Presents the major design and construction features of the East Huntington Bridge over the Ohio River in West Virginia. The author discusses the conceptual plan, component design and erection method used to build only the second, long span prestressed concrete cable stayed bridge completed in North America.

Design and Construction of the East Huntington Bridge

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The East Huntington Bridge (Fig. 1) over the Ohio River in West Virginia is the second, long span, precast prestressed concrete cable stayed bridge completed in North America. The project is an extension of the successful features incorporated in our firm's first cable stayed bridge built over the Columbia River at Pasco-Kennewick.[1-4] This paper will describe the new design elements of the East Huntington Bridge and discuss some of the key features involved in the design and construction of cable stayed bridges.

In order to promote engineering development, the United States government requires two different competing designs for all major bridges. When an alternate concrete design was authorized for the East Huntington Bridge, a steel girder system had already been completed. Also, the main river piers for the designed steel system had already been built.

In competitive construction contract bidding for both designs, steel and concrete, the concrete alternate received a \$10,000,000 lower bid (\$23,500,000 ver-

Fig. 1. Scale model of the East Huntington Bridge.

sus $33,500,000) and was accepted. The bridge was opened to traffic in August 1985.

The East Huntington Bridge is a precast prestressed concrete cable stayed bridge with one tower only and main spans of 900 and 608 ft (274 and 184 m). The structure is built using 250 ton (227 t) prefabricated high strength prestressed concrete elements and incorporates steel floor beams in a hybrid arrangement.

The bridge's dynamically insensitive structural system is lighter than concrete cable stayed bridges built earlier, and is especially suitable for spans longer than 1650 ft (500 m) without modification.

The southern 640 ft (195 m) of the 2000 ft (610 m) long bridge girder was built using the cast-in-place segmental cantilever method and travelling formwork; the remainder of the girder was assembled segmentally using 45 ft (13.7 m) long, 250 ton (227 t) precast concrete elements. The main section of the bridge (Fig. 2) is supported from a 420 ft (128 m) high stay cable tower and 62 stay cables. The two stay cable supported spans — 900 and 608 ft (274 and 185 m) long — are of a constant 5 ft (1.52 m) depth and incorporate steel crossbeams in the precast elements.

Only two expansion joints accommodate longitudinal movements in the 2000 ft (610 m) girder. At the bridge tower, the girder is permitted to move only vertically. This structural configuration comprises one-half of a traditional, symmetrical two tower cable stayed bridge with an equivalent main span of 1650 ft (500 m), proving that segmental concrete cable stayed bridges can be built to accommodate very long spans.

The plan, elevation and typical cross section of the bridge are shown in Fig. 2.

Special Design Considerations

The presence of the previously constructed piers, which were designed to support the originally intended steel cable stayed bridge, required that the concrete alternate not exceed the load

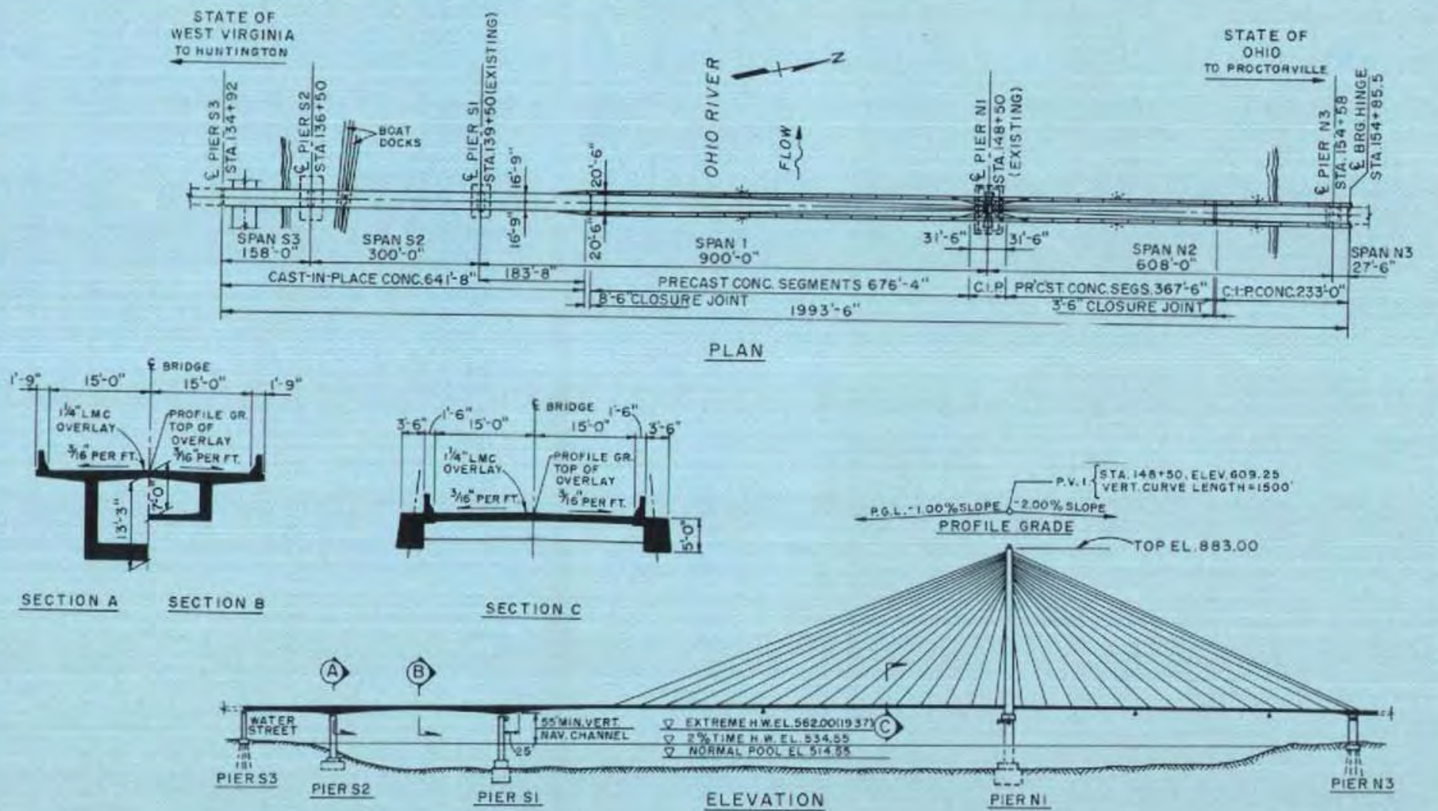

Fig. 2. Plan, elevation and typical cross section of East Huntington Bridge.

Fig. 3. A 250 ton (227 t) precast girder segment being transported to project site.

carrying capacities of the existing piers and foundations.

All major bridges built earlier in the East Huntington area are steel and use of concrete as a primary structural material was not well established. The objective for the concrete design was to develop a system that was not too heavy, yet could accept all loads and forces necessary for satisfactory service and durability.

A research program was initiated prior to design to develop applicable data on local production and availability of high strength concrete. As a result of these preparations, a 28 day concrete design strength of 8000 psi (55 MPa) was adopted.

Reasons for Selecting Very High Strength Concrete

Long term durability is the uppermost priority of any new bridge. For concrete, the density of the material, wear resistance, and residual tensile stress capacity are the features which fulfill this quality. Although high strength concretes have been found to be less ductile than conventional concretes at the ultimate load state, very high strength concretes can assume a broader spectrum of stresses at normal loading ranges. This is due primarily to the fact that they are more dense and have a higher tensile stress capacity than ordinary concretes.

Perhaps the most important property is the residual tensile stress capacity of very high strength concrete to resist the many small, cumulative and incidental service load effects which may lead to the structure's slow deterioration. The East Huntington Bridge incorporated precasting techniques for low water-cement ratio, densely consolidated concretes.

Hybridization of Steel and Concrete

Reinforced concrete by its very constitution is a hybrid material. When the designer extends this technique even further, via hybridization of major steel members with concrete elements, not only can member size and structural weight be reduced, but so can overall unit cost.

In order to achieve these benefits, the designer must also adequately provide for temperature changes and distribution forces. In the East Huntington Bridge, the successful interactive arrangement of the steel and concrete members reduced the bridge's size, weight and cost, as well as the complexity of the required workmanship.

Fig. 4. The southern portion of the bridge was built using cast-in-place segmental cantilever construction and traveling formwork.

Concrete Girder

The 640 ft (195 m) long bridge girder on the south approach is of the traditional, varying depth, continuous box girder design. The high concrete strength permitted a girder with a very slender shape, only 13 ft (4 m) deep over the piers, varying to less than 7 ft (2 m) elsewhere.

The cable stayed part of the concrete girder is made up of precast concrete elements, 45 ft (13.6 m) long, 40 ft (12.2 m) wide, 5 ft (1.5 m) deep and weighing 250 tons (227 t) each. Each precast concrete girder element has anchorages for two stay cables, one in each side of the girder.

The girder cross section is simple — it consists of reinforced concrete edge beams, 5 ft (1.5 m) deep by 3.5 ft (1 m) wide, and an 8 in. (200 mm) thick roadway slab. This slab is supported by 33 in. (840 mm) deep rolled steel beams, framed into the concrete edge beams and spaced 9 ft (2.75 m) apart.

The girder face is blunt. The streamlined, aerodynamic shape of the girder used earlier has been omitted as unnecessary. The standard size, rolled steel cross beams are modified for the required camber, with attachments to develop fixity at the concrete edge beams. Simplicity in arrangement for prefabrication of the precast elements was intended and achieved.

Tower

The hollow, sloping tower legs contain an electric elevator for access to the cable anchorages. These legs terminate at the towerhead. The concrete towerhead is I-shaped and features a central core 6 ft (1.83 m) thick for receiving the 62 cable anchorages and their compression forces.

The cable anchorage part of the towerhead is 89 ft (27 m) high. The anchorage area is protected from weather conditions with dark colored precast concrete panels 3½ in. (90 mm) thick.

Cable System

BBR type cables with Hi-Am anchorages were specified and used. These cables consist of straight 6 mm wires encased in forged steel anchorage assemblies, covered with polyethylene pipes and filled with grout for corrosion protection.

The cable sizes vary from 83 to 307 wires each; their length varies from 200 to 769 ft (61 to 233 m). The cables were prefabricated to their prescribed length and installed from top to bottom with force adjustments at the bottom anchorages.

Both upper and lower stay cable anchorages contain rigid steel pipes surrounding the part of the cable end in which neoprene dampers were installed to control potential cable vibrations. The use of these neoprene dampers has proven to be very successful. For example, the stay cables used in the Pasco-Kennewick Bridge have the dampers at the lower end only and the cables occasionally experience slight, barely perceptible oscillations. At East Huntington, cable oscillations seldom occur and are not easily perceptible.

Aerodynamic Stability

Suspended girder response to wind has been studied extensively and the knowledge gained from such studies has been beneficial for the proper design of suspension bridges. Lacking comparable knowledge about cable stayed bridge girder behavior in wind, the suspension bridge criteria were used for the cable stayed bridge girder design.

The presence of many cable stays, high longitudinal forces in the girder, and the effects of girder mass in concrete bridges measurably enhance the concrete cable stayed girder's dynamic stability. The Pasco-Kennewick Bridge, being the first of its kind, received stringent suspension bridge treatment. The Pasco-Kennewick girder has a streamlined, aerodynamic shape and subsequent motion studies have revealed that the expected motions do not occur or are not measurable.[5]

Conventional wind tunnel section model studies were carried out in accordance with FHWA policy.[6] The test section exhibited vortex induced oscillations of less than 2.5 percent of gravity for 12 to 15 miles per hour (5.4 to 6.7 m/sec) wind speeds. Actual bridge motion noted to date has been imperceptible.

The girder is also safe against flutter instability in an extremely strong wind. Aided by the stiff A-frame tower, the torsional to vertical oscillation frequency ratio is 3.0 at 2 percent critical damping. The potential flutter producing wind speed has been estimated at the 230 miles per hour (103 m/sec) level or higher.

Other Design Parameters

Critical elements for structural organization were:

1. Steel cross beam framing into the concrete edge beams, and management of differential temperature stresses in the region where the steel girders frame into the edge beams, both during casting of the girder elements and in service.

2. Stress array distribution in the tower head core would have to withstand all forces generated from the entire cable system. Critical were the upper cables because their forces are the highest.

3. The areas where the girder stiffness and tower stiffness change rapidly, for example, at the cable stayed girder ends and at the ends of the tower legs.

To avoid concrete transitions with undue rapid stress rises or stress con-

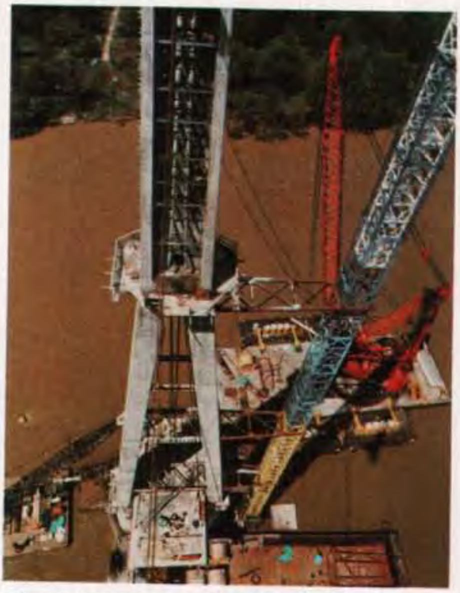
Fig. 5. Aerial view of tower.


Fig. 6. Closeup of towerhead before installation of cables.

centrations, local prestressing and liberal distribution of local mild steel reinforcement have been provided at regions where large force and stiffness transitions occur.

Construction

In order for the bridge construction process (Figs. 3 to 12) to conclude with all design objectives accomplished, it is imperative that a high level of workmanship and quality control discipline be maintained. All operations must be thoroughly planned in advance and constructors must adhere to such plans without improvisation. The design engineer should guide the work sequence and quality control procedures to ensure compliance.

These principles were adhered to during construction of the East Huntington Bridge. The concrete operations program was developed beforehand and strictly implemented. Due to the owner's rigid guidelines pertaining to the minimum strength requirements of the concrete, all concrete was made to 10,000 psi (69 MPa) 28 day strength. The concrete mix had a water-cement ratio of 0.30 and was produced in a specially built floating concrete plant equipped with electronic moisture monitoring and batching controls.

The cable stayed girder elements were match cast in a specially built, long line casting yard near the bridge site, then barged and lifted by a 600 ton (544 t) floating crane into position. Match cast surfaces were coated with epoxy and prestressed onto the previously erected girder parts. To control the stability of the tall tower on the narrow foundation, and to resist the effects of imbalance on the long girder, temporary stability cables were used during erection of the girder.

Aesthetics

The purpose of engineering design is to organize the least complicated system possible that will fully serve all objectives. If correctly done, an observer of

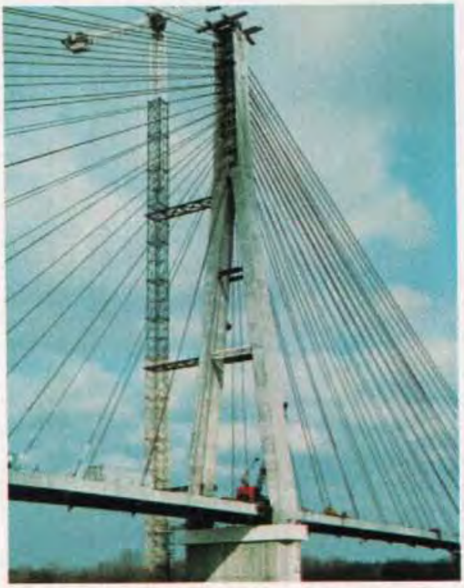

Fig. 7. Towerhead with cables in place.

Fig. 8. Closeup of towerhead after installation of cables.

the East Huntington Bridge will perceive the purpose of the visible order, will accept its simplicity, and will sense the latent power and strength of the structure.

All three of the above are positive, gratifying perceptions that are easily made. And, when positive feelings do result, the work is termed aesthetically acceptable, aesthetically correct or pleasing, and satisfying.

With regard to the overall organization of the East Huntington Bridge, the observer notes that the river is wide, the tower is tall, the girder is slender, and the cables are white and thin. The system is simple and graceful and strong, all at the same time. This perception communicates a message and a feeling that great strength can be obtained, and much service received, from a simple arrangement. This emotional acceptance of the whole structure is acclaimed freely by the users of the completed bridge; and this is the essence of aesthetics in the work of a bridge engineer.

Concluding Remarks

The completed work, built on piers originally meant for a steel bridge, reduced the expected project costs considerably. The main span material — concrete — was made in the field to very high strength requirements. The result was an overall reduction of the structure's weight, increased durability, and the availability of residual tensile stress capability for accommodating incidental stresses. In addition, the low water-cement ratio in the concrete markedly reduced concerns about concrete creep and shrinkage.

Incorporation of structural steel members in the concrete girder resulted in simple workmanship, low girder weight and low project costs. It also proved that the hybridization of concrete and steel components can be used successfully in concrete bridges. Furthermore, the concrete bridge system increased the original steel bridge's foundation loads by less than 20 percent, making foundation changes un-

Fig. 9. Nearly completed East Huntington Bridge.

Fig. 10. The 300 ft (91.4 m) segmentally cast end span. Note temporary cables used to stabilize tower girder during erection.

necessary. The bridge concrete girder unit weight is 23 percent lower than that of the Pasco-Kennewick and Brotonne Bridges.

The cable system and the main girder are insensitive to potential oscillation producing forces. No oscillations have been noted, either in the cables or in the girders, confirming the correctness of the assumed member damping properties and design reasoning. This conclusion indicates the presence of system damping, as suggested by Dr. Leonhardt earlier.

In conclusion, it should be stated that the structural system used to construct the East Huntington Bridge is capable of supporting a 1650 ft (500 m) or longer main span when used in a two tower, symmetrical configuration. This is possible without altering member size.

The East Huntington Bridge was a winner in the 1985 PCI Professional Design Awards Program.

Credits

Owner: West Virginia Department of Highways, sponsored by the Federal Highway Administration.

General Contractor: Melbourne Bros., Inc., North Canton, Ohio. Stay cables manufactured by Shinko Wire, Japan.

Engineer for Project Design and Construction Control Guidance: Arvid Grant & Associates, Inc., Consulting Engineers, Olympia, Washington. Arvid Grant, project concept and system; Conrad Bridges, detailed design; David Goodyear, construction control.

Fig. 11. Roadway view of the East Huntington Bridge.

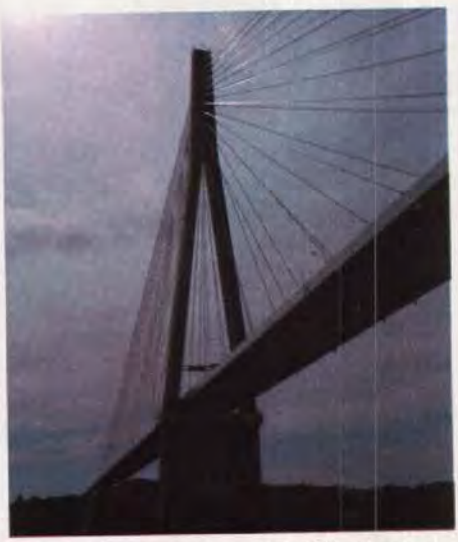

Fig. 12. Finished view of East Huntington Bridge at twilight.

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