Computer Integrated Steel Bridge Design and Construction

Expanding Automation

FINAL REPORT

Mission
Establish a roadmap for integrating steel bridge design through-construction processes and for advancing the state-of-the-practice in steel bridge manufacturing automation and productivity

April 23-25, 2001
at Edison Welding Institute
1250 Arthur E. Adams Dr.
Columbus, OH 43221

Sponsors

Federal Highway Administration
American Association of State Highway and Transportation Officials
National Steel Bridge Alliance
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NOTICE

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Computer Integrated Steel Bridge Design and Construction: Expanding Automation

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Acknowledgments

The Workshop, "Computer Integrated Steel Bridge Design and Construction - Enhancing Automation", was jointly sponsored by the Federal Highway Administration (FHWA) of the U.S. Department of Transportation and the National Steel Bridge Alliance (NSBA). It was cosponsored by the American Association of State Highway and Transportation Officials (AASHTO), Edison Welding Institute (EWI) and National Institute of Standards and Technology (NIST).

Following individuals served on the Workshop Steering Committee:

- Krishna Verma, Federal Highway Administration
- Arun Shirole', National Steel Bridge Alliance
- Robert Kratzenberg, Edison Welding Institute
- Thomas Siewert, National Institute of Standards and Technology
- Stuart Chen, State University of New York (SUNY) at Buffalo
- Theodore Ferragut, TDC Partners

Preface

You hold in your hands the report of a unique workshop on Automation in Steel Bridge Design and Construction. Participants in this workshop represented diverse constituencies: the public sector (owners), fabricators, academics, software developers, and the Edison Welding Institute (EWI). This workshop is believed to be the first of its kind anywhere. The report provides a glimpse of both the excitement and the challenges facing us in utilizing the benefits of automation for producing steel bridges of the highest quality and value and to do so more expeditiously and more economically.

The report represents the snapshot in time when the workshop was held in April 2001. Since then, several initiatives have been undertaken. These initiatives include the following:

1. An NCHRP funded study has been initiated on "Evaluation of 3D Computer Modeling and Electronic Information Transfer for Efficient Design and Construction of Steel Bridges." The objective of this study is twofold: (i) Review and synthesize available technical information relevant to the automation of steel bridge design and construction, and (ii) Summarize the 3D modeling and electronic information transfer technologies which most merit being transferred or adapted to expand use of automation in steel bridge design and construction. This study is a direct outgrowth of Theme Area 1 arising from the workshop.

2. Several owners and fabricators are exploring varying degrees of paperless approval processes. These explorations were identified in Theme Area 2.

3. A number of initiatives of task groups within the AASHTO/NSBA Collaboration (www.steelbridge.org) are addressing some of the concerns raised in Theme Area 3, "Standardized Design Details to Facilitate Automation." Two of these, for example, are Guidelines for Design Drawing Presentation and Design for Constructibility.

4. A meeting was held at the recent (January 2002) TRB Annual Meeting to plan next steps for Theme Area 4, "Showcase of Benefits of Automation." More information on this initiative will be forthcoming as it becomes available.

Computer Integrated Steel Bridge Design and Construction: Expanding Automation

Stuart S. Chen, Ph.D., P.E.

INTRODUCTION

In April 2001, the Federal Highway Administration (FHWA) Office of Bridge Technology in collaboration with the National Steel Bridge Alliance organized a workshop to discuss integrating advanced computer-aided technologies in the design, fabrication, and construction of steel bridges. The mission of the workshop was as follows:

Establish a roadmap for integrating steel bridge design through-construction processes and for advancing the state-of-the-practice in steel bridge manufacturing automation and productivity.

Edison Welding Institute (EWI) hosted this three-day workshop in Columbus, Ohio, with AASHTO and EWI co-sponsoring the event. Fifty-three individuals with diverse expertise and from three continents participated in the workshop, representing government and consulting engineers, fabricators, erectors, welding experts and academia. Appendix D lists the attendees.

Four theme area statements and accompanying action plans were developed. The action plans included objectives, rationale, short-, medium- and long-term tasks, potential resources to implement the plan, obstacles and potential payoffs.

BACKGROUND

In 1999, an international review tour of steel bridge fabrication sites was conducted by a study team headed by the Federal Highway Administration (1) focusing on the role of steel bridge design, innovation, and fabrication in modern steel fabrication facilities in Japan, Italy, Germany, and the United Kingdom. The objective of this scanning tour was to conduct a broad overview of newly developed manufacturing techniques that are in use abroad for steel bridge fabrication and erection.

The team recommended several areas involving automation on which the U.S. industry should focus to improve competitiveness. The “Workshop on Computer Integrated Steel Bridge Design and Construction: Expanding Automation” was organized as a follow-up to pursue automation aspects of these recommendations.

WORKSHOP FORMAT

General Session

In preparation for the workshop, a Pre-Workshop Survey and Questionnaire and a Pre-Workshop Fabricator Questionnaire were sent to prospective workshop attendees. The questionnaires asked the attendees to comment on the major obstacles toward automation in our industry. The information contained in their replies helped workshop organizers structure the general session and breakout sessions of the workshop.

The workshop's first day was devoted to hearing presentations regarding automation and computer integrated systems from domestic and foreign sources. The second and third days were spent brainstorming ideas and writing action plan statements. First day presentations included the following and involved authors from Europe and Japan as well as the U.S. (2):

- *Observations from FHWA's Steel Bridge Automation-International Review Tour (K. Frank, U. of Texas)*
- *Looking for Optimal Factory Automation Balanced Against Demand Capital (S. Tada, Kawada Industries)*
- *Electronic Data Transfer and Processing for Automation (S. Chen, SUNY at Buffalo)*
- *Automated Fabrication and Detailing Methods in the UK (G. Booth, Fairfield Mabey)*
- *Bulldozers or Bridges--What's the Difference (T. Jutla, Caterpillar, Inc.)*
- *Automation and Process Improvement in the Shipbuilding Industry (J. Dydo, Edison Welding Institute)*
- *Systemization with CAD/CAM Welding Robots in Steel Bridge Fabrication (Y. Kanjo, NKK Industries)*
- *Advances in Arc Welding Technology for Heavy Manufacturing (D. Harwig, Edison Welding Institute)*
- *Steeling the Competitive Edge - Is there a place for Robots (J. Weston, The Welding Institute)*
- *Automation Generation of Contract Plans for Steel Bridges (J. Jang and R. Teli, Columbus Engineering Consultants)*
- *Computer Integration in Fabrication and Erection (J. O'Neil, Cleveland Bridge)*

Opening Session

Welcoming Remarks

Mr. Krishna Verma, Senior Welding Engineer with the Office of Bridge Technology in the Federal Highway Administration (FHWA), welcomed the assembled participants on behalf of the sponsoring agencies and pointed out that the 1999 International Review Tour served as the basis of this workshop. That tour revealed to U.S. experts that steel bridge members can be fabricated efficiently and economically using automation and robots. Still, no fully integrated design/fabrication/erection process exists currently, as steel bridge fabrication practice in the U.S. is currently highly decentralized. With the large number of steel bridges that are fabricated in the United States each year, and with our expanding bridge program, Computer Integrated Manufacturing technology has tremendous potential.

Mr. Arun Shirole', Executive Director of the National Steel Bridge Alliance (NSBA), welcomed the participants and pointed out the diverse constituencies they represent: the public sector (owners), fabricators, academics, software developers, and the Edison Welding Institute (EWI). This workshop is believed to be the first of its kind anywhere.

Plenary Session 1: Automation in Steel Bridge Design and Construction – Current Status

"Observations From FHWA's Steel Bridge Fabrication Review Tour"
Prof. Karl Frank of the University of Texas at Austin, a participant in FHWA's 1999 International Review Tour, presented a summary of observations relating to aspects of automation from that tour of steel bridge fabrication plants in Japan, Italy, Germany, and the United Kingdom. Although none of the plants were fully automated, the ones with the highest degree of automation had fully automated thermal cutting lines, girder lines and web lines which included automated stiffener welding, and a semi-automated stiffened plate straightening station.

Implications for changes to U.S. practice, if these advances were to be deployed here, include the following:

- Elimination of radiographic inspection in favor of automation-friendly ultrasonic inspection, which would require new definitions of equipment and operator qualifications and new acceptance specifications based on fitness for purpose rather than the present workmanship requirements,
- Elimination of submerged-arc welding (and required flux handling systems) in favor of automation-friendly GMAW or MIG/MAG welding processes, and
- Use (and long-term archival) of a single 3D CAD model as the sole source of information on detailing, shop drawing information, CNC drilling and cutting instruction, automated inspection and virtual assembly (geometry verification), and
- Possible contractual ties between fabricator and erector in order to facilitate virtual assembly

"Looking for Optimal Factory Automation Balanced Against Demand, Capital Investment and Efficiency"

Mr. Satoshi Tada of Kawada Industries presented a description of the automation history of the Shikoku plant in Japan, where steel box girders are much more prevalent than in the U.S. The CAD/CAM system in this plan provides a 3D model of fabrication geometry. This model enables checking of all three-dimensional relationships of all components within the structure and virtual assembly. It also generates CNC fabrication data obtained through "a 2D unfolding process within the system."

Another feature of the fabrication plant is extensive use of robotic welding equipment, processes, and attendant automation-friendly detailing. Interestingly, there is little automation downstream (box assembly, welding, straightening, and finishing). Quantitative comparisons of costs to produce project documentation before and after automation were presented.

“Electronic Data Transfer and Processing for Automation”

Prof. Stuart Chen of State University of New York (SUNY) at Buffalo described the need for standardization and automation in the context of the currently fragmented nature of the industry, along with a review of some current developments towards standardization and a case study showcasing benefits of automation based on 3D CAD modeling. Standardization should focus on the specifications (intellectual requirements) that “stay the same” from job to job, e.g., design details, inspection methods and acceptance criteria. Automation is envisioned via design and detailing software, hardware and software for electronic information transfer, and fabrication equipment and processes. A review of the various consensus standards developed (or under development) by the AASHTO/NSBA Steel Bridge Collaboration highlights aspects of both the content of and the process underlying standards that owners/specifiers need to adopt before automation and its attendant economies can move forward. What these standards accomplish for information transfer for human eyes needs to be extended to electronic means of information transfer. Then the present “islands of automation” will begin to be bridged, likely based on rapidly developing web-based standards for software integration and business-to-business electronic commerce.

Benefits of 3D CAD modeling in a steel bridge rehabilitation project were highlighted in a case study of a deck replacement. The 3D modeling in combination with a GIS-based site survey was indispensable not only for fabrication but also for the visualization and planning of construction sequencing that involved installing a temporary gantry crane system, maintaining traffic, replacing utility lines and girders, jacking and re-using existing trusses, and pouring a new deck.

EWI Facilities Tour

Dr. Robert Kratzenberg and his associates of the Edison Welding Institute (EWI) hosted a tour of EWI’s internationally recognized laboratory and training facilities.

Luncheon Keynote Session

“Automated Fabrication and Detailing Methods in the U.K.”

Mr. Geoffrey Booth of Fairfield-Mabey in England described the use of fully integrated 3D modeling, which in spite of being 30% slower than 2D CAD has huge spin-off benefits. The single 3D model is the basis for CAM (computer-aided manufacturing) as well as CAD, since the model serves as a template for CNC layout. The model is used to inform machines, not shop floor people. Thus, there are no shop drawings (!). The model is a single source of data about all relevant

attributes of the structure that can be packaged in various ways. Quantity takeoffs for estimating and scheduling, for example, can be extracted from the single database of structure attribute information.
Fabricator workflow involves issuing RFI's (requests for information) to designers upon scrutinizing the designer's drawings, with the 3D model generated after answers are received. Full numerical descriptions of each attribute of each piece enable generation of plate nesting instructions as well as CNC machine instructions. It is suggested that the 3D modeling system is the most significant advance and is the one to implement first; robotization can then follow. A "sensible mix of human skills and hi-tech machines" is desirable, "otherwise the technology owns you." Weld preheat does not fit well within automated processing and the need for it should be eliminated. ISO 9001 certification is used as the basis of quality assurance. The most typical contracting mechanism in the U.K. is DBFO (Design-Build, Finance, Operate), where the contractor recruits the designer and fast turnarounds are valued.

Plenary Session 2: Experience with Automation for Steel Fabrication

"Bulldozers or Bridges – What's the Difference?"

Dr. Tarsem Jutla of Caterpillar described the digital design and manufacturing employed by Caterpillar's $3.5 billion business in fabricated structures, specifically earth-moving machines that are more complicated than our bridge structures, with tighter tolerances. Computer simulations using high-powered finite element analyses extracted from CAD solid models are employed, for example, for the following:

- rolling and flattening operations, including cold rolled residual stress distributions,
- laser cutting, including thermal distortions.

Thus, adaptive forming can compensate for "springback" and welding process simulations predict residual stress and distortions and enable robot process planning to work right the first time.

This presentation essentially pointed out, via the illustrative example provided by Caterpillar bulldozers, that customized job-shop fabrication of large steel structures could be highly automated around robust 3D computer modeling and that such automation increased throughput and reduced turnaround time. Future trends point to increased use of laser technology not just for cutting (currently up to 35 mm thick) but also for shaping parts, removing mill scale and machining. Working closely with the supply chain is considered important to establish strategic relationships to share both risks and rewards.

"Automation and Process Improvements in the Shipbuilding Industry"

Dr. James Dydo of Edison Welding Institute provided an overview of current procedures and recent developments in steel fabrication within the shipbuilding industry. Increased use of robotics and laser process methods are evident, as are changes in design for fabrication, e.g., design for modular assembly. Robust techniques that reduce welding distortion and improve fitup accuracy are of interest to the Navy. Accordingly, they have initiated the following development projects(described further in the full paper):

- Advanced modeling techniques for prediction of distortion: buckling, angular change, and in-plane shrinkage ("We can predict distorted shape"),
- "Thermal tensioning" techniques that reduce the amount of welding distortion via application of auxiliary heat and/or cooling during the welding process, and
- "Thermal forming" techniques that apply heat selectively to the surface of a plate for the purposes of inducing curvature, even the compound (multi-axis) curvatures required of ship hulls.

"Systemization with CAD/CAM Welding Robots in Steel Bridge Fabrication"

Mr. Yoshihiro Kanjo of NKK Industries described multi-robot CAD/CAM welding systems developed for bridge fabrication and shipbuilding at NKK's Tsu works. The key technologies facilitating welding automation in the robotic systems are focused on four areas:

- High-speed rotating arc welding process for increasing welding efficiency,
- A coordinate transformation system tied in with multifunctional arc sensors that corrects the positional mismatch before and during welding,
- An altered production process (panel subassembly distinct from box assembly) in order to accommodate multiple simultaneous robots for welding for increased throughput, and
- An integrated 3D CAD/CAM computer system that generates not only 2D drawing views, material lists, and CNC data, but also robot motion simulation and path data (in conjunction with the welding motion pattern database) and the multi-robot control system (e.g., to avoid robot collisions during welding).

"Advances in Arc Welding Technology for Heavy Manufacturing"

Mr. Dennis Harwig of Edison Welding Institute presented emerging arc welding technologies and opportunities for heavy manufacturing. Principal drivers for these developments are the need for increased welding speed and higher quality weldments. Key technologies are identified as the following:

- high deposition processes (possible with SAW, FCAW, or GMAW-T),
- welding procedure optimization accounting for interactions between process and production factors,
- real-time data acquisition and quality monitoring with statistical process control,
- robotics using both cartesian and articulated arm approaches,
- adaptive welding technology with real-time through-arc sensing and dimensional inspection and application-specific adaptive fill algorithms, and
- hybrid welding (e.g., hybrid laser/GMAW welding).

Plenary Session 3: Implementation Issues

"Steeling the Competitive Edge – Is there a place for Robots?"

Mr. John Weston of the Welding Institute in England described the manufacturing processes used in the steel fabrication industry in terms of requirements for automation and robotics. Fabrication shops have been quick to implement islands of automation for operations such as CNC drilling, cutting, or machining. But there has been a reluctance to adopt a more widespread robotization of fabrication shop operations. These operations include:

- Cleaning (typ. blast cleaning), where a robotic arm could manipulate the blasting nozzle,
- Cutting and profiling, where robots in the automotive industry have been used in place of press trimming or punching,
- Hole forming, which can be done via drilling or punching on multi-headed NC machines in 3D on a range of section shapes,
- Joining, including not just arc welding robots but also bolting, nailing, riveting, and bonding with adhesives,
- Bending and pressing, where NC operation is increasingly being deployed,
- Rolling, where NC operational controls are increasingly being deployed,
- Machining, a longtime NC process where robots are increasingly being used,
- Applications of protective coatings, and
- Handling, which has thus far resisted robotic solutions owing to the sheer size and diversity of product dimensions and shapes.

Soon, robots may be applied in the following areas:

- Cutting and marking (increasingly with laser systems),
- Welding (initially using arc processes and eventually lasers),
- Nondestructive examination (NDE), and
- Coatings (painting robots), with their increased health and safety requirements.

Information technology (IT) is seen as a key enabling technology that in this context requires robust linkages between numerous computer based applications such as CAD, simulation cells, administration, scheduling, planning, purchasing (ordering), and maintenance control.

"Automated Generation of Contract Plans for Steel Bridges"

One of the disconnects in the process of producing a steel bridge is the need to generate contract drawings after the bridge is actually designed. This presentation focuses entirely on this particular disconnect. Dr. Jack Jang and Mr. Raju Teli of Columbus Engineering Consultants described commercial software, cecSTEEL, that generates contract plans compliant with Ohio standards, for steel beam and plate girder bridges. Superstructure drawings, for example, include:

- Typical transverse sections,
- Deck reinforcing plan,
- Framing plan and beam elevations,
- Deflection/camber table,
- Screed elevations table,
- Bearing and splice details, and
- Parapet transitions.

In effect, the development of the software required the parameterization of the information contained in a set of contract plans for an entire typical steel bridge crossing. Secondary calculations such as detailed structure dimensions, beam seat elevations, screed elevations, material quantities, pay item quantities, reinforcing steel list, etc., are directly performed by the software in order to reduce the tedium of data entry. The software prompts the user for only the governing design parameters, performs all secondary calculations, and then generates the AutoCAD or MicroStation files containing the contract plans for the bridge in a fraction of the time it would normally take.

“Computer Integration in Fabrication and Erection”

Mr. James O’Neill of Cleveland Bridge in England described construction methods employed in building two very different large bridge projects: asymmetric box girder bascule bridges on the Bellmouth crossing in London and the Boyne cable-stayed bridge in Ireland. Modularization was successfully employed to minimize site risks associated with working at heights and reducing construction period by maximizing off-site activities. Planning of construction, using purpose-built temporary decks and incremental launching assisted by temporary stays, was greatly facilitated by use of the 3D CAD model. This presentation highlights the role of automation in the fabrication – erection interface.

Plenary Session Summary

There are a number of error-prone, inefficient and time-consuming disconnects at the transitions between the various stages in the design, plan generation, fabrication, and erection of a steel bridge. The Day 1 introductory and plenary presentations at the workshop each examined various aspects of those disconnects and the emerging technologies that potentially could help to remedy them.

Some recurrent themes coming out of these presentations (and in the breakout sessions that followed) highlighted the need for the following:

- Solid modeling based on a single 3D model as in other industries (3), not just 2D CAD drafting, enabling direct links to manufacturing (e.g., CNC machines)
    - Virtual assembly
    - Model as a single source of data that can be extracted and packaged in various ways
- Automated inspection and data recording as being done elsewhere and in related industries,
- Use welding processes (e.g., GMAW) suitable for automation,
- Modifying/eliminating current specs that are unduly restrictive and outdated,
- Development of standard specifications, to replace the current myriad variety of state specifications, that would facilitate automation,
- Design-Build type of approach that overcomes the adversarial barriers that plague the traditional contracting approach typically employed in bridge construction.
- A cost effective systems approach that does not merely introduce robots or increase the speed of one of the processes.

The table below provides an overview of some of the recurrent themes, by speaker.

Plenary Speaker	3D CAD Model	Automated Inspection and Data Recording	Automation-Friendly Welding (e.g., SAW GMAW)	Automation-Friendly Inspection (e.g., RT UT)	Virtual Assembly	Specs: Need to Consolidate and Modernize	DB(FO)	Prediction &/or Control of Fabrication Operations	Systems Approach
Frank	•	•	•	•	•	•	•		•
Tada	•	•	•		•				•
Chen	•								•
Booth	•	•	•	•	•		•		•
Jutla	•		•					•	•
Dydo	•							•	•
Kanjo	•	•	•		•			•	•
Harwig		•	•					•	
Weston	•		•						•
Jang									•
O'Neil	•								•

Implementation Panel Discussion and Open Forum

As a precursor to the small-group brainstorming sessions to follow, the entire group of 53 participants engaged in some collective brainstorming. Some of the opinions and suggestions expressed during this collective brainstorming, slightly edited, were as follows:

1. The model of information flow presented by Mr. Kanjo was helpful.
2. Focus first on 3D information modeling (rather than robotics).
3. We see that it can be done. What are the barriers to doing it here? We need to spend some time dealing with these barriers.
4. Design-build breaks down the adversarial barriers that our system has in it. The issue is who is taking the risk, and how to share the risk. Construction Managers (CM's) are not builders.
5. (In the U.K.) through DBFO, we're back to managing work, and expertise is valued. The issue is culture. When "FO" was added, expertise became valued.
6. Can we (in the U.S.) invest useful energy into DBFO? Perhaps DB advocates should be encouraged to push for DBFO.

7. We should define a list of items that need to be standardized along with associated impacts, e.g., gas welding and alternatives to RT (i.e., automation-friendly fabrication and inspection technologies).

8. Caterpillar, like the auto industry, produces customized, made-to-order products. What do they standardize?
9. Issue: how to set standards that make use of the knowledge out there (e.g., regarding welding). The basis for such standards ought to be fitness for service.
10. We need to articulate the benefits of change.
11. Comments thus far emphasize that lack of standardization is a hurdle. The steel industry keeps saying that they will give customers what they want, rather than articulate benefits of standardization.
12. DOTs at times have inexperienced engineers in charge of fabrication. They in turn are reluctant to consider spec changes.
13. Problem: how far can the owner be expected to bend?
14. A further problem is that owner-fabricator exchanges don't get communicated back to the designers.

Breakout Sessions

The objectives for the breakout sessions and group sessions on the second and third days were as follows:

1. Identify advances needed in the state-of-the-art of the various technical support technologies (e.g., robotics, open software standards), and
2. Identify high-payoff pilot projects, potential teams for those projects, and mutually agreed-upon statements of "where do we go from here?" to explore implementation issues and business process re-engineering required to implement available and emerging technologies needed.

On the second day, four breakout groups were formed based on the pre-workshop questionnaires (shown in Appendices B and C) and first day discussions. Each breakout group was constituted to have a mix of fabricators, DOT engineers, and other stakeholders. The breakout groups' first task was to brainstorm ideas on what the steel bridge industry's focus should be regarding automation. The four breakout groups identified over 100 ideas, listed in Appendix E. Participants then voted to identify the most important ideas for further development.

Workshop facilitators then organized these ideas into common themes. The breakout groups reconvened to write action plans for the resulting four theme areas. The action plans included objectives, rationale, short-, medium- and long-term tasks, potential resources to implement the plan, obstacles and potential payoffs. The four theme areas are as follows:

1. **Computer Generated Drawings/Modeling and Electronic Information Transfer (Electronic Design and Drawings Transfer and Modeling)**
2. **Standardized Specifications and Paperless Approval Processes**
3. **Standardized Design Details to Facilitate Automation**
4. **Showcase of Benefits of Automation**

The action plans for these four theme areas appear in Appendix A of this report.

WORKSHOP OUTCOME

The mission of the workshop, as stated earlier, was to establish a roadmap for integrating steel bridge design through-construction processes and for advancing the state-of-the-practice in steel bridge manufacturing automation and productivity. That "roadmap" took shape primarily along the lines of the four theme areas described above. The first theme area already has served as the basis for a NCHRP Problem Synthesis statement on "Evaluation of 3D Computer Modeling and Electronic Information Transfer for Efficient Design and Construction of Steel Bridges." Other theme areas are being pursued partly via several of the task groups in the AASHTO/NSBA Steel Bridge Collaboration (www.steelbridge.org).

Ultimately, the consensus standards that have emerged or will emerge from such efforts will need to be accepted and adopted by owners if the objective of improved economies from increased automation is to be addressed.

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2. ___, "Computer Integrated Steel Bridge Design and Construction: Expanding Automation," Collection of Plenary Session Papers, sponsored by Federal Highway Administration, American Association of State Highway and Transportation Officials, National Steel Bridge Alliance, and Edison Welding Institute, Columbus, Ohio, April 23-25, 2001.

3. ___, "Electronic Data Interchange," www.aisc.org (August 2001).

APPENDIX "A"

Theme Areas

Theme Area 1: Computer Generated Drawings/Modeling and Electronic Information Transfer (Electronic Design and Drawings Transfer and Modeling)

Objective

Identify and document the various computer automation and data communication technologies needed to build cost-effective and quality bridges in a time efficient manner, from planning through in-service.

Rationale

Existing bridge building processes typically involve time-consuming information transfer and approval procedures that involve traditional paper handling and document transfer between entities. Computer automation and data communication technologies could make this process faster, better and cheaper.

Short-Term Tasks:

1. Identify and evaluate existing internet file transfer formats for a) contract plans, b) contract documentation, and c) shop plan submittals and approvals. Electronic file transfer could be used for bidding considerations by contractors, fabricators, RFI's, shop drawing and erection plan approvals and contract documentation.

2. Investigate potential for standardization of these formats (e.g., MicroStation? CIMSteel?).

3. Monitor what is being done:
   - In more advanced industries (e.g., automotive)
   - On current Design/Build projects
   - In New York State with High Steel
   - In Great Britain re: owner-exported central models to all parties whom each build on that model, resulting in a complete record of the project.
   - Airports, Ove Arup, Cleveland Bridge, Strucad, Xsteel and NSBA

4. Form multi-entity collaboration with several fabricators and owners to examine file formats, develop test cases, etc.

5. Fabricators: Advocate and implement e-transmittal & e-redlining of shop drawings etc.

6. Quantify benefits of 3D solid modeling (used in automotive industry) vs. 3D wireframe modeling.

Medium-Term Tasks:

1. Identify data information constraints and hidden time delays between owner, fabricator, erector and contractor.

2. Investigate CAM processes to utilize 3D model data in order to generate individual program instructions for various automated fabrication machines.

Long-Term Tasks:

1. Establish software (accompanied with training) enabling designers to generate 3D models of the structure. Fabricators, Contractors and Erectors could then download data from the 3D model directly into their computers for specialized processing.

2. Flesh out corollary information to accompany 3D CAD model.

3. Radically alter workflow with all aspects of design and design/construction information transfer on the computer.

Potential Resources:

1. Software companies specializing in computer generated drawings and electronic data transfer systems
2. University researchers
3. AASHTO/NSBA Collaboration
4. Fabricators using CAD
5. Detailers using internet transfer
6. AASHTO and FHWA could furnish funding and education transfer
7. NCHRP/TRB

Obstacles:

- Lack of knowledge to manipulate computer data systems
- Contractual issues
- Consulting engineers think of their product as drawings
- Current fee structures and how work is priced
- Lack of coordination of computer data systems within Governmental agencies
- Security concerns
- Owners may want to limit software/hardware selections

Potential Payoffs:

- Faster process from contract bid documents to completed bridge
- A more reliable schedule
- Lower costs
- More accurate (construction process) and longer life structures
- Better record of contract history for potential compensation litigation

Theme Area 2: Standardized Specifications and Paperless Approval Processes

Objectives:

1. Establish among various owners the same demands, expectations and flexibility, in order to facilitate automation and level the playing field.
2. Enable owners, contractors, fabricators and erectors to ***work together*** for:
   - Easier approval on changes
   - Better communications
   - More cost-effective structures

Rationale:

Current wide variations in owners' method specs prevent automation; standardized specs are needed to facilitate automation and the benefits thereof. Build partnerships, trust.

Short-Term Tasks:

1. Include mill certs in fab specs; don't restrict e-submittal.
2. Allow UT in lieu of RT; consider auto-UT (review criteria used by fabricators in Japan). Who: (i) FHWA NDE validation center for tech changes in leadership; (ii) Joint AASHTO/AWS Bridge Welding Code committee for implementation in code.
3. Review TWI-generated acceptance criteria and Japanese work in this area for possible direct use in US practice (fit-for-purpose based rather than workmanship based). Who: leading fatigue/fracture academics in US, UK, and Japan.
4. Review research on (robot-friendly) operations which specs prohibit (re: laser/plasma cutting, drilling full-size holes, painting, etc.) Who: TRB Committee A2F07.
5. Performance-based specs (rather than method-focused):
   - Encourage states to work through issues that stymie standardization: AASHTO/NSBA Steel Bridge Collaboration.
   - Begin regional implementation of Collaboration-authored fabrication spec: Collaboration and associated regional and local quality groups.
6. AASHTO T-14 (Steel Structures) needs to hear from fabricators, erectors, and G.C.s regarding constructibility with LRFD designs. Who: fabricators who attend T-14 meetings.
7. Investigate robotic painting/metallizing technologies, reliability, payback. Who: Collaboration Task Group 8, Coatings.
8. Fabricators and erectors need to inform AASHTO T-17 (Welding) and A-9 (AWS) regarding constructibility with LRFD designs.
9. Review U.K.'s certification and auditing processes for fabricators and erectors. AISC Committee CFOS.

Medium-Term Tasks:

1. Make fabricator certification have a category such that owners do not feel the need to have inspection hold points. Who: AISC Certification committee, with emphasis and interest expressed by member fabricators.
2. Continue ongoing support of the AASHTO/NSBA Collaboration. All industry and owner leaders.
3. Finish and implement Collaboration constructibility guide (Beckmann) and standard details (Gatti). Who: AASHTO/NSBA Collaboration.
4. Certification of erectors: encourage owners to require. Who: Collaboration, through erection specification; AISC, through speaking engagements; NSBA newsletter.

Long-Term Tasks:

1. Establish certification protocols for robotic welders (Ref. ISO standard for mechanized welding, ASME 9): Bridge Welding Code committee.
2. Enable PQR Reciprocity: Collaboration.
3. More Design-Build-Maintain or DB(FO) – need paradigm shift: product as long-term monitorable facility not just fabricated steel: Information Mode, Training Mode Who: NSBA.

Potential Resources to Tap:

- Japanese fabricators and Ohio DOT: Auto-UT acceptance criteria and trial
- Turner-Fairbank NDE validation center
- AISC Certification Program/Committee
- Group 4 “Road Show”

Obstacles:

- Reliability, payback
- Resistance to change

Potential Payoffs:

- Faster construction
- Competitive, cost-effective structures
- Higher quality, less defects
- Standardization

Theme Area 3: Standardized Design Details to Facilitate Automation

Objective and Rationale:

The design process should lead to a structure that provides the best lifetime value to the owner. Automation has been shown to reduce initial cost and improve quality in the final product. Enhancing bridge designers' knowledge of the total construction processes (fabrication, steel production, erection, etc.) will improve the quality of their designs. In addition, standardizing practical bridge details reduces cost by ensuring that details are constructable and cost-effective. Automation is cost-effective when repeatable tasks are included in the process. Performance–based specifications and increased automation open the door to new bridge types with more complex component assembly and without a cost penalty.

Short-term Tasks:

1. Survey the industry to determine the effect of design decisions and specifications on the use of and potential for automation in fabrication shops in the United States
2. Gather available data from sources to determine the impact on cost and speed of fabrication for design details in the industry. Evaluate the available information to determine if it is applicable to current practice and compatible with automated processes.

Medium-Term Tasks:

1. Produce a Designer's Guide for Value and Economy in a Constructed Steel Bridge, hardcopy and online. Ongoing in the AASHTO/NSBA Collaboration.
2. Virtual bank of pre-approved standard details that could be substituted by the fabricator.
3. Produce a Fabrication Tour for Designers (Virtual Tour with system and equipment, describe how you build a plate girder through an automated process).
4. Develop a Virtual Steel Mill Tour for Designers (plate and rolled shape mills)
5. Make materials available for free download from the internet.

Long-Term Tasks:

1. Contribute to the development of Performance-based Specification for steel bridge design and construction to encourage creativity and innovation.
2. Develop new steel design bridge types and specs that will make more effective use of automation.
3. Develop incentive system for the designer to create bridges, which are the best value to the owner.

Potential Resources:

NHI, AISI, NSBA, Bethlehem/Lukens, US Steel, Nucor-Yamato, Oregon Steel Mills, Chaparral, individual fabricators, Regional Groups (Texas Quality council, SCEF, North Central States) State Bridge Design Manuals, Japan, UK, Value Engineering studies performed by states and FHWA, Alternate designs performed by states, FHWA and D/B, FHWA, AISC, State DOTs, EWI, TWI, Lincoln Electric, AWS, Hobart, AREMA, University researchers, Carolina Steel & others (shop tour).

Obstacles:

- “WE’VE ALWAYS DONE IT THAT WAY”
- “WE TRIED THAT 15 YEARS AGO”
- “IF IT WAS A GOOD IDEA, SOMEONE ELSE WOULD HAVE DONE IT BY NOW”
- Communication through the ranks to the designers, who turn over frequently
- Fabricators not necessarily interested in sharing cost data or process data
- Resistance to Unconditional Acceptance (of pre-approved substitutes) by DOTs
- Designer lack of time to iterate and fine-tune
- Lack of a single (unique) governing specification
- Lack of a single (unique) unit of measurement

Potential Payoffs:

- Reduced initial and life-cycle costs
- Faster delivery of structure to the traveling public
- Platform for continuous improvement
- Enhanced quality which improves public safety
- Increased competition between materials

Theme Area 4: Showcase of Benefits of Automation

Objective:

Prepare/Present 'road show' to show benefits and improve awareness of advanced technology; case studies are preferred, (multiple demos of combinations of software/equipment) to include:

- Advances in 3-D modeling and engineering (2-D) drawings software
- Cutting and welding equipment and demonstrations, including distortion-free processing
- Automated inspection
- Discussion of improved steels (low CE) to suit automation
- Cost-effective coatings technology (automated application and long-term maintenance)
- Value Engineering

Primary audience consists jointly of owners, who have to revise specs, etc to allow advancements; and the fabricating industry, as they must make the investments. This project is a follow-up to FHWA Scan Tour. We need to understand the current culture, and plan this to be acceptable to the various stakeholders.

Rationale:

To demonstrate how automation will make steel bridge construction more economical/faster to complete and to disseminate the information gained on the FHWA Fabrication Scan Tour.

Short-Term Tasks:

1. Identify lead, advisory panel, estimate costs
2. Identify content to be included (currently available)
3. Identify 'hot buttons' for owners
4. Prepare proposal for funding to ???
5. Develop promotional material/website
6. Design/identify program performance measures
7. Do we need to write a proposal for a contractor to establish a cost?
8. Develop calendar

Medium-Term Tasks:

1. Complete slide/script; begin presenting programs
2. Assess performance measurement

Long-Term Tasks:

1. Consider alternate media (videos, CD, computer presentations, web sites) once we see what works
2. Consider alternate audiences (tech schools, university design and engineering programs)

Potential Resources:

1. Funding – government, industry (software vendors, equipment manufactures, trade groups), regional trade initiatives/zones, assistance in kind (AIK)
2. People – develop, teach/present, AIK, universities, government
3. Content – other tasks, as well technology providers

Obstacles:

1. Identify lead/Champion, develop consortium, logistics
2. Limited resources
3. Hesitance to share information
4. How do designers fit in?
5. Possible lack of synchronized planning
6. Catch 22: Industry must push for advances, owners (jointly) must allow. Which comes first?

Payoffs:

1. This demonstration will become a resource for themes 1 to 3 for two-way flow of information.
2. Enables potential user to evaluate cost/benefit
3. Elevates visibility/image of steel bridge industry capabilities
4. Educational material will attract a younger generation to industry
5. Will supplement other projects aimed at increasing the use of automation with tangible/ high-impact examples
6. Health benefits (to workers) from automation
7. Better collaborations over long distances through automation

APPENDIX "B"

Pre-workshop Fabricator Questionnaire

Summary of Responses

Summary of Responses Based on 6 responses

What, in your opinion, are the major obstacles to aggressively automate steel bridge fabrication in the US?

Equipment Limitations - I would need equipment to do the following:

- Automated equipment would require flexibility. There are so many variables in the size, weights, and geometry in bridges.

- I visited a Herman bridge fabrication shop over ten years ago and watched Robotic Assembly and Welding. This equipment at the time wasn't available in the US. Our industry needs this level of technology immediately for assembly and welding.

- Adequate equipment currently exists to automate steel bridge fabrication if design and codes are standardized.

- Girder to girder referencing (NDEVC laser system) and CNC drilling equipment could lead to elimination of the lay down and reaming operations.

- CNC flame cutting of webs and flanges would improve accuracy and efficiency.

- Acceptance of CNC controlled flame cutting of splice plates and stiffeners to include holes for bolts would improve accuracy and efficiency.

- Utilization of girder assembly machines, similar to those used in the metal building industry would improve efficiency by eliminating the fit up and tacking process as well as combining welding into one operation.

- Universally accepted welding processes and procedures could lead to more development of more efficient equipment.

- **Too Expensive - I would need additional $$$ to acquire/implement the following:**

- The $$$ available depends on the cash flow of the business. Larger companies will have more cash flow for larger investments, but any project with a satisfactory return on investment (ROI) will be done.

- Obviously the type of equipment is very expensive and most small to mid-size fabricators couldn't afford the price.

- Not an issue if standardization allows sufficient ROI.

- Although a lot of expense can be realized when exercising new equipment options, most expense can be justified if its use is universally accepted enough to generate a market to keep it busy.

Software-would need to do the following that it doesn't do now:

- Software needs more consistency and "diagnostic tests" to prevent errors and ease of use.

- The software to operate the German System was in a continuous state of improvement, as robot technology welding technology changed.

- Ideal would be an industry/DOT standard design package to allow electronic interchange of data and download to CNC equipment without any hard copy drawings.

- The most ideal situation would be original design software that is capable of downloading into a fabricators detailing system for preparation of shop drawings and ultimately downloading into CNC equipment on the shop floor.

Business Processes - I would need to "re-invent" how my company does things:

- Business will readily adapt if and when State DOTs standardize.

- Utilizing the technology and equipment we described would take time to integrate to our technologically unsophisticated workforce.

Contractual Mechanisms and Liability Exposure - would need to change:

- In the short term contracts would need to allow for this level of technology, but once started it would become commonplace. Liability exposure should be minimal.

- With a continuous flow of data from the original design through fabrication on the shop floor, liability issues with regards to the correctness and final fit-up of the final product would have to be resolved.

Other (Describe):

- Protective Coating Systems
- Consistency, accuracy, & completeness in contract drawings & specifications
- Availability & consistent pricing of raw steel materials
- State D.O.T. Specifications; there would need to be acceptance by more than one or require code of specification changes.

One objective of the workshop is to identify high-payoff pilot projects to explore implementation of available and emerging technologies for increasing automation and productivity in steel bridge manufacturing. Would you be willing to participate as a member of a team pursuing such a project?

YES	**1**
NO	
May-Tell Me More	**2**
No Response	**3**

Other Comments, Suggestions, and Questions:

- If there are large developmental costs there are always financial obstacles

- The mental images of the German System for manufacturing girders remains clear in my memory. My hope is to have that type of system some day. But it doesn't appear it will happen during my generation. By then where will the Germans be?

- Your list of "obstacles" above implies that equipment financing is retarding automation, In reality, the provincial codes and specifications of DOTs are the constraint. Living proof is AISC building fabrication - one code, one spec, and even the smallest fabricator is highly automated.

- We work outdoors and the subarc is as automated as we go at this time. Most often we work with rolled beams, so we don't see a lot of room for automation.

- There are a number of automated fabricating opportunities available to the bridge fabricator. However, before any fabricator can justify the expense, much work has to be done to minimize the many standards, policies and procedures that result from each state going their separate way. A single governing factor would encourage the duplication and consistency necessary to develop a market that would support the various automated processes.

APPENDIX "C"

Pre-Workshop Survey

Summary of Responses

Summary of Responses Based on 15 responses

What is your primary area of interest/expertise:

Information Technology	1
Design	7
Fabrication (including Robotics & Welding)	6
Erection	1
Other ▪ Fabrication Inspection	1

What is your secondary area of interest/expertise, if applicable:

Information Technology	1
Design	2
Fabrication (including Robotics & Welding)	4
Erection	3
Other ▪ Servicing & Automation ▪ Eng- Shop Detail Drawings ▪ Administration	3

Identify the following:

High-Payoff (short term) Opportunities For Increased Automation	**Gaps, Needs & Potential Obstacles to Implementing These Opportunities**
Electronic Submittal of Shop drawings	a) ability to make designer comments during review on the electronic copy b) ability to stamp and approve shop drawings & provide approved & current copies to required personnel
Standardize details to enhance automation	a) getting all owners to agree upon common details
Electronic shop drawings:streamline drwg transfer, use for mat'l takeoffs/tracking	Must agree on standard file format(pdf, TIFF), authentication & protection
Improve shop documentation and info flow in shop (weld proc. NDT, paint, bar codes)	Educate users (ongoing process) and make available for smaller shops
Information transfer/storage/retrieval for shop owners, including exchange	Standard file format & protocol, insuring medium won't be abandoned in future
Nondestructive testing and production monitoring for both QC and QA	System cost, owner acceptance/trust in results, common stds, small shop access
Automated layout for cutting, NC cutting and drilling	Initial cost for new equipment is high, requires retraining of employees

High-Payoff (short term) Opportunities For Increased Automation	**Gaps, Needs & Potential Obstacles to Implementing These Opportunities**
Electronic Submittal/Approval of Shop Drawings	Liability & Security questions
Combining analysis, design & geometry software together	Weak link is current software
Repeat elements – cleats, stairs, supports	Design for repeat product
	IT knowledge and strategies Data-detail
Data Tracking	Low pay for Information
Web Management	Technology People
Shop Layout	Low Pay for Engineers Poor or no Management Support
Faster Construction Lower Costs	Communication between design software & fabricator software
Computer Based design and fabrication	Fabrication considerations at design stage, particularly at structural details
	Code requirements should be improved
Autonomous Welding (less supervision by welders) Automated inspections	Sensor Integration
Automation of Girder fit & weld CNC	Is the Equipment available?
Detailing software for bridges	
Uniform Details	Varying state practices
Medium and Longer term Opportunities for Automation	**Gaps, Needs & Potential Obstacles to Implementing These Opportunities**
Using shop drawings for direct production control (mat'l select, cut, weld, paint)	Develop various systems; "cost" of shop errors, correcting errors found in field
Flexibility to handle wide range of work (beams, I-grdrs, tubs, haunches, curves)	System limits may exclude configurations and thwart innovative design concepts
Workers more productive and have broader responsibilities with automation	Fewer workers, older empl resist tech trng (or unable), lose knowledge/manual skills
For repair & widening jobs, integrate new and existing shop drawings	Major thrust in the next 50 yrs. Very labor-intensive unless "intelligent scanning"
Increased automation of all welding processes, automated fit-up and assembly (web to flange and stiffener assembly)	Variability of girder size and many changes in flange size is an obstacle to automation
Use of electronic design info in fabrication	Design software limitations. Enough interest in industry to see benefits
Automated contract drawing preparation	Lack of software

Medium and Longer term Opportunities for Automation	**Gaps, Needs & Potential Obstacles to Implementing These Opportunities**
Changed connection design	Code acceptance Designer acceptance Appropriate equipment Design rules
Columns and beams	Product volumes
Modular buildings	Designs
Failing Infrastructure	Poor Scoping
	Lack of Timely use of resources
Bridge Programs	
Synergistic considerations from structural design to fabrication/erection procedures - CAD/CAM	1) CAD/FEA design connecting? Not consider manufacturing effects in eng. Welding/cutting 2) E.g. welding sequence effects that significantly improve fatigue performance ????
Yes, Welding robot System	Engineering for integration of Welding System
Robotics for Welding	Software and Hardware not able to handle submerged arc welding process
Robotics for welding Conn & total CNC program @ Eng. Or shop floor	
Fewer plate thickness variations which could lead to more uniform designs and details. Also this could lead to more advanced plate purchasing contracts which may speed up projects.	Designers wanting to "optimize" all portions of girder

Other comments, suggestions and questions:

- How does automation affect the design specification and procedures?

- "Automation" is a very generic term, so the panel must be cautious to avoid assigning inappropriate goals. Reducing labor costs with fewer, less qualified shop personnel is not applicable. Fabricators must also understand that this will be an evolutionary process, with changes, improvements and (inevitable) corrections occurring at irregular intervals. These modifications will have some negative effects on production and costs.

- We should see what is being done in the building industry.

- In order to implement Robotics in bridge building the expanded use of MIG, inner shield and or Dual Shield welding process will be required.

APPENDIX "D"

Roster of Attendees and Affiliations

DOT

Lian Duan	Caltrans
Ralph Anderson	IL/DOT
John Edwards	IL/DOT
Ken Hurst	KS/DOT
Todd Niemann	MN/DOT
George Christian	NYS/DOT
Paul Rimmer	NYS/DOT
John Randall	OH/DOT
Henry Pate	TN/DOT
Thomas Quinn	TN/DOT
Ron Medlock	TX/DOT

FHWA

Milo Cress	FHWA
Lou Triandafilou	FHWA
Krishna Verma	FHWA

Fabricators

Dennis Noernberg	AFCO
Owen Sims	Augusta
W.H. Reeves	Carolina Steel
N. Kannan	Contour Steel
Jim DeLong	DeLong's
Dan Moore	Industrial
David Johnson	PDM Bridge
Bob Graham	Steadfast
Richard Inserra	Stupp Bros
Tom Guzek	Trinity Ind.
James Tyvand	Addison Corp

EWI

Bob Kratzenberg	EWI
James Dydo	EWI
Dennis Harwig	EWI

NSBA

Mike Beacham	NSBA
Lynn Iaquinta	NSBA
Bill McEleney	NSBA
Arun Shirole'	NSBA
Dale Thomas	NSBA

Other (United States)

Dave Mackey	Columbus Engg.
Karl Frank	U/Texas
Stu Chen	SUNY-Buffalo
Tarsem Jutla	Caterpillar
Jack Jang	Columbus Engg.
Tom Siewert	NIST
Toshio Omura	Kawada - USA
Kevin Lehr	Steelox
Richard Sause	Lehigh University
Robert Smith	Mabey Bridge & Shore
Alex Lowery	Pittsburgh Coatings

Other (International)

James O'Neil	Cleveland Bridge
Geoffrey Booth	Fairfield-Mabey Ltd
Tsuyosho Sakura	Kawada Industries
Satoshi Tada	Kawada Industries
Yoshihiro Kanjo	NKK Industries
Chitoshi Miki	Tokyo Institute of Tech
Steve Maddox	TWI Ltd
John Weston	The Welding Institute

APPENDIX "E"

Brainstormed Topics

G-1 Brainstorming Ideas

This appendix documents the various ideas generated during the brainstorming sessions in the four breakout groups. Group 3 devised the subheadings herein as a preliminary step towards articulating the four Theme Areas that appear in Appendix A.

Group 1 Brainstorming Ideas

Facilitators: John Weston (TWI), Mike Beacham (NSBA)
Participants:

Owners/Gov't	Fabricators	Other
Lian Duan, Caltrans	Owen Sims, Augusta	Jack Jang, CEC
Ralph Anderson, ILDOT Milo Cress	Dave Johnson, PDM Satoshi Tada, Kawada Kevin Lehr, Steelox	Richard Sause, Lehigh U.

G1 - 1 (jj) Understand information flow

G1 - 2 (jj) Produce plans at speed of thought

G1 - 3 (ra) standardize details

G1 - 4 (os) reduce plan errors

G1 - 5 (jw) design and build contracts and creation

G1 - 6 (oa) combined fabrication and erection

G1 - 7 (ra) warehouse common plate sizes

G1 - 8 (tw) facilitate cash flow

G1 - 9 (os) reduce paper via electronic plan preparation review and approval

G1 - 10 (ra) standardize owner data format given to fabricator and contractor

G1 - 11 (sJ) simplify and speed fabrication drawing approval

G1 - 12 (os) standardize information flow (detailer / fabricator / contractor)

G1 - 13 (oj) detailer to work directly with engineer

G1 - 14 (jw)	design build finance operate
G1 - 15 (rs)	design for automation (detail)
G1 – 16 (os)	simplify standards and detail options (for instance x-frames)
G1 – 17	converter to change any plans to details that fit any fabricators automated processes
G1 - 18 (dt)	each state / owner establish practices details, products
G1 - 19	be competitive with steel and prestressed
G1 - 20	reduce labor intensiveness of steel fabrication and construction
G1 - 21	Decrease requirements / increase use of Ultrasonic test (how to record)
G1 - 22	Confidence and lower cost of NDT
G1 - 23	Weld sensing (smart) used instead of after the fact NDT
G1 - 24	Use parameters during process to enable acceptance (min after weld NDT)
G1 - 25	Quality control QA integrated in process
G1 - 26	Reduce cost of certification or use of Certification vs. NDT
G1 - 27	Standardize depth of intensity of inspection between steel and concrete and FRP
G1 - 28	Education (owner / consultant / shop drafting)

Group 2 Brainstorming Ideas

Facilitators: Ronnie Medlock (TXDOT), Geoff Booth (Mabey)

Owners/Gov't	**Fabricators**	**Other**
Ken Hurst, KSDOT	Jim DeLong, DeLong's	Tarsem Jutla, Caterpillar
Paul Rimmer, NYSDOT	Dan Moore, Industrial Steel	Tsuyoshi Sakura, Kawada
Lou Triandafilou, FHWA	Dennis Noernberg, AFCO	Toshio Omura, Kawada
		Dale Thomas, NSBA

G2 - 1	National standardization (Development and implementation)
G2 – 2	Bidding / Contracting system
G2 – 3	Customer Focus (include life cycle costs / values) (design / build) (DBFO)
G2 - 4	Performance specification instead of method specification / Contract alternatives
G2 - 5	Performance standards (shift to risk including fit / assembly)
G2 - 6	File transfer (DGN)
G2 – 7	CA Modelling
G2 - 8	Gather and inform about existing technology / training exposure

Group 3 Brainstorming Ideas

Facilitators: Karl Frank (U. Texas), Lynn Iaquinta (NSBA)

Owners/Gov't	Fabricators	Other
John Edwards, ILDOT	Jim O'Neill, Cleveland	N. Kannan, U. at Buffalo and Contour Steel
John Randall, OHDOT	Bob Graham, Steadfast	
Tom Quinn, TNDOT	Alex Lowery, Pgn Coatings	
	Richard Inserra, Stupp Bros.	

AUTOMATED SHOP

G3 - 2 acceptance of virtual laydown

G3 - 6 standard acceptance of automated fabrication methods

G3 - 7A automated NDT with document support (with high reliability)

G3 - 9 designers flexibility during fabrication to change details to fit automation of selected shop

G3 - 23 automated record keeping of quality parameters in shop and acceptance by owner

G3 - 33 how do we qualify robotic-weld in bridges?

G3 - 38 Training of workforce for automated positions

G3 - 39 Continuing Advancement of automated processes creates a barrier (my investment is given free to next guy)

DEVELOPMENT OF STANDARD BRIDGE SYSTEM

G3 - 1 standard bridge complete package

G3 - 3 standard bridge deck prefab system and design

G3 - 4 modular construction (snap or connect standard parts) (reduce construction time)

G3 - 18 short span standard rural stock bridges (drop in place)

G3 - 19 strategic initiatives with precast concrete industry

G3 - 20 acceptance of material that is pre-fabricated

G3 - 21 letting of multiple bridge fabrication packages (1 year of work vs. 1 bridge)

ELECTRONIC DATA SYSTEMS

G3 - 7 acceptance of electronic documentation in lieu of traditional paper documents

G3 - 8 communication links between fabricators and designers

G3 - 30 archivable medium for future use of electronic documents

G3 - 42 Standard Protocol for Electronic Data Transfer

G3 - 43 Life cycle cost database for future maintenance program

DESIGN AUTOMATION STEPS

G3 - 5 common national steel details

G3 - 7 acceptance of electronic documentation in lieu of traditional paper documents

G3 - 8 communication links between fabricators and designers

G3 - 13 designers need to be aware of mill rolling availability

G3 - 14 steel interchange site to exchange information on steel availability (AISI)

G3 - 15 cost data base (idea of cost / sq ft or lb/ sq ft to designers

G3 - 25 incentive program for designer, - economy, life-cycle quality (value)

G3 - 26 designer training in fabrication and construction (on-site)

G3 - 28 designer / detailer / fabricator / contractor to use one accepted computer model

G3 - 35 standard plate products to create fewer rolling sizes (allow some stock piling) (lump sizes)

G3 - 36 Database of upcoming events by year and type to allow fabrication / production some project planning (market forecast)

SPECIFICATIONS & CONTRACTS

G3 - 6	standard acceptance of automated fabrication methods
G3 - 7	acceptance of electronic documentation in lieu of traditional paper documents
G3 - 9	designers flexibility during fabrication to change details to fit automation of selected shop
G3 - 10	revise contractual arrangements to allow flexibility
G3 - 11	certification program acceptance (Requiring Certification)
G3 - 12	improve certification process with more categories (higher standards)
G3 - 20	acceptance of material that is pre-fabricated
G3 - 23	automated record keeping of quality parameters in shop and acceptance by owner
G3 - 29	comprehensive as built plans with details as constructed
G3 - 31	National acceptance of coating systems

Group 4 and Unattributed Brainstorming Ideas

Facilitators: Tom Siewert (NIST), Bill McEleney (NSBA)

Owners/Gov't	**Fabricators**	**Other**
Henry Pate, TNDOT Krishna Verma, FHWA Todd Niemann, MNDOT	Tom Guzek, Trinity Bob Smith, Mabey James Tyvand, Addison	Dave Mackey, CEC Yoshihiro Kanjo, NKK Chitoshi Miki, Tokyo Inst. of Technology
George Christian, NYSDOT		

G4 – 1	Need to increase SPEED of construction
G4 – 2	Reduce initial COST of structures
G4 – 3	Certification based on quality of work and work force
G4 – 4	Standardize transport requirements across country for oversize, overweight loads
G4 – 5	Elimination of fabricator weld acceptance testing (PQR's)
G4 – 6	Cost of robot – savings (research data)
G4 – 7	Deliver man-hours per ton through automation
G4 – 8	Research on entire cycle of bridge construction (initiation of design through final punch list); Evaluate ability to change time of process
G4 – 9	Standardize repair details
G4 – 10	Coating system suitable for automation

APPENDIX "F"

Glossary

AASHTO: American Association of State Highway and Transportation Officials. May refer to the Standard Specifications (or LRFD Specs) for Design of Highway Bridges or to the organization whose committees (e.g., T-14 for Steel Structures) recommend changes to those Specifications.

AISC: American Institute of Steel Construction, which provides a certification mechanism for fabricators.

AISI: American Iron and Steel Institute

ASME: American Society of Mechanical Engineers. May also refer to the code governing welding of pressure vessels.

Auto-UT: Automated Ultrasonic Testing (NDE) of welds

AWS: American Welding Society. Also often refers to the D1.5 Bridge Welding Code

B2B: Business-to-Business (e.g., as contrasted with Business-to-consumer)

CAD: Computer Aided Design, or Computer Aided Drafting

CAM: Computer Aided Manufacturing, where software drives fabrication machines

CE: Carbon Equivalent, a measure of the influence of chemical composition on the susceptibility of a weld to cracking

CM: Construction Management, Construction Manager

CNC: Computer Numerical Control (that increasingly drives steel fabrication shop machines)

DB, D/B: Design/Build

DBFO: Design/Build/Finance/Operate

DGN: The file format used by MicroStation CAD software

DOT: state Department of Transportation

e - : electronic, typically using the Internet. e. g.,
e -   commerce: electronic commerce, i.e., utilizing the Internet for buying/selling
e – submittal/transmittal: electronic “shipping,” e.g., of shop drawings
e – redlining: electronic markups, e.g., of shop drawings

EWI: Edison Welding Institute, Columbus, Ohio

Fab: steel fabrication including cutting, bending, punching/drilling, welding, handling, and painting

FCAW: Flux-Cored Arc Welding

FEA: Finite Element Analysis

FHWA: Federal Highway Administration

G.C.: General Contractor

GIS: Geographical Information System

GMAW: Gas Metal Arc Welding process

Inner Shield: One supplier's name for FCAW welding electrodes

ISO: International Standards Organization

IT: Information Technology

Laydown: physical pre-assembly of the superstructure framing of a steel bridge prior to shipping of the fabricated girders to the job site

LRFD: Load and Resistance Factor Design, which is the basis of the AASHTO LRFD Bridge Design Specifications.

MIG: Metal Inert Gas welding process, a type of GMAW

Mill cert: Steel mill provided certification of steel mechanical properties and chemical composition for a particular heat of steel produced

NC: See CNC

NCHRP: National Cooperative Highway Research Program, the research arm of AASHTO

NDE: Nondestructive Examination, Nondestructive Evaluation

NDT: Nondestructive Testing, often used interchangeably with NDE

NHI: National Highway Institute

NIST: National Institute of Standards and Technology

NSBA: National Steel Bridge Alliance

PDF: Portable Document Format, a popular file format for electronic documents

PQR: Welding Procedure Qualification Record (for weld acceptance testing)

QA & QC: Quality Assurance and Quality Control

Reaming: re-drilling undersized holes to achieve full-size holes after physical pre-assembly to assure proper fitup

RFI: Request For Information

ROI: Return on Investment

RT: Radiographic Testing for NDE of welds

SAW: Submerged-Arc Welding process

SCEF: Mid Atlantic States Structural Committee for Economic Fabrication Standards

Subarc: see SAW

TIFF: a popular file format for graphical images

TRB: Transportation Research Board

Turner-Fairbank: FHWA’s research laboratory in northern Virginia

TWI: The Welding Institute, located in the U.K.

UT: Ultrasonic Testing for NDE of welds