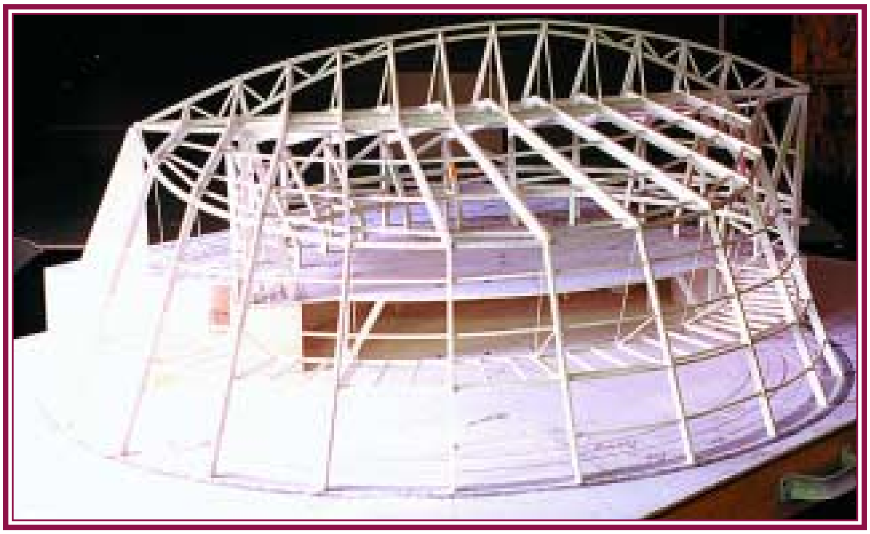
A detailed quality assurance program was created to minimize the owner's risk on a very complex project

By George F. Pavarini, Jr., AIA

Quality Assurance For Steel Projects

EARLY NEXT SUMMER, THE NATION'S LARGEST AND MOST COMPREHENSIVE NATIVE AMERICAN MUSEUM is scheduled to open. The 308,000-sq.-ft. Mashantucket Pequot Museum & Research Center will contain exhibits depicting the culture and history of the Mashantucket Pequot Tribal Nation and its library and research facilities will provide books, artificats and related resources concerning all



North American tribes.

"All of the tribe's activities over the past few decades have been conducted with the goal of preserving Pequot history and culture," explained Richard "Skip" Hayward, Chairman of the Tribal Council. "We have worked hard to re-establish our community on tribal land and the opening of the Museum and Research Center will be the culmination of that effort." Added Theresa H. Bell, Director of the facility: "This achievement represents one of our tribe's greatest goals."

The $135 million facility will include a 150,000-volume-capacity library, 10,000-volume children's library, archeology labs, 85,000 sq. ft. of permanent interior exhibits, a 420-seat performing arts auditorium, two film theaters, a 300-seat restaurant, administrative offices, a 200'-tall observation tower and a central "gathering place".

The gathering place is the central architectural feature and one of the most complex of the center's spaces. The multi-level, multi-function space will enclose approximately one million cubic feet. The maximum clearspans of the roughly circular space are 166'x149' and the space is more than 60' high. Erection of the upper portion of the gathering space structure began in April 1997 and was completed—including field welding—in September. Approximately 850 tons of structural steel frame the space.

To minimize the owner's exposure to certain risks associated with materials, fabrication and erection, the construction manager—in conjunction with the fabricator and erector—developed a detailed quality assurance program for the structural steel portion of the project.

Project Complexity

Adding to the complexity of the gathering place is that it is

composed of a complex, asymmetrical geometry that includes HSS sections, built-up sections and curved members. Most of the members are structurally interdependent, including long-span beams that partially form the bottom chords of a heavy truss. Also, numerous members are fabricated of thick sections with full penetration welds that are subject to lamellar tearing.

Connections were also difficult on the project. There are many shop and field welded connections, including some that contain more than 1000 lbs. of weld per connection, which creates a condition subject to significant shrinkage and distortion. Most of the connections are exposed to view, which thereby imposes further restrictions on the aesthetic quality of the welds.

As on any project, adherence to the established tolerances is mandated by structural integrity requirements. In addition, however, the established tolerances on this project had to allow for the limited adjustability of the glazing system that enclosed most of the structure. The contractors liability relative to tolerances and lamellar tearing is limited to causes due to workmanship. The owner assumed a limited risk for the structure falling outside the established tolerances if such failure is not due to workmanship.

QA Objectives

Given the complexity of the project and the desire to minimize the owner's risk exposure, it became necessary to develop a detailed quality assurance program.

The primary goal of the QA program was to identify defects in workmanship or material at the earliest opportunity to enable corrective work to proceed, thereby avoiding conditions that could cause this work to be outside the established dimensional tolerances. The secondary goal was to document fabrication and erection activities so that if the resultant work is outside the established tolerances, the cause can be readily attributed to either workmanship or other causes. An alternate goal was to ensure that if conditions were identified where the work was outside the established tolerances and not attributable to workmanship, forensic engineering would be readily available to determine causes and propose immediate remedies.

QA Program Success

One necessary drawback to the program was that it was very time consuming to administer. We knew a program of this detail would take a lot of man-hours and this program required attention every day—morning, noon and night. Two members of the CM team had primary responsibility for administering the details: Dan Roth, project manager, and John Carlos, superintendent.

Also, if we were going to do another program of this magnitude, we would change from utilizing a narrative description of what makes an acceptable weld aesthetically to photographic descriptions. Most likely we would utilize AWS' Guide for Visual Inspection of Welds (B1.11-88). It's hard for an owner to interpret exactly what the specs were saying.

On the positive side, we were very successful at controlling shrinkage and distortion. We ended up being within tolerance except for two spots where there was a very slight variation. It didn't cost the owner one penny to go back to correct work to get it within an acceptable range for other trades to be able to complete their work. However, it's important to remember that if you're going to do a program like this, you have to be willing to devote the time.

From the erectors viewpoint, the quality assurance program operated quite smoothly, though there was some additional time spent on monitoring preheating, weld sequences, etc. "We didn't have any problems, such as lamellar tearing, on the project, so the program did not come fully into play," reported Mark Lajoie, a project manager with The Berlin Steel Co., the project's erector. "But had we had any problems, the program would have been a big plus in identifying the cause and suggesting a solution."

Project Team

Architect on the project was Polshek & Partners, New York City, and structural engineer was Ove Arup & Partners, New York City. Construction manager was Pavarini Construction Co. and George F. Pavarini wrote the quality assurance program with advice from Richard L. Tomasetti of Thornton-Tomasetti Engineers in New York City.

Steel fabricator was AISC-member Cives Steel Co. and erector was AISC-member The Berlin Steel Co. Detailer on the project was Computer Detailing Inc. in Salt Lake City.

The testing lab was Independent Materials Testing Lab in Plainville, CT, the welding engineer (field inspections) was John H. Brooks & Associates, Middletown, NJ, and the surveyor was Harris & Clark, Jewett City, CT.

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QA Program Outline

Preconstruction Phase

1. The design team to submit the following information:
   • Critical points (connections, points along members) where tolerances are most consequential.
   • Anticipated deflections of the fully loaded structure (diagram of dead load deflections).
   • Acceptance criteria for ultrasonic testing.
   • Erection procedure recommendations.
2. Peer review engineer to confirm critical points and conditions where a welding engineer may be recommended to inspect welding work in progress.
3. Steel contractor to advise which connections are most likely to be affected by lamellar tearing or distortion.
4. Steel contractor to advise, in advance, when required testing can be performed.
5. Steel contractor to submit erection procedure.
6. Steel contractor to submit written quality control program for shop certification and field work, including qualifications and certifications of key personnel.
7. Steel contractor to engineer and submit welding procedures and distortion control program, per AWS D.1.1, for all connections for approval by Engineer of Record (EOR). EOR to review/approve procedures. The welding procedures shall include: specification of filler metal; welding method; preheat and interpass temperature requirements; sequence of welding within each connection; stress relieving procedures; joint details; deposition rate; type of shielding; and post weld heat treatment. Record as follows:
   • Welding sequence of joints throughout structure.
   • Procedures for pre-approved welds.
   • Procedures for field welds.
8. Steel contractor to submit a Distortion Control Program per the requirements of AWS D1.1-90, section 3.4.3 for review by the EOR.
9. Steel contractor to submit a program for reducing the risks of lamellar tearing.
10. Steel contractor to submit a detailed schedule (by block number) for fabrication, erection, welding and finishing.
11. Steel contractor to prepare a weld sample to establish a mutual agreement with the owner regarding acceptable weld spatter. Owner to review/approve sample.
12. Steel contractor to initiate and submit a procedure for propping and depropping the temporary falsework for approval by the EOR. EOR to review/approve procedure.
13. Steel contractor to submit material certifications as follows:
   • For steel members—mill test reports for ladle analyses, tensile elongation, bend tests and Charpy V-notch toughness requirements.
   • For steel greater than 1⅜” in thickness—through-thickness testing in accordance with ASTM A770
   • For connection material—certificates of compliance for fasteners
   • For welding electrodes—certifications of compliance with Charpy V-notch toughness requirements
14. Construct a physical model of the structure to identify each member and connection.
15. Surveyor generate a 3D computer model based on approved shop drawings to calculate theoretical positions of each end of each member, prior to depropping, and in consideration of anticipated dead load deflection (of the structure alone). Theoretical coordinates shall be based on USGS geological coordinates for North-South and East-West positions and elevations relative to sea level.
16. Set up a reporting system to document certifications of all imperative data relative to each member, connection and critical point. Cross reference appropriate inspection reports from surveyor and testing labs.
17. Surveyor to establish stations at the roof of the museum and at the office building to survey work in progress. Establish permanent precision benchmarks outside the perimeter of the area of disturbance, and within sight of the survey stations to routinely check the positions of the survey stations. Prepare site plan indicating proposed stations and benchmarks.
18. Surveyor to survey the points where the gathering place structure will connect to the existing structure to confirm that existing work is within acceptable tolerances. Record survey data on work sheets.
19. Surveyor to survey the points on level four, where temporary shoring will rest, to monitor deflection in the existing structure as the shoring is assembled and the gathering space is erected. Record survey data on work sheets.

Fabrication Phase

20. Testing lab to audit work of its subcontractor performing ultrasonic testing through observation and cross-checking.
21. Testing lab to perform and submit reports of all heavy members (over 1⅜” thick) to identify inclusions that could increase the risk of lamellar tearing. The following testing procedures shall be performed:
   • Straight beam ultrasonic examination, per ASTM A435/A 435M-82, scanning shall be performed after material is cut. Scanning shall be continuous along parallel paths parallel to the major plate axis, on 3” or smaller centers.
   • Ultrasonic testing shall be per-

formed continuously within 6” of each side of welds on all groove welds and fillet welds of leg length greater than 3/8” in welded moment connections and in base material greater than 1⅜” thick.
• Review test results per Acceptance Standard (Voids greater than 3” in any direction).
• Perform magnetic particle testing on material that has been precut and beveled.
• All material passing the above tests shall be permanently stamped for in-field verification. Where stamps have not been used, testing lab shall explain traceability to inspection reports based on piece numbers.

22. Testing lab to inspect and measure all shop fabricated members and connections to confirm work is within standard AISC tolerances (except truss canoe shall be within 10% of AISC tolerances) and submit report. Construction manager to record in reporting system whether work is within allowable tolerances.
23. Construction manager to arrange a preconstruction meeting with all related parties to present the goals, procedures and respective responsibilities for this program. Attendees shall include:
• Project executive representative for the contractor
• Quality control representative for erection from the contractor
• Quality control representative for the erector
• Surveyor party chief
• Inspector providing field testing
• Welding engineer providing special weld inspections
• Representative for the EOR
• Representative for the architect
• Project executive representing the construction manager
• Project manager representing the construction manager
• Superintendent representing the construction manager
• Representatives from the owner

At the conclusion of the preconstruction meeting, all parties must agree that all reasonable measures to assure quality control have been taken and that no further actions are necessary to monitor workmanship or quality control.

Erection Phase

24. Construction manager to monitor erection progress to confirm work follows the schedule submitted by the steel contractor
25. Construction manager to hold regular meetings with the contractor, erector, surveyor and testing lab to review ongoing submittals and progress of the work.
26. Surveyor to measure each critical point as structure following plumbing and fixing, but prior to welding. Confirm each critical point is positioned correctly, with acceptable tolerances, according to the 3D model in step 15 above. Construction manager to record in reporting system whether work is within allowable tolerances.
27. Inspection labs to monitor each bolted and field welded connection and confirm it is performed in accordance with approved procedures and submit reports. Construction manager to record in reporting system whether work is per approved procedures.
28. Re-survey each critical point after welding to confirm that it remains within acceptable tolerances relative to its preloaded geometric position. Construction manager to record in reporting system whether work is within allowable tolerances.
29. Welding engineer to monitor welding procedures at particular conditions where recommended by peer review engineer and submit reports. Construction manager to record in reporting system whether work is per approved procedures. Should unacceptable conditions occur, welding engineer to provide forensic engineering to recommend remedial action.
30. Construction manager to confirm all inspections for each member. Identify members, connections and critical points that exceed allowable tolerances to owner. EOR and architect to determine whether corrective measures are required for reasons of structural integrity, aesthetics or to accommodate other trades.
31. Architect to perform periodic inspections and provide field observation reports addressing the following issues:
• Confirm weld finishing satisfies contract terms.
• Identify misfabrication of members or connections.
• Identify work that is aesthetically unacceptable as a result of being outside tolerances.
• Issue field observation reports.
32. EOR to perform Special Inspections of work as it progresses and submit field observation reports.
33. Owner to review weld finishes to determine whether weld finishing beyond the contract terms is required.
34. Construction manager and EOR to monitor removal of falsework to confirm the approved procedure is followed.
35. Surveyor to perform a final survey of all members to determine final de-propped position of members. Survey to be submitted for review by EOR and for use by other trades. Construction manager to record in reporting system whether final position of members is within allowable tolerances.