Preservation of Historic Iron and Steel in Bridges and Other Metal Structures

2010-04

National Center for Preservation Technology and Training

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Narrative Final Report

NCPTT 2009 Grants

Grant Number: **MT-2210-09-NC-08**

Project Title: **Preservation of Historic Iron and Steel in Bridges and Other Metal Structures**

Beginning Date: **March 1, 2009** Ending Date: **June 30, 2010**

Date of Final Report: **July 14, 2010**

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Executive summary

In the restoration of historic metal structures engineers and preservationists are often confronted with the decision to repair or replace historic metals. The *Preservation of Historic Iron and Steel in Bridges and Other Metal Structures* project demonstrated an alternative to the destruction of important elements of the historic fabric and addressed the urgent need for greater awareness and more widespread expertise in preservation techniques for historic metals. Key to the project's success was the demonstration of proven techniques for the restoration of historic metals to a wide audience of engineers, preservationists, transportation officials, contractors, craftsmen and students. The three main components of the project were all successfully completed: development and implementation of a three-day workshop including hands-on demonstrations, creation of six informational web-based videos, and the development of two training courses.

Preparation for the workshop included research and training in restoration processes using both old and new technologies. The welding staff at Lansing Community College were trained in the historic process of hot riveting, including research in rivet heating methods, and also used their expertise of current welding practices and state of the art facility to refine welding techniques for restoring historic metals. In addition, LCC welding and machining staff prepared welded wrought iron samples for tensile testing and created a display of the results for the workshop.

The workshop was held March 8-10, 2010, with two days of hands-on demonstrations following one day of presentations. Participants not only watched experts perform the restoration processes but also used the equipment themselves. This firsthand experience of the processes, along with the interaction among the variety of attendees (from blacksmiths to engineers) was a highlight for many participants. Collaboration with businesses resulted in three important contributions to the workshop: an extensive display of rivet equipment from Michigan Pneumatic Tool, a heat-straightening demonstration from National Bridge Company, and representation from The Lincoln Electric Company for welding processes.

Professional quality videos were produced by LCC to illustrate hot riveting, rivet removal, pack rust removal, pad welding, heat-straightening and welding processes for restoration. These videos were made available to the public on LCC, NCPTT and YouTube websites. In addition, a DVD of Workshop speakers was produced for Workshop participants.

Two courses have been developed to further training in restoration processes for historic metals beyond the workshop. The courses are in module form and will be offered by LCC's Business and Community Institute starting Fall 2010.

Introduction

In the restoration of historic metal structures engineers and preservationists are often confronted with the decision to repair or replace historic metals. The lack of knowledge of historic metals, combined with the tendency to use today's standard materials of known characteristics and properties, often results in the replacement or destruction of historic metals. In the decision making process regarding restoration of a historic metal structure, three groups of people figure prominently: those who want to restore the structure, the engineers who develop the restoration plans, and the craftsmen who do the restoration work. It is the engineer who often has the most impact on the restoration process. Engineers make many of the decisions that determine the type of restoration that will be performed and the percentage of original material to be saved.

There are few opportunities within the engineering community for engineers to see restoration processes demonstrated and to gain personal experience through hands-on activities. The *Preservation of Historic Iron and Steel in Bridges and Other Metal Structures* project created this much needed opportunity, important in providing engineers different options to the replacement of historic metals and to better comply with The Secretary of the Interior's Standards for Rehabilitation. These standards state, in part, that *"deteriorated architectural features shall be repaired rather than replaced, wherever possible"* and *"removing or radically changing architectural metal features which are important in defining the overall historic character of the building so that, as a result, the character is diminished"* is discouraged. Engineers (and the historic preservationists who work with them) may not become experts in the specific restoration processes, but it is important that they gain enough understanding of how the processes work to be able to recommend them within the scope of work of a preservation project and to communicate more knowledgeably with contractors and craftsmen.

The project also created the opportunity for the contractors and craftsmen who do the restoration work to learn and share their knowledge in an environment that includes engineers and preservationists. In addition, the project addressed the need for greater knowledge among those who want to undertake the restoration of a historic metal structure, including preservationists, transportation officials and various public and civic entities. The project's three components (a three-day workshop including hands-on demonstrations, six informational web-based videos, and two courses for ongoing training) contributed to the goal of increased knowledge and expertise necessary for good communication and sound decision making among the various groups responsible for the preservation of historic metal structures and the historic record they represent.

Methods and Materials

Part 1 Methods for Restoration of Metals

The *Preservation of Historic Iron and Steel in Bridges and Other Metal Structures* project provided training in the restoration of wrought iron, cast iron and historic steel using an innovative blend of historic methods such as hot riveting and modern methods such as welding and the adaptation of current steel fabrication techniques to historic preservation. The restoration methods are summarized below, followed in Part 2 by the training methods used to achieve the project's goals to address the national need for expertise in the preservation of historic metals.

Welding

Electric arc welding was not used in the fabrication of historic metal structures until the early twentieth century, but the various welding processes used in modern steel fabrication have been used successfully in the restoration of historic metals. The Shielded Metal Arc Welding (SMAW) process, adapted to historic preservation by using electrodes designed for welding difficult metals, is especially useful. Wrought iron contains a high level of slag that can be detrimental to making a sound weld. Nineteenth and early twentieth century steels often have higher levels of elements such as phosphorus and sulfur that are not present in high levels in later twentieth century steels. Using welding procedures recommended by the American Welding Society (AWS), wrought iron and historic steels can be repaired and pass both Destructive Testing (DT) and Non-Destructive Testing (NDT). One SMAW electrode that has proven to be useful in welding wrought iron is a low-hydrogen electrode, E7018 (AWS), designed for welding difficult-to-weld metals.

Welding techniques for wrought iron were highlighted at the March 2010 Workshop in a presentation by Lon Yost, Senior Application Engineer from Lincoln Electric, who presented his research (based on work he conducted at Lincoln Electric, 2001) showing that wrought iron can be welded successfully with the SMAW process. He emphasized the following:

- *Wrought Iron can be successfully welded using the SMAW process*
- *Don't expect base material to have consistent mechanical & chemical properties*
- *SMAW, E7018 provides sufficient tolerance of base metal inconsistencies*
- *Heat input of arc welding reduces mechanical properties but not enough to impact service performance*
- *Preheat the wrought iron to 300 degrees Fahrenheit*

Lansing Community College welding and machining staff produced welded samples of wrought iron with E7018 low-hydrogen electrodes and subjected the samples to tensile testing in the LCC metallurgy labs. The tests showed no failure in the weld area or the area between the weld and parent metal referred to as the heat affected zone. A display of the wrought iron samples and the test results was prepared and made available for view at the Workshop.

Section loss due to corrosion in original metals can be corrected with a technique in welding called padding. (Weld padding is used in industry to build up worn machine parts to be machined down later to their original dimensions.) During the Workshop in a hands-on activity the padding technique was demonstrated on a wrought iron eyebar using the AWS low-hydrogen electrode E7018. This process can also be used successfully to repair section loss in other steel bridge members. [View video: Pad Welding for section loss in historic steel and wrought iron]

Wrought iron and steel are not the only metals encountered in the preservation of historic metals. Many nineteenth century metal structures contained cast iron sections. These are difficult to replace or replicate. However, repairing cast iron with electric arc welding processes has proven successful. The SMAW, Oxygen Fuel brazing (OF), and the Gas Tungsten Arc Welding (GTAW) processes have all been used successfully in repairing cast iron. During the Workshop these processes were demonstrated, and many workshop participants actively participated in the welding. A cast iron finial from an 1895 wrought iron bridge that had been damaged during dismantling was repaired using the GTAW process and also with the SMAW process using an electrode specially designed for cast iron repairs, Certanium 889SP. The repairs, started in preparation for the Workshop, were continued as part of the demonstrations for Workshop participants. In addition, cast iron brazing was demonstrated during the Workshop. Participants used the brazing process on cast iron sections supplied by the East Jordon Iron Works. Participants had the opportunity to actually see and experience this process.

Electric Arc welding and Oxygen Fuel welding can be valuable tools in the restoration of historic metals. Ongoing research in these welding procedures is important to contribute to preservation expertise and to encourage engineers and preservationists to recommend such repairs as an alternative to the replacement of original historic metals. [View video: Welding processes for the restoration of Cast Iron]

Hot Riveting

Hot riveting of historic metals or the replication of historic metal sections such as truss bridge components using the hot riveting process preserves an important historic manufacturing process. Many historic iron and steel structures were originally manufactured using hot riveting, both in the shop and in

the field. Hot riveting is often referred to as a "lost art," and while riveting is rarely used in building construction today it is a viable method being used in the restoration of historic metals and the replication of historic metal structures. Riveting was successfully used during the restoration of five historic metal truss bridges for the Calhoun County Historic Bridge Park in Michigan, and Dr. James Cooper, Professor Emeritus of History DePauw University, cited many examples of Indiana restoration work using riveting in his Workshop presentation "Beauty and Efficiency in Historic Hoosier Highway Truss Bridges." Specific examples of restoration involving hot riveting, along with the hands-on demonstrations of hot riveting during the Workshop, addressed the lack of knowledge about this process among many engineers and historic preservationists and showed that hot riveting is a viable method for preserving important historic features of iron and steel structures and, indeed, the historic manufacturing process.

Cost is often used as a primary reason for rejecting the replacement of rivets with rivets in the preservation of historic metal structures. Another argument against riveting is that it is difficult to locate sources of steel rivets, riveting equipment, and experienced craftsmen. Original rivets are often replaced with high strength bolts or with button head tension control bolts. In fact, for some projects, riveting can be done at reasonable cost with readily available materials and with properly trained workers.

Although qualified riveters may be few and far between, workers with heavy industrial experience can easily be trained to rivet in order to carry out such work on a historic preservation project. This is a message that was conveyed to participants in the project's March 2010 Workshop and also demonstrated in the preparations that led up to the Workshop. None of the welding staff at Lansing Community College, except for the project's PI Vern Mesler, had had any prior experience with heating rivets and driving rivets with a rivet hammer. During the months leading up to the Workshop, training sessions were scheduled for several members of the welding staff and resulted in these craftsmen becoming very proficient in the use of the rivet hammer and the proper procedures for the critical task of heating rivets in a forge.

Availability of rivet equipment and steel rivets was also addressed at the Workshop, both in presentations and in Michigan Pneumatic Tool's extensive display of rivet equipment and rivets of various sizes and shapes. Steel rivets can still be purchased today and in most sizes that were available years ago.

The cost of riveting, often cited as a barrier to the use of hot riveting in historic preservation projects, was a topic included in the Workshop to make participants aware of two main aspects to be taken into consideration: the cost of hot riveting may not be as great as is often thought, and there are hidden costs in using other methods (for example, replacing rivets with button head tension control bolts) that are

often not part of the discussion. Specialized wrenches for installation are required for tension control bolts, and tension control bolts are more expensive than regular structural bolts.

To replace historic rivets with rivets or with bolts is a serious discussion among engineers and preservationists, and not having accurate information to make informed decisions for using the hot riveting process prevents the process from being specified in restoration or rehabilitation of historic metal structures. The March 2010 Workshop was designed in part to address this issue, to give engineers and preservationists an opportunity to see the process in use and experience it through a hands-on activity. [View video: The Hot Riveting process with a field rivet hammer]

Rivet removal

Rivet removal is an important task in the restoration or rehabilitation of a historic metal structure and is often overlooked in restoration specifications. Rivet removal by an inexperienced construction worker can seriously damage original historic metals. There are several methods for removing rivets, the most popular being the oxy-acetylene cutting torch with a regular cutting tip or a rivet washing tip. The oxy-acetylene method used by an experienced operator can be an effective means for removing rivets. Another tool to remove rivet heads is the "rivet buster," a pneumatic tool designed to shear off rivet heads quickly. Chisels and punches of various sizes and styles are available to be placed in the rivet buster to punch out rivets after the rivet heads are removed.

The air carbon arc process is another method that is very effective in removing rivets without damage to the parent metal. The air carbon arc torch is connected to an electric welder and air compressor. The process is an arc-cutting process that severs or removes rivet metal by melting it with the heat of an arc struck between a carbon-graphite electrode and the base metal. A stream of compressed air blows the molten rivet head from the surface of the base metal. All the cutting processes mentioned above, except for the oxy-acetylene cutting tip, require a second operation with a pneumatic hammer to punch out the rivet after the head is removed. If the rivet cannot be punched out with the pneumatic hammer, the oxy-acetylene torch with a regular cutting tip is used to pierce the center of the rivet and cut out as much of the rivet as possible while avoiding the edge of the hole.

These processes for removing rivets were demonstrated and thoroughly explained during the Workshop, and participants had an opportunity to handle the equipment during the hands-on activities. [View video: Methods for Rivet Removal]

Pack Rust Removal

Pack rust has always been an issue with engineers when doing a structural analysis for a historic metal structure, particularly in analyzing metal truss bridges. In some cases, an entire bridge may be deemed unsalvageable because of the presence of pack rust. In the absence of effective methods of pack rust removal, engineers have not had the option to remove pack rust and re-use these bridge components.

Pack rust forms between rivets in the joint where a plate and a structural shape (channel or angles) come in contact. A process for removing pack rust was developed during the restoration of historic bridges for the Calhoun County Historic Bridge Park using a rivet hammer and an oxygen-fuel heating torch with a heating tip. The process begins by heating a buckle with a heating torch at 800 to 1,000 degrees Fahrenheit; a plate with a handle is placed over the buckle, the rivet hammer hammers the buckle, and the rust breaks up and is driven from the buckle. The buffer plate prevents scarring or any possible case hardening of the plate. Sequencing the heats and hammering helps prevent distortion; heating a few buckles in one area and then moving on to another buckle further away keeps from concentrating too much heat in any one area. [View video: Pack Rust Removal from historic metal structures]

Three top chord sections from an 1895 historic bridge were brought in from the Calhoun County Historic Bridge Park storage yard and set up at Lansing Community College for the pack rust removal demonstration during the Workshop. Participants saw firsthand how the method works on components of a historic metal structure. Discussions included examples of restoration projects in which pack rust was removed and the metal component re-used in the restored structure, as well as examples where the pack rust was severe enough to use a different approach to restore the structure (such as replacement of top chord plates with new plates riveted on the original channel or angle). In these examples, the presence of pack rust did not result in the automatic rejection of the structure for historic preservation, an important message for the Workshop participants whose work involves making decisions about the feasibility of restoration for a particular metal structure.

Heat straightening

Heat straightening of structural steel sections has been used for years to remove distortion within steel. *"Use of the oxyacetylene flame in performing difficult – even seemingly impossible – tasks in steel work is often underestimated. There are many jobs that beginners as well as old-timers pass up because they are not acquainted with the advantages offered by contractive forces which set in after heat has been properly applied."* This article by Joseph Holt appeared in the October 1955 issue of the Welding Engineer. These processes are well established in the steel fabrication industry, but they are not well

known or understood by bridge preservationists, engineers or General Contractors. Lack of this knowledge can lead to the specification of inappropriate preservation techniques for bent or otherwise distorted components of a historic metal structure, sometimes resulting in the increased cost of the restoration project. During the Workshop the heat straightening method was demonstrated and participants informed of the ways in which steel and wrought iron are dealt with slightly differently in this process.

For the heat straightening demonstration Dan Garijo, part owner of National Bridge Company, provided Workshop participants with work-related applications of straightening damaged steel bridges and other steel structures. In some steel the application of heat is all that is needed, and the addition of hydraulic or pneumatic jacking is not required (in fact, in some structural codes not permitted). In straightening wrought iron, on the other hand, a combination of heating and jacking is required. This is necessary because, unlike steel (which is a homogenous composition of iron, carbon, and other elements), wrought iron is a two-component metal made up of iron silicate (a type of glass-like slag) and high purity iron. [View Video: Heat Straightening for steel and wrought iron]

Methods and Materials (continued)

Part 2 Methods for Training in Restoration of Metals

The *Preservation of Historic Iron and Steel in Bridges and Other Metal Structures* project featured an innovative combination of three training components: informational web-based videos, a three-day workshop including hands-on demonstrations, and two training courses. All three components shared the goal of addressing the national need for preservation expertise involving historic metals, with the aim of preserving as much of the original fabric of historic metal structures as possible.

Informational Videos

Informational videos demonstrating six restoration processes were a key component of the project. These were produced by staff in Lansing Community College's Media Department, with videotaping done in the LCC welding facility and professional narration added in production, based on expertise shared by the project P.I. Vern Mesler. The purpose of the videos was to have a audiovisual record of the restoration processes that could be used both for advertising the Workshop (letting potential

attendees know ahead of time the kinds of processes to be demonstrated) and for widespread dissemination through websites in order to reach those who need this information for historic preservation. Although not intended as stand-alone training videos, they could be used as an introduction to metals restoration processes as part of more comprehensive, hands-on training sessions. The videos were produced in such a way that the same videos could be used to advertise future workshops in case it were possible to offer a metals restoration conference on a regular basis beyond the grant-funded period.

The project originally proposed two videos, each to be distributed on DVD, with shorter segments produced for web-based viewing. The two proposed videos were titled *The Restoration of Historic Metals* and *Hot Riveting*. After videotaping was completed, it was decided to produce the six shorter segments (four for *The Restoration of Historic Metals* and two for *Hot Riveting)* to offer on the LCC and NCPTT websites (and on YouTube) rather than on DVD. (On the other hand, the presentations from Day 1 of the March 2010 Workshop, which were originally proposed to be available on website only, were produced on DVD instead.) In the future, the web-based restoration videos could also be made available on DVD. The six video segments appeared on an LCC website specifically developed for the March 2010 Workshop:

The Restoration of Historic Metals

- Pad Welding for section loss in historic steel and wrought iron
- Pack Rust Removal for historic metal structures
- Heat Straightening for steel and wrought iron
- Welding processes for the restoration of Cast Iron

Hot Riveting

- The Hot Riveting process with a field rivet hammer
- Methods for Rivet Removal

By late August 2010, outside of the grant-funded period, a stand-alone webpage featuring the six videos will be created and the link made available to NCPTT and other organizations with an interest in historic preservation and metals restoration.

Workshop

The central component of the *Preservation of Historic Iron and Steel in Bridges and Other Metal Structures* project was the three-day workshop held March 8-10, 2010, at Lansing Community College, designed to inform participants of feasible, proven preservation techniques for the restoration of historic

metals. The methods demonstrated at the workshop have been described in Part 1 of this section of the report. The workshop was divided into two segments, paper presentations on Day 1 and hands-on demonstrations on Day 2 and Day 3. The first day was offered as a stand-alone conference, attracting 53 attendees. Participation for Days 2 and 3 was limited to 40 people due to the hands-on nature of the demonstrations. This portion of the Workshop filled to capacity. Most attendees for Day 1 chose to participate in all three days. A sit-down lunch on Day 1 proved to be an excellent occasion for discussion, along with luncheon speaker James Cooper's well-received presentation on Indiana bridges.

The presentations on Day 1 (March 8, 2010) were given by a variety of experts from business, government and academia:

"Michigan Historic Bridge Inventory"
Lloyd Baldwin, Project Manager for Michigan Historic Bridge Inventory, Michigan Department of Transportation
Sigrid Bergland, Historian, Michigan Department of Transportation

"Design and Performance of Riveted Bridge Connections"
Bill Vermes, Project engineer for Euthenics, Inc., Cleveland, Ohio

"Engineering and Historic Metal Truss Bridges"
Frank J. Hatfield, Professor Emeritus of Civil Engineering, Michigan State University, East Lansing, Michigan

"Wrought Iron and Historic Steel"
Dario Gasparini, Professor of Civil Engineering, Case Western Reserve University, Cleveland, Ohio.

" 'The Continuous Clatter': Practical Field Riveting"
David A. Simmons, Editor of *Timeline*, Ohio Historical Society, Columbus, Ohio

"Arc Welding Wrought Iron"
Lon Yost, Lincoln Electric Global Application Engineer, Lincoln Electric Company, Cleveland, Ohio

"Beauty and Efficiency in Historic Hoosier Highway Truss Bridges"
James Cooper, Professor Emeritus of History, DePauw University, Greencastle, Indiana

All seven presentations were videotaped in order to document this portion of the Workshop and to provide a vehicle for dissemination. The Lansing Community College Media Department produced three DVDs that, together, provide a record of Day 1 of the Workshop. The PowerPoint slides submitted by each speaker were integrated into the video of the speaker's presentation, resulting in a high quality record of the seven presentations. Each Workshop participant received a set of the three DVDs.

The demonstrations on Day 2 and Day 3 featured the restoration processes described in an earlier section of this report (Methods and Materials, Part 1), as well as proper safety procedures for all aspects

of the work. Hot riveting, pack rust removal and heat straightening were demonstrated on Day 2. Rivets were heated in a propane gas forge (commonly used by blacksmiths for making knives) and riveting with the field rivet hammer was done using a steel fixture designed for rivet training and fabricated in the LCC welding facility. Top chord sections from a historic metal truss bridge were used to demonstrate pack rust removal, and heat straightening was performed on a modern structural steel member. The demonstrations on Day 3 focused on welding processes adapted for restoration of historic metals. In two cases, the metals used for the welding demonstrations were from historic metal structures: a wrought iron eye-bar from a bridge of the 1880's with section loss was repaired by pad welding using the Shielded Metal Arc Welding process; and a cast iron finial from a 1895 bridge that had been badly damaged in the removal of the bridge from the river was repaired using the Gas Tungsten Arc Welding process.

Demonstrations of the restoration processes ran in concurrent, repeated sessions so that participants were able to view each process in a group small enough to allow for easy viewing and interaction with the demonstrators as well as hands-on participation. Demonstrators were experienced instructors, most of them faculty in the welding program at Lansing Community College, assisted in some cases by LCC students.

Day 2 (March 9, 2010)

Methods for heating steel rivets: ***Jeff Haynes*** (LCC faculty)

Driving rivets using field riveting equipment: ***Roger Morrison*** (LCC faculty) assisted by ***Adam Mena*** (LCC student)

Pack rust removal: ***Roy Bailiff*** (LCC faculty) assisted by ***Dan Stinson*** (LCC student)

Heat straightening wrought iron and steel: ***Dan Garijo*** (National Bridge Company, Okemos, Michigan) and ***William Eggleston*** (LCC faculty)

Day 3 (March 10, 2010)

OFW (Oxygen Welding and Brazing): ***Jeff Haynes*** (LCC faculty)

SMAW (Shielded Metal Arc Welding): ***Vern Mesler*** (LCC faculty) assisted by ***Dan Stinson*** (LCC student)

ACA (Air Carbon Arc Gouging) and *OFC (Oxygen Fuel Cutting):* ***Roger Morrison*** (LCC faculty) assisted by ***Adam Mena*** (LCC student)

GTAW (Gas Tungsten Arc Welding): ***William Eggleston*** and ***Roy Bailiff*** (LCC faculty)

Training Courses

Two training courses were developed: *Restoration of Historic Metals* and *Hot Riveting with a Field Rivet Hammer*. The courses will be administered through the Business & Community Institute (BCI) of Lansing Community College and available starting with the Fall 2010 semester. These two courses are designed to accommodate small groups within business or government agencies such as engineering firms, consulting firms, or State and Federal transportation departments. The Business & Community Institute, "committed to economic growth and improving the quality of the area's workforce" <www.lcc.edu/bci/about-us>, has considerable experience serving the training needs of business and industry and is well equipped to advertise and offer these two courses. It was originally proposed that the Technical Careers Division of Lansing Community College offer the courses as part of its college curriculum, but it became clear that BCI would be better equipped to make sure the courses reach their intended audience and can be offered "on demand" as requested by businesses.

The courses are designed for those whose responsibility it is to write specifications for a scope-of-work or to make recommendations for the preservation of a historic metal structure. These include (but are not limited to) State Departments of Transportation, State Historic Preservation Offices, historians, historic preservationists, engineers, consultants, and contractors.

The training courses are meant to address the project's goal to increase the number of designers, builders and others who can confidently specify rehabilitation procedures for the restoration of historic metals using current steel fabrication and historic technologies. The courses will give participants a better understanding of and sensitivity toward historic iron and steel bridges and other metal structures and their fabrication technologies, with hands-on experience in the repair and rehabilitation of historic metal structures using hot riveting and careful application of welding technology and related processes. The curriculum is guided by the Secretary of the Interior's Standards for Rehabilitation, emphasizing that the replacement of historic structural members and connections with modern materials should be avoided when not necessary or when detrimental to the characteristics that give a historic metal structure its historical and technological significance.

The course *Restoration of Historic Metals* provides an introduction to processes for the repair of wrought iron, historic steels, and cast irons, including the Shielded Metal Arc Welding (SMAW), Flux Cored Arc Welding (FCAW), Gas Tungsten Arc Welding (GTAW), and Oxygen Fuel Welding (OFW). The course has the following learning outcomes:

- Identify wrought iron, and historic steel and cast iron, and describe their properties
- Describe the Secretary of the Interior's Standards for Rehabilitation
- Recognize historic manufacturing processes and their impact on the restoration of historic metals
- Identify the appropriate use of Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Gas Tungsten Arc welding (GTAW), and Oxygen Fuel Welding (OFW) processes.
- Make recommendations for the most efficient welding process for the restoration of a metal
- Identify the appropriate use of Oxygen Fuel (OF) cutting process including types of fuel gas available for the process and the metal most efficiently cut with the process.
- Identify appropriate use of the Air Carbon Arc (ACA) cutting process and the metal most efficiently cut
- Identify the appropriate use of the Plasma Arc cutting process and the metal most efficiently cut with the process.
- Describe and recommend heat straightening for the restoration of historic metal
- Demonstrate an understanding of welding and fabrication terms and definitions

The course *Hot Riveting with a Field Rivet Hammer* provides an introduction to the pneumatic field rivet hammer process for the restoration or replication of historic wrought iron or steel riveted connections. Included in the course is an introduction to the process of heating steel rivets to their proper temperature with a propane gas forge, driving rivets with a pneumatic field rivet hammer, removing age worn or defective rivets with the air carbon arc process and the oxygen fuel process, and removing pack rust with the pneumatic field rivet hammer. The course has the following learning outcomes:

- Demonstrate properly heating steel rivets in a propane gas forge
- Identify when the correct heat of a rivet is reached by the color of the heated rivet
- Identify the parts of a pneumatic field rivet hammer
- Properly buck-up (to hold a hot rivet in the rivet assembly hole) a heated rivet with a bucking bar or holder-on in preparation for driving a rivet
- Safely drive a heated rivet with a pneumatic field rivet hammer
- Safely remove age worn or defective wrought iron and steel rivets with a rivet buster
- Remove wrought iron and steel rivets with the air carbon arc and oxygen fuel torch
- Remove pack rust with a pneumatic field rivet hammer and buffer plate

Results and Discussion

"The workshop fills a national preservation need to better understand and be sensitive to historic metal-truss bridge fabrication technologies, with both training on the history of iron metallurgy and truss technology, along with hands-on practical training in using the relatively lost art of riveting, along with careful application of welding technology, to make non-destructive and compatible repairs that limit the loss of a truss bridge's historic fabric. The multi-disciplinary curriculum is directed at practitioners, including government officials, engineers, consultants, and contractors, who often have limited training and understanding of old iron, and due to this lack of practical experience choose to replace truss members and connections with modern materials when it may not be necessary and detrimental to the characteristics that give a truss bridge its historical and technological significance." (Harshbarger 2009).

Patrick Harshbarger, Principal Historian/Architectural Historian, Hunter Research Inc. (and Newsletter Editor for the Society for Industrial Archeology) has recognized, as have many preservationists, the need for greater exposure to the details of metals restoration methods among a wide variety of practitioners on a national level. This project successfully demonstrated to a diverse audience restoration methods for cast iron, wrought iron and historic steel through practical demonstrations; shared research relevant to metals restoration in historic preservation; and addressed engineering concerns related to historic metals.

Among the results of implementing this project, several stand out. (1) In-depth training for a core group of professional instructors was key in preparation for a successful Workshop, for contributing to ongoing research and curriculum development, and for demonstrating the effectiveness of the training methods. (2) Recruiting and funding university students resulted in a valuable experience for future engineers and historic preservationists to attain a greater awareness of historic metals and feasible restoration methods early in their careers. (3) The opportunity for hands-on involvement by participants during the demonstrations of restoration methods was invaluable in conveying both an understanding of the methods and a practical sense of what is entailed in using or specifying these methods for historic preservation projects. (4) Interaction and exchange of information among the variety of people who came together for the Workshop was a rare and much appreciated opportunity for participants. (5) The involvement of businesses whose work relates to the processes or the equipment for metals restoration was educational both for Workshop participants and for the business representatives themselves. (6) The web-based videos, widely accessible, have already become an important resource for people trying to save a historic metal structure or to become aware of restoration methods.

Professional Development of Trainers

To prepare the LCC welding staff for the hands-on demonstrations, one-day workshops were scheduled and implemented on a regular basis during the year prior to the March 2010 Workshop. These workshops were open to the public and gave the staff an opportunity to sharpen their skills in the following methods: heating and driving rivets, welding cast iron, heat-straightening, and welding historic metals. The success of these training workshops was affirmed by the written comments from the March 2010 Workshop participants (on Participant Feedback Forms and in later communications):

- *The enthusiasm and energy of the instructors, their helpfulness-all coupled with their great knowledge and experience*
- *The hands on activities were tremendous, the staff was very knowledgeable, and patience was abundant, the facility was perfect for this conference/training*
- *All instructions thoroughly explained the processes used*
- *Every instructor was always patient, never dismissive, and encouraging with each of us as we wrestled with this equipment, all of which is potentially dangerous if not handled carefully. They really know how to teach, and that hands-on experience was valuable.*

Through in-depth training of professional instructors, this project resulted in a core group of staff both proficient in the restoration methods and expert in the craft of training others. This sustained professional development made possible their effective demonstrations and hands-on guidance during the Workshop, critical to the project's goal that engineers and historic preservationists, who need not become experts in the specific restoration processes, gain an understanding of how the processes work to be confident recommending them within the scope of work of a preservation project.

Contributing to the success of the pre-Workshop training sessions was careful planning (including appropriate equipment and materials) and the enthusiasm, dedication, and collegiality of the LCC staff who worked on this project.

Training for Future Engineers

To advance the craftsman's legacy in engineering education, five $600 scholarships were awarded to university/college students to attend the March 2010 Workshop. Supporting students to participate in the Workshop contributed to one of the goals of the project, namely that future engineers gain a better understanding of historic preservation and of restoration methods early in their careers to carry forward in their future work. The scholarships were advertised through engineering departments and historic preservation programs at universities, as well as in all advertising related to the Workshop. Recruitment

efforts resulted in the selection of four engineering students and an artist craftsman to attend the Workshop. The following students attended all three days of the Workshop (included are excerpts from their applications for an indication of their particular interest in this opportunity):

Robert Carr, Ferris State University

The content of this workshop will build my understanding of steel bridges and structures. It will help me to understand how to design better structures. I also hope that the knowledge gained from this workshop will allow me to become knowledgeable in steel preservation techniques that I can carry with me through my career.

Matthew Daly, Eastern Michigan University

In 2007 I received my Bachelor's in Civil Engineering with a focus in transportation at Montana State University. My desire to work with historic structures has brought me to Eastern Michigan University's Graduate Program in Historic Preservation where I am in my second semester in the program's preservation technology and materials conservation discipline. This workshop will augment the courses I'm currently taking and will provide invaluable information for my final project this semester on the historic uses of iron and steel.

Rick DeTroyer, College for Creative Studies

I envision using the techniques learned in this workshop to enhance my metal working abilities in my art studio and to include the restoration of historic cast iron fences, handrails and details on historic buildings.

Tim Francisco, Michigan State University

After working on the Michigan State University Steel Bridge Team for almost 4 years, I have developed a significant interest in the design of bridges, as well as their construction and maintenance.

Kyle MacMillian, Lansing Community College and Lawrence Technological University

These old bridges are amazing in the fact that they can withstand 100 years with minor maintenance, and most of the bridges I work with at MDOT can barely last 50 years. This is part of the reason that I am so interested in these historical bridges. I feel this workshop would open a realm of new insight on current day bridges and those of historic value.

Value of Hands-on Demonstrations

The *Preservation of Historic Iron and Steel in Bridges and Other Metal Structures* project provided those attending the three day workshop and viewing the six informational web-based videos demonstrations of proven preservation techniques for the restoration of historic metals. Integrated into the demonstrations on Day 2 and Day 3 of the Workshop were opportunities for participants to handle the equipment and try out the restoration methods under the attentive guidance of well trained staff. For almost all participants, this was the first time they had used a field rivet hammer or held a welding torch.

Written feedback from participants provided compelling evidence that the hands-on activities were the most beneficial and appreciated by the workshop participants. "*Hands-on, it is one thing to hear about a technique but much more helpful to do it"* was one of many positive comments about the experience shared through the Workshop Participant Feedback Form.

Participants were very receptive to using the equipment. Their eagerness to participate in the hands-on demonstrations and not simply watch, whatever their profession, was somewhat of a surprise. "*I never handled a rivet hammer or a welding torch in my life, before walking into the welding lab this week. … that hands-on experience was valuable. What a rare opportunity for us historians!"* (Robert M. Frame III, Ph.D., Senior Historian, Historic Preservation, Mead & Hunt, Inc.)

Clearly there is enormous value in exposing a variety of people, even those who are not responsible for doing the actual restoration work, to restoration methods through first hand experiences and opportunities not only to observe demonstrations but also to participate actively in the process.

Interaction and Exchange of Information

One of the many benefits of the Workshop was the exchange of information among participants and between demonstrators and participants. This exchange was enriched by the fact that the Workshop attracted such a diverse group of people. Unlike an engineering conference attended primarily by engineers or a blacksmith convention attended mostly by blacksmiths, the Workshop brought engineers, transportation officials, contractors, historic preservationists and others together in a setting conducive to interaction and with a schedule designed to encourage discussion and the sharing of expertise, interests and concerns. When asked about the value of the Workshop, many participants indicated that this interaction was one of the highlights, such as the following:

- *Interaction with other participants and source data for tools, equipment, etc*
- *I enjoyed the wide variety of participants which allowed questions of theory and practice to be explored*

Some exchanges resulted in ideas for other processes or equipment that could be used in metals restoration. For example, during the rivet removal demonstration, one of the participants (Rod LeMasters, Sales Engineer, P.E. at U.S. Bridge, Ohio) recommended Arcair® SLICE systems for removing rivets and pins. Plans have been made at Lansing Community College to purchase this system and to demonstrate this method during a future workshop on the preservation of historic metals.

Involvement of Businesses

Collaboration between Lansing Community College and local and international businesses whose work relates to the processes or the equipment for metals restoration was educational both for Workshop participants and for the business representatives themselves. The involvement of businesses resulted in three important contributions to the workshop: an extensive display of rivet equipment from Michigan Pneumatic Tool, a heat-straightening demonstration from National Bridge Company, and representation from The Lincoln Electric Company for welding processes.

Jeff Dever, Project Coordinator/Technician for Michigan Pneumatic Tool, Inc. (Detroit), an expert in the repair and maintenance of rivet equipment, got an opportunity to see the equipment in action and use it himself in a metals restoration application, an experience that gave him a greater understanding of the riveting process and the rivet hammer and a firsthand look at its application in historic preservation. In addition, he worked with welding processes that increased his confidence in using them in his work. The large display of rivet hammers and different styles of rivets from Michigan Pneumatic Tool was of great interest to Workshop participants and of significant educational value.

Dan Garijo of the National Bridge Company (Okemos, Michigan) demonstrated the use of heating methods to straighten steel. The Workshop provided him an opportunity to teach the skills he uses in his work. Feedback from participants made it clear that they valued his excellent teaching style and his ability to address the technical questions of the audience based on considerable work experience in this field. His involvement with the Workshop made him aware of the impressive facilities available at Lansing Community College and the suitability of LCC's West Campus as a venue for this kind of demonstration.

The Lincoln Electric Company has an established relationship with Lansing Community College, having supplied state-of-the-art welding equipment to LCC's welding facility over the years. Lincoln Electric supported the Workshop by sending Lon Yost (Senior Application Engineer) to make a presentation during Day 1 on research performed at the company's international headquarters in Cleveland, Ohio, and by sending a district salesman to Day 3 to be available to observe the welding demonstrations and to answer participants' questions.

Web-based Videos as Valuable Resource

The videos produced as part of this project have proved to be especially valuable as a web-based resource for information about metals restoration processes that are not widely known nor widely documented in a form available to the general public. There is already evidence that the videos have

become an important resource for people trying to save a historic metal structure or to become aware of restoration methods.

Conclusions

The project work, especially the success of the Workshop, has confirmed that there is not only a need for this kind of training but that professionals of varied backgrounds and professional responsibilities are eager to have opportunities for such training. In addition, it was clear from conversations at the Workshop and evaluations of the Workshop that attendees valued the rare opportunity to meet with and share expertise with a wide range of people interested in historic preservation. A recommendation arising from this project is that more conferences be held to educate people on restoration methods for historic metals, making sure that advertising and recruiting draw from the varied constituencies interested in and responsible for historic preservation of metal structures, bringing together contractors and engineers, historians and blacksmiths, government officials and people interested in saving the historical record of bridges and other metal structures. This suggestion includes a strong recommendation that hands-on demonstrations and opportunities for participants to handle equipment and experience the restoration methods firsthand be included.

It is worth noting that the success of the project was greatly enhanced by the excellent facilities at LCC's West Campus that included full conference services and a state-of-the-art welding facility, by outstanding instructors and professional support staff who engaged in regular training and planning throughout the grant year, and by professional film/videographers with an award-winning record in producing high quality media. Also important to the project's success was the involvement of an advisory committee during the proposal writing stage and beyond, and the selection of external speakers for the Workshop who brought direct experience with the restoration of historic metal structures to their presentations. Speakers and advisory committee members were drawn from across the United States. Finally, the grant period of 16 months (March 1, 2009 to June 30, 2010), rather than 12 months, contributed to the success of the entire project and to a natural pacing for completion of its component parts, especially within the calendar of an academic institution.

Training in metals restoration methods requires ongoing research into effective and feasible practices, especially regarding those methods that are least familiar to most engineers and other decision makers. As a result of discussions and conversations at the March 2010 Workshop, specific areas for future research were identified, including a comparison of rivets and bolts in restoration work

(effectiveness, cost, etc.) and the testing of wrought iron repaired with various welding processes. Research could be carried out as a collaboration between a research university and the community college.

In a letter of support for this project, David A. Simmons, President of the Ohio Historic Bridge Association, Ohio, wrote: *"There is an urgent need for the type of expertise covered by your proposed workshop on historic metal restoration techniques. Too often, if a metal truss bridge is saved from demolition, it must then face inappropriate preservation techniques from well intentioned but misinformed engineers and general contractors. Over the three decades I have been involved in historic bridge preservation, I have seen the unfortunate use of these techniques time and time again. You are working to regain what many in the engineering and contracting worlds had assumed was lost. It is an extremely important effort."* The grant from the NCPTT, with matching funds from Lansing Community College, has supported the effort to educate people in a variety of appropriate techniques for the restoration of historic metals. In order to sustain this effort beyond the grant-funded period, plans are already underway to organize and raise funds for a Conference in March 2011 to be sponsored by Lansing Community College, designed to offer something new to those who attended the NCPTT-LCC March 2010 Workshop and also to introduce additional people to the restoration methods featured in this project. The goal is to make this an annual event, providing leadership in metals restoration for historic preservation.

Acknowledgments

There are many people to thank for the success of the NCPTT-LCC grant-funded project ***Preservation of Historic Iron and Steel in Bridges and Other Metal Structures.*** During the planning stages and proposal writing, the Advisory Committee created for this project provided valuable advice from a variety of perspectives. Throughout the year leading up to the March 2010 Workshop, dedicated faculty and staff at Lansing Community College supported the project in a multitude of ways, including weekly meetings with Vern Mesler, participation in training sessions, professional videotaping and production, and conference planning and implementation. The president of the college, as well as deans, department chairperson, and welding program leader, have been enthusiastic about the project and key to its success. The Workshop owes a great deal to an outstanding group of professionals who agreed to speak on Day 1 and to excellent instructors who demonstrated the restoration processes on Day 2 and Day 3. A variety of companies, government entities and professional organizations also contributed to the project through sharing their expertise, providing equipment and material, and advertising the Workshop. Finally, the project became a reality because of the vision and funding of the ***National Center for Preservation Technology and Training*** and matching funds from ***Lansing Community College***. Both organizations recognized the value of ongoing training in the restoration of historic metals and the capacity of the proposed project to make an important contribution toward this goal.

The project team would like to thank the following people for their involvement in the ***Preservation of Historic Iron and Steel in Bridges and Other Metal Structures.*** In the list below, names are given alphabetically within each category.

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Andrew Ferrell, Grant Manager

Sarah Jackson, Architectural Conservator

[Thanks also to NCPTT's Jason Church for participation in the Workshop and creation of podcast]

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Companies and Organizations

Robert Arthur, Michigan Pneumatic Tool, Inc., Detroit, Michigan

Jeff Dever, Michigan Pneumatic Tool, Inc., Detroit, Michigan

Dan Garijo, National Bridge Company, Okemos, Michigan

Patrick Harshbarger, Society for Industrial Archaeology Newsletter

Kitty Henderson, Historic Bridge Foundation, Austin, Texas

Kevin Henning, Calhoun County Road Commission, Marshall, Michigan

Tom Klemens, Modern Steel Construction Magazine, American Institute of Steel Construction

Larry Kruth, Douglas Steel Fabricating Corporation, Lansing, Michigan

Veldboom Lee, East Jordan Iron Works, East Jordan, Michigan

Lon Yost, Lincoln Electric Company, Cleveland, Ohio

David Snider, Lincoln Electric Company, Cleveland, Ohio

Jim McGuire, Purity Cylinder Gases, Inc., Lansing, Michigan

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