conference preview

FUTURE FABRICATION

Advancing the state-of-the-art in steel bridge fabrication.

BY PAUL FUCHS, PH.D., AND RONNIE MEDLOCK, P.E.

WHAT DOES THE FUTURE hold for bridge fabrication? Virtual assembly and phased array ultrasonic testing are certainly part of the picture. The first can eliminate bridge assembly steps while the second involves a technology that came to prominence in the medical field. Both can prove beneficial to steel bridge projects.

Space Saver

To better understand the advantages of the first concept, virtual bridge assembly, it's a good idea to review the current fabrication practice for splice connections, which involves a match-drilling process. A pair of girders to be joined with a splice are laid on their sides and manually aligned based on a string-line reference placed on the shop floor. Once aligned, splice plates with full-sized holes already in the plates are clamped to the girder pair and used as a template to match-drill the holes in both girders. This process is used to make sure that all holes are in alignment and has the benefit of guaranteed hole alignment; however, it is very time-consuming and expensive. Some estimates put the cost of this step at 15% to 20% of the cost of a steel bridge. In addition, match-drilling holes at the end of the fabrication process typically requires inefficient drilling operations or expensive drilling equipment. Depending on the shop, the lay-down area may require one-third to half of the floor space of the entire shop. Girders are laid on their sides and set end to end, taking up several hundred feet of space. Curved girders, when set on their sides, need to be appropriately blocked and can be even more difficult to work with as they extend high off the shop floor.

Paul Fuchs (paul.fuchs@fuchsconsultinginc.com) is the president of Fuchs Consulting, Inc., a consulting business he has operated for more than 14 years. **Ronnie Medlock** (rmedlock@high.net) is vice president of technical services at High Steel Structures in Lancaster, Pa. (AISC member/AISC certified fabricator/NSBA member). He is also a member of the AWS D1 Structural Welding Committee and the joint AASHTO/AWS D1.5 Bridge Welding Code subcommittee.

However, by piecing together individually measured girders virtually, the need to physically lay down, align and match-drill spliced pairs can be completely eliminated. Fuchs Consulting, Inc., has delved into this concept and developed BRIDGE VAS (Virtual Assembly System), which measures key aspects of completely fabricated bridge girders and virtually assembles multiple girders by designing custom splice plates to fit the girders together. The system uses a noncontact 3D coordinate measurement system that measures key aspects of a completely fabricated girder, stores measurements as a permanent record and combines these measurements with measurements from other girders to create a virtual assembly. The girders are fabricated with full-sized splice holes and are then measured in the standing position. Software tools interface with existing shop processes, existing 2D shop drawings are automatically converted to 3D CAD models, data is automatically processed and splice plate design files are sent directly to CNC drilling machines.

Accurate and Automated

BRIDGE VAS can virtually manipulate and align girders and produce a combined camber diagram of a girder pair. Based on the virtual fit-up, it can output custom-designed splice plates and any number of girders can be virtually assembled. Not only can multiple girders in a line be virtually assembled, but multiple lines can be virtually assembled; the system also eliminates the need to bring girders that are fabricated at different facilities physically together at one location. Plus, floor space previously dedicated to match-drilling can be reused for other purposes.

In addition, the system provides substantially more documentation than currently exists, as well as access to types of information that are not available under the traditional process. Conventional measurements are based on string lines, rulers and tape measures. Most records are kept on paper, with handmade notes made on the shop floor. BRIDGE VAS replaces these subjective, limited methods with a full digital record, providing full documentation of what is fabricated. This digital record is certifiable and traceable and can be used to fully document the as-built girder at the fabrication shop, and customized reports can be automatically generated. The system measures all key aspects of a girder—length, camber, sweep, stiffener locations and web panel distortions—and provides immediate feedback of fabrication errors in real time, with actual measurements overlaid on a shop drawing-based model. All girder measurements are made directly on the girder surface, with no special targets or markers, eliminating the need for an operator to manually make any measurements. The system software is flexible and can generate customizable reports and output standardized CAD files.

Perhaps the biggest benefit of the system is its versatility. The system does not require the significant setup and maintenance expenses of a gantry system or a customized measurement room.

BRIDGE VAS measures fully fabricated girders in the standing position (left) and replaces conventional match-drilling and girder lay-down (right).

Instead, it works in virtually any shop, requiring only an open area of shop floor. Minimal changes are required to an existing shop and the system interfaces with existing processes (from converting 2D shop drawings to 3D models to direct output to CNC drilling equipment). And it can measure all girders, from more standard straight and curved plate girders to complex tubs or boxes. The system is designed to work in and around all normal shop processes (welding, grinding, drilling, etc.) and can work with the dust, debris and vibrations typically encountered.

BRIDGE VAS was recently implemented on a job for the State of Tennessee (fabricated by AISC member Hirschfeld Industries—Bridge). This is the first time that a virtual assembly system has been used in a production setting to design custom splice plates and the first time entire lines of girders have been measured, demonstrating that very large, complex girders can be virtually assembled and that the system can be implemented in a typical steel bridge fabrication shop. The Tennessee structure is currently being erected; a second bridge project (in Virginia) that will use the system is being planned as well.

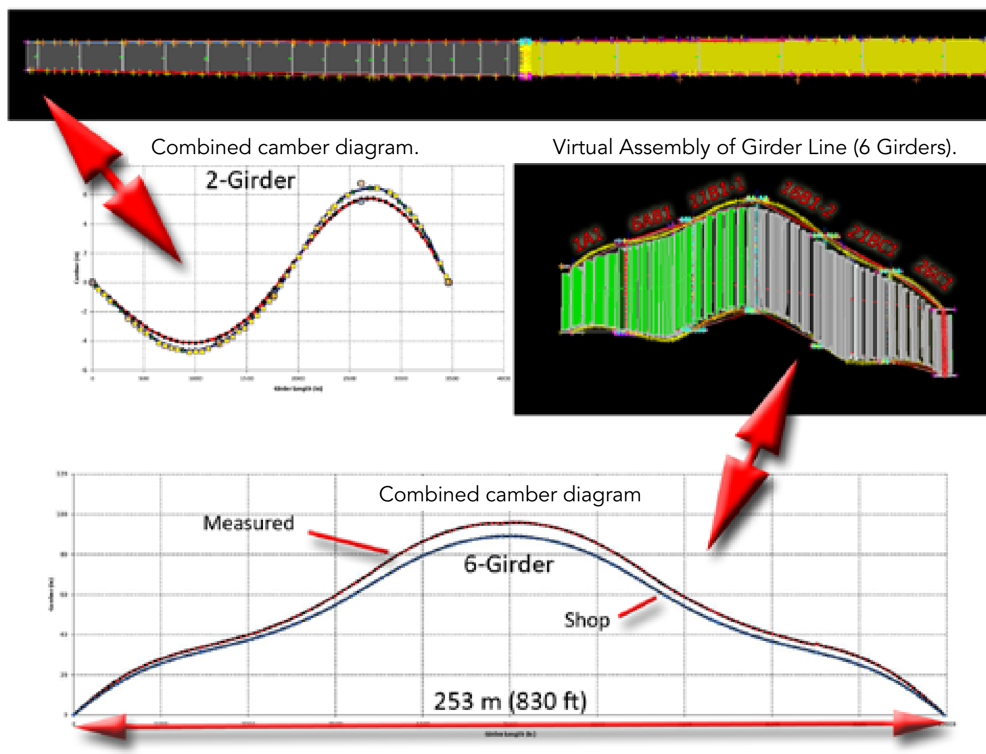
A New Ultrasonic Option

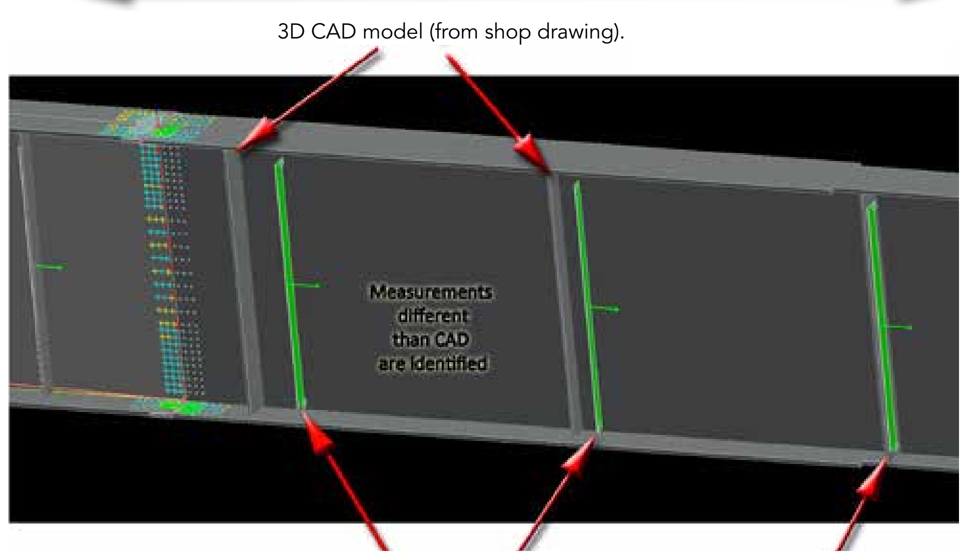
While BRIDGE VAS works to improved assembly efficiency and provides vastly improved documentation, a second emerging bridge fabrication technology focuses on testing efficiency.

Traditional ultrasonic testing (UT) has been used for quality assurance testing of complete joint penetration (CJP) bridge welds for many decades with little change to the technique. However, another type of ultrasonic testing, phased array ultrasonic testing (PAUT), has emerged as a viable option for bridge fabrication.

PAUT has been used in the medical field for many years, including for imaging of internal organs, measuring heart wall thickness and, coupled with Doppler techniques, examining blood flow through heart valves. It uses an array of ultrasonic transducers mounted

Virtual assembly of a girder pair and an entire girder line (six girders).





The BRIDGE VAS software automatically identifies fabrication errors in real time, with actual measurements superimposed on a 3D CAD model.

on a single probe. The transducers provide scanning at a range of angles, allowing a broad scan and increasing the likelihood that sound will be normal to the plane of the defect.

While PAUT is seen as a mature technology in the medical world, it is in its infancy when it comes to bridge fabrication. But its benefits over traditional UT in fabrication—better test documentation, faster testing and improved accuracy—have been recognized and efforts are now underway to bring it to the shop floor there.

Volumetric (through thickness) testing of flange and web butt splices is customary and expected in steel bridge fabrication. Most steel bridges comprise steel I-girder erection pieces that are about 100 ft to 150 ft long and about 5 ft to 10 ft deep, with two to four butt welded splices in each flange and one to two butt splices in each web. The AASHTO/AWS *Bridge Welding Code* (D1.5) requires significant testing of these splices, including:

- 100% of flange tension or stress reversal splices, with either radiography (RT) or UT
- 100% of fracture critical flange splices, with both RT and UT
- Roughly 30% to 40% (depending on girder depth) of web tension or stress reversal splices
- 25% of compression web and flange splices.

Further, additional testing is required if defects are discovered, and all CJPs accomplished by electro-slag welding must be tested by UT and RT, whether they are in tension and compression. The testing adds good value because it helps ensure that bridges are safe and durable. However, it is costly and time-consuming, so fundamental test method improvements have a significant impact on fabrication costs and cycle time.

Better Test Documentation

The improved documentation offered by PAUT will increase acceptance of UT testing in lieu of RT testing for many bridge owners, thus improving both testing and throughput in the shop. The *Bridge Welding Code* allows either RT or UT for butt splice testing. Many owners prefer and required RT, though others prefer UT because it is much less costly and intrusive to the shop and fabrication workflow than RT (RT requires stand-off for safety for radiation and access to the weld is needed from both sides) and does not require film and processing chemicals, which are expensive.

However, RT test results are read on a medium that also becomes the permanent test record: the RT film. Conversely, traditional UT results can only be read in real time; the inspector finds defects by measuring sound loss of a discrete wave at a given time that he reads on an oscilloscope, and he documents his findings with notations as he proceeds, usually on paper.

Faced with the choice of seeing an actual indication on physical RT film versus documented test results in a UT report, many owners opt for RT. PAUT offers the ability to characterize flaws in multiple dimensions, unlike just one dimension for RT, yet can produce a permanent record format that can be visualized like RT. PAUT can be paired with encoding to capture results as the test is accomplished, and this encoding can be played back at any time to revisit the actual test results. Further, PAUT can generate images of the welds as they are tested, so images of sections with defects can be captured and stored permanently, ready for reconsideration at any time. Thus, implementation of PAUT can significantly reduce RT testing for owners who would like to make the switch from RT to UT but are looking for better test documentation. The data from PAUT can provide a view perpendicular to the plate surface that provides a graphical representation of flaw length and height.

Faster Testing

Generally, ultrasonic testing, whether traditional or PAUT, is faster than RT, so if PAUT facilitates a switch from RT to UT, this will make testing faster. Further, PAUT is faster than traditional UT.

Three factors add considerable time to traditional UT, and PAUT successfully addresses each of them (see table at right).

Faster testing leads to reduced impact on workflow and less testing time, resulting in lower steel bridge costs and improved delivery, and the improved sizing capability and accuracy of PAUT also result in time savings.

Factor	Traditional UT	PAUT
Scrubbing	The probe must scrub back and forth to get the testing sound through the complete section of the weld.	The probe makes one single swipe along the length of the weld at the scan index line.
Raster scanning	If an indication is discovered, the inspector must raster the probe to direct sound from many angles until the angle of maximum impact is established.	Does not lend itself to raster scanning, but acceptance criteria based on the amount and quality of the test data from PAUT may be defined without this technique.
Inspection angles	Sound can only be delivered from one angle at a time, so testing at multiple angles requires testing multiple times; each angle must be tested on its own.	With sectorial scans, dozens of angles are considered at once.

Finding Flaws

Phased array UT provides superior results in flaw location and characterization over traditional UT. For general purposes, the level of accuracy achieved with traditional UT is sufficient; the D1.5 criteria are pass fail and UT testing simply needs to establish whether or not the joint passes. But better flaw characterization will help fabricators accomplish repairs. Excavating a failed joint takes time, and the better information fabricators have about flaws, the more efficiently and expeditiously the flaws can be addressed. With PAUT, the scan index points are targeted to cover the entire weld section between the angles of 45° and 70° and, using encoded PAUT, the ambiguity of reporting the exact location of flaws that often occurs in traditional UT is eliminated. Further, while it is not current practice, the

VAS measuring a girder in a fabrication shop.

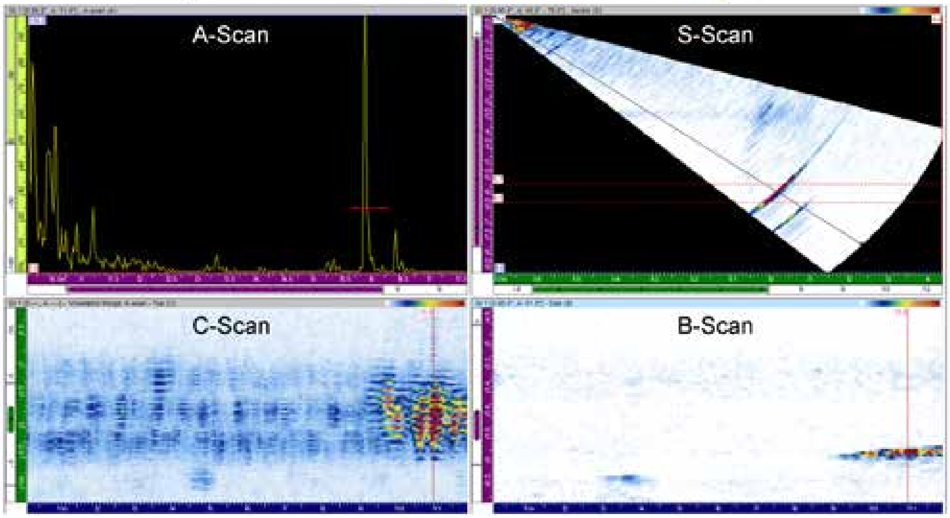
Phased array ultrasonic testing is conducted by passing a probe parallel to the weld with one single swipe along the scan index line.

enhanced flaw characterization of PAUT has the ability to unlock fitness-for-service evaluations of flaws, which would allow educated decisions to be made about whether or not repairs need to be made based on the actual performance demand of the joint. Also, PAUT can converge (focus) or diverge (bend) sound by controlled time-delay firing of the sensor, allowing access to locations that are otherwise difficult to reach.

Path to the Future

Efforts are underway to bring PAUT to the mainstream of bridge fabrication. Already, the committee responsible for the AWS D1.1 - *Structural Welding Code* has developed language that is under ballot to incorporate PAUT. The same will be done for AWS D1.5, with a slant towards bridge fabrication needs. Key issues to address include acceptance criteria and qualification requirements. Though it is possible to use traditional UT acceptance criteria for PAUT, doing so will not take advantage of the method. One possibility is to base acceptance on RT criteria; another approach might to conduct initial testing with PAUT and then explore and accept defects using traditional UT. These questions need to be addressed to advance the bridge fabrication state-of-the-art with PAUT. MSC

This article serves as a preview of Session B5 at NASCC: The Steel Conference, taking place April 17–19 in St. Louis. Learn more about the conference at www.aisc.org/nascc.



As this single examination shows, PAUT significantly enhances weld examinations with reduced effort.