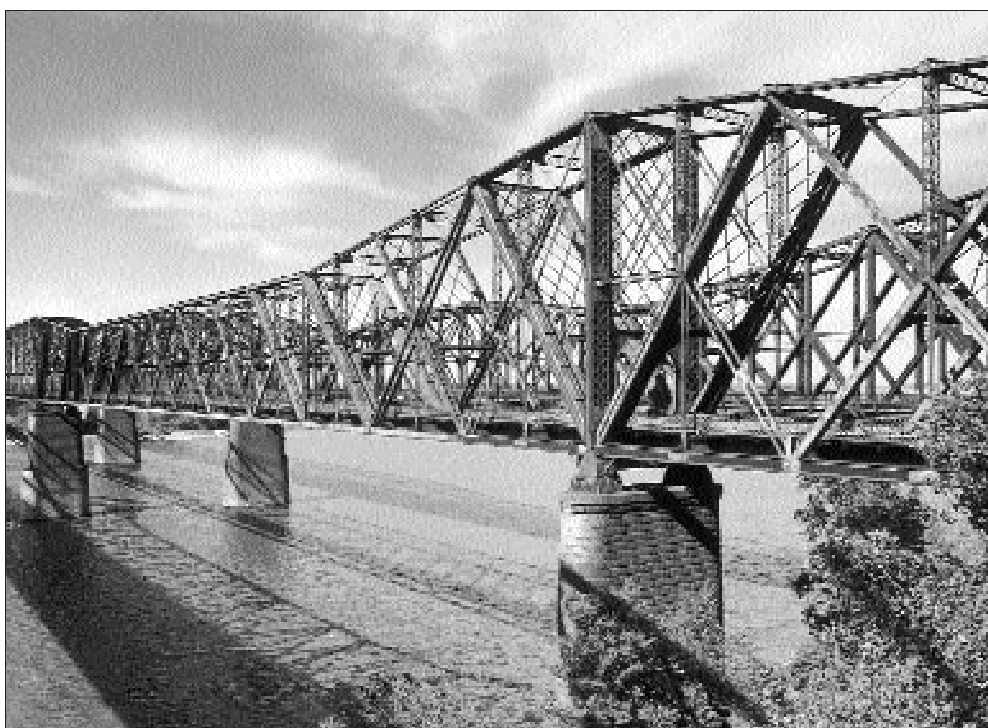
INSIGHT™
ISSUE NO. 11

A technical newsletter by Raths, Raths & Johnson, Inc. for the construction industry.

"Insight: to see into and understand; an item of knowledge gained by this power."

This issue of *RRJ Insight,* highlights two examples of RRJ's work on bridges. Both articles demonstrate additional facets of RRJ's expertise, and our methods for combining field testing with analytical techniques to solve unusual problems. This issue's *Project Profile* discusses a diagnostic field testing program implemented to evaluate the floor system and main trusses of an historic Mississippi river crossing. *Testing News* provides a brief description of how vertical lift bridges work, and RRJ's approach to balancing these immense structures.

INSIDE



RRJ evaluated the floor system and main trusses of this historic Mississippi River bridge.

Project Profile

Field Testing of the 1892 Memphis Bridge

RRJ was retained by the Burlington Northern Santa Fe Railway (BNSF) to plan and conduct a diagnostic field testing program on the Memphis Bridge in order to measure and evaluate behavior of the bridge's floor system and main trusses. In particular, they were interested in **heavy freight train loading capacities using unit coal trains and also loadings created by a special new type of coal train, the "Trough Train,"** designed to transport more coal in a shorter train length (Figure 1). The Trough Train eliminates most of the open spaces between car ends, resulting in more material hauled per unit foot of train and consequently more train load carried by the bridge. Prior to testing, this significant load increase was questionable for the 107 year old bridge.

The Memphis Bridge was the first bridge built over the "real" Mississippi River and is still in use today. Construction took place from 1888 to 1892 at Memphis, Tennessee, 232 miles south of the confluence of the Mississippi and Ohio Rivers at Cairo, Illinois (hence the term "real"). Although the bridge was to be owned, operated and built by a railway company, an Act of Congress was required to approve construction. The Act required provisions be made for "passage of wagons and vehicles of all kinds, (and) for the transit of animals." It also set the minimum size requirements of a 770 foot main-channel clear span and a height above high water of 75 feet. A very large steel bridge, 4,989 feet long, was designed that included four main cantilever through-truss spans, one deck truss span, and girder trestle approach spans.

Today, the Memphis Bridge is used and maintained by the BNSF and stands between two newer bridges — the Union Pacific Railroad bridge on the north side and the Interstate I-55 highway bridge on the south side (see cover photograph). The bridge presently carries a single open-deck railroad track and maintenance walkways. It was designated as an "ASCE National Historic Civil Engineering Landmark" in 1967.

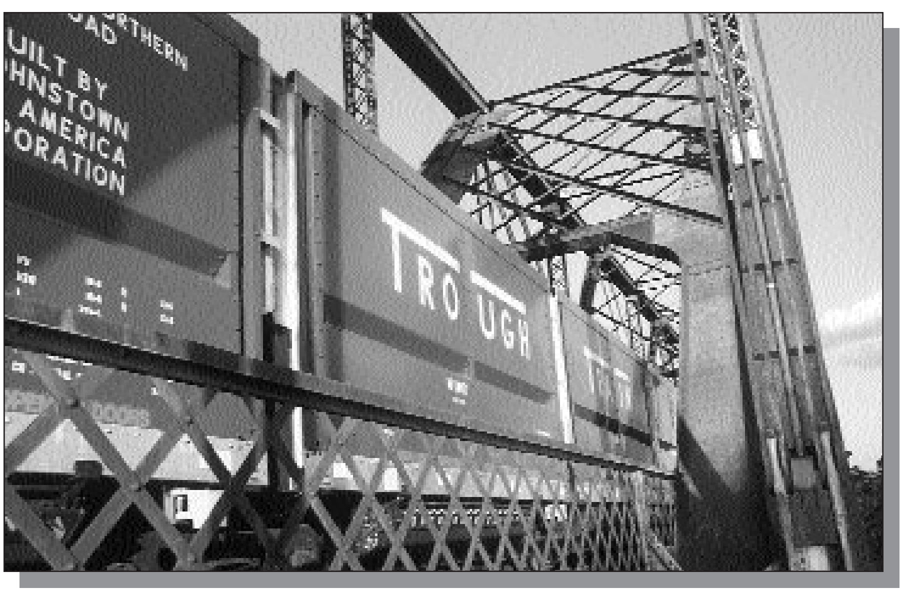


Figure 1 - View of East Main Span of the Memphis Bridge.

With assistance from the BNSF, RRJ developed a testing program for the bridge floor system consisting of 27 electrical resistance strain gages mounted on selected representative sections of the repetitive floor system framing. **Care was taken to plan enough gages within the test area to understand and verify measured stresses at critical locations by accounting for and measuring structural effects such as end connection continuity and out-of-plane bending.** Test data were dynamically recorded at digital sampling rates of up to 500 samples per second per strain gage in order to capture dynamic effects ("impact") of the moving train engines and cars.

A testing program was also developed to evaluate actual behavior of representative critical members (carry the highest loads) of the main span trusses using a total of 30 strain gages (Figure 2). The test members selected included multiple eyebar members as well as large built-up box sections which required RRJ's engineer and technician to climb inside them to install the strain gages (Figure 3).

(Continued on page 5)

Testing News

Evaluating Lift Bridge Imbalance

Vertical lift bridges are a river crossing mainstay in congested urban areas. They allow railroads and commercial navigation to peacefully coexist by reducing required rail approach heights while simultaneously providing a clear channel for ship and barge traffic. (Low approach heights reduce bridge costs and enhance a railroad's ability to service waterfront customers.) **This feat is accomplished by lifting up the entire over-water portion of the bridge for ships to pass, and then lowering it back down to track level to allow trains to cross.**

The movable portion of the bridge over the water is known as the lift span (refer to Figure A). Raising of the lift span is accomplished through a series of electric motors, reduction gears, drive shafts, hoist drums, cables, pulleys, and counterweights similar to those used for building elevators, but *much* larger. The lift operation is controlled by a bridge tender from a control panel in the machinery house, which is typically located on the top of the lift span, positioned over the bridge railroad tracks.

Hoist motor size is minimized by balancing the weight of the lift span with massive concrete counter-weights suspended from fixed support towers (Figure B). When properly balanced, the motors need only provide enough force to overcome bearing, cable, and span guide friction

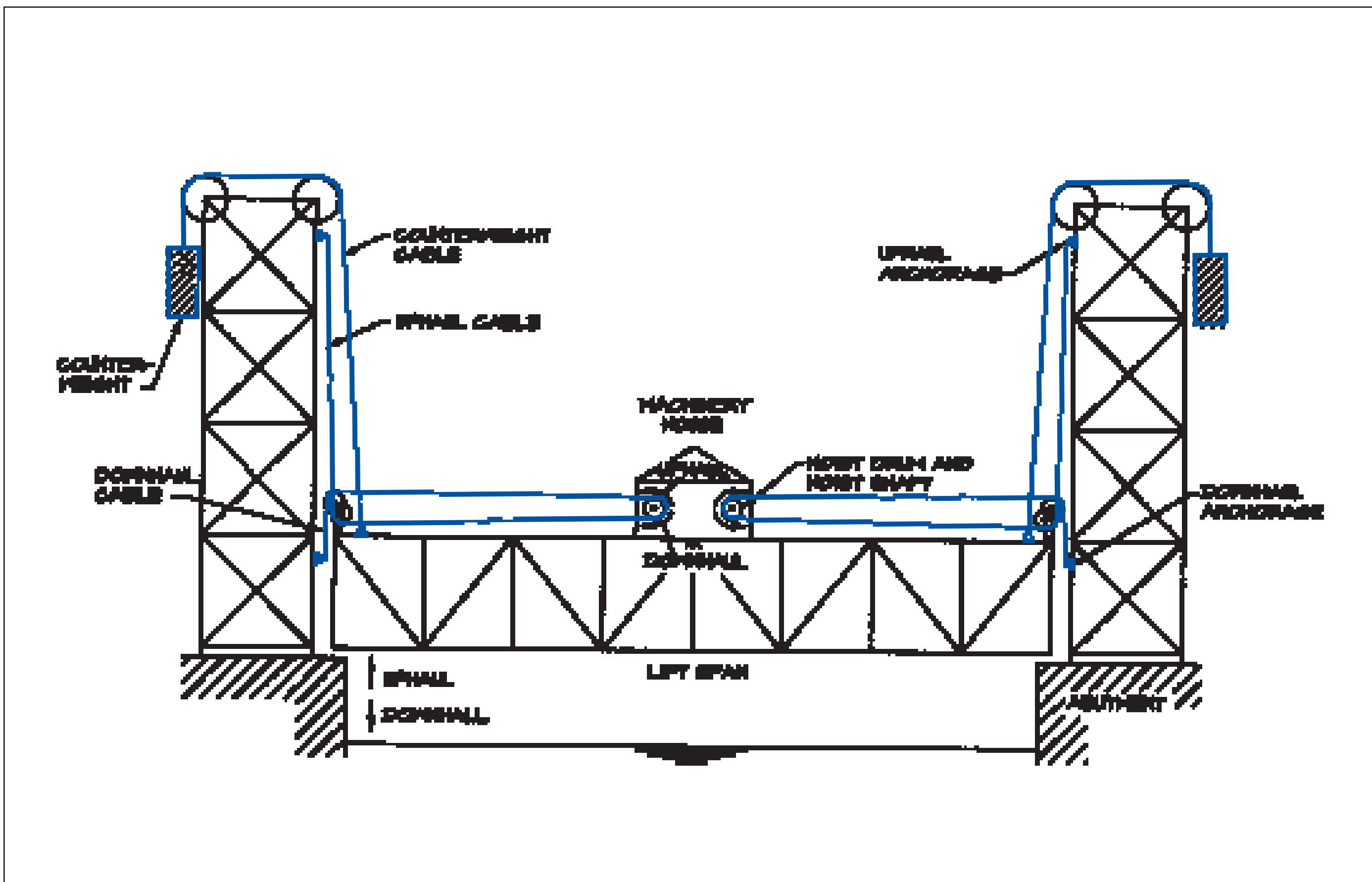


Figure A - Schematic View of a Typical Lift Bridge.

(Continued from page 3)

(greased guides keep the lift span from swaying when not locked in the lowered position). Bridge imbalance occurs when the lift span and counterweights are mismatched, with either item being too heavy.

During a recent bridge refurbishment, RRJ was retained to evaluate imbalance of a Chicago area lift bridge owned by Conrail. Our approach was to use the four hoist drum drive shafts (two on each side of the bridge) as torsional load cells. Each drive shaft was instrumented with two pairs of bonded electric resistance strain gages to measure torsional shear strains while automatically correcting for undesirable bending and beam shear effects. Dynamic data acquisition recordings of shaft torque measured at 50 samples per second during bridge lifting and lowering (uphaul and downhaul, respectively) were used to calculate the degree of imbalance, as well as the amount of friction present. **RRJ's test data indicated the bridge was overly span heavy, and that friction exceeded the amount of imbalance** (the bridge had to be pulled closed). Final adjustments included adding 9,000 pounds to each counterweight to reduce the imbalance level while maintaining a safe, slightly span-heavy state.

– Kurt R. Hoigard, P.E.

Figure B – Two adjacent lift bridges, one with span raised and one with span lowered. Note the large concrete counterweight.

RRJ Bridge Testing Services

RRJ offers state-of-the-art capabilities pertaining to strength evaluation and condition assessment rating of old and deteriorated structures. The specialized bridge evlaution services offered by RRJ include:

- Field Inspection and Condition Surveys
- Nondestructive Testing, Instrumentation and Measurements
- Full-Scale Load Tests
- Fatigue Evaluation
- Laboratory Material Testing
- Dynamic Response Tests
- Structural Analysis
- Load Rating Evaluation
- Repair Design

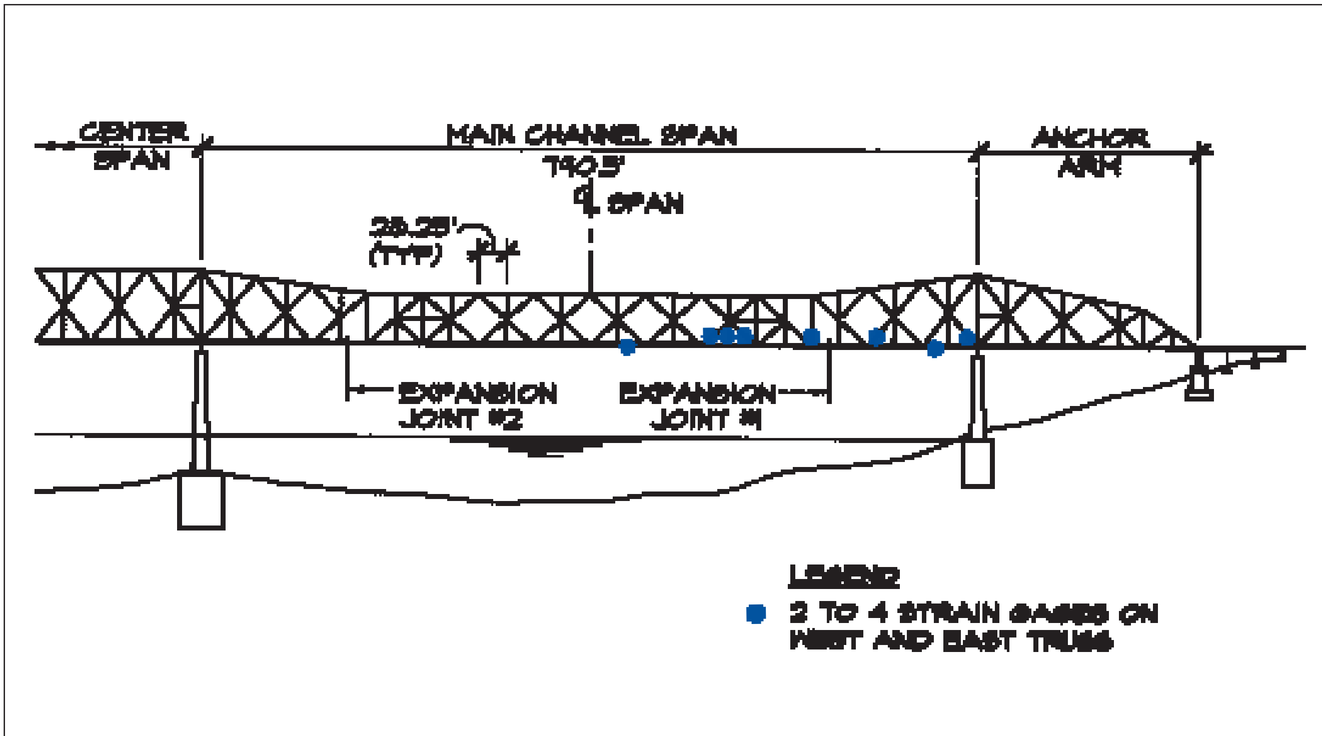


Figure 2 - Main Channel Span.

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Strain gage locations were selected to measure and allow evaluation of secondary bending and load sharing effects for each truss member tested. A digital sampling rate of 25 samples per second was used to evaluate individual member behavior and a rate of 200 samples per second was used to measure maximum stresses including moving train dynamic effects ("impact"). RRJ also analyzed the main trusses in order to compare field-measured stresses with calculated values.

This field testing program provided the BNSF Railway with enhanced stress level accuracy and reliability based on actual bridge behavior under heavy train loadings, than was possible with analytical methods alone. Testing accounted for the complex interaction between the large bridge truss members, the bridge floor framing members, secondary bracing members, including all the end connections acting as a three-dimensional "system." **The field testing program also provided reliable and accurate data (stress ranges) for fatigue evaluation and calculated fatigue life of the affected components of this bridge.** The knowledge obtained from this field testing program helped the BNSF Railway optimize maintenance of this great bridge, which is still functioning as an important transportation link 107 years after its construction...although no horse traffic is allowed today!

– Robert W. Kritzler, S.E., P.E.

Figure 3 - Technician Installing Strain Gages.

Professional Services

<u>Design</u>

Structural
Restoration
Renovation
Architectural
Curtain Wall Redesign
Historical Preservation
Material Failure Redesign

<u>Investigation</u>

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Failure/Collapse
Tolerance Evaluation
Cladding Performance
Expert Witness Service
Material Evaluations
Specification Conformance

<u>Testing</u>

Onsite Testing
Instrumentation
Laboratory Testing
Material Properties
Performance Analysis
Full Scale Load Testing
Manufactured Products

<u>Client Services</u>

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Dispute Resolution
Courtroom Exhibits
Document Reviews
Job History Reconstruction
Cause/Fault Determination
Litigation Support

RRJ is available to help you with any questions you may have regarding our services or a specific article in our newsletter.
For additional information call:

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