Welding Considerations With High-Strength Steel

By Peter Lawlor

It was evident from the project's inception that the Colonial Stadium (used for soccer and other sporting events), currently under construction in Melbourne, Australia, would be a challenging fabrication project due to the structure's difficult design that includes a retractable roof that will fully open and close in just twenty minutes. Alfasi Construction was awarded the job in January 1998 by Baulderstone Hornibrook for the fabrication of the stadium's steel structure. The job incorporated more than 5,000 tonnes of steelwork, including major tubular trusses with lengths up to 220 m (722').

As the project progressed, several common construction issues were addressed. From this experience, the following lessons were learned: materials with higher strength and alloy content are weldable, but attention to details such as hydrogen and preheat control are essential; tubular construction requires extremely close fit-up and tolerance control; and pre-production planning and training pay big dividends.

Main Roof Chords

The steel (European EN10210) supplied for the construction of the main roof chords is a newly developed 460 MPa (65 ksi) micro-alloyed high-strength steel for structural use. The welded fabrication required special treatment to ensure that the high strength characteristics of the steel could be fully utilized.

The higher alloy content and thicker sections of the main support beams (up to 58 mm [2.3"]) required that close attention be paid to three main elements: the selection of the correct welding consumable; the development of realistic and reproducible welding procedures; and a focus on welder skills to ensure quality throughout. It was clear that the project schedule would not allow time for delays or re-work, "We had to get it right from the very first joint," said Terry Phelan, general manager of Alfasi Construction.

Aware that accurate fabrication is dependent on good preparation, Alfasi purchased a Maruhide CNC controlled tube profiler. Since some of the most costly and time critical elements of tubular construction are the preparation, fit-up and tolerances of the tubular members, this step was essential. This machine is capable of plasma-cutting complex profiles in tubular members up to 12 m (39') in length and with a 60 mm (2½" wall thickness, and is the only one of its kind in South Eastern Australia. Throughout the project, this unit was used to cut and prepare complex weld profiles on most of the tubular sections.

Although there was an assortment of welded joint configurations, there were three main types of joints to be considered: Grade 460 MPa (65 ksi) steel for the main chords; Grade 460 MPa (65 ksi) steel to Grade 350 MPa (50 ksi) steel for connections to the main support frame; and Grade 350 MPa (50 ksi) for general connections and supports.

Top: After field welding, a tubular truss awaits installation as part of the retractable roof assembly.

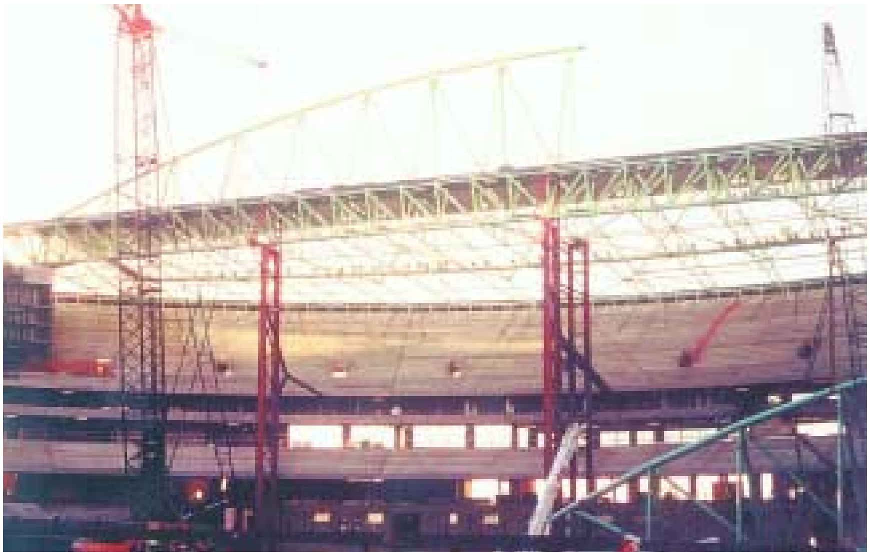
Above: Shop fabrication of some of the large tubular trusses used in the Colonial Stadium.

Matching the Weld Metal Properties

The governing code for the construction of the beams was AS1554 Part 1. However, the higher alloy content of the steel (carbon equivalent of 0.63-0.68) meant the construction specification required further clarification to ensure optimum strength and quality were achieved. For instance, care was taken to ensure weld metal properties closely matched the parent plate and weldments that returned heat affected zone hardness of less than 300HV.

In order to meet the high strength properties of the tubular steel (minimum specified yield strength of 460 MPa [65 ksi] and minimum ultimate tensile strength of 560 MPa [80 ksi]), as well as meet the minimum specified Charpy V-Notch impact properties, while maintaining low hydrogen values, an E81T1-Ni1 (Outershield 81Ni1-H) gas shielded flux cored electrode was used to join the main chords. Straight lengths were joined by a submerged arc combination of F7A6-EM14K-H8 (LA71 electrode with 880M flux).

Initial weld tests indicated that the 460 MPa (65 ksi) steel was prone to high heat-affected zone hardness if preheat and welding heat input requirements were not followed. To ensure that operators were aware of the importance of these factors, additional training was provided to the construction crew to explain the correct handling of the steel and the importance of following the proper welding protocol. The minimum preheat temperature for each joint (varied between 125°C [250°F] and



Installation of a section of the retractable roof.

225°C [440°F] depending on the specific joint details) was maintained and monitored using electric heat blankets. It was this pre-production planning and training that enabled the construction to move along at such an efficient pace.

Achieving Desired Mechanical Properties

Welding the main beams involved careful control of preheat and heat input to achieve good mechanical properties. The welding of the high strength 460 MPa (65 ksi) steel to 350 MPa (50 ksi) steel created a few problems.

As Merril Degee, workshop foreman of Alfasi's Dandenong facility explained, "The welding of the 460 MPa to 350 MPa joints was relatively straight-forward once we determined the effect of preheat and heat input on joint strength and hardness values." However, providing for elasticity and a smooth transition of strengths between the 460 MPa and 350 Grade material wasn't so easy. For example, when we first went to do a procedure for a T type joint made up of a Grade 350 vertical plate with a 460 cap, we used a standard E71T-1 electrode, which did not meet the bend test acceptance criteria. Therefore, it was determined that a different electrode was required.

An electrode with a controlled hydrogen content was selected for these joints (Outershield 71C-H) to meet the testing criteria. The electrode, which meets the E71T-1 classification, was designed to meet 5 ml (max) of hydrogen per 100 grams of weld metal. The new welding procedure with OS71C-H and careful bead placement gave excellent results. The moderate yield and tensile strength of the weld metal gave a smooth transition between the Grade 350 steel and the high strength Grade 460 steel. The end result was a joint with good flexibility, strength and low hydrogen contents. For joining the Grade 350 steel we used a GMAW ER70S-4 electrode (L54) and an FCAW-g E71T-1 electrode (Outershield 71M). Currently, the project is 85% complete and we are ahead of schedule. It is obvious now that without the early focus on welding processes, procedures and electrode selection we wouldn't be in this position.

Over 5,000 tonnes of steel have been processed so far, using more than six tonnes of electrode with very few weld defects.

Construction Logistics

Given the considerable size of some of the weldments, distortion was a potential problem. However, with careful fixture building and continuous monitoring of dimensions during fabrication, distortion was kept to a minimum. The main chords were fabricated in Alfasi's Dandenong workshop in lengths up to 40 m (130'), then transported to the site where they were joined using field welding procedures.

Engine driven welders and portable wire feeders were used to complete the final field welds on the main trusses. Small site tents were erected to ensure that preheat and gas shielding would not be affected by the elements.

For joining the Grade 350 steel to itself, an all-position E71T-8J self-shielding electrode (Innershield NR203MP) was used.

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Building Team

Architecture, Engineering, Construction Management & Landscaping: **WS Atkins & Partners Overseas**

Superstructure Contractor: Joint venture of **Fletcher** of New Zealand, **Murray and Roberts** of South Africa and locally based **Al Habtoor**

Steel Fabricator: **Genrec** (10,000 tonnes)

Island Contractor: **Dutco Balfour Beatty**