The National Museum of Australia, Canberra.

The National Museum of Australia

INNOVATIVE DESIGN AND CONSTRUCTION

CLIENT

National Museum of Australia

ARCHITECTS

Aston Raggat McDougall

Robert Peck von Hartel Trethowan

BUILDER

Bovis Lend Lease

STRUCTURAL ENGINEER

ARUP

FABRICATOR

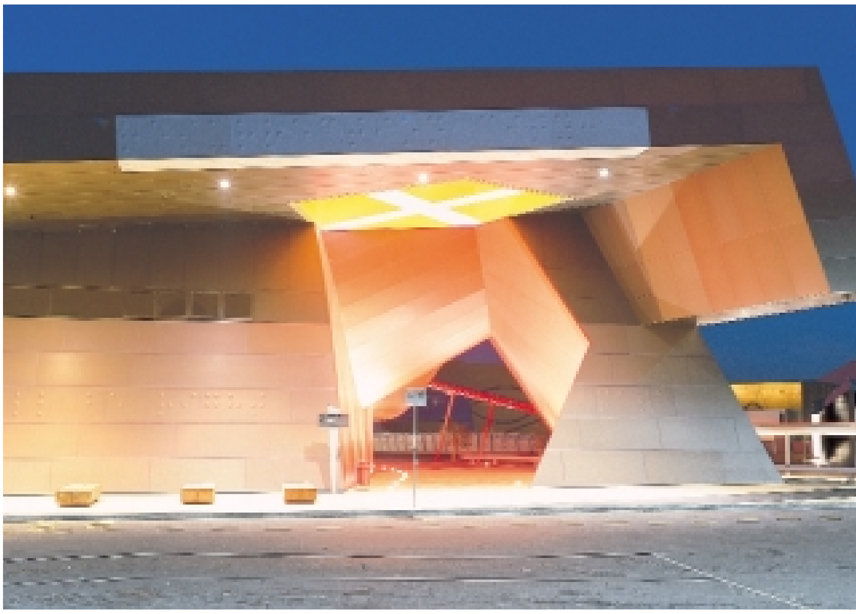
National Engineering

SHOP DETAILING

S&J Drafting

"...The design of the structure takes advantage of the flexibility of steel and uses cutting edge construction techniques."

Structural steel solutions have achieved the architectural intent for The National Museum of Australia and Australian Institute of Aboriginal and Torres Strait Islander Studies in Canberra.



This is a museum of Australian social history and one dedicated to people, events and issues that built a nation. The unconventional form and finish are clearly reflected when visiting the structure for the first time. Horseshoe shaped in plan, the Museum stands on the Acton Peninsula by the side of Lake Burley Griffin in clear view of Parliament House.

Melbourne architects, Ashton Raggatt McDougall in association with Robert Peck von Hartel Trethowan Archiectects won the competition to design the National Museum of Australia and the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS). The result is a complex of low steel-framed buildings which include the Main Hall, Permanent Galleries, Theatres, the Gallery of Aboriginal Art, and AIATSIS and an Administration Block, all of which are linked by an imaginary cord that threads between them.

The design intent was to create a series of buildings that connect the whole of the site without creating an obvious monument. More than 1500 tonnes of intricate steelwork, in all its manifestations, was a key element of the development, with the majority of the building's steel framework concealed in the completed structure.

To meet the March opening, a deadline that was fixed before building began, a construction alliance was formed, bringing together Bovis Lend Lease, Tyco International, Honeywell Australia, Ashton Raggatt McDougall Architects in association with Robert Peck von Hartel Trethowan Architects, Anway Exhibition Design, ACT Government and the Commonwealth Government of Australia. The alliance was a project delivery system where all the disciplines of the project team worked in cooperation, sharing risk and profit to a pre-agreed level with all jointly responsible for the project results.

The design of the structure takes advantage of the flexibility of steel and uses cutting edge construction techniques that offered some major opportunities to the engineers, Arup. One of the most significant was the steel framework and facades, which can only be described as a highly original and innovative use of structural steel. Solutions were achieved through extensive consultation with National Engineering, the contractors for the structural steel fabrication, and S&J Drafting, one of National Engineering shop detailers.

The buildings are geometrically complex and incorporate large propped spans of 30 metres. Additionally, many of the vertical structures (columns and walls) are angled in one or more directions. Unique bay windows, evocative of the Sydney Opera House, undulate while curved facade treatments unfold along the sloped surfaces. These surfaces are the protrusion of the internal "knot surface" developed by the architect. In an ABC interview, Howard Raggatt and Paul Minifie of Ashton Ragatt McDougall explained that this was part of a dream to adopt conical and complex surfaces which unfold, transforming the facade into a kind of giant dressmaker's pattern that comes together as the pattern develops.

According to Pippa Connolly, who leads the design team in the Melbourne office of Arup, despite the complex geometry, every effort was made to simplify the structural solution to make it as efficient as possible in the detailing, fabrication and erection phases. This consisted of minimising the use of butt welds, and eliminating site welding where possible, use of simple fin plate connections and minimising the number of connections (even if an increase in some member sizes was required). These aims were

generally achieved, making the structure simpler to fabricate and erect than it would otherwise have been.

"The overall stability of the structures required careful thought due to the many eccentricities from leaning columns and non-symmetrical arrangements" said Pippa.

In the Main Hall, fabricated by National Engineering the designers utilised the irregular ceiling void created by the "knot" to their advantage and concealed the props that reduced roof spans. This area of the building is framed by seven internal and six perimeter trussed towers, or trees. The columns were formed using vertical tubular cantilever towers. These towers are triangular in plan and form both the major vertical structure and provide the lateral stability through the cantilevered prop and tower arrangement. All the towers are identical except for their vertical alignment which is governed by the building envelope. Each triangular tower consist of three 168 CHS chords and 89 CHS web members. Columns were made up in a lattice arrangement using profile cut tubes fixed to their foundations so as to act as a cantilever. The roof was formed by a series of rafters which make up a spider's web of members.

To achieve the structural stability of the reduced roof spans, and at the same time create the internal building "knot surface", the 150UC and 200UC props were arranged to suit the skylight layout and ceiling/wall profiles. Co-ordination with the architects ensured that the "props" did not conflict with the ceiling/wall envelope and at the same time provided a platform for support of the large skylights.

Arup also co-ordinated the service risers within the trussed towers to ensure maximum use of the concealed spaces without compromising the architectural intent.

Being a museum storing priceless artworks, controlled humidity and temperature levels was mandatory. The majority of the structural steelwork is within this environmentally controlled air space and is not visible. All hidden internal steelwork within this controlled environment was left unpainted delivering a significant cost saving.

The skylights in the main hall roof plane provided a different challenge as the steelwork was fully exposed. Pippa Connolly says Arup worked closely with the whole team, including the glazing suppliers to ensure that the connection details complemented the architecture and provided sufficient construction tolerances for the glazing installation.

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The roof skylights were fully welded CHS frames with stub column legs for fixing to the roof structure. They were entirely prefabricated at ground level on temporary supports, including all the north-facing glazing and sheeting. All the roof skylights were lifted into position with a 200 tonne crane, allowing skylight construction simultaneously with the roof structure and reducing the risk associated with working at height.

The Sydney Opera House style bay window systems, bulging from the inclined walls, were constructed with fabricated mullions inclined in two directions consisting of twin 89 CHS with a 6mm thick plate web. The framing system is tied back to the wall framing members using a twin tension rod on

three lines and an adjustable threaded knuckle connection to each mullion. The bay windows frame into a teardrop opening in the inclined façade and is trimmed with a 457mm diameter CHS curved member and has a stiffened torsion connection integrated into the trussed tower members to resist the numerous combined actions applied. The top of the 457 CHS arc is strutted back into the roof plane to resolve the out-of-plane forces and the opposing end connected with a fin plate arrangement to the adjacent inclined triangular tower chord.

The facades leading up to the Great Hall, and in specific feature areas around the building, presented different challenges. These have 5mm thick steel plate cladding fixed to a tee section or RHS support member, resembling ribbing in the framework of a ship. These plate areas are painted orange and create much of the cut and fold around the different buildings, achieving some complex geometry. Close cooperation between the engineers, National Engineering and their various detailers and Bovis Lend Lease was established to satisfy buildability issues during construction.

According to Pippa Connolly, a preferred method was established to provide a basic angle frame with point connections to steel plate panels, which were then welded and sealed. The basic frames were rotated to form the geometry.

The single point connections were achieved with a threaded stud welded onto the plates. Slotted holes in the connection angles accommodated any adjustments in plane to support the members. All 5mm plate walling was left unpainted until installed to prevent any damage during the installation processes and again internally the plate was left unprotected. Above the curved 5 mm thick plate facades (now orange) and on all the main hall inclined walls is a grey aluminium sheeting fixed over a waterproof sheeting layer.

Leading away from the Main Hall through the Theatre and into the Gallery Space, is a (two level) composite structural steel mezzanine area. These areas are interlinked with composite ramps for additional disabled access between levels and the whole area is enclosed with 700WB115 portal frames. These portals are unpainted, span 22 metres and also have inclined columns, as in the main hall. The curved facade walling is framed with C250 cold formed vertically spanning girts, clad externally with the aluminium sheeting and lined internally.

"The Australian National Museum is complex and unconventional."

The National Museum is complex and unconventional. To realise the optimum design for the structure close collaboration with the design and construction team was required. Everyone involved needed the ability to think and design in 3-D to account for the loading conditions created by angled wall planes, while always looking for the simplest solution. The resulting structure has benefited from the input of all parties during detailed design, particularly through designing to preferred fabrication methods.