder layout along the complex horizontal geometry, a wide range of girder lengths was required. In an effort to standardize fabrication of the bracing panels, constant panel spacing was used in the central region of every span. The span end-panels varied to suit the variety of span lengths. This approach minimized the variation in bracing angle lengths, simplified the connection plate details, and allowed for economical repetitive details. In order to accommodate lateral load transfer to the bearings and to prevent rolling/overturning of the overall superstructure, stocky galvanized rolled steel W-sections were used as end diaphragms. Numerous threaded inserts were required to be cast into the girders to receive the connection bolts for the diaphragms and bracing. Careful coordination with the precaster was required to confirm that inserts were accurately positioned.

Typical open deck steel girder bridges use a J-bolt to connect the timber ties to the steel girder. The J-bolt passes through the tie and clips under the girder top flange. Since the top flange of the concrete girders is very thick, another unique detail was developed to receive the standard J-bolt tie connector. A galvanized steel WT-section was cast into the outboard edge of each girder top flange for the full-length of each girder. The outstanding leg of the WT-section provides a "flange" for the J-bolt to clip under. This detail will allow the trackwork installer to use standard J-bolts to install the track on top of the concrete girders.

Conclusions

The L/B Viaduct provides an example of where it was appropriate and beneficial to the project to use precast, prestressed concrete girders. These girders can be designed and spaced to accommodate a variety of complex alignments.

Precast, prestressed concrete girders can be detailed with a wide range of inserts to accommodate connection hardware that facilitates their use in applications where they might not commonly be used. In the case of the L/B Viaduct, common diaphragm details and simple lateral bracing connections were used so the economical open deck track system could be used for the majority of the length of the structure. This deck type allowed HRT to take advantage of a significant construction cost savings when compared to using DF deck.

Designers produced a simple cost-effective structure with repetitive details that could be rapidly constructed. Aside from meeting these objectives, the design also will provide HRT with a highly durable and a low-maintenance girder structure. The L/B Viaduct is expected to be completed in mid-2009, and will represent one of the first open deck light rail transit structures to be designed and built with precast, prestressed concrete girders in the United States. In addition to the L/B Viaduct, there are several thousand linear feet of aerial structure in the Norfolk Light Rail Transit Project currently under construction with a similar open deck system with precast, prestressed concrete girders.

Jason R. Doughty is a senior structural engineer with PB, Morrisville, N.C. He served as the superstructure design engineer for the concrete girder spans of the L/B Viaduct.

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ACAA

American Coal Ash Association

The American Coal Ash Association (ACAA) is devoted to educating engineers, concrete professionals, standards organizations, and others about coal combustion products or “CCPs”—materials produced by coal-fueled power plants. These include fly ash, bottom ash, boiler slag, and flue gas desulfurization materials. Fly ash concrete has been specified because of its high strength and durability for numerous bridge projects worldwide, including the longest cable-stayed bridge in North America, the John James Audubon Bridge near Baton Rouge, La. The I-35W bridge near Minneapolis, Minn., has been reconstructed using a unique mix design that included fly ash concrete to ensure a long-lasting, high performance structure. Caltrans required high volume fly ash mixes for the largest bridge project in its history—the San Francisco-Oakland Bay Bridge. Using innovative specifications and blending techniques, Caltrans was able to improve its workability, hardening, and permeability properties of the bridge’s concrete. A number of engineering standards and specifications define CCP applications, thus ensuring high quality performance and products.

Though these materials’ properties vary according to coal composition and power plant operating conditions, experts can advise on quality and determine the best mix design for most any condition and project. Mix designs exceeding 40 percent fly ash have proven successful in many projects. Experts with first-hand experience may be located by contacting ACAA. The technical, environmental and commercial advantages of CCPs contribute to global sustainability.

In addition to a myriad of core performance attributes in sustainable construction, CCP use can conserve natural resources, reduce greenhouse gas emissions and eliminate need for additional landfill space. For more information, contact ACAA at info@acaa-usa.org or call 720-870-7897.

General view of the aerial structure looking west at a typical pile bent and the open deck spans. The embedded WT steel section can be seen in the outside edges of two of the girders.
Photo courtesy of HRT.

Construction of the spans over Lamberts Point Branch Line.
Photo courtesy of PB.

Girder erection in open deck spans.
Photo courtesy of HRT.

The girders can be designed and spaced to accommodate a variety of complex alignments.

Separate single track open deck spans, looking east from bent 38.
Photo courtesy of Bryant Contracting.