ECONOMICAL STEEL BRIDGES FOR THE MARYLAND APPROACH ROADWAYS TO THE WOODROW WILSON BRIDGE

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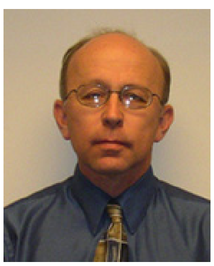

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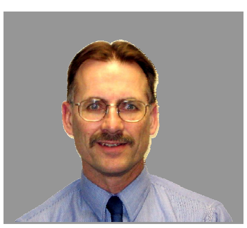

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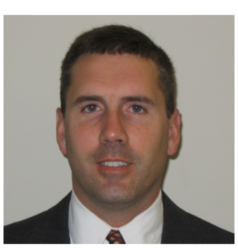

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BIOGRAPHIES

Robert J. Healy, P.E. has had a twenty-eight year career in civil engineering. He began his career with the Maryland State Highway Administration in 1977 where he served as a design engineer, project engineer and senior team leader.

Bob currently serves as the Deputy Director of the Office of Bridge Development and has been involved in a number of major projects such as the Woodrow Wilson Bridge and the Intercounty Connector. Bob has also worked for T.Y. Lin International as office manager for their Alexandria, Virginia office.

Bob received a Bachelor's degree in civil engineering from the University of Delaware and a Master's degree from the Virginia Polytechnic Institute. He is a registered professional engineer in Maryland and Virginia is a member of ASCE and the Maryland Association of Engineers.

John W. Narer, P.E. is a Senior Project Engineer with the Maryland State Highway Administration. He has been employed with the Office of Bridge Development for 23 years where he has served as a design engineer and project engineer primarily for in-house designed bridge projects. He has also been involved in a number of major projects such as the review of plans for the approach roadways to the Woodrow Wilson Bridge and the multi-phase reconstruction of the I-70/I-270 Interchange in Frederick, Maryland.

John received a Bachelor's degree in civil engineering from Virginia Polytechnic Institute and a Master's degree from Johns Hopkins University. He is a registered professional engineer in Maryland as well as a Certified Public Accountant.

Gary R. Miller, P.E. is a Senior Vice President and Chief Structural Engineer for the engineering firm of Johnson, Mirmiran & Thompson. He has over thirty years of bridge engineering experience working for federal, state and local transportation agencies in the mid-Atlantic and Florida regions. Mr. Miller has been with JMT for over twenty-one years and manages the Structures Section in their Baltimore, Maryland office.

Mr. Miller holds a Bachelor's degree in civil engineering from Tri-State University in Angola, Indiana. He is a registered professional engineer in Maryland, Pennsylvania, Florida and the District of Columbia, and a member of ASCE and the American Concrete Institute.

Walter P. Miller, P.E. is a Senior Associate with the mid-Atlantic consulting engineering firm of Whitman, Requardt and Associates, LLP. Mr. Miller has been with WR&A for twelve years and manages the Bridge Design Department at WR&A's Headquarters Office in Baltimore, Maryland. He has eighteen years of bridge engineering experience working for state and local transportation agencies in the mid-Atlantic area.

Mr. Miller holds a Bachelor's degree in civil engineering from Tri-State University. He is a Maryland registered professional engineer, and is a member of ASCE and the Maryland Association of Engineers.

SUMMARY

This paper focuses on the design and construction of numerous steel girder bridges that are located on the interchanges and approach roadways to the new Woodrow Wilson Bridge currently being constructed on I-95/I-495 over the Potomac River near Washington, D.C. The bridges constructed on the approach roadways consisted of a variety of steel girder designs including medium to long spans, straight and curved bridges as well as girders with parallel flanges and haunched webs.

The benefits of utilizing steel bridges within complex, modern interchanges are discussed. Steel bridges are becoming prevalent as owners seek to rehabilitate and upgrade their highway facilities to meet current and future needs. The paper focuses also on the economical design and detailing that was used to make these bridges a cost effective solution for the project. Many of the fabrication friendly details that were developed by the National Steel Bridge Collaboration and are marketed by the steel bridge industry were incorporated in the design of these bridges to develop constructible "work horse" bridges that represent the state-of-the-art for steel bridge design in Maryland. Typical design details discussed include welded I-girders, welded cross frames, stiffened vs. unstiffened webs, painted vs. unpainted steel, standardized bearing details, and bolted connections to simplify erection in the field. The role of aesthetics is also discussed.

In addition to the use of standard or typical design details, several of the bridges had integral steel pier caps incorporated into superstructures to minimize horizontal and vertical clearance issues.

The paper also discusses the bidding of alternative designs for steel and concrete superstructures that were developed for several of the bridges. Contractors were allowed to bid on either steel bridges or segmental concrete bridges. In the head to head bidding, steel bridges were found to be the more economical solution.

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by

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INTRODUCTION

Bridge owners, and the engineers that work for them, are frequently faced with an increasingly common and difficult problem in the 21st century. The nation's system of Interstate highways and expressways, mostly built in the 1950's and 1960's, are degrading both functionally and conditionally. This is especially true for bridges and structures. In order to meet the ever-increasing traffic demands and restore functionality, the nation's highway systems frequently need, not only to be rehabilitated or replaced, but also to be expanded greatly beyond their originally constructed scope.

This problem becomes even more acute in highly developed urban areas, where the increasing traffic demands are often the greatest, while the available space to build the necessary facilities is sparse, if it exists at all. Extremely complex urban interchanges are often the only solution, with complicated bridges and ramps to provide the needed connections between greatly expanded expressway and local systems. Numerous examples of this phenomenon exist around the country. Some have already been built, some are under construction and many more are planned or will become necessary.

Steel bridges are well suited for these applications. They are fully capable of providing the versatility and flexibility needed to meet the challenges of complex interchange structure design in the 21st century.

A good example of applying modern steel bridge design to a difficult urban interchange challenge is now taking place on the Maryland roadway approaches to the new Woodrow Wilson Bridge. Economical design and detailing was used to make these bridges a cost effective solution for the project. Many of the fabrication friendly details that were developed by the National Steel Bridge Collaboration and are marketed by the steel bridge industry were incorporated in the design of these bridges to develop constructible "work horse" bridges that represent the state-of-the-art for steel bridge design in Maryland.

THE WOODROW WILSON BRIDGE PROJECT DESCRIPTION

Interstate Route 95 (I-95) extends from the Canadian border of Maine to Miami and connects most of the major cities on the East Coast of the United States, including Boston, New York, Philadelphia, Baltimore and Washington DC. The existing Woodrow Wilson Memorial Bridge carries I-95 across the Potomac River, connecting Maryland and Virginia at the southern tip of the District of Columbia. The Woodrow Wilson Bridge is a vital link in I-95 and the Capital Beltway (I-495), the circumferential freeway surrounding the core of the Washington DC Metropolitan Area.

Figure 1: The Washington DC Metropolitan Area

The bridge was designed in the 1950s and opened in 1961 as the southern crossing of the Potomac River for the Capital Beltway (I-495). When the Capital Beltway was completed in 1964, I-95 in the Washington region was still in the planning stage and its proposed alignment extended north through the center of the District of Columbia. In 1976, it was decided that constructing an interstate through the heart of Washington DC would be too disruptive to existing neighborhoods and this portion of the highway was never built. As a result, I-95 was made coincident with the eastern side of the Capital Beltway bypassing the downtown DC area. Due to this decision, the Woodrow Wilson Bridge also became the Potomac River crossing for all I-95 traffic (see Figure 1).

I-95 was anticipated to carry 75,000 vehicles per day over a six-lane divided highway. When the Capital Beltway was completed in 1964, the average daily traffic (ADT) of the bridge was 47,900. In the early 1970s, the anticipated 75,000 ADT was surpassed. Today the Capital Beltway is eight lanes wide on either side of the Woodrow Wilson Bridge, but the bridge itself remains six lanes wide, creating one of the worst bottlenecks on I-95. In 1997, the I-95 ADT was 203,000. By comparison, the new upgraded facility is expected to accommodate an ADT of 300,000.

INTERCHANGE PROJECT DESCRIPTION

The Woodrow Wilson Bridge Project corridor is seven and one half miles long (see Figure 2). In addition to the Potomac River crossing, the bridge also encompasses four interchanges: Telegraph Road and US 1 in Virginia, and I-295 and MD 210 (Indian Head Highway) in Maryland. All four interchanges will have increased capacity and will be realigned to connect to the new Potomac River crossing.

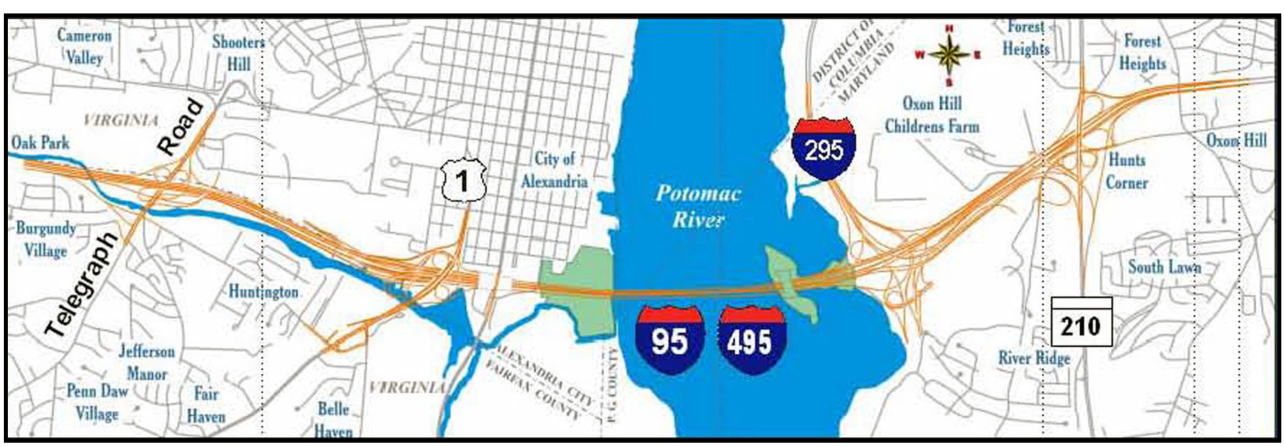

Figure 2: The Project Corridor

The I-95/I-295 Interchange project is needed to increase capacity along the I-95 corridor and provide for more efficient movement of traffic along the mainline and secondary roadways through the Woodrow Wilson Bridge corridor. This corridor is the busiest interstate roadway in Maryland. In addition to increasing capacity and improving traffic flow, interchange tie-in ramps from a newly constructed major private development adjacent to the interchange were required. The I-95 mainline is being increased from a 6 lane mainline section to a 10 lane mainline section with mainline and local roadways.

This paper will focus on the steel bridges that have already been built or are currently under construction as

Figure 3: I-95/I-295 Interchange Under Construction, looking Southeast

part of the I-95 interchange with I-295 (see Figure 3).

Preliminary Structure Studies

The construction of the I-95/I-295 Interchange project presented the design team with enormous challenges. The design team was required to balance the need to construct cost-effective, low maintenance, and aesthetically pleasing structures within a complex interchange while maintaining all existing through lanes of traffic on mainline I-95 and I-295 and all secondary traffic movements during all construction phases within the heaviest traveled interstate corridor in Maryland. In addition, construction needed to be performed in multiple contracts to keep contract values in a range to ensure competitive bids. These challenges presented the design team with severe limitations on the placement of substructure units, arrangement of spans, and areas necessary for construction of substructure and superstructure elements.

The interchange has 25 new and two widened bridges of varying lengths, widths and number of spans. These new structures were divided into four main groups based on location within the overall interchange and on the perspective from which they would be viewed. No predetermined decisions were made regarding structure types and materials for any of the individual structures or groups of structures. Because of the widely varying nature of the many bridges, it was unlikely that any one type or material would be the ideal choice for all of the bridges. The merits of each feasible type and material were considered and rational decisions were made for each group. The factors considered for each group included complexity, cost, aesthetics, constructability, durability, future maintenance and redecking considerations.

The first group (see Figure 4) included the longer and most visible ramp structures that crossed over the I-95 mainline. They were the longest structures, varying in length from 485 to 1,987 feet and having spans lengths up to 240 feet, mostly curved and some with varying widths. These six structures were also those that had the most difficult issues to resolve regarding placement of substructure units and span arrangements.

Figure 4: I-95/I-295 Interchange Group 1 Bridges, looking East

To meet these challenges while ensuring competitive bidding, the design team evaluated both steel plate I-girder and segmental concrete structures under the first interchange construction contract, which was to include three of the six bridges in this group. Both structure types were considered feasible and comparable with regard to the key factors considered. MSHA made the decision to proceed with alternate designs using both steel plate I-girder and segmental concrete. Design and aesthetic criteria were established for both superstructure types to provide similar structures and fair bidding. Per Maryland SHA's policy, Working Stress design is normally used for steel bridge design. For this project both the steel and segmental concrete alternates were designed by the Load Factor method. The horizontal and vertical alignments of the roadways as well as the overall bridge lengths were identical to avoid the need for separate highway plans. However, individual span lengths for the steel and segmental concrete alternates were permitted to vary in order to allow the alternate designs to be optimized for material type and construction methods. Although the locations and exact shape of the piers were varied for each alternate, the basic pier shapes were similar for each alternate to achieve a uniform aesthetic theme throughout the entire interchange. The steel alternates were designed using weathering steel with constant depth webs and constant deck overhangs. The segmental concrete alternates were design with constant depth webs and constant deck overhangs.

Contract documents were prepared, and bids received, for alternate structural designs consisting of all steel plate I-girder structures and all segmental concrete structures for the three I-95/I-295 flyover ramp structures in the contract. Six bids were received, five choosing the steel girder design and one choosing the segmental concrete design. The total bid using segmental concrete structures was the fifth out of the six bids received, although looking at only the specific bridge bid items indicates a much more competitive situation. Following this initial success of the steel girder superstructure for the first three bridges in this group, in order to maintain similar aesthetics throughout the interchange, only steel plate I-girder structures were designed for the major ramp structures in succeeding construction contracts.

The second main group of bridges was one- and two-span structures carrying the I-95 mainline and ramps over other ramps. For the most part these eleven structures would not be visible to traffic on mainline I-95 and therefore could have a different aesthetic look than those bridges in the first group which are all visible from I-95/I-495. These structures were generally straight, had little skew and the span lengths were under 120 feet.

Steel plate I-girder and prestressed concrete I-girders were considered. Due to their simplicity, prestressed concrete I-girders were determined to be more economical, and therefore selected for these structures.

The third main group of bridges (see Figure 5) involved ramp structures over a local roadway network connecting I-95 and I-295 with the adjacent proposed major private development. These bridges would be viewed by slower moving traffic operating in more of a community situation removed from the busy interstate highway setting. It was felt that this group of four structures should have a slightly different aesthetic look to differentiate them from the main part of the interchange. These bridges were two and three-span structures with span lengths up to 120 feet and skews up to 48 degrees. Also, several bridges varied in width and were curved. Due to their more complex geometry and to provide great flexibility with their aesthetic appearance, steel girders were determined to be more economical, and therefore selected for these structures. To achieve a different aesthetic appearance than the weathering steel, constant depth girders used for the bridges over I-95, the girders for these bridges were haunched and painted.

Figure 5: I-95/I-295 Interchange Group 3 Bridges, looking North

The fourth group of bridges (see Figure 6) involved three structures that carry a hiker/biker trail through the interchange. Each of these structures was evaluated independently to determine the appropriate superstructure type since these bridges varied greatly in location, width, length and span arrangement. Criteria used in the evaluation included cost, aesthetics, constructability and future maintenance. It was decided that steel girders were the best choice for the two structures over, adjacent to and visible from I-95 while the third structure over Smoot's Cove should utilize prestressed concrete girders.

Design

The design team collaborated with MSHA, contractors and fabricators to incorporate many features developed and marketed by the National Steel Bridge Collaboration into the design of the steel structures to improve constructability while minimizing initial construction cost and future maintenance costs. Weathering steel was used to reduce future cleaning and painting costs on those structures over interstate highways. Unstiffened girder webs were used to minimize material and fabrication costs. Girder flange sizes and lengths were selected to simplify fabrication by permitting slab welding and plate stripping. The number of

Figure 6: Rosalie Island, Group 4 Bridges, looking Northeast

diaphragms was minimized, the number of individual diaphragm members was reduced, member sizes were optimized, and rectangular connection plates were used to reduce material and fabrication costs. Edge distances for bolt holes were increased by 1/8” to provide steel fabricators with the ability to make minor adjustments without violating AASHTO’s minimum edge distance criteria. Spherical bearings and finger joints were used on long curved girder bridges while MSHA standard bearings and compression seal joints were used on short straight girder bridges. Haunched girders were evaluated to reduce material costs but due to the skewed curved geometry of many bridges over I-95, constant depth girders were used for the bridges over I-95 to achieve better overall aesthetics.

Due to considerable geometric constraints imposed by this complex interchange, the use of conventional piers to support the steel girder superstructures at several locations created substantial span imbalances or required vertical profile increases to provide the required horizontal and vertical clearances. To improve the span balance and reduce vertical profiles, integral pier caps supported on narrower concrete piers were used at various locations. While developing integral pier cap concepts, maintaining consistent pier aesthetics was critical. A single concrete column pier with an identical shape as the multiple concrete column piers was developed. Both post-tensioned concrete and bolted structural steel integral pier caps were evaluated. Because most of the integral piers needed to be constructed adjacent to active I-95/I-495 traffic, the steel integral cap was selected.

This innovative steel integral cap concept was designed and detailed so the pier element could be erected, held in place with a holding crane, while the adjacent span girders were erected and spliced to the pier element. This concept required no temporary falsework as required for the post-tensioned integral pier cap. The elimination of temporary falsework permitted traffic on I-95/I-495 to be maintained without costly lane shifts or closures because the footprint for construction was narrower.

A two-girder system was used with each girder capable of carrying the full dead and live loads (see Figure 7). The integral caps were still considered fracture critical members so particular attention was given to fatigue stresses and the design of the members and their connections, both bolted and welded. The webs were spaced approximately 4 feet apart to facilitate fabrication and to provide sufficient access for future inspection.

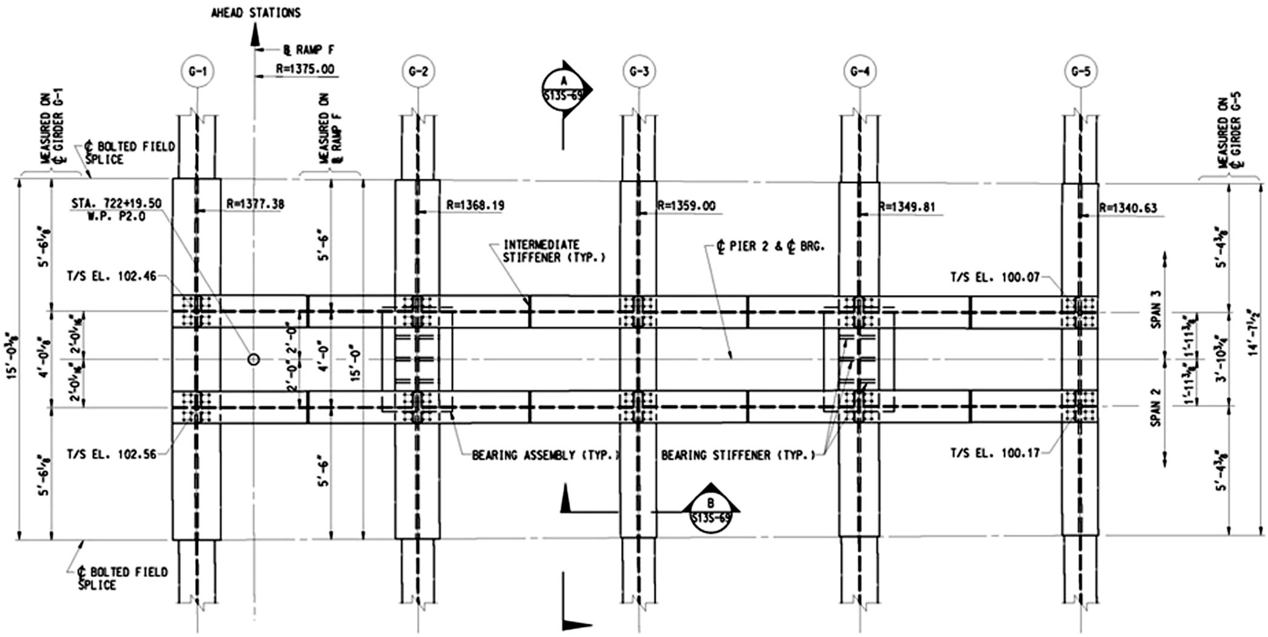

Figure 7: Plan View of Steel Integral Pier Cap

The steel integral pier cap consisted of a 12-foot long structural steel superstructure pier section completely constructed prior to erection. It is supported on two bearings directly under two interior girders. All five main girders are stubbed out into both spans from the pier section. After erection of the pier section, the main girders were spliced to it while the pier section was held in place (see Figure 8). After erection and splicing of several main girders, the superstructure becomes stable and the holding crane can be removed.

Figure 8: Steel Integral Pier Cap

SUMMARY

Highly complex urban interchange reconstruction projects are becoming more and more commonplace as the nation's traffic demands increase and its infrastructure ages. Bridges that are built or replaced to meet these needs must be able to meet a wide variety of issues. Steel bridges exhibit the characteristics and flexibility to provide outstanding solutions to bridge owners facing these problems.

During the design of the complex urban interchange project on the Maryland approaches of the Woodrow Wilson Bridge project, it was easily apparent that steel provided the ability to accommodate complex geometries that are not easily attained with precast concrete. High, variable width, curved structures, unbalanced span arrangements resulting from complex interchange geometry, and future deck replacement requirements were easily accommodated while providing a wide variety of aesthetic options. In addition, steel structures gave MSHA and the design team significant flexibility in how construction contracts were established and constructed. Use of economical design and detailing made these bridges a cost effective solution for the project. Many of the fabrication friendly details that were developed by the National Steel Bridge Collaboration were incorporated in the design of these bridges to develop constructible bridges that represent the state-of-the-art for steel bridge design in Maryland.

CREDITS

Owner:	Maryland State Highway Administration
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Design Consultant:	Joint Venture of Johnson, Mirmiran and Thompson and Whitman, Requardt and Associates, LLP
Contractor:	G.A. & F.C. Wagman, Inc.
Fabricators:	High Steel Industries, Inc. and Carolina Steel, Inc.
Erectors:	High Steel Industries, Inc.