STEEL TUBS OVER THE MISSISSIPPI, FAIR AND SQUARE

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BIOGRAPHY

Ms. Manjula Louis holds the Position of Design Unit Leader with the Bridge Office of the Minnesota Department of Transportation. She has over 25 years of experience in structural design and her responsibilities include preparation of plans and specifications for bridges and miscellaneous structures. She holds a Masters degree in Civil Engineering from the University of Minnesota. Her signature projects include Fast Track Replacement Bridge over Mississippi River in St.Cloud, MN, and the Lafayette Bridge Replacement over the Mississippi River, St. Paul, MN. She is currently serving as the Project Manager for Segmental concrete bridge over Mississippi River in Dresbach, MN

Mr. Vincent Gastoni is a Principal Bridge Engineer and Senior Project Manager with Parsons in the Minneapolis office of Parsons. He is one of Parsons leading Design-Build and complex bridge Project Managers with over 20 years of structural experience in the design and management of major transportation projects and complex. Mr. Gastoni's signature projects include the New Carquinez Suspension Bridge, Vallejo, CA; I-64 Design Build, St. Louis MO; and the Lafayette Bridge Replacement over the Mississippi River, St. Paul MN. He is currently serving as the Design Project Manager for the free-standing tied arch bridge over the Mississippi in Hastings MN.

SUMMARY

The Minnesota Department of Transportation (MnDOT) is replacing the existing 1968 Lafayette Bridge located in historic downtown St. Paul, Minnesota to address both the structure and geometric sufficiency issues for future traffic demands.

To promote competition in bidding MnDOT decided to develop both a steel and concrete bridge alternatives of trapezoidal box sections for consistent overall project aesthetics. Through the competitive bidding process the steel tub alternative was the low bid alternative selected by the contractor in November 2010.

In addition to the technical challenges involved with the design, the project proved challenging due to significant site constraints, agency interactions and community involvement. The new 3000 feet long parallel trapezoidal steel tub bridges utilize 14,407 tons of structural steel, involved intensive industry coordination and to produce a winning state-of-the-art bridge design.

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Introduction

The Lafayette Bridge is located on TH52 over the Mississippi River in historic downtown St. Paul. Minnesota. It is also on a major regional corridor connecting cities of Rochester and St. Cloud and carries 81,000 vehicles per day. The existing bridge was completed in 1968 and is a two girder fracture critical structure with a history of fatigue related issues. While not an immediate risk, Minnesota Department of Transportation (MnDOT) selected to replace the bridge through competing concrete and steel designs to address the structural sufficiency issues and improve the interchange of TH52 and I-94 in downtown St. Paul.

The new structure carrying northbound TH 52 traffic will be built to the east of the existing bridge. Upon completion of the northbound structure, traffic will be placed on the new northbound bridge. After traffic is shifted onto the new northbound structure, the existing bridge will be removed and the new southbound bridge will be constructed on the existing bridge footprint. The new bridge decks will provide two 12-ft traffic lanes and a 12-ft auxiliary lane. A 12-ft pedestrian walkway runs along the east side of the northbound bridge and includes two overlook areas located at each of the river piers.

Figure 1 - Rendering of final bridge against the City of St. Paul with the Minneapolis skyline in the background.

Site Constraints and Project Coordination Challenges

The new 3000 feet long side by side bridges will carry traffic over Mississippi River, several city streets, railroad tracks, future Light Rail Transit (LRT) maintenance yard, an historic wall, and a levee. The Port of St. Paul service center and barge mooring areas are located under the bridge and the river navigation season runs from late April to mid October. There is also a high tension power line crossing close to the bridge. Thus there were restrictions to the pier placement and close coordination was needed with various stakeholders. Regular meetings and continuous exchange of information expedited project coordination and delivery.

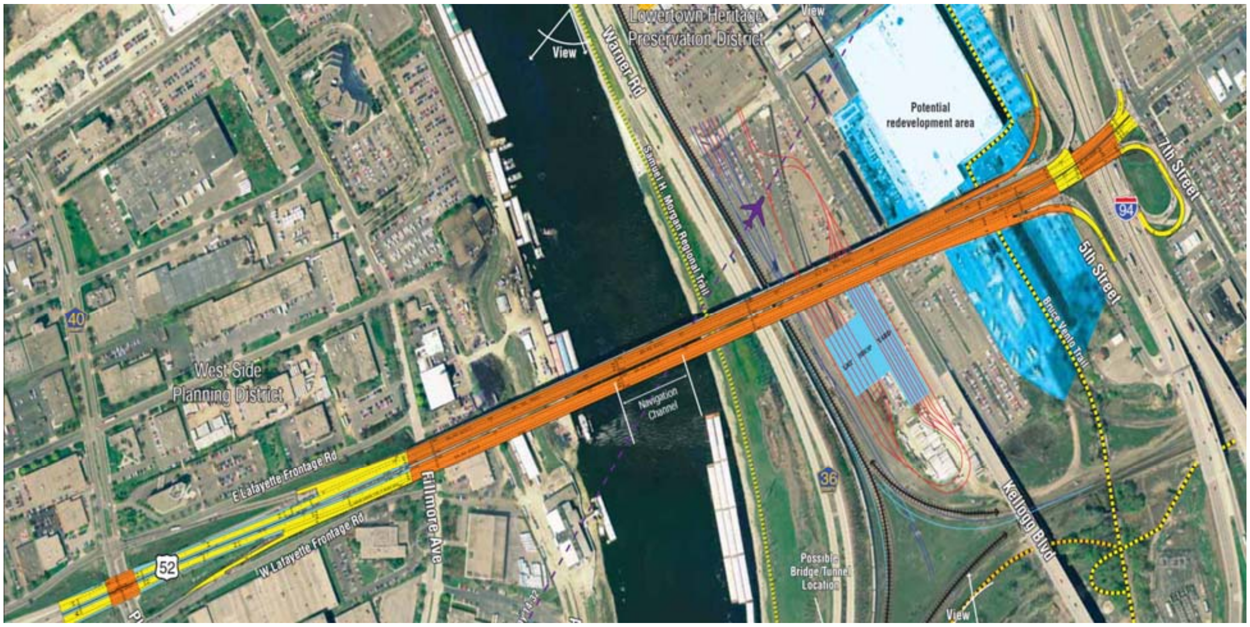

Figure 2 - Bridge site constraints included the St Paul Executive Airport, river navigation, railway lines, commuter rail lines, light rail lines, power lines, public trails, city streets and parking.

Community Involvement and Structure Type Selection

The Lafayette Bridge is a prominent feature of the downtown St. Paul landscape and MnDOT implemented a Visual Quality Management process during the design development and prepared a Visual Quality Manual (VQM) that addressed the visual impacts and provided aesthetic design recommendations regarding the bridge elements.

To ensure community support, MnDOT also formed a 10 member Citizen Advisory Committee (CAC). The committee included citizens from various groups representing the Bike Advocacy Group, St.Paul Public Art, River Front Design center, Metro State University and several other area councils. The purpose of the committee was to advise MnDOT regarding project design issues and to ensure community participation in the Visual Quality Management process.

The St. Paul Downtown Airport, Holman Field, is in close proximity to the structures, located on the south side of the Mississippi River. The flight paths that originate at Holman Field introduce a restriction surface above the bridges throughout the project area. In addition, a high voltage electrical transmission line crosses above the bridges on the north side of the Mississippi River. Location and height of the transmission lines were dictated by the airport flight paths and minimum clearance above the TH 52 roadway.

The St.Paul Airport flight path restrictions, the Xcel power line and navigational clearance requirements played a major role in structure type determination. Due to restrictions located above and below the deck the maximum depth available for the superstructure was 30 feet. As a result of this maximum structure depth constraint, the only superstructure type available was a Girder/Concrete deck option. MnDOT decided to develop designs for both a concrete and steel alternative. Per the CAC recommendation to keep the appearance of the two alternatives similar, MnDOT chose to proceed into the design phase developing plans for a Concrete Box Girder and a Steel Box Girder.

Cost Risk Analysis and Value Engineering Study (CRAVE) and Preconstruction Pile Test Program

MnDOT has a policy to conduct a CRAVE study for any project with total construction costs in excess of $20 million dollars. The primary objective of the study is to identify opportunities to improve the design by studying key project issues using a multidiscipline team. Value Engineering team members included MnDOT Traffic, Bridge, and Geotechnical engineers, alongside several consultants from similar disciplines, City of St. Paul representatives, economists and context sensitive design representatives. The CRAVE team developed 12 recommendations that yielded potential total cost savings of $50,000,000. One of these recommendations was the inclusion of a preconstruction pile test program.

The preconstruction pile test contract was let over a year before the project letting date. The purpose was to determine actual capacity and additional capacity that could develop through soil "set up". A single static pile test was conducted on the south side of the river. Due to variation in soil profile on the north side of the river, test piles were driven at several locations to determine capacity through "set up". The types of pile tested included H-piles, steel shell piles and mono tubes. Ultimately, steel shell piles were used in substructure design throughout all non-river pier substructures. Total piling cost savings approximately $500,000.

Figure 3 - MnDOT conducted a pile test program in preliminary design to capture significant cost savings in the final design.

Dual Design Approach

The decision to fully develop two alternative designs via two separate consultants immediately led to a high spirited friendly design competition through the design process. MnDOT held monthly project coordination meetings including both teams in order to assure a consistent policy approach to programmatic design issues.

Similarities- In order to assure the compatibility of both bridge designs to the single grading/civil design package, the following elements were identical for both alternatives:

- Bridge Length and Deck Geometry
- River Pier Locations
- Foundation Types (Driven Piles)
- Roadworks and Roadway Tie-in Points
- Girder Aesthetics (Box Girders with Surface Coatings)
- Project Staging

Differences - MnDOT had developed detailed Preliminary Bridge Plans (30% designs) for each alternative as the starting point for the final design for each bridge. Both teams optimized their respective "base designs" for constructability and costs. The resulting differences between the two alternatives were;

- Superstructure Type & Material
- Number of Spans
- Span Lengths & Substructure Locations
- Substructure Geometry
- Deck Joint Locations
- Structural wearing course to the concrete box integral wearing course.

Through the competitive bidding process the steel tub alternative was the low bid alternative selected by the contractor in November 2010. Parsons Transportation Group (Parsons) had been selected to lead the steel design. The steel tub design team worked through MnDOT and NSBA to bring the steel manufacturing, fabrication, and construction industry into the design process to assure a cost effective, biddable product.

Project Goals and Objectives

The steel box girder design team set out to meet MnDOT's goals and objectives to achieve a balanced design of economy, durability, aesthetics, and constructability while meeting the absolute requirements related to capacity, safety, and mobility for both construction and the service life of the bridge.

The overall objectives of the project are to:

- Replace existing bridge with new dual bridges.
- 100-year design life.
- Meet current geometric and structural standards in same regional transportation system corridor.
- Improve traffic capacity, safety, and mobility on TH 52.

The final design needed to accommodate:

- Existing streets, trails, and future light rail accommodations, Xcel energy high voltage lines and USACE levee underneath the bridge.
- Traffic capacity, safety, and mobility on TH 52.
- Pedestrian and bicycle facilities.
- River navigation clearance.

- Barge traffic patterns on the river.
- Vessel impact loads in the river.
- River hydraulics and scour.
- Future light rail transit facilities near the structure.

Span Arrangement and Bridge Layout

A design that merely satisfies design code requirements does not guarantee success. Parsons prepared a systematic approach to design development addressing constructability, in-service loads, and environmental conditions. This approach applied a comprehensive understanding of detailing for durability and constructability, fabrication and erection constraints and methods, and construction specifications and quality control to assure an economical and durable bridge design that could be fabricated and erected efficiently and safely. The specific goals of the bridge design were:

- Use durable details and design to meet MnDOT's specific climate requirements.
- Constructible and cost-effective details and design.
- High-quality analysis and design approach leading to a safe and Load and Resistance Factor Design (LRFD) compliant design.
- Aesthetic design and details that meet the VQM.

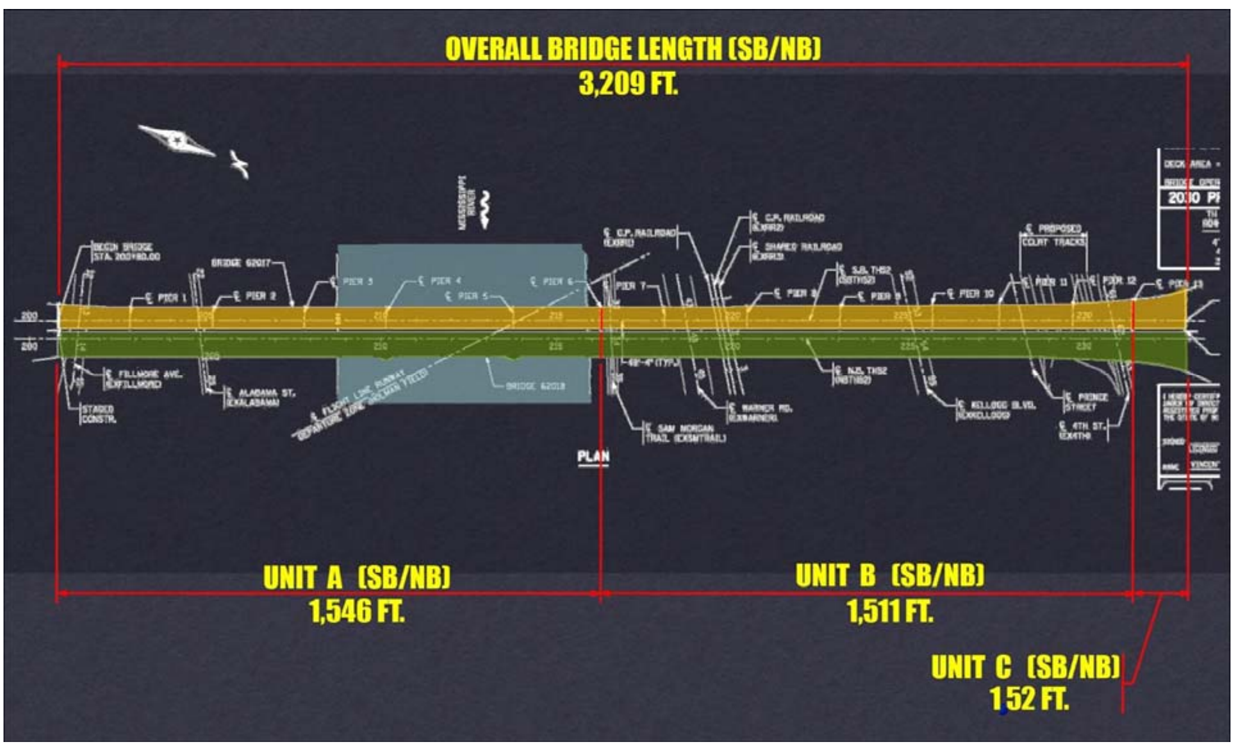

Figure 4- Overall bridge layout. Both Northbound and southbound bridges is comprised of three separate structural units each.

As a first order of work, the steel team performed a Value Engineering style review of the preliminary design. From this review the 7'-6" deep approach spans were lengthened by reducing two piers on each bridge and the haunched box section was optimized and reduced in depth by 18-inches to 15'-6". The substructure units and expansion joint locations were refined in order to optimize the properties of the steel box structure type. High performance steel was evaluated but not incorporated because of the potential costs and schedule impacts due to the thick plates required in the negative moment regions.

Design Criteria and Studies

The design criteria developed for the steel box girder designs was based on the AASHTO LRFD Specifications as modified by MnDOT. MnDOT identified this structure as an Important Structure and the design included an importance factor load modifier of 1.05 for Strength Limit States.

Special Load Cases - Additional live loads included the MnDOT standard permit trucks for evaluation under the AASHTO Strength II load combination. MnDOT also specified a live load deflection limit of L/1000 for the structure carrying the pedestrian sidewalk. In addition MnDOT specified a modified Strength IV load combination (HL-93 only) of:

$$STR\ IV(M) = 1.4DL + 1.4LL$$

Vessel Study - With the river piers located in the major inland waterway of the Mississippi, a Vessel Impact Study was performed to evaluate the susceptibility of the structure to vessel collision by barges transiting the river and establish a minimum vessel collision design load. The design team utilized the AASHTO Method II analysis which determined the vessel collision design strength load of 2,500 kips based on the design vessels transiting the river during normal operations at the mean high water elevation (2% flowline). A minimum empty barge impact load of 888 kips was established based on an empty jumbo hopper barge drifting at the head water elevation and mean velocity of the 100 year flood.

Bridge Security - The bridge was required to be designed to prevent a disproportionate or progressive collapse from potential hazards and threats. A threat and vulnerability assessment was performed early in the design process and integrated into the design of the structure.

100 Year Service Life – This structure is designed for a 100 year service life. MnDOT identified certain project parameters to meet this goal such as stainless steel reinforcing bars in the deck, painted weathering steel, specialized high performance concrete mix design specification, and a specialized deck placement sequence to minimize concrete cracking for improved durability.

The use of stainless steel reinforcement was required in the deck of both bridge alternatives to obtain the desired 100 year bridge service life. This also included all bars extending into the bridge railing.

MnDOT also decided to include a concrete mix that is to be designed by the contractor in accordance with the performance based special provisions. This performance based special provision should provide a concrete mix to achieve the 100 year bridge service life and satisfy strength and durability requirements. The contractor will provide their own job-mix designs based on the project performance specifications which detail the minimum requirements such as strengths, permeability, full scale test pours and special superstructure requirements of:

- Quantified 100 year design life.
- Low alkalis cement.
- ASR requirement for coarse and fine aggregates.
- ASTM C 157 testing for shrinkage (.040 limit).

Geotechnical – Large diameter pile foundations were identified early in the project as optimal for this site. Both drilled shaft and driven steel shell piles were evaluated based on the vertical, overturning, and lateral design loads. Based on the site conditions, schedule, risk, and cost; 42-inch diameter ¾-inch wall driven steel shell piles were selected for the design.

The 42-inch steel shell piles are 90 feet long and driven to refusal into the underlying bedrock. Maximum factored pile bearing resistance of 850 ton/pile was based on high strain dynamic testing with restrikes and CAPWAP. The piles will be concrete filled and fixed into the footing for increased lateral stiffness to account for the vessel impact loads and potential scour. The designs account for the total estimated scour of over 36 feet based on the 500 year scour event. Preliminary cofferdam design was also developed and included in the design load cases.

Figure 5 - River piers utilized 42-inch steel shell piles constructed inside deep

The pile design supporting the approach structure were provided by MnDOT as 16-inch concrete filled driven shell piles with a maximum factored pile bearing resistance between 350 ton/pile and 250 ton/pile. MnDOT developed 16-inch pile capacities through a separate pile test program concurrent with the bridge designs. The preconstruction pile test program provided MnDOT assurance of the expected resistance and depth of the 16-inch driven piles. This program resulted in a significant cost savings which was achieved in design through the use of higher allowable resistance factors.

Industry Coordination – MnDOT held a steel industry review of the in-progress plans in order to gain early comments for fabrication, detailing, shipping and erection. Comments from this meeting were instrumental in the design development, and additional studies which ensured a biddable set of plans that met industry expectations and capacities. Elements such as optional splice locations and alternative details were able to be incorporated directly into the plans for fabricators and erectors to utilize. This approach provided flexibility and allowed contractors to bid the job with greater confidence and minimal risk of change order delays.

Shipping Considerations – As part of Parsons constructability review the hauling configurations, restrictions, and cost impacts of the heaviest fabricated steel box pieces was studied. The study contacted regional fabricators to identify typical hauling requirements. From this, the study focused on overland haul restrictions, costs, and axle configurations based on the steel box girder segment weights summarized below:

Hauling loads from 100 to 150 tons were more specialized but not uncommon. The 15’-6” deep haunched river pier segments were identified by haulers as the most restrictive since any overweight load with a total trailer height greater 16 feet is a Superload which requires very specific route designation, escorting, and even electrical crews for overhead obstruction removals.

Weight	No. of Pieces
<80 T	124
80 T to 100 T	24
>Than 100 T	30
Total	178

Figure 6 - Summary of segment shipping weights.

The design team evaluated weight mitigation strategies throughout the design process utilizing a cost-benefit analysis. High performance steel was evaluated but not used due to the cost and schedule risk of obtaining the thicker plate sizes and the overall reduction in weights was not significant. Additional segment splices were analyzed but negatively impacted structural efficiencies and were not incorporated. Optional field splice locations were identified on the plans for contractors to utilize at their discretion to minimize segment sizes. The team also evaluated the use of horizontal splices in the river haunch sections but was deemed undesirable due to durability and visual quality concerns.

Superstructure

Steel tub girders are rare in Minnesota and not a common inventory type in most other states as well. This regional unfamiliarity presented challenges that needed to be addressed in the design and constructability evaluation of the bridge. Parsons and MnDOT reached out through NSBA to bring the steel manufacturing, fabrication, and construction industry into the design process to assure a cost effective, biddable product. From this effort, state-of-the-art detailing and design practice was combined with a focused constructability assessment at every stage of the design.

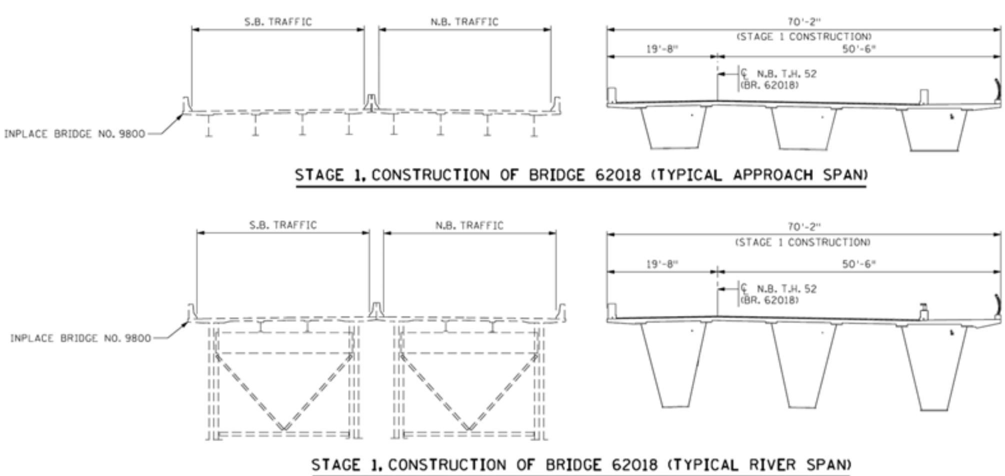

Figure 7 - Stage 1 construction; build new northbound bridge adjacent to existing structure.

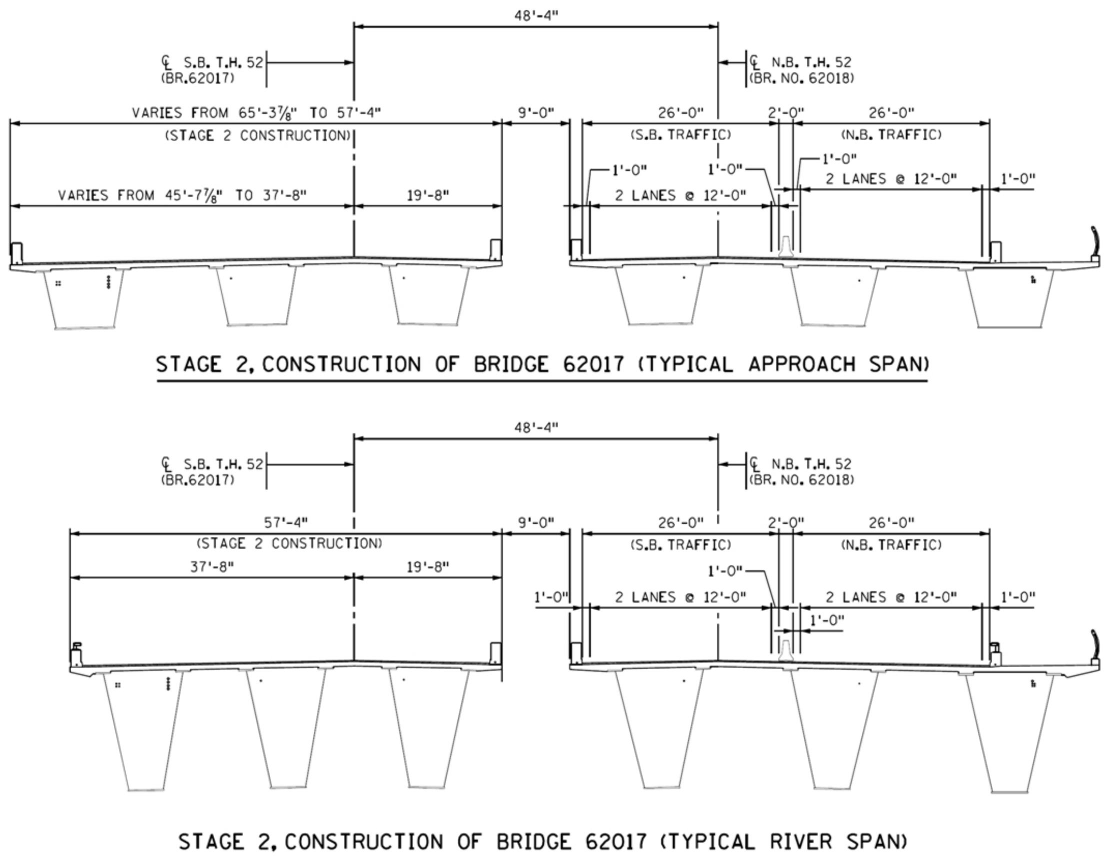

Figure 8 - Stage 2 construction; remove existing structure and build new southbound structure.

Detailing – Good designs start with good details. The key reference for current detailing practices was provide by AASHTO/NSBA “Guidelines for Design Details, G1.4-2006”. The design team also performed an industry review of current practice to ensure state-of-the-art detailing practices were utilized. Texas, Pennsylvania, and Florida served as focus point for this effort. Parsons also include Mr. Walter Gatti of Tensor Engineering to provide an internal peer review of the detailing practices

Design Components – The design team worked to identify the leading design drivers that typically impact construction cost and schedule. Elements indentified as critical to cost and schedule included, external bracing, bearings and pier diaphragms.

Based on this study, a key focus of the design team was to eliminate the need for permanent or temporary intermediate external bracing between the box girders wherever possible. Since AASHTO does not directly address the issue of allowable box rotations, particularly under construction load cases, the design team reviewed industry best practices to determine a practical critical value of vertical differential deflection as a requirement for external bracing to control deflections and erection fit up. As a result of this research, a value of ½” vertical differential deflection between flanges of a box as an appropriate and practical value for an unbraced box girder ("Design Guidelines For Steel Trapezoidal Box Girder Systems"; FHWA/TX-07/0-4307-1) by T. Helwig, J. Yura etc.). Based on these criteria the design team was able to eliminate the external bracing at all locations expect for the last span due to its curved geometry.

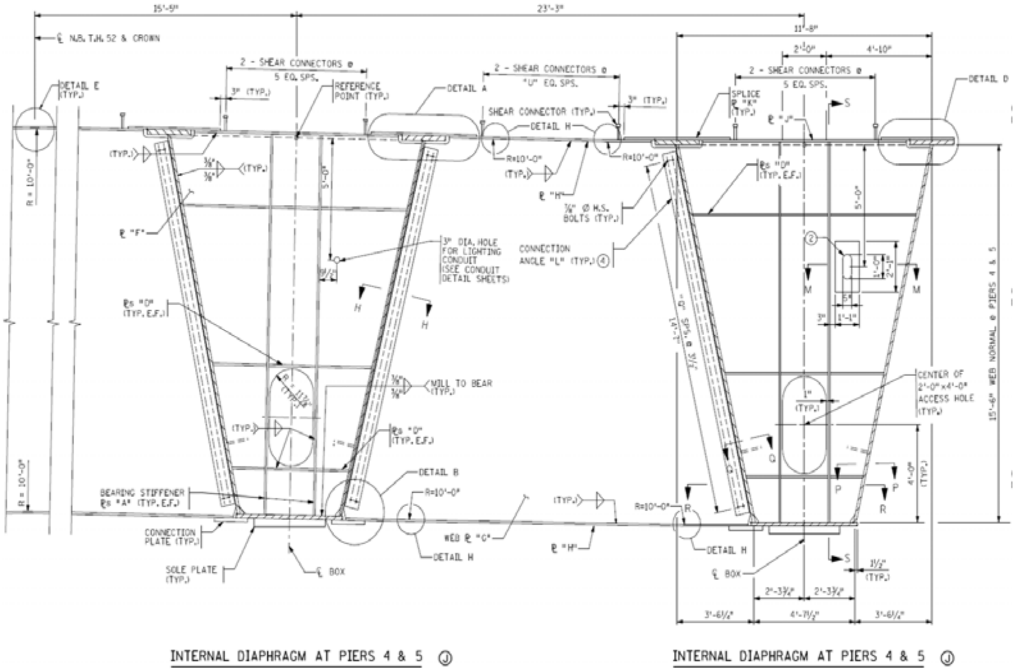

Figure 9 - Haunched tub section and diaphragms at river pier supports.

At the initiation of this project, the design team recognized the complex system behavior of a trapezoidal steel box girder superstructure and the importance of fracture critical and fatigue issues in the design of this bridge type. Based on our initial project review, value engineering review, and previous experience, a single bearing support per box was selected as the most appropriate support system for this structure due to its reliability, proven performance, structural efficiency, and bridge system geometrics.

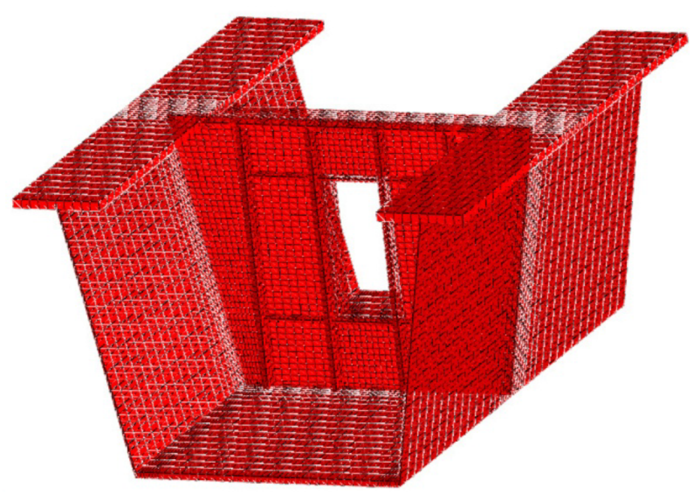

Figure 10 - LARSA FEM Model of tub section at typical approach pier.

In addition to the AASHTO LRFD Articles and Commentary on the use of single bearing systems (6.11.1.2) and the use and detailing of diaphragms (6.7.4.3), the design team also reviewed current literature and best practice guides which represent the state of the art of steel box girder design including:

- AASHTO/NSBA "Guidelines for Design Details, G1.4-2006"
- NSBA "Practical Steel Tub Girder Design"
- Preferred Practices for Steel Bridge Design, Fabrication, and Erection, (TxDOT)
- Design Guidelines for Steel trapezoidal Box Girders, (FHWA/TX-07/0-4307-1).

Experience throughout the industry has shown that a single bearing design provides superior performance. Construction tolerances and unequal thermal effects (due to uneven solar radiation or other causes) commonly contribute to field variations that lead to unequal bearing of dual bearing systems. Since box girders with top flange lateral bracing are quite stiff, it is difficult to correct out of tolerance girders back into position to fully bear on both bearings. The external diaphragms are detailed with oversize holes to allow for minor fit up and rotational variations in the field during erection to assure even load distribution.

Solid plate internal and external diaphragms was selected as part of the bearing/force resisting system due to their higher efficiency and ease of fabrication and fit up over a “K-Brace” cross frame system. Both types are acceptable under AASHTO LRFD 6.7.4.3 and the greater resistance to torsion twist of the solid plate diaphragms will more effectively accommodate the local and global torsion loads generated from unbalanced construction loads, environmental loads such and differential thermal heating and wind, as well as in-service live loads. This is an important feature since the framing system for the bridge is designed without intermediate external diaphragms and the global torsion of the system is resolved through the bearing/diaphragm system at the supports.

Fatigue – The structural system can be designed as either a flexible system allowing distortion and higher fatigue stresses, or the system can be made rigid preventing distortion and relative movement between elements minimizing distortion-induced fatigue. While proper design is necessary to achieve this performance goal for both load induced and distortion induced fatigue, addressing distortion induced fatigue is critical to assuring long life durable details and proper load paths for both intended and unintended forces between transverse and longitudinal members. The new Lafayette bridge is highly redundant and contains no “fracture critical” details based on the NBIS standards of practice and the 100 year service life criteria required all details to be checked for theoretical “infinite life” fatigue cycles.

Since steel box girders are inherently stiff, and relative movement and distortion are undesirable in a closed cell box, taking a “stiff system” approach was selected for this project by providing a rigid load path to adequately transmit the force from the transverse member to the web and flange. This rigid load path is provided by the pier and end diaphragms which provide the global stiffness of the multiple box system while the individual box cross sectional distortion is

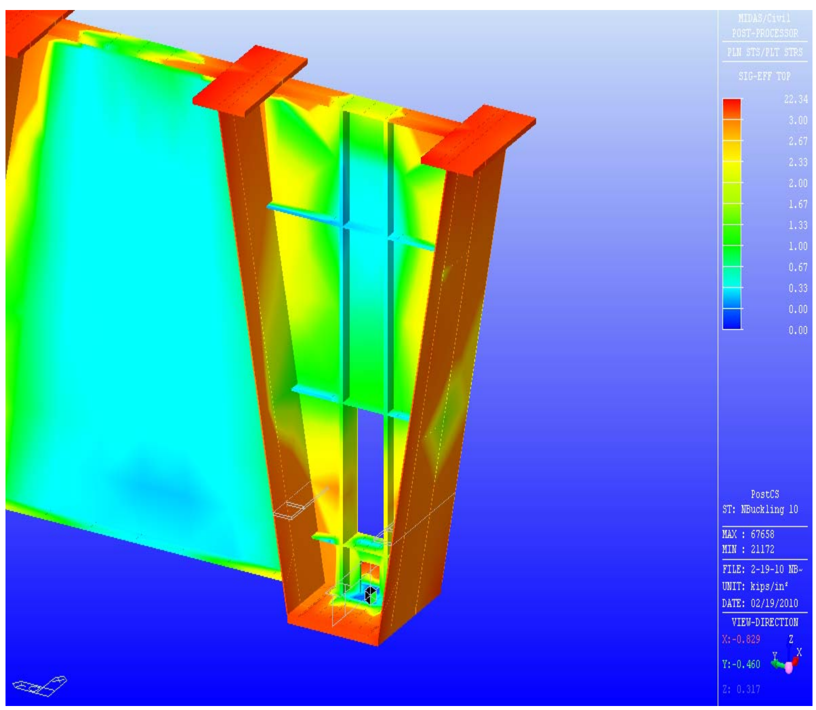

Figure 11 - MIDAS model results at river pier diaphragm showing stresses for maximum shear loading.

managed by internal K-brace diaphragms throughout the length of the box.

Proper attention to connection detailing will result in the required fatigue performance. The design team detailed the connections for this project in compliance with AASHTO 6.6.1. Fatigue sensitive details at the diaphragms and the connection of the diaphragm to the webs are investigated using principal stresses. Significant efforts were made to eliminate Category E or E' details and to provide unconstrained joints which minimizes the potential for constraint induced fractures of welded connections.

The plate diaphragms are designed as part of the primary load path system and resist the cross section distortion, torsional moments and transmit the vertical and lateral forces from the box to the bearing. The diaphragm plate is designed for the vertical force carried by the bearing stiffeners, the horizontal stress due to out of plane bending and web inclination, shear, and torsion as well as out of plane moments resisted by the bearing stiffeners. The strength limit state of the member is based on principal stresses rather than simple beam theory, material yielding criterion, and bucking behavior. The additional lateral loads and stresses generated by the inclined webs through the change in the horizontal component of the web dead load shear and St. Venant torsional dead load shear are included in the evaluation for fatigue and strength limit states.

The design teams approach to the modeling, investigation, design and detailing of the diaphragms utilized classical methods based on the global and local loads from our MDX and LARSA models while our Independent Design Checker, Michael Baker Jr. Inc., performed their review using the Midas 3D FEM software. In general, the design results indicated that the fatigue stress range across the web-to-diaphragm is generally low (<Cat E range) and the resulting strength design of the weld is such that the system can be considered relatively conservative.

Deck Design - The deck placement on steel girder bridges is normally sequenced to minimize the potential for concrete cracking in the deck negative moment regions over the piers during placement. These "locked in" stresses are typically low but in some cases, unbalanced spans may increase these stresses to a point where the early strength of the reinforced concrete deck section is insufficient to prevent transverse cracking.

For maximum deck durability the design team performed a refined deck stress analysis to study the "locked in" deck stresses generated by the deck placing sequence. The sequence was then adjusted to minimize deck stress levels to 150 psi and the percentage of mild steel reinforcement was increased where this level could not be met.

SB Bridge

Pour No.	Base	Final
1	-66	-63
2	-292	-91
3	-117	-122
4	-20	0
5	-52	0
6	-48	-61
7	0	0
8	-61	-60
9	0	0
10	0	0

NB Bridge

Pour No.	Base	Final
1	-122	-89
2	-202	-191
3	-234	-
4	-158	-147
5	0	0
6	-0	-16
7	-13	-75
8	-8	-20
9	-7	-11
10	-33	-94
11	0	0
12	-3	-72
13	0	0

Figure 12 - Maximum deck stress (psi) results before and after placement study.

The traditional "Base" case was analyzed and refined to minimize the deck stress for the "Final Configuration. Final stress results are listed below:

This refined analysis was based on limiting the deck stress to 150 psi tension during placement and extending the negative moment longitudinal deck steel through deck regions which could not meet this requirement. This limitation was based on utilizing a traditional modulus of rupture of plain concrete (tensile strength) of 7.5 x √f’c combined with a factor of safety of 1.5. This limiting stress level therefore corresponds to a minimum concrete strength (f’c) of 900 psi which is a reasonable value for concrete strength gain within 24 to 72 hours of placement.

Substructure

The substructure was typically controlled by the project aesthetic requirements which presented challenges for both efficiency and detailing. The design team worked diligently to utilize a family of common pier geometrics to minimize forming costs and schedule impacts. Additionally, the project team worked with the Visual Quality Team to refine the aesthetics for better material efficiency while maintaining the overall intent of the original details.

Approach Piers - The approach piers are typical in shape and vary in height from 25 ft to 50 ft in height. Aesthetics drive the concrete dimensions and minimum reinforcing limits typically control. Due to the V shaped pier significant cap tension forces can be realized and additional reinforcing was required in the cap beams to accommodate these loads. The large single bearing supports were analyzed via strut and tie methods to assure proper reinforcement detailing in the local zones under the bearings.

Figure 13 - Strength and shape of approach form compliments trapezoidal tub style and site context.

River Piers – For constancy with the segmental concrete alternative, the river pier aesthetics included a twin wall design. This design presented challenges since superstructure is not framed into the piers and a cap beam element was necessary. The typical river pier was over 78 ft tall from footing to seat.

Construction

The project was advertised to contractors in November of 2010. The advertisement included plans for the segmental concrete box girder alternate designed by FIGG Bridge Engineers and the steel box girder alternate designed by Parsons Transportation Group. The two alternate plan sets were developed to promote competitive bidding. The construction contract was awarded to Lunda Construction Company of

Black River Falls, Wisconsin along with their steel box girder fabricator, PDM, from Eau Claire, Wisconsin. Lunda's successful low bid was $96,850,000 for river bridges. For comparison, the lowest bid for the concrete box alternative was $131,653,000.

The bridge construction is scheduled to be completed by the fall of 2014. There is an important intermediate milestone date of July 2013. This milestone requires the contractor to complete the northbound bridge and portion of the southbound bridge over LRT maintenance yard. After July 2013, the LRT maintenance yard will be under construction in order to meet the Central Corridor Light Rail project construction schedule. There is an incentive of $2,000,000 for the river bridge contractor to complete these portions of work by July 2013. Conversely, the construction contract also includes a penalty of $65,000 per calendar day for work that remains incomplete after that date.

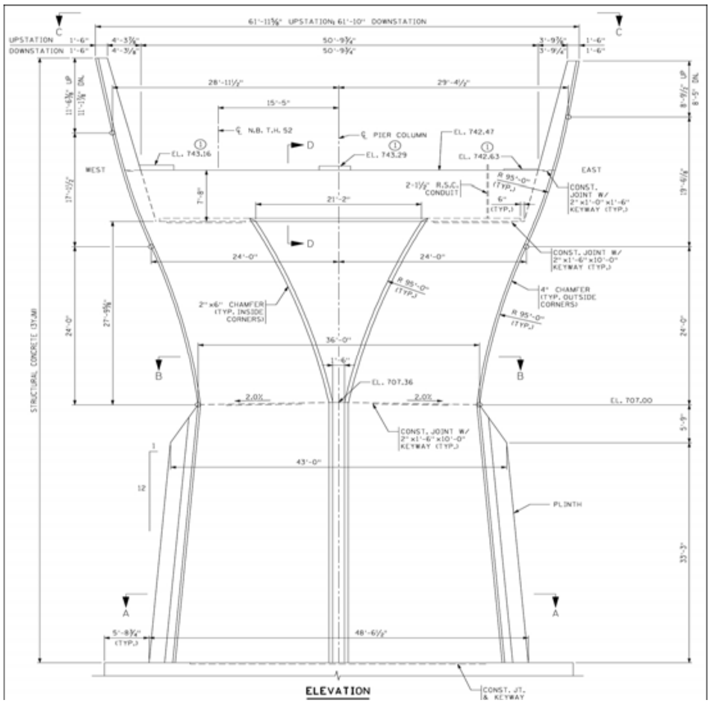

Figure 14 - Twin wall river piers will provide a strong, elegant support for the hanuched river spans.

Figure 15 - River pier construction is well underway and scheduled for completion in Spring of 2012.