Value Engineering Expands Bulb-Tee Girder Market

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The authors' firm has applied the principles of value engineering to eight bridge projects in Ohio during the past several years. Six projects were for the Ohio Department of Transportation, one was for the City of Moraine and one was for the Hamilton County Park District. All eight value engineering proposals were submitted and approved using precast bulb-tee girders. All of the value engineering projects resulted in construction cost savings, and two of the projects saved both time and money. Key design features and project highlights are discussed in a case study format.

Value engineering has been practiced since 1954 when the United States Navy Bureau of Ships first coined the term. The Society of American Value Engineering defines value engineering as:

> "The systematic application of recognized techniques which identify the function of a product or service, establish a value for that function, and provide the necessary function reliability at the lowest overall cost. In all instances, the required function should be achieved at the lowest possible life-cycle cost consistent with requirements for performance, maintainability, safety and aesthetics."

In 1970, the United States Congress supported value engineering on Federal-aided highway projects,[1] and since then, many states have developed their own value engineering programs. Some states, including Missouri, New Jersey and Virginia, have been implementing value engineering programs since the late 1980s.

On January 7, 1998, Ohio instituted guidelines for value engineering change proposals in construction. Value engineering proposals are usually thought of as proposals originated, designed and submitted for approval by the successful low bidder after contract award. Two proposal notes, 103-97 "Value Engineering Change Proposal-Construction Costs" and 104-97 "Value Engineering Change Proposal-Construction Costs & Time," provide Ohio contractors with a description of the requirements for value engineering change proposal procurement.[2]

The driving forces behind highway value engineering change proposals

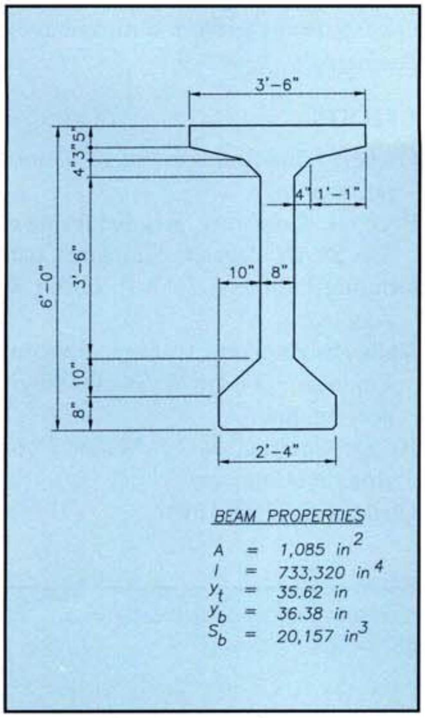

Fig. 1. AASHTO Type VI beam, 72 in. (1829 mm).

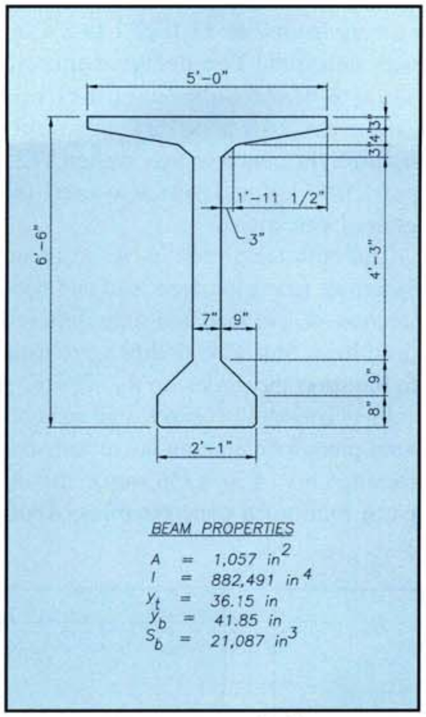

Fig. 2. 78 in. (1981 mm) bulb-tee girder.

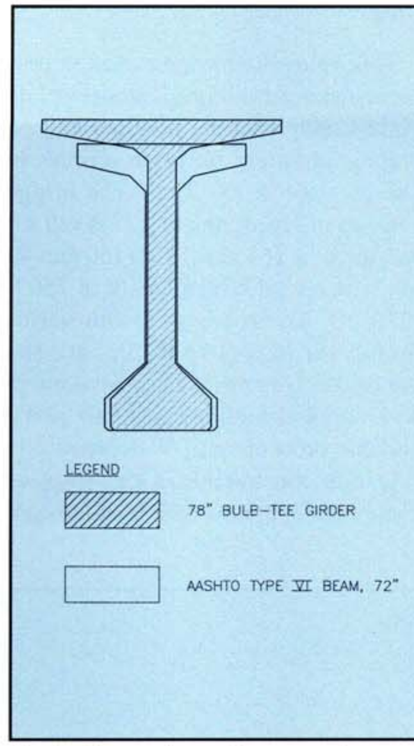

Fig. 3. Comparison of beam sections.

are cost and/or construction time. Many collateral benefits and factors influence the decision-making process of value engineering change proposals, including maintenance, aesthetics, environmental quality, replacement costs, life-cycle costs, safety, materials, quality, performance and constructability. Savings are shared by the owner and contractor.

PRECAST CONCRETE BULB-TEE GIRDERS

During the 1950s, the Bureau of Public Roads adopted the standard precast, prestressed concrete bridge I-beam shapes known today as the AASHTO (American Association of State Highway and Transportation Officials) Standard Sections, Types I to VI (see Fig. 1). There were apparent cost savings due to standardization; however, this resulted in the hindrance of the evolution of structural efficiency.

Individual Precast/Prestressed Concrete Institute (PCI) Regions and State Department of Transportation Offices have already adopted modified bridge I-beam sections in place of the standard AASHTO sections. Modified or optimized girder shapes (i.e., bulb-tee girders or modified AASHTO girders) have been used since the 1960s and are more efficient than the original AASHTO standard sections (see Figs. 2 and 3).

Bulb-tee girders optimize the girder section by providing the highest section modulus with the least amount of girder area. Other benefits of bulb-tee girders include wider girder spacing [9 to 11 ft (2.7 to 3.4 m)] because of the wider top flange and minimization of deck forming, resulting in an overall in-place decreased cost of the girders and deck.[3] In addition, the wider top flange increases worker safety and improves stability during handling and transportation.

Safety to roadway users is a major concern for bridge owners. For bridges with grade separations, use of long-span precast bulb-tee girders with reduced span configurations minimizes hazardous projecting substructure units. This results in an overall safety increase to the general public. Generally, a preferred span arrangement that minimizes the number of substructure units should be used (i.e., fewer piers with longer spans). For grade separation structures spanning any divided highway, a two-span bridge with spill-thru slopes is preferred.[4]

Enhanced span capabilities are made possible using high performance concrete together with the more efficient bulb-tee girder section.[5] Concrete strengths of up to 7000 psi (48.3 MPa) and semi-lightweight concrete [125 pcf (2000 kg/m^3)] have been used. Even longer span bridges can be attained by splicing girders.[6,7,8]

Precast concrete bulb-tee girders offer owners excellent durability and performance from a maintenance standpoint.[9] In addition to competitive initial costs, bulb-tee girders provide optimum life-cycle costs.[10]

CASE STUDIES

Except for the pedestrian bridge (Case Study 2), these projects were designed for an HS20 live load and a future wearing surface (FWS) of 60 psf (2.7 kPa). This Ohio loading is equivalent to an HS25 live load and FWS of 20 psf (1.0 kPa).

CASE STUDY 1 (FIGS. 4a-4d)

FRA-315-0210 Road "OE" and "OF" over Olentangy River (Columbus, Ohio)

This value engineering change proposal replaced the original steel plate girders with what are now the longest precast concrete bulb-tee girders in Ohio — 168 ft (51.2 m). The bridge consists of five spans of 127 ft (39 m) and three of 164 and 131 ft (50 and 40 m), with a total bridge length of 756 ft (230 m). The roadway width varies from 54 to 76 ft (16.5 to 23.2 m), and the bridge contains a horizontal curve with super-elevation transitions and a variable skew of up to 50 degrees.

During construction, a cast-in-place concrete diaphragm with post-tensioning was placed at midspan. Structural expansion joints and elastomeric bearings were used. A 91 in. (2311 mm) chorded bulb-tee girder with variable spacing from 7 to 11 ft (2.1 to 3.4 m) was detailed. The design concrete strength of the bulb-tee girders was 7000 psi (48.3 MPa). A semi-lightweight concrete mix design [125 pcf (2000 kg/m^3)] was also used for girder fabrication.

The bulb-tee girders were designed as simple spans for dead load and continuous for live load and superimposed dead load. Steerable dollies were used to transport the girders to the jobsite.

Piers consist of concrete cap and column piers with continuous rectangular footings on 14 in. (356 mm) cast-in-place reinforced concrete piles. Abutments are semi-integral on two rows of piles with turn-back wingwalls.

This unique structure shows the potential of long-span precast concrete bulb-tee girders with complex geometry.

CREDITS

Owner: Ohio Department of Transportation

Precast Concrete Manufacturer: TECSPAN Concrete Structures, Inc.

Original Engineer: John E. Foster & Associates

Value Engineering Change Proposal Engineer: Janssen & Spaans Engineering, Inc.

Bridge Contractor: C.J. Mahan Construction Company

Completion Date: 1996

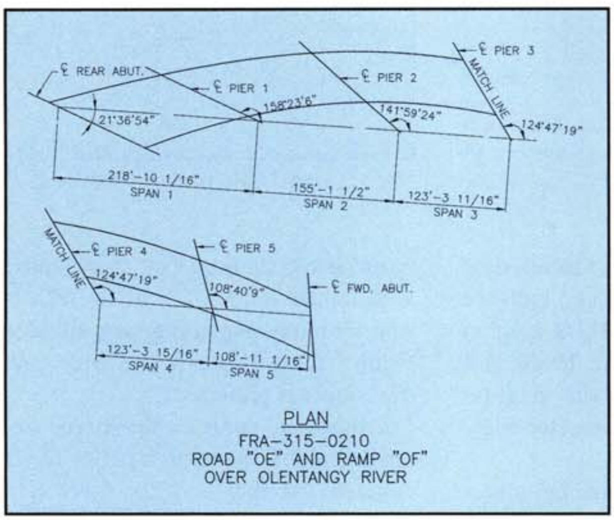

Fig. 4a.

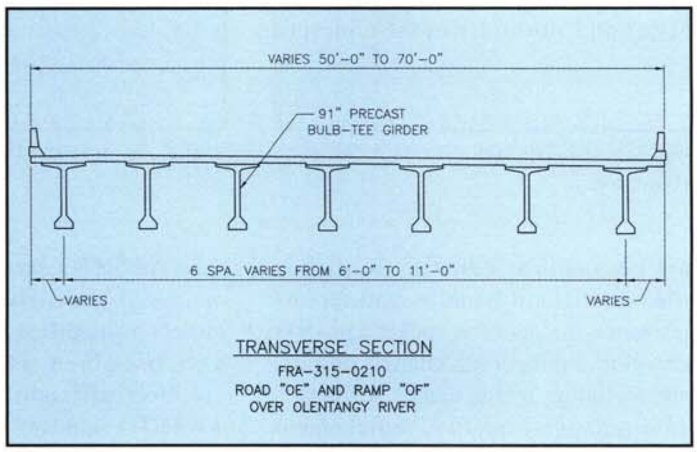

Fig. 4b.

Fig. 4c.

Fig. 4d.

CASE STUDY 2 (FIGS. 5a-5d)

Pedestrian Bridge over Winton Woods Harbor (Cincinnati, Ohio)

This project was a "superstructure only" value engineering change proposal using 72 in. (1829 mm) precast concrete bulb-tee girders in place of AASHTO Type IV girders. The original transverse section of the superstructure contained three AASHTO Type IV girders. Janssen & Spaans Engineering, Inc., proposed eliminating 33 percent of the girders by utilizing bulb-tee girders.

The pedestrian bridge contains five spans of 90 ft (27.4 m) each, for a total bridge length of 450 ft (137 m). A girder spacing of 9 ft (2.7 m) was chosen, with an 8 in. (203 mm) cast-in-place concrete deck. A design concrete strength of 6000 psi (41.4 MPa) and normal weight concrete were specified for the bulb-tee girders. The bulb-tee girders were designed for a maximum live load of 85 psf (4.1 kPa).

The typical deck width is 14 ft (4.3 m) face-to-face of guardrail and widens to 26 ft (7.9 m) at the scenic overlooks. Aesthetic features incorporate sets of twin 3 ft (0.9 m) diameter concrete circular columns at each pier. Scenic overlooks were detailed using cast-in-place supports between the deck and pier cap.

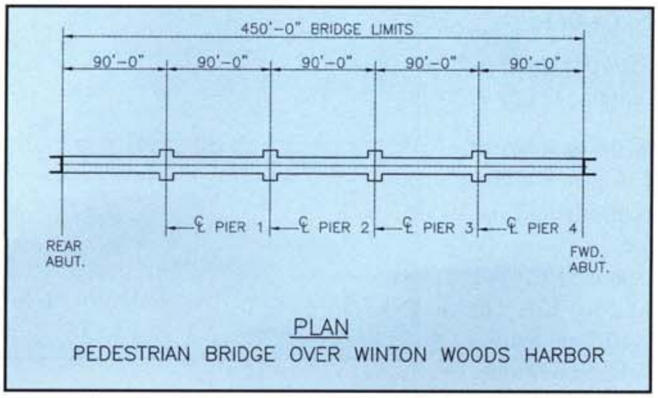

Fig. 5a.

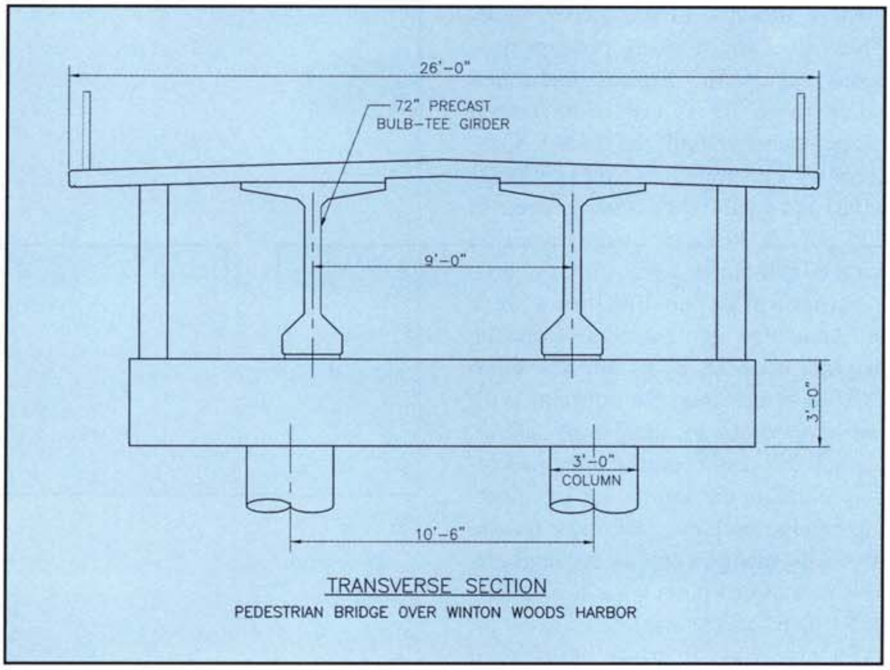

Fig. 5b.

Fig. 5d.

Fig. 5c.

CREDITS

Owner: Hamilton County Park District

Precast Concrete Manufacturer: TECSPAN Concrete Structures, Inc.

Original Engineer: Graham, Obermeyer and Partners, Ltd.

Architect: Brandstettler Carroll

Value Engineering Change Proposal Engineer: Janssen & Spaans Engineering, Inc.

Bridge Contractor: Trend Construction

Completion Date: 1997

CASE STUDY 3 (FIGS. 6a-6e)

FRA-670-1.25, A-3, Souder Avenue over Scioto River (Columbus, Ohio)

This project reduced the number of spans in the original contract plans from four to three and eliminated one pier. The overall bridge length is 406 ft (124 m) with three spans: 132, 142, and 132 ft (40, 43, and 40 m). The bridge width is 35 ft (10.7 m) with a 5 ft 6 in. (1.7 m) sidewalk on one side.

Heavy utilities were supported in two bays via cross-bracing in between girders attached to the girder webs. The value engineering change proposal replaced the original steel rolled beams with 72 in. (1829 mm) deep precast concrete bulb-tee girders. Concrete with a strength of 7000 psi (48.3 MPa) and semi-lightweight concrete at 125 pcf (2000 kg/m^3) were specified for the bulb-tee girders.

Structural expansion joints were eliminated at the abutments from the original contract plans and the Ohio DOT's semi-integral abutment with two rows of 14 in. (356 mm) cast-in-place reinforced concrete piles was incorporated in the final value engineering change proposal (see Figs. 6a and 6b). The bridge skew is 38 degrees. The redesigned piers were a hammerhead design (see Fig. 6e) on 14 in. (356 mm) cast-in-place reinforced concrete piles.

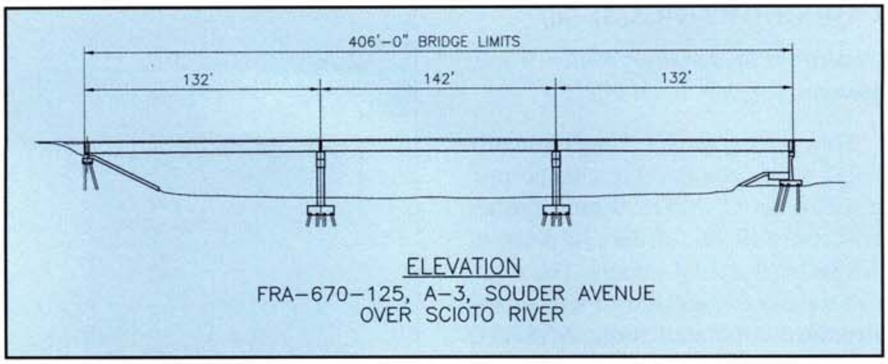

Fig. 6a.

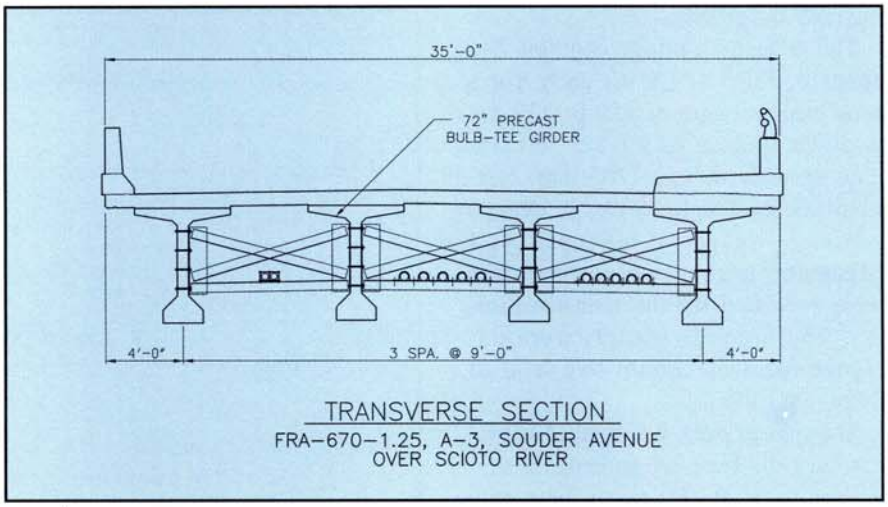

Fig. 6b.

Fig. 6c.

Fig. 6d.

Fig. 6e.

CREDITS

Owner: Ohio Department of Transportation

Precast Concrete Manufacturer: TECSPAN Concrete Structures, Inc.

Original Engineer: L. Thompson Consultants and Columbus Engineering Consultants

Value Engineering Change Proposal Engineer: Janssen & Spaans Engineering, Inc.

Bridge Contractor: C.J. Mahan Construction Company

Completion Date: 1998

CASE STUDY 4 (FIGS. 7a-7c)

Sellars Road over CSX Railroad (Moraine, Ohio)

A two-span bridge, 120 and 140 ft (36.6 and 42.7 m), carrying four lanes of traffic with a 6 in. (152 mm) raised concrete median and 10 ft 6 in. (3.2 m) sidewalk over the railroad dictated a fast-track construction schedule that was met by replacing the original steel plate girders with 78 in. (1981 mm) precast concrete bulb-tee girders.

The transverse section consisted of a 78 ft 2 in. (23.8 m) deck with seven girder lines spaced at 11 ft 8 in. (3.6 m). The design concrete strength of the bulb-tee girders was 7000 psi (48.3 MPa) and semi-lightweight concrete at 130 pcf (2083 kg/m^3) was used. One diaphragm was used at midspan.

Integral abutment details on a single row of steel HP12x53 piles helped reduce construction costs. Reinforced concrete hammerhead piers with two 4 x 10 ft (1.2 x 3.1 m) elliptical columns on individual rectangular footings and steel HP12x53 piles were designed.

CREDITS

Owner: City of Moraine

Precast Concrete Manufacturer: TECSPAN Concrete Structures, Inc.

Original Engineer: Woolpert Consultants

Value Engineering Change Proposal Engineer: Janssen & Spaans Engineering, Inc.

Bridge Contractor: C.J. Mahan Construction Company

Completion Date: 1994

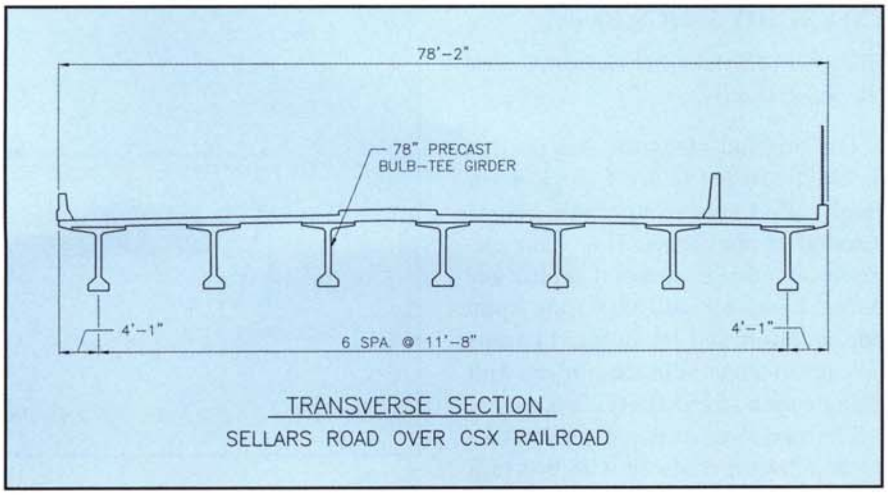

Fig. 7a.

Fig. 7b.

Fig. 7c.

CASE STUDY 5 (FIGS. 8a-8c)

BEL-7-1548 over McMahon Creek (Bellaire, Ohio)

The original plans for this project detailed 110 ft (33.5 m) single-span steel rolled beams with full-height counterfort abutments. This value engineering change proposal project reduced costs by utilizing long-span construction and 91 in. (2311 mm) precast concrete bulb-tee girders with a single span of 155 ft (47.2 m).

The transverse section consisted of a 44 ft (13.4 m) roadway with 6 ft (1.8 m) sidewalks, and the bulb-tee girders were spaced at 7 ft 6 in. (2.3 m) on centers. Structural expansion joints were eliminated and the Ohio DOT's semi-integral abutment details with two rows of steel HP12x74 piles were incorporated into the new structure. An epoxy (gray) concrete sealer was specified on the fascia girders, along the abutments, and around the concrete parapets for a uniform appearance.

Debonding of top strands was detailed for transportation. The design concrete strength of the bulb-tee girders was 7000 psi (48.3 MPa) and semi-lightweight concrete of 125 pcf (2000 kg/m^3) was used. Diaphragms were placed at span third-points. The bridge is on a 26-degree skew.

CREDITS

Owner: Ohio Department of Transportation

Precast Concrete Manufacturer: TECSPAN Concrete Structures, Inc.

Original Engineer: BENATEC Associates, Inc.

Value Engineering Change Proposal Engineer: Janssen & Spaans Engineering, Inc.

Bridge Contractor: Armstrong Steel Erectors

Completion Date: 1997

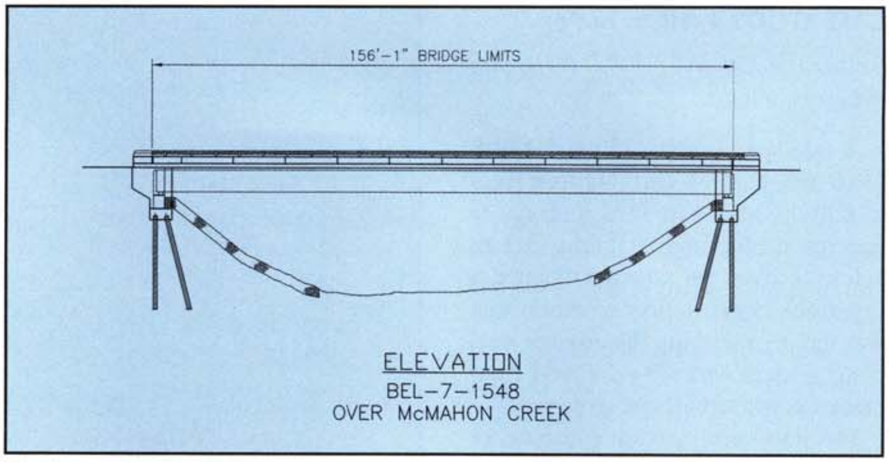

Fig. 8a.

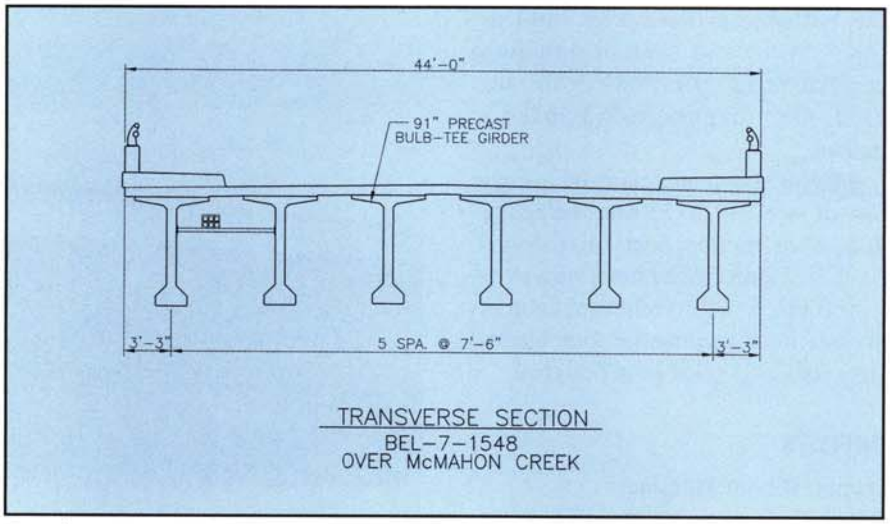

Fig. 8b.

Fig. 8c.

CASE STUDY 6 (FIGS. 9a-9c)

SCI-73-41276 over Scioto River (Portsmouth, Ohio)

Three individual bridges with spans of 155, 155, and 139 ft (47.2, 47.2, and 42.4 m), 139, 139, 155, and 155 ft (42.4, 42.4, 47.2, and 47.2 m), and 155, 155, and 155 ft (47.2, 47.2, and 47.2 m) separated by structural expansion joints make up the 1508 ft (460 m) combined bridge length. The transverse section consisted of a 37 ft 6 in. (11.4 m) roadway with a 6 ft (1.8 m) sidewalk on one side and bulb-tee girders spaced at 10 ft (3 m) on centers.

The value engineering change proposal reduced costs and construction time by utilizing 91 in. (2311 mm) precast concrete bulb-tee girders to replace the original steel plate girders. The design concrete strength of the girders was 7000 psi (48.3 MPa) with a semi-lightweight mix of 125 pcf (2000 kg/m^3). The draped prestressing reinforcement consists of 64 0.5 in. (12.7 mm) seven-wire low-relaxation 270 ksi (1860 MPa) special prestressing strands with a guaranteed ultimate tensile strength of 45 kips (200 kN) per strand.

Piers are reinforced concrete cap and columns on drilled shafts embedded into bedrock. The piers were designed for six girder lines to accommodate future widening of the bridge from two lanes to four lanes (see Fig. 9a). Buoyancy details were provided throughout the structure because the bridge is inundated by the 25-year and 100-year backwater pools from the Ohio River. Galvanized steel diaphragms were provided at girder third-points. Debonding of top strands was detailed for transportation.

CREDITS

Owner: Ohio Department of Transportation

Precast Concrete Manufacturer: TECSPAN Concrete Structures, Inc.

Original Engineer: W.E. Quicksall & Associates, Inc.

Value Engineering Change Proposal Engineer: Janssen & Spaans Engineering, Inc.

Bridge Contractor: C.J. Mahan Construction Company

Completion Date: Currently under construction

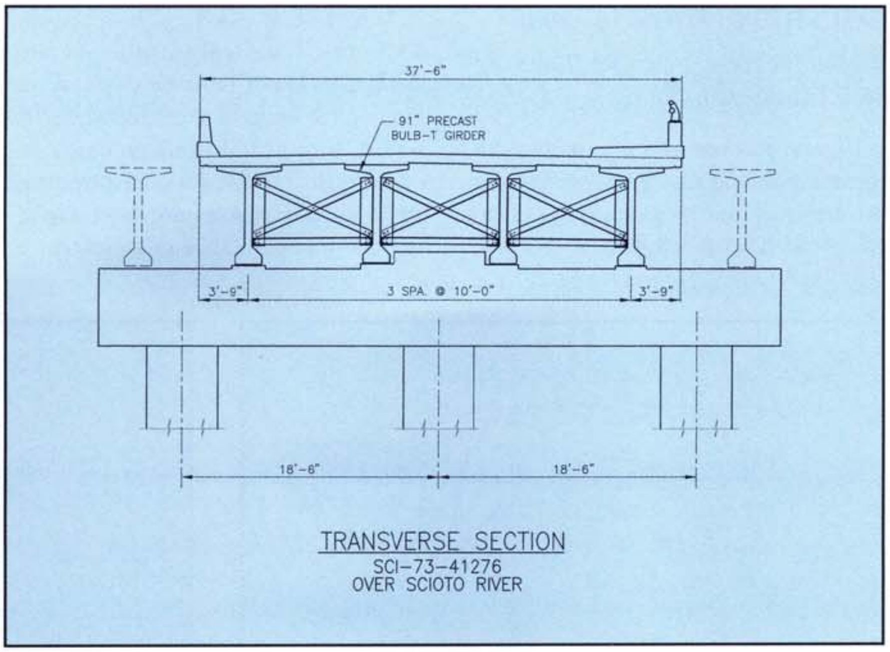

Fig. 9a.

Fig. 9b.

Fig. 9c.

CASE STUDY 7 (FIGS. 10a-10d)

COS-036-2064 over Walhonding River (Coshocton, Ohio)

This project consists of a part-width construction and major widening from two lanes to four lanes for a four-span bridge with span lengths of 78, 107, 107, and 78 ft (23.8, 32.6, 32.6, and 23.8 m). The value engineering change proposal reduced costs by replacing the original steel rolled beams with 60 in. (1524 mm) precast concrete bulb-tee girders, eliminating structural expansion joints and providing the owner with a completely rebuilt semi-integral abutment utilizing existing and proposed 12 in. (305 mm) cast-in-place reinforced concrete piles. Existing and proposed 12 in. (305 mm) cast-in-place reinforced concrete piles at the piers were used with a wall-type pier supporting the bulb-tee girders on elastomeric pads.

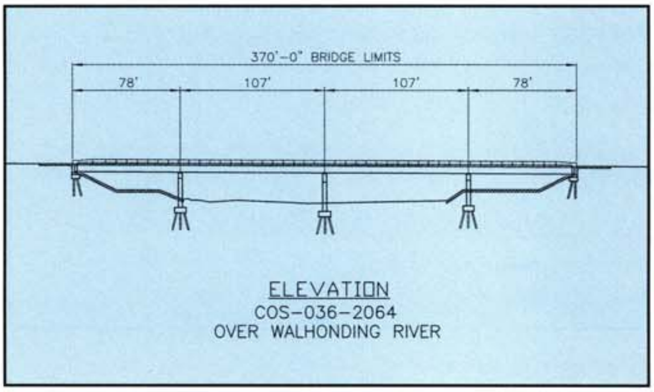

Fig. 10a.

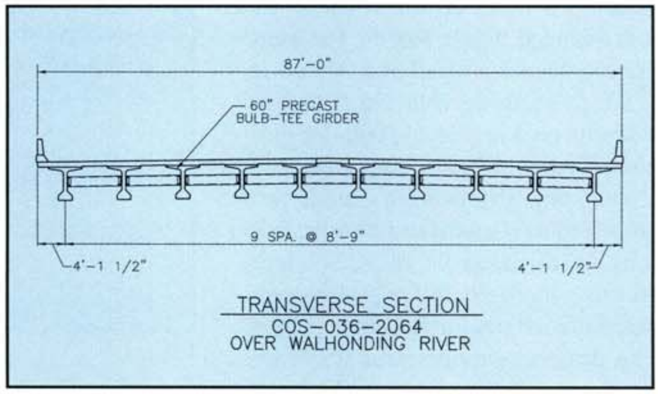

Fig. 10b.

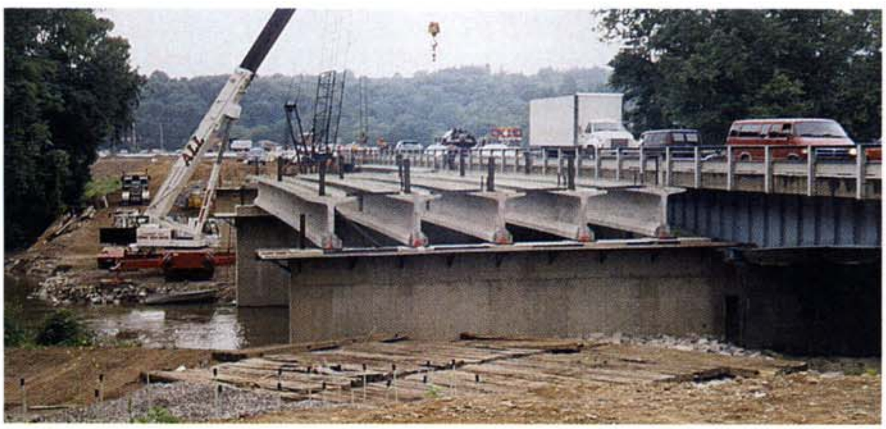

Fig. 10c.

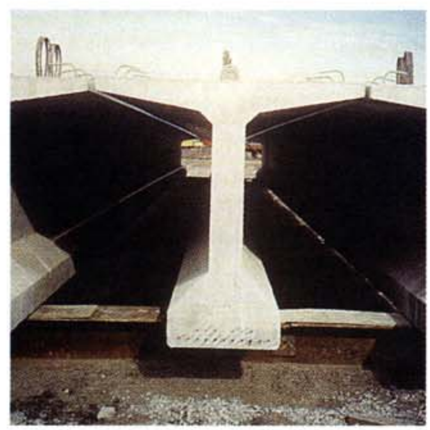

Fig. 10d.

CREDITS

Owner: Ohio Department of Transportation

Precast Concrete Manufacturer: TECSPAN Concrete Structures, Inc.

Original Engineer: Ohio Department of Transportation

Value Engineering Change Proposal Engineer: Janssen & Spaans Engineering, Inc.

Bridge Contractor: C.J. Mahan Construction Company

Completion Date: Currently under construction

CASE STUDY 8 (FIGS. 11a-11d)

WAR-741-0006 over Interstate 71 (Cincinnati, Ohio)

This project consists of a part-width construction and major widening from two lanes to four lanes for a two-span bridge with span lengths of 130 and 130 ft (39.6 and 39.6 m). The value engineering change proposal reduced costs and construction time by utilizing 66 in. (1676 mm) precast concrete bulb-tee girders to replace the original steel plate girders.

The transverse section consisted of an 83 ft (25.3 m) roadway with bulb-tee girders spaced at a 9 ft (2.7 m) maximum. The bulb-tee girder design concrete strength was 6500 psi (44.8 MPa) with semi-lightweight concrete of 125 pcf (2000 kg/m^3). The girders were transported and erected at night to minimize interstate traffic disruption.

Piers are reinforced concrete cap and columns on rectangular footings and steel HP12x53 piles. The abutments contain reinforced earth walls and semi-integral details on a 35-degree skew as per the original contract plans.

CREDITS

Owner: Ohio Department of Transportation

Precast Concrete Manufacturer: TECSPAN Concrete Structures, Inc.

Original Engineer: Woolpert Consultants

Value Engineering Change Proposal Engineer: Janssen & Spaans Engineering, Inc.

Bridge Contractor: C.J. Mahan Construction Company

Completion Date: Currently under construction

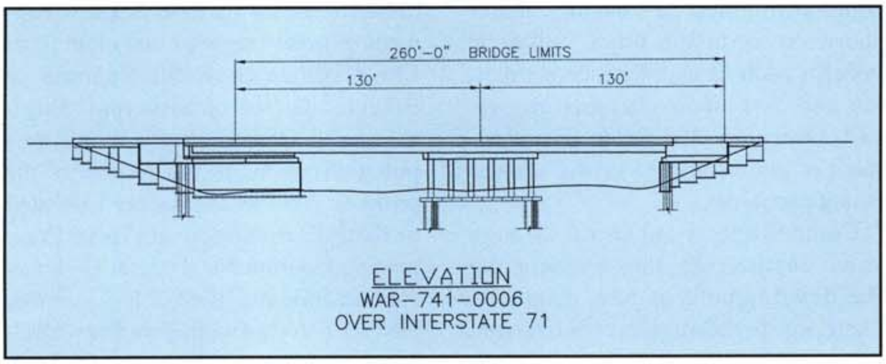

Fig. 11a.

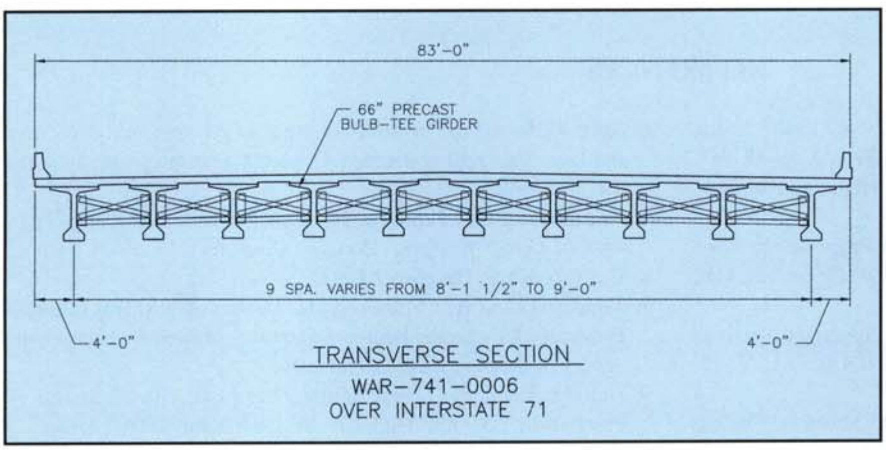

Fig. 11b.

Fig. 11c.

Fig. 11d.

SUMMARY

The following trends are evident from these eight value engineering case studies:

1. The average span was 131 ft (40 m), with the shortest span equal to 78 ft (23.8 m) and the longest span equal to 168 ft (51.2 m).

2. The majority of the projects were either new construction or complete replacement. Two of the projects contained part-width construction for major widening from two lanes to four lanes.

3. Girder depths ranged from 60 to 91 in. (1524 to 2311 mm).

4. The majority of the mix designs used concrete strengths of 7000 psi (48.3 MPa) and contained semi-lightweight concrete weighing 125 pcf (2000 kg/m^3).

5. Precast concrete bulb-tee girders replaced either steel-rolled beams or steel plate girders as per original contract plans in seven out of eight cases; the eighth case reduced the number of girders by 33 percent by using bulb-tee girders in place of AASHTO girders.

6. Cost savings resulted in every case. Two of the projects resulted in reduced construction time.

CONCLUDING REMARKS

A resurgence of value engineering practices in Ohio is paving the way for precast concrete bulb-tee girders. In addition to initial cost savings and/or shorter construction times, collateral benefits such as maintenance, aesthetics, and even life-cycle costs may result. Over time, the return on investment of the value engineering savings is quite apparent.

Competition is enhanced through value engineering, thus encouraging the development of new products, changing technologies, innovation, improved designs and creative thinking. Value engineering maximizes limited funds and resources, which in turn benefits the users of our transportation system — now and in the years to come.

ACKNOWLEDGMENT

The authors would like to thank the State of Ohio and the Ohio Department of Transportation for implementing guidelines for value engineering change proposals in construction. Teamwork and cooperation were required from all parties. Acknowledgment of timely reviews and input from Lloyd Welker (Assistant Engineer of Bridges, Office of Structural Engineering — Ohio Department of Transportation) added to the success of the projects. Special thanks are extended to Keith E. Borkenhagen (Value Engineering Coordinator, Federal Highway Administration, Office of Engineering, HNG-10) for providing various handouts and the Value Engineering Textbook (Ref. 1).

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