Space-age roof rates top-notch fabrication

Iowa U. rooters cheer Hawkeye hoopsters beneath a skewed-chord truss roof built up of welded beams, tubes, and plates

Can welding shops fabricate a 1,600-ton roof of beams, welded tubing, and plate so that welds need no repair in the shop or rework at the erection site? Yes, as proven by L.L. Le Jeune Company, fabricators of the roof structure for the Carver-Hawkeye Sports Arena. The Minneapolis firm did everything right the first time with vital assistance from welding engineers and inspectors of Barckhoff and Associates, Inc., who supervised quality control from beginning to end.

Dedicated May 1983, the University of Iowa arena seats 15,000 spectators under a space-truss roof structure that measures 378 feet wide, 420 feet long, and 26-1/2 feet deep, supported by eight columns spaced around the periphery.

Knowing the angles

Fabrication was tricky. Designers had opted for a skewed-chord roof, the top chord aligned 45 degrees to the bottom chord. Roof decking lies atop the bottom chord, exposing the 45-degree diagonals and top-chord members to the weather.

For the exposed members (diagonals, top roof-chord trusses, and top hub-connection assemblies), designers chose ASTM A588 Grade A (Cor-ten) weathering steel to avoid the need for periodic painting. Protected members, the lower chord trusses and bottom hub connectors, are of A 572 Grade 50, painted and shielded from the weather by flashing at the deck line. Le Jeune fabricated truss members, beams and tubing, welding connection plates to them, and subcontracted the 251 hub-connection assemblies to Paxton Vierling Steel Company, Omaha.

Barckhoff welding engineers, headquartered in Minneapolis, made sure that welders, AWS-code qualified, followed approved procedures. Barckhoff personnel verified correct settings on power supplies, monitored shop welding procedures and techniques, and verified weld quality on the spot in the shop and in the field. Fabricators and inspectors worked so well together that practically all dimensions met tolerances in every subassembly. When workers at the site bolted truss members and hub assemblies together, only six bolt holes out of 25,000 needed reaming to line them up.

Details of construction

Hub-connection assemblies attach to horizontal and diagonal trusses at upper and lower roof levels. These connectors are vertical plates sandwiched between horizontal plates. Each vertical plate contains several bolt holes to match holes in truss-connection plates. Welded in pairs to ends of trusses, diagonal and horizontal, connection plates tighten up against both sides of matching vertical plates in hub-connection assemblies, creating knife joints that put bolts in double-shear stress, a safe, efficient design.

Complex tension and compression stresses in this roof structure called for careful development

Beams and pipe trusses, held together by bolts and welded connection plates, make up the open-truss roof of the Carver-Hawkeye Sports Arena.

At the site, riggers fit pipe-end connection plates to plates of hub-connection assemblies, then bolt them together.

Inspectors monitored welders and shop welding procedures, and verified weld quality in the shop and field.

and review of welding procedures and techniques all the way from the design stage, through fabrication, to site erection. Welding consultant J.R. Stitt and Barckhoff engineers reviewed joint designs and welding procedures, developed by Le Jeune engineers using AWS-prequalified joints. Procedures spelled out joint preparation, filler metals, machine settings, welding sequences, and heat-straightening methods.

Since stability of the roof structure depended on the truss-hub connections, the fabricator flamecut 5,000 plates, which he sent to subcontracting machine shops for drilling of bolt holes, using numerically controlled drills to hold dimensions and spacing to tight tolerances. Then the fabricator welded plates into assemblies, firmly restrained to forestall warping.

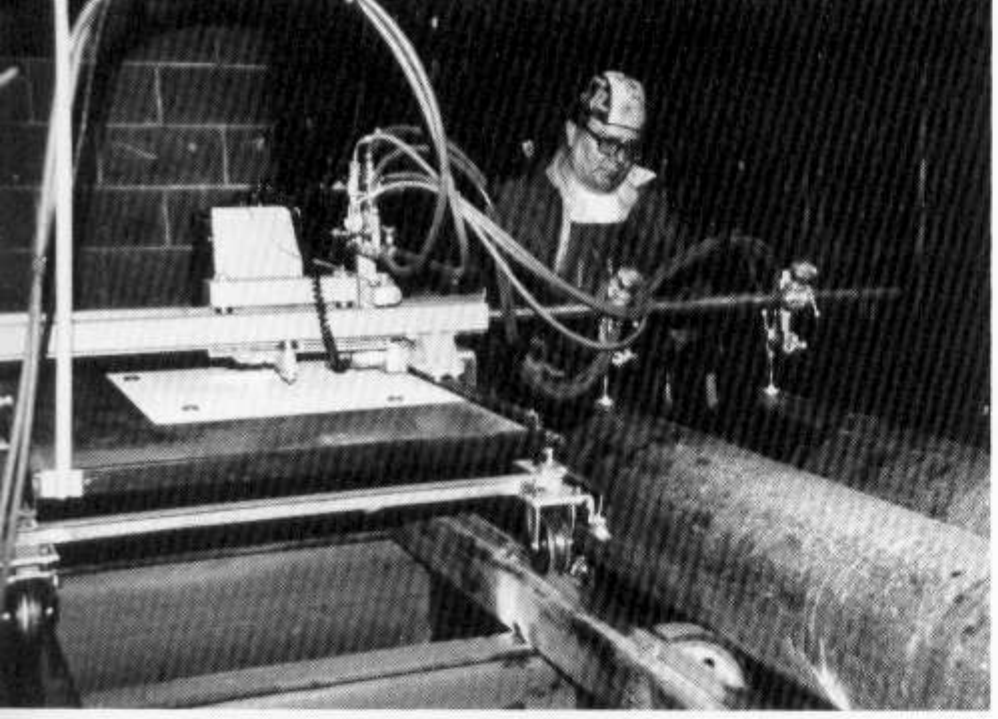
Compensating for warpage

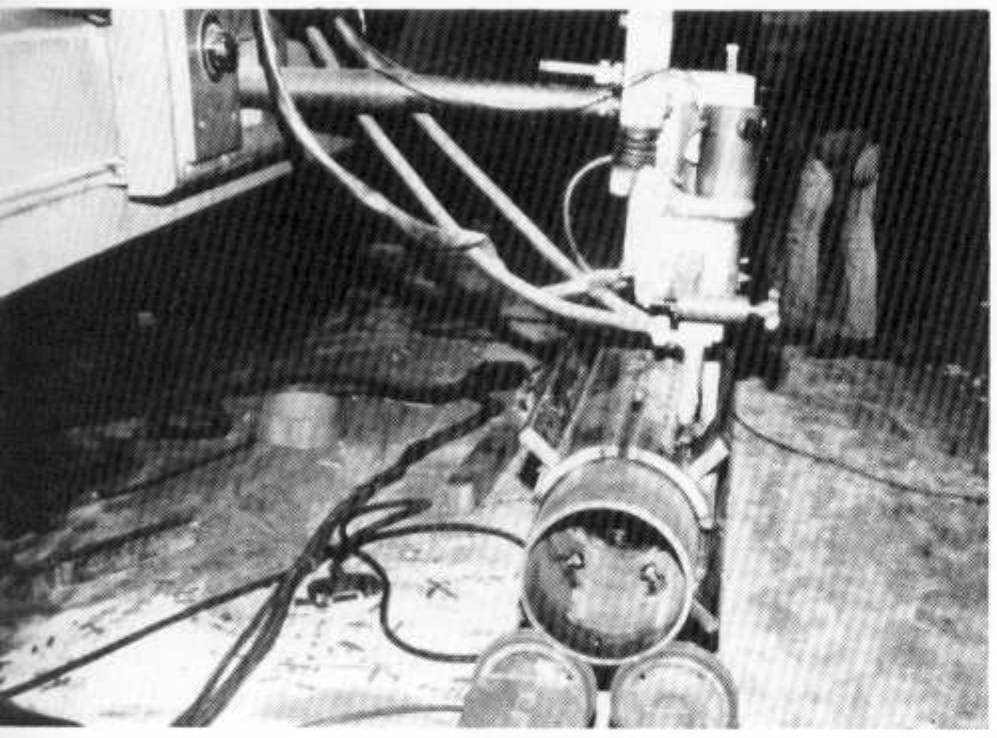
Some connection plates for compression members required stiffeners. To make sure that stiffeners would come out straight and flat, the fabricator precambered them in a fixture, bending them just enough to compensate for longitudinal shrinkage that would occur during welding. Then, operators continuously welded each stiffener, using two semiautomatic submerged arc welding (SAW) guns mounted on a portable tractor.

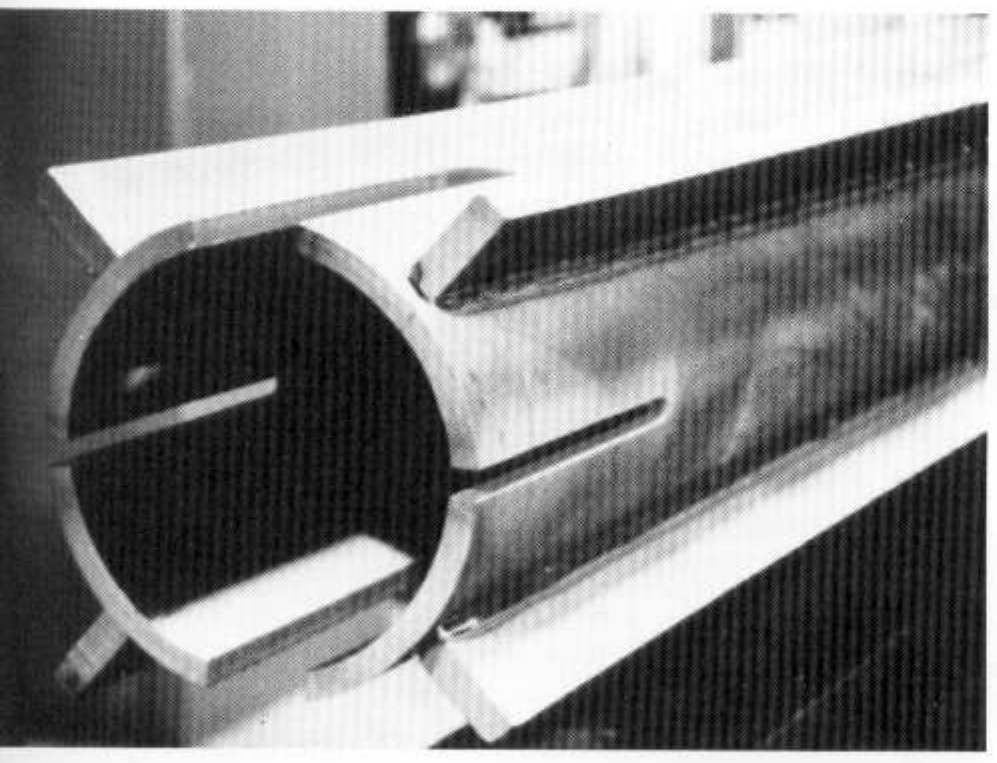
After welding, the operator mounted a gas torch on the tractor and ran a flame along the back of the weld to counter distortion, heating it enough to restraighten the assembly. Dick Anderson and Clayton Lacroix, Le Jeune engineers, won a Bug-O Bowl award for devising this work-saving piece of equipment.

Ends of truss members required smooth, straight, accurately aligned slots, into which connection plates fit firmly. To cut the slots, Le Jeune engineers devised a two-torch flame-cutter guided by track-mounted optical tracers. Aligned parallel to a double-pipe roller positioner, the torches indexed around the tube, cutting slots at preset angles. At the start, operators soon learned that cutting heat distorted the tubes enough to throw slot sides off parallel. Engineers solved that problem by drawing up a tapered pattern for the torches to follow, counteracting the warping effect enough to assure parallel slots.

Before welding truss members, fabricators tacked them together in





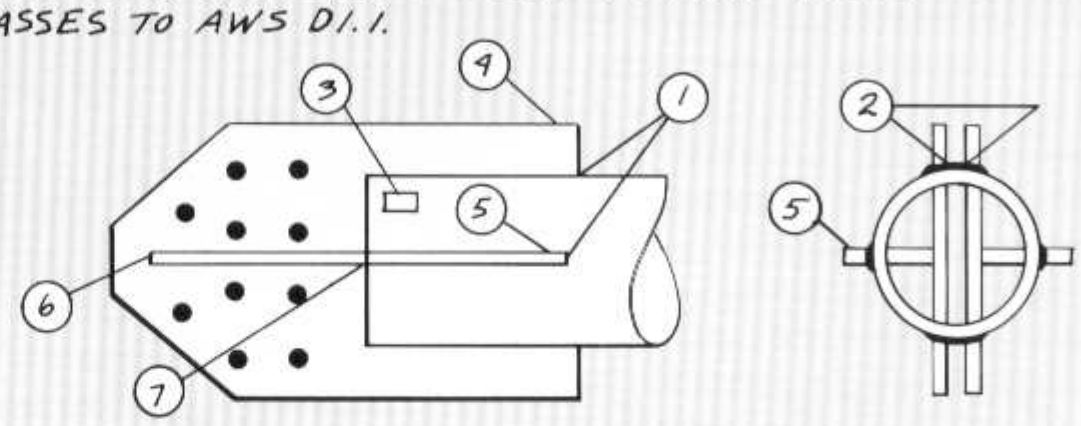


fixtures, using stick welds made with E8018-C3 electrodes, then moved them to welding stations. Made of A588 tubing, top-roof horizontal and diagonal trusses were SA-welded with hand-held guns, using

HAWKEYE SPORTS ARENA
PIPE END CONNECTION
INSPECTION REQUIREMENTS

BARCKHOFF
AND ASSOCIATES, INC.
1-13-81
WRE

CHECK ALL WELDS FOR SIZE & LOCATION TO PRINT & FOR ROLLED WELDS, NONFUSION, CRACKS, END WRAPS, TIE-IN, UNDERCUT, UNFILLED CRATERS & SHARP VALLEYS BETWEEN PASSES TO AWS D1.1.



1 HIGH STRESS AREA-
NO UNDERCUT IN PIPE TRANSVERSE TO PIPE LENGTH.
NO OVERLAP OR ROLLED WELDS.
NO STEEL STAMPING IN PIPE WITHIN 6" OF WELD.
WELD ACROSS ENDS OF RIBS TO FAIR SMOOTHLY INTO PIPE.

2 VISUALLY CHECK FOR SHORT CRACKS IN LINE WITH FAYING SURFACES OF SPACER & CONNECTION PLATES AT UPPER TOE OF WELD.

3 STEEL STAMP "MARK NUMBER" WITHIN 6" OF PIPE END.

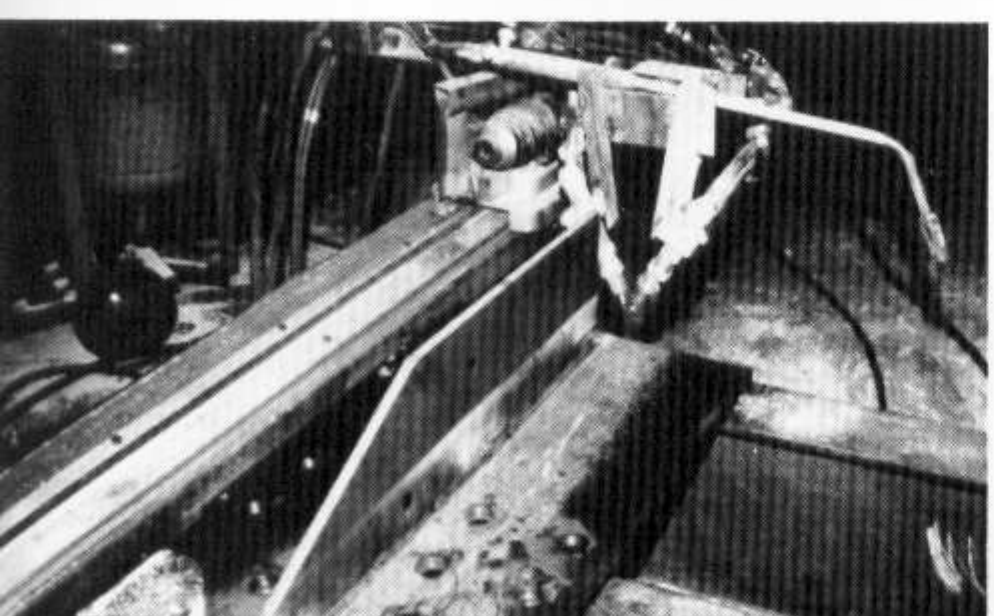
4 STEEL STAMP "SERIAL NUMBER" WITHIN 1" OF CORNER.

5 STEEL STAMP "WELDER'S NUMBER" ON OUTER CORNER OF STIFFENER RIB.

6 RETURN FILLET WELD AROUND END TO SEAL OUT WATER. UNDERCUT OF RIB EDGE AT UPPER JOB OF WELD ACCEPTABLE - TYPICAL ALL RETURN WELDS.

7 CHECK CORNER FOR OVERLAP, NONFUSION & SLAG POCKET

Le Jeune operators fabricate truss connections. Top left: Operator monitors flame-cutting as tandem torches, guided by optical trace, cut slot in truss end. Second from top: Automatic SAW lays fillet weld joining fin to tube. Third from top: Slotted end, finned for strength, ready for connection plates. Bottom left: Tractor-mounted SAW torches fillet-weld connection plates. Bottom center: Fixtured plates, fins ready to be tacked. Bottom right: Welder runs manual SAW torch, joining plate to truss end.



CARVER-HAWKEYE SPORTS ARENA PROJECT ASSIGNMENT

Fabrication Quality Assurance/Quality Control Program

The Concern

The structural engineer, Geiger Berger Associates and the owner, The University of Iowa, decided from the start of the project that because of highly publicized problems on other space framed structures quality would be of prime consideration. The engineer decided the key was to be certain the welding was done right the first time.

The Objectives

- Ensure the welded connection details meet all design and code requirements.
- Develop a quality assurance/quality control plan that would ensure the structure is fit and welded right the first time to avoid costly and possibly detrimental repair work.
- Provide detailed inspection and non-destructive testing to verify the safety of the structure.

How It Was Accomplished

Prior to start of fabrication L. L. LeJeune Company prepared detailed procedures for joint preparation, fixturing and welding of all members. Barckhoff and Associates, Inc. checked and approved these procedures, assisted in development of workmanship performance standards and established inspection requirements that included an in-process surveillance from fit-up through completion and final inspection of the welds.

At the very beginning of LeJeune shop fabrication and then routinely during production, Barckhoff monitored each welder's technique to ensure acceptable welds prior to inspection. This was unique compared to typical weld quality programs in that it provided the means for in-process correction of any deviations from required procedures and techniques before welds were completed. Results of follow-up inspections (visual, magnetic particle and ultrasonic examinations, and weld size measurement) were closely monitored to detect quality trends that needed corrective action.

The Results

- Only minor touch-up welding was required after inspection.
- There were no schedule delays due to welding during shop fabrication and field erection.
- Welds met all design specifications as verified by specified methods of nondestructive examination.

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