A MESSAGE FROM THE
Executive Director

As we enter the fall and reflect upon the past few months, consider that 70 million Americans traveled more than 100 miles from their homes to visit family and friends this summer. One should not forget the transportation infrastructure that allows us to make these visits. It is in fact the ability we Americans have to travel and enjoy the many wonders of our country that makes this such a great place to live. Yet there is a price to pay for these arteries that bring us together.

The collapse of the I-35W Bridge in Minneapolis reminds us of the need to continue, if not renew, the vigilance necessary for keeping the safety of our roads and bridges up to par.

Members of the National Steel Bridge Alliance should realize the challenge before us in improving our infrastructure. I'm confident we will rise to the occasion and display the technical knowledge, pride, and sprite needed to keep our nation's bridges safe and usable for generations to come.

This task will require the consensus of the entire steel bridge community, with efforts to influence our congressional representatives, state and local government agencies, and decision makers to properly assign funding to projects in areas that need it the most.

Our current Buy America laws will need to be supported, if not enhanced, to protect the industry base of steel producers and steel bridge fabricators. Technical advancements in techniques to accelerate construction, improve design, enhance maintenance criteria, and raise bridge safety measures will be the industry's and transportation department's responsibility.

The opportunity for a bright steel bridge future is achievable with a concerted effort on our part. Let's use the recent tragedy in Minneapolis to springboard our industry to renewed greatness for years to come.

Best regards,
Conn Abnee
NSBA Executive Director

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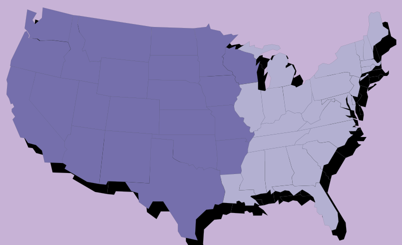
Regional Directors' Territories



Steel Bridge NEWS
NATIONAL STEEL BRIDGE ALLIANCE
SEPTEMBER 2007

You Can't Judge a Cable by Its Cover

BY RONALD M. MAYRBAURL, P.E., AND HELEN GODDARD

"Getting to the heart of the matter" is a good philosophy to adopt when evaluating suspension bridge cables.

THE NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM (NCHRP), IN 2004, PUBLISHED THE FIRST-EVER STANDARDIZED GUIDELINES FOR INSPECTING AND EVALUATING SUSPENSION BRIDGE PARALLEL-WIRE CABLES. A report on background research accompanied the book, concluding a four-year effort by Weidlinger Associates to develop a nationally recognized procedure. It was a significant milestone in the battle to extend the service life of cables on U.S. bridges, the majority of which are more than 50 years old and carry increasingly heavy traffic.

Less conservative and rigorous techniques, based on limited data and unexplored assumptions, can lead to overestimations of strength or unnecessary repairs. Weidlinger's method is statistical, encompassing other methods that depend on minimum or average wire strengths. When a bundle of wires is tested in a machine, the wires break one at a time as the strain is increased. By exploiting this phenomenon, Weidlinger's strength calculations rationalize the process and give owners of aging bridges a crucial bonus: information about how the cable is likely to fail.

The cables on Scotland's 3,300-ft-long Forth Road Bridge were recently inspected for damage.

Survey Says

The cables are the major carrying elements on a suspension bridge. They are constructed of many thousands of individual wires, usually laid parallel to one another and clamped at points where the suspenders connect with them to support the deck. The wires are galvanized or otherwise protected, but are susceptible to corrosion and an even more sinister form of degradation: the development of transverse cracks. In a survey of U.S. and Canadian suspension bridge owners, Weidlinger confirmed that the degree of internal corrosion can vary widely, from zinc deterioration to the presence of broken wires inside the cable. The survey results indicated that inspections are limited and inconsistent (wrapping removed for several inches to full cable length), but sufficient to correlate degree of damage (major vs. minor) with bridge age at inspection, leading to the conclusion that early inspection is best.

No Crystal Ball

There is no shorthand method or engineer's sixth sense that can predict cable condition. The only foolproof method is to unwrap the cable and do sample wire testing, because even bridges with perfectly formed and well-maintained cables surprise inspectors. Weidlinger's experience inspecting bridge cables since 1978 confirms that it is prudent to begin at 30 years or soon thereafter and make sure the inspections are complete enough to determine the type and

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severity of deterioration. Early intervention is always more effective, because the type of protective measures to be implemented, if needed, and the schedule of future inspections can be better tailored to the conditions on a particular bridge. That's late-arriving advice, as most existing suspension bridges have passed the 30-year milestone; because of the costs involved, rare is the bridge inspected before 60 years.

Forth Road Bridge

A recent investigation of the cables on the Forth Road Bridge in Scotland should persuade everyone to rethink the one-size-fits-all, let's-wait-to-the-last-possible-minute approach.

Alastair Andrew, general manager and bridge master of the Forth Road Bridge, first learned about Weidlinger's work during one of many presentations made at national and international conferences. Andrew was impressed enough to think it wise, if overcautious, to inspect his 40-year-old cables. Based on their excellent external condition, he surmised they were "a long, long way from wires breaking" and would pass inspection easily. One of the longest suspension bridges in Europe, the Forth spans 3,300 ft and carries 24 million vehicles a year in four traffic lanes. Its construction in 1964 ended an 800-year history of ferry-boat transport across the Firth of Forth. Weidlinger led the investigation and trained engineers from the UK firm Faber Maunsell in its new standardized technique; testing was conducted by Bodycote, Ltd.

The process began with a cable walk to observe the condition of the wrapping. The cable appeared to be well maintained: There were no visible water leaks, rust stains, or bulges, although the presence of ridges indicated that wires were crossed and susceptible to rust because of the voids they created. Next, a total of ten cable panels were unwrapped. To be economical, several feet of wrapping wire were left in place at one end of each inspected panel, so that only one machine was required for rewrapping. That still left a generous 55 ft per panel for internal inspection. Eight lines of wedges were driven into the center of the cable, and the condition of visible wires was recorded by inspectors. Much to everyone's surprise, broken wires were found to a six-wire depth, as well as a considerable number of corroded wires. Eighty wires were removed and rigorously tested. The wires were graded according to the corrosion stages developed by Hopwood and Havens (1984), from 1 (wire and zinc coating barely oxidizing) to 4 (more than 30% covered with brown rust). The data were used to estimate how many of the 11,618 wires in each cable were in each stage and how many were cracked.

Analysis confirmed that the cable had lost 8% to 10% of its strength. Early estimates before the number of cracked wires was known suggested almost double that loss, based on experience with other bridges. Testing revealed fewer cracked wires than anticipated and confirmed that every bridge is unique in this regard. Cracked wires are the major determinant in calculating cable strength. Unfortunately, cracks are not visible during inspection. When broken wires are found, cracks are likely to exist in unbroken wires; but they only become evident after testing, when the failure surface is inspected under a microscope. When wire sample selection and testing are as rigorously specified to yield consistent and sufficient data as they were on the Forth Road Bridge, it ensures confidence in the conclusion. An owner armed with a statistically clean set of data and a safety factor rating can plan and budget more efficiently. As more inspections take place, a central database of test results would be invaluable to keep track of cable strength results versus age and help engineers estimate future deterioration rates more precisely.

Digging Deeper

One cannot safely predict cable condition from observation alone, nor how much strength loss can be sustained on a particular bridge. There is no rule about permissible strength loss, but a safety factor below 2 spells trouble. Even this number is not absolute when there is careful monitoring. Based on the sobering experience with the Forth Road Bridge, another suspension bridge in Great Britain was inspected and yet another is under consideration. The NCHRP guidelines are also being used to assess cables on the Bear Mountain Bridge in New York, among other spans. MSC

Ronald Mayrbaurl is consulting principal and former director of bridge engineering with Weidlinger Associates in New York. Helen Goddard, also with Weidlinger, edited the NCHRP Guidelines and Report.

Cable Dehumidification

Although early inspection may be controversial, the cure is not. Dehumidification at the early stages of deterioration extends cable life, as does improving the wrapping to prevent water from entering. Acoustic monitoring to detect breaking wires and dehumidification using the Japanese system of dry-air injection for prevention are being implemented on the Forth Road Bridge in Scotland. Both cables should be water-free by late 2009 or early 2010. The bridge continues to be monitored for further wire breaks.

Close-up view of cable corrosion on the Forth Road Bridge.

All Wrapped Up

Here's what's involved in inspecting and repairing the cables for Scotland's Forth Road Bridge.

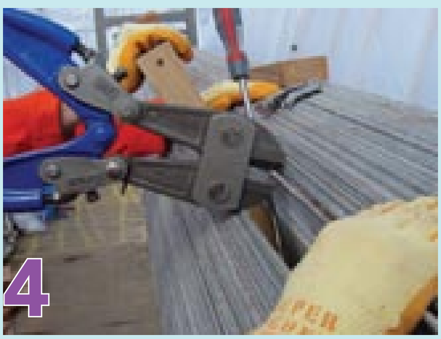
1

The existing wrapping is removed from the cable.

2

3

Wedges are driven into the center of the cable so that they can be inspected.



4

A sample wire is cut and tested.

5

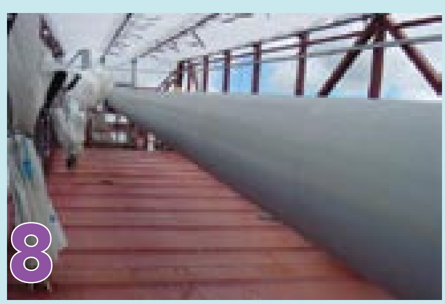
New wires are installed as necessary.

6

The cable is recompacted…

7

…rewrapped…



8

…and repainted.

Making a Statement

BY STEVE HAGUE

Designers blend clean, sweeping lines with creative use of steel to produce a signature span for Ohio's capital.

CIVIC LEADERS THESE DAYS ARE ALL TOO EAGER TO ATTACH THE LABEL "SIGNATURE BRIDGE" TO ANY NEW SPAN THAT ENHANCES THE LOCAL SKYLINE. Other bridge designs, however, deserve the label because they are so bold and innovative that they quickly become synonymous with the city where they were built.

The new Main Street Bridge now under construction across the Scioto River in Columbus, Ohio is in this latter group. Given the opportunity to create a new structure, city leaders wanted a bridge that would support and add value to urban and regional development plans, create desirable public spaces, and ultimately make an unmistakable statement.

In fact, one state transportation official expects the Main Street Bridge to achieve the iconic status of the Brooklyn Bridge or the St. Louis Arch. The dramatic design represents several significant firsts:

- The inclined single-rib arch will be the first of its type in the United States and one of only a handful in the world.
- It will be the first inclined arch—designed or built—tied together with cables and struts.
- It will be the world's first single-inclined arch bridge that incorporates separate pedestrian and vehicular decks.

Meeting a Pressing Need

The Main Street Bridge will link downtown Columbus with the older community of Franklinton to the west. The previous Main Street Bridge, a 70-year-old concrete span that was on the National Register of Historic Places, had deteriorated to the point that the city was forced to close it in 2002. Because the multiple-span, open-spandrel concrete deck arch bridge was an important eastbound artery, Columbus needed an efficient and effective solution for commuters. So, ODOT and the City determined that building a new bridge would be more cost-effective than renovating the existing one.

The diverse group of stakeholders involved in the design process underscores the project's significance to the city. That group includes state and federal transportation officials, city leaders, the Ohio historic preservation office, the Franklin County engineer, developers of a high-rise residential complex near the bridge, the Greater Columbus Arts Council, and the City's Historic Preservation Office. This group agreed on specific design criteria:

- Access for bikes and pedestrians in addition to vehicles.
- Aesthetic and architectural compatibility with the Broad Street Bridge, the primary artery into downtown Columbus, and with the Civic Center Historic District.
- An unobstructed view of the river and skyline for motorists and pedestrians.
- Structural life of 100 years.
- The ability to accommodate the transportation needs of an expected 400,000 new residents over the next two decades.
- A link to the Riverwalk project now under development.
- Accommodation for several area summer festivals.
- Low-maintenance service.

A Design that Works

All of these criteria culminated in what could be called a tall order for the design team. The team developed more than 50 preliminary concepts during a two-day charrette, which were narrowed down to six. At that time, S.N. Pollalis of the Harvard University Graduate School of Design was invited to join the team, and three new design concepts were presented to City officials. By public vote, the inclined arch concept developed by Pollalis was chosen as the preferred option.

A paramount design consideration was the use of clean, classical lines that evoke the city's neighboring arched bridges and art deco buildings. The final design is a single rib-tied steel arch inclined at a 10° angle from vertical. The arch emerges through the bridge deck, and steel hangers descend from the arch to support members below the deck. Unlike traditional tied-arch bridges, stay cables are used for the tie.

The bridge features three vehicle lanes for eastbound traffic, a 5-ft sidewalk on the south side, a steel box girder roadway, a concrete pedestrian path, piers that complement the superstructure design, and a pedestrian deck that sweeps horizontally and vertically away from the roadway to provide an unobstructed view of the city's downtown.

The overall length of the three spans is approximately 660 ft. The main span is 400 ft long, and the spans on each end are 130 ft long. The three-lane vehicular deck is 35 ft wide, and the pedestrian walkway is 18 ft wide. The curved pedestrian bridge is connected to the arch by a series of cables and struts that support the structure.

Committed to Steel

The design team was committed to using steel, in large part because of budget constraints (overall cost is $42 million); although the location and structure type determined materials to some degree, cost was the overriding decision point.

Designers originally selected concrete to achieve the pure, smooth lines the project required. They later decided they could attain the same look with steel, which would be lighter and easier to fabricate, and take less time to construct. The use of box girders under the roadway achieves the same clean look as concrete. Designers and engineers also recognized that steel would require a shorter erection time, which would reduce the length of time the temporary supports were exposed to flooding risk.

The creative use of steel solved several engineering challenges. For example, designers switched from concrete to steel boxes to support the road deck and enable it to span the river more safely. Using steel also lightened the bridge load and allowed the removal of composite concrete that originally was going to be put in the arch.

Nearly 3,000 tons of ASTM A709 Grade 50 steel will be used during construction. The general contractor ordered

The new Main Street Bridge in Columbus will be completed in 2009.

steel when the old Main Street Bridge was removed last fall, and fabrication was expected to take about one year. Because the bridge is being built in a heavily developed area, the logistics of shipping fabricated parts required careful planning.

As soon as foundation and substructure work is completed, contractors will build temporary towers along the roadway box girder to support construction of the vehicular steel box and the arch. After these are completed, workers will install floor beams to support the pedestrian deck on the north side and the permanent struts and hangers for the arch. Finally, the contractor will build the pedestrian and bridge decks before removing the towers.

A Strong Statement

Building a bridge that meets the needs of diverse stakeholders is always a challenge. Making an architectural statement that will define the city's skyline for the next century takes the challenge to an even higher level. The Main Street Bridge is on track to meet this challege when it opens in 2009. MSC

Steve Hague is chief structural engineer for HNTB Corporation's Kansas City Bridge Group and the firm's project manager for the Main Street Bridge.

Owner
Ohio Department of Transportation

Design
DLZ Ohio, Inc., Columbus
HNTB Ohio, Inc., Columbus

Project Architect
Dr. S.N. Pollalis, Harvard University Graduate School of Design, Cambridge, Mass.

General Contractor
Kokosing Construction Co., Inc., Fredericktown, Ohio

Erection Engineer
Janssen & Spaans, Indianapolis, Ind. (AISC Member)

Steel Detailer
Tensor Engineering, Indian Harbour Beach, Fla. (AISC Member)

Steel Fabricator
PDM Bridge LLC, Eau Claire, Wis. (AISC Member)

Main Street Bridge by the Numbers

- 42 million – project budget in dollars
- 1937 – year original bridge was built
- 100 – years new bridge is designed to last
- 10 – degrees of angle from vertical of the rib-tied arch
- 5 – width in feet of sidewalk on south side
- 18 – width in feet of pedestrian deck
- 660 – overall length in feet of three spans
- 400 – length in feet of main span
- 130 – length in feet of end spans
- 35 – width in feet of vehicular deck
- 3,000 – tons of ASTM A709 Grade 50 steel that will be used

The Other Side of the Tracks

SUBMITTED BY HDR ENGINEERING, INC.

A new viaduct provides motorists with an alternate route over multiple tracks in a western Iowa railroad town.

THE ORIGINAL STARTING POINT FOR THE TRANSCONTINENTAL RAILROAD, COUNCIL BLUFFS, IOWA, HAS TRULY BECOME A RAILROAD TOWN. The presence of multiple railroad companies in the city divides the community physically with tracks dissecting it in both the east-west and north-south directions.

This creates some life safety issues in the event that the only east-west railroad overpass becomes blocked or closed for any reason. It therefore became a priority for the city to construct a second viaduct over tracks of the Union Pacific (UP) Railroad and the Chicago Central and Pacific (CCP) Railroad.

The chosen location for the new railroad overpass is north of the primary central business district on an arterial route, the Avenue G corridor, through a primarily residential area of Council Bluffs. As Avenue G crosses the two railroad companies' tracks, it is also flanked by various industrial buildings and a school. The locations of these facilities, as well as numerous primary utilities in the tight Avenue G corridor, eventually led to a partially offset alignment for the overpass. To provide adequate offset to the adjoining buildings, the alignment of the bridge structure required reverse curvature.

Smooth Curves

The Avenue G Viaduct project incorporates a four-lane cross-section in its 54-ft clear roadway and includes a 10-ft wide trail on the south side. The 1,290-ft long bridge crosses two city streets, a three-track cluster of the CCP Railroad, two yard tracks and a proposed future yard track of the UP, and a separate five-track cluster of the UP. This five-track cluster includes the UP's two mainline tracks, an industrial lead track, and two additional yard tracks. The curving bridge alignment also passes within approximately 10 ft of an existing brick railroad maintenance building that was formerly a UP roundhouse, and within approximately 15 ft of an industrial building housing a furniture manufacturing facility. To minimize the required bridge length, the abutments at each end of the bridge are situated behind mechanically stabilized earth (MSE) walls.

Preliminary design of the viaduct presented several challenges including:

- Consideration of steel plate girder and prestressed concrete beam superstructures.
- Detailed cost estimates for each superstructure type.
- Minimization of MSE wall heights at the abutments because of settlement and stability constraints stemming from poor geotechnical conditions.
- Accommodation of the reversed curve alignment.
- Minimization of the required utility relocations for bridge substructures.
- Accommodation of vertical and lateral clearances to adjacent railroad tracks and city streets.

In addition, because of the curving bridge alignment, there was also a preference for providing constant bridge deck overhang widths and having the fascia of bridge girders follow the curved

The proximity of the bridge to adjacent industrial structures required a reverse-curve alignment.

alignment of the bridge rather than using chorded girders.

Decision Time

When weighing steel plate girder against concrete prestressed concrete beam alternatives, both standard Iowa Department of Transportation (IaDOT) bulb-T prestressed concrete beams and IaDOT's newer metric bulb-T beams were considered. These inventories of prestressed beams allowed a maximum span of approximately 140 ft using IaDOT's design criteria for providing structures that are considered continuous for live load. The prestressed beam structure type would have required a 12-span structure, given the constraints of pier placement that resulted from the locations of existing roads and railroad tracks. The limitation on the maximum span length also would have placed one pier within a 25-ft clearance envelope of a proposed future track for the UP. This constraint would have required approval from the UP as well as the addition of a crash wall to protect the pier. Furthermore, the reversed curve alignment would have prevented the desired uniformity in casting lengths for prestressed girders in a given span, which promotes efficiencies in this type of structure.

The steel plate girder structure type, on the other hand, would allow for longer span lengths of up to 180 ft within the same structure depth as required for the standard prestressed concrete bulb-T beams. These longer span lengths would provide a particular advantage for this bridge, considering the locations of the existing streets and railroad tracks. As a result, the steel plate girder option would require only an eight-span structure, thus saving three pier elements throughout the length of the bridge. Because the alignment of the bridge is on a reversed curve, the sweeping alignment crossed over the center line of the existing Avenue G corridor. This sweeping alignment would wreak havoc with the existing utility facilities in the corridor. Consequently, a reduction in the number of piers also translated into fewer utility conflicts.

Early On

IaDOT typically does not take alternate steel girder and prestressed beam bridge designs all the way through final design and letting. The agency's normal practice is to evaluate the different structure types in the preliminary design stage and to make a decision on the structure type at the conclusion of this design. Therefore, a detailed quantity and cost estimate was prepared for each alternative at the preliminary design stage. Substructure dimensions were estimated, and reinforcing densities were assumed based on past projects utilizing similar multi-column bents and abutment types. The number of piles per substructure element and pile lengths were also estimated. The number of girder lines could be determined and the structural steel quantities could be estimated based on preliminary girder designs for both the steel and prestressed beam alternatives. The bridge deck concrete quantities could be determined based on the assumed bridge cross section, and deck reinforcing quantities were estimated based on deck reinforcing densities from similar IaDOT projects. Finally, recent IaDOT average bid tab unit prices were applied to the appropriate quantities to establish base estimates for the steel girder and the prestressed concrete beam alternatives. These detailed estimates indicated that the steel alternative was slightly (approximately 2%) less expensive than the concrete alternative.

Because the cost estimates of the two structure types were very close, a decision matrix was also prepared to compare various parameters. The matrix indicated the advantages and disadvantages of the steel girder and prestressed concrete beam alternatives.

After consideration of the expected cost and functional advantages of the steel girder alternative, a decision was made to proceed with steel. The contract was awarded with an in-place bid price for fabricated structural steel of $1.13 per lb, which closely matched the unit price estimated in preliminary design. With an expected opening by late November of this year, the Avenue G Viaduct will provide a welcome alternative route over the tracks for Council Bluffs residents. MSC

Owner
The City of Council Bluffs, Iowa

Bridge Design
HDR Engineering, Inc., Omaha, Neb. (Subconsultant to HGM Associates, Inc., Council Bluffs)

Project Architect
RDG Planning & Design, Des Moines

General Contractor
Cramer & Associates, Des Moines

Steel Fabricator
PDM Bridge Wausau, Wis. (NSBA Member)

Engineering Software
STLBRIDGE, Bridgesoft, Inc.

Comparison Matrix of Steel and Prestressed Concrete Bridge Alternatives

	Advantages	Disadvantages
Steel Girder	✓ Slight cost advantage ✓ Longer spans/increased lateral railroad clearances ✓ Fewer piers/fewer potential utility conflicts ✓ Fewer pier footings next to UP roundhouse ✓ All piers outside of desirable 25-ft railroad clearance ✓ Better overall aesthetics (no chorded girders)	✗ Generally longer lead time on girder fabrication ✗ More field pieces to erect ✗ Potential staining of piers from weathering steel
Prestressed Beam	✓ Improved speed of erection ✓ Faster fabrication/delivery turnaround	✗ Slight cost disadvantage ✗ Chorded girders not as aesthetic ✗ Variable slab overhang more difficult to form ✗ Piers on both sides of UP mainline less than 25 ft clear ✗ More piers/more potential utility conflicts ✗ Span limitation doesn't allow for future UP railroad track ✗ Variation of beam lengths in curved sections