This case study was written at the time when OneSteel was part of BHP. In that context, in some instances within this case study, reference may be made to BHP.

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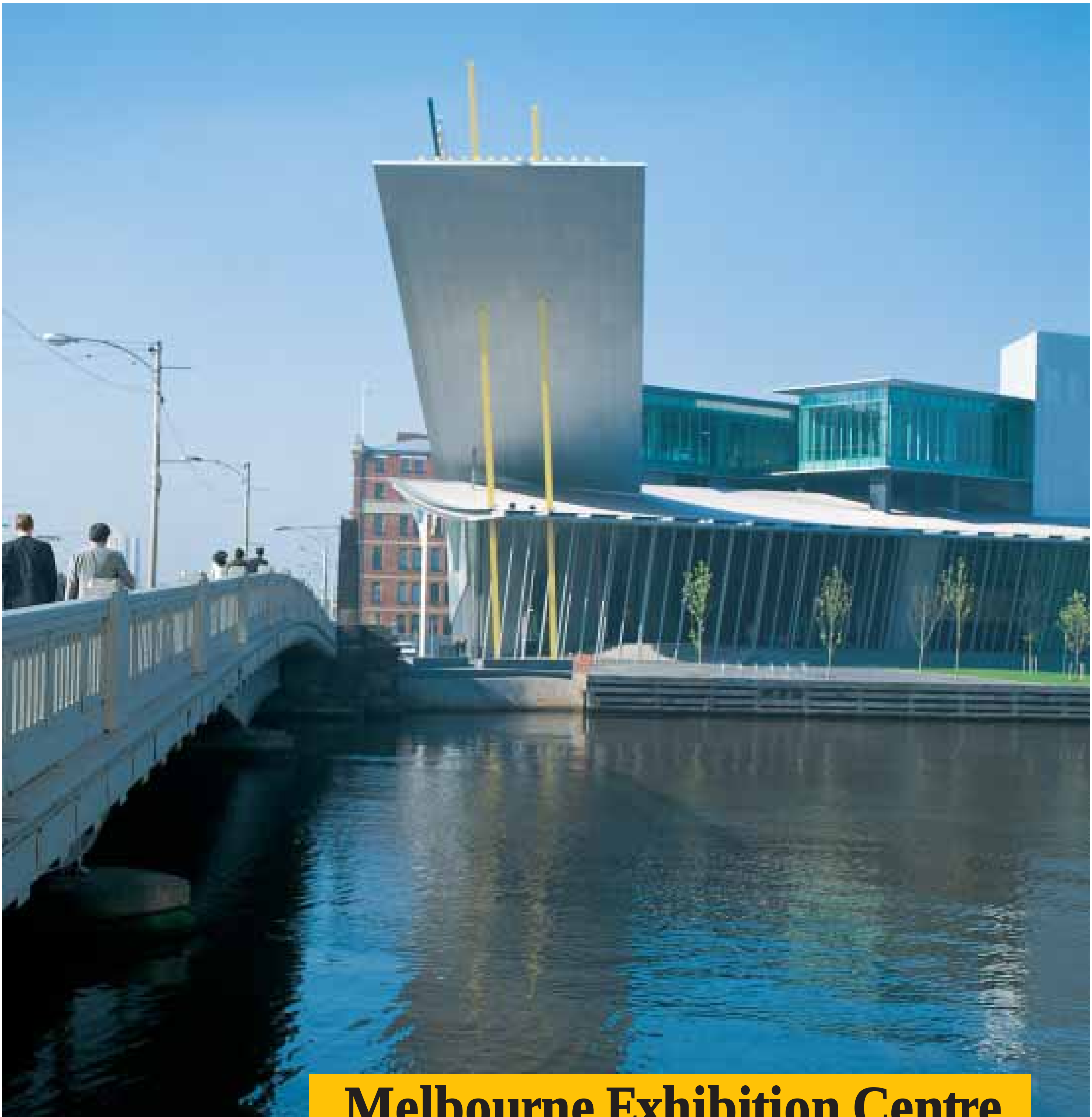


Melbourne Exhibition Centre

Steel's high strength-to-weight ratio enabled the use of extremely large spans in Melbourne's exciting new Exhibition Centre Complex. Recently completed at a cost of $125 million, it is the nation's largest and best equipped, it is distinctive, functional and adaptable, offering the most advanced technical services and facilities. Baulderstone Hornibrook, on a novated design and construct contract, built this prestigious centre within time and budget for the Victorian Government.

Situated conveniently close to the city on the south side of the Yarra River, it is part of the rapidly developing Southbank precinct. Accommodation and convention facilities are within easy reach across the river at the World Congress Centre and adjacent at the huge new casino which is progressing rapidly towards completion. The Exhibition Centre will be operated by the World Congress Centre who will utilise the two centres to compliment each other.

The project comprises a 30,000m^2 exhibition hall, entry building, underground carparking to accommodate 1100 cars, several office and amenities buildings as "pods" adjoining the exhibition area, a concourse and landscaping. Site works and external landscaping of over 60,000m^2 incorporate the Polly Woodside Maritime Museum and pedestrian board walks along the Yarra River.

The exhibition hall is column free and provides uninterrupted space for its total area. This area can be divided by four moveable walls at 13 locations. These divide the open area into smaller spaces in increments of 1500m^2 (modules of 18m x 84m) with the minimum hall configuration being 3000m^2.

Project Architects, Denton Corker Marshall, have created a theme which is analytical, logical and based on a strong idea carried clearly throughout the design. In describing the function of the centre, Director, Bill Corker said:
"We adopted a linear model in line with new exhibition centres overseas resulting in a single large hall which can be divided. This contrasts with Sydney and Brisbane which have distinct halls."

The main entry to the centre has been achieved through the conversion of an existing structure. The remodelling of the building included a distinctive canopy structure (also known as a blade) constructed of structural steel which acts as a focal point ensuring the centre's visibility from Southbank.

Design details

The project comprises three main components:
- Main Hall
- Entry Building
- Concourse

Prior to commencing detailed design and documentation, an industry briefing session was held with potential fabricators. Scheme design details were presented to the fabricators, together with typical connection details, member sizes and total steel tonnages. A concept erection sequence was also tabled. The input from fabricators at this stage was highly valued as the consultation process enabled a number of issues to be raised and subsequently considered in the final design.

Material supply was also addressed at this time. "Product availability to meet project delivery requirements was achieved through early discussions with the steel suppliers, BHP and Tubemakers and the steel distributor, Union Steel," said Peter Bowtell, Associate Director, Ove Arup and Partners.

Floor Slab

The suspended pre-stressed concrete slab is designed to accommodate a live load of 20kPa to allow for any type of exhibition load and for semi-trailers traversing the floor. There are five service pods to the south and the main loading apron for the direct access of semi-trailers to the exhibition floor. The single level basement car park is under this floor.

Roof Structure

The roof of the exhibition hall has clear spans of 84 metres and is supported by 20 roof trusses at 18m centres. The trusses provide an 11.5m clear height above the floor. Secondary beams run east-west at 6m centres between trusses providing intermediate support for mechanical services as well as the overlying roof system. Design of the trusses included the following loads:

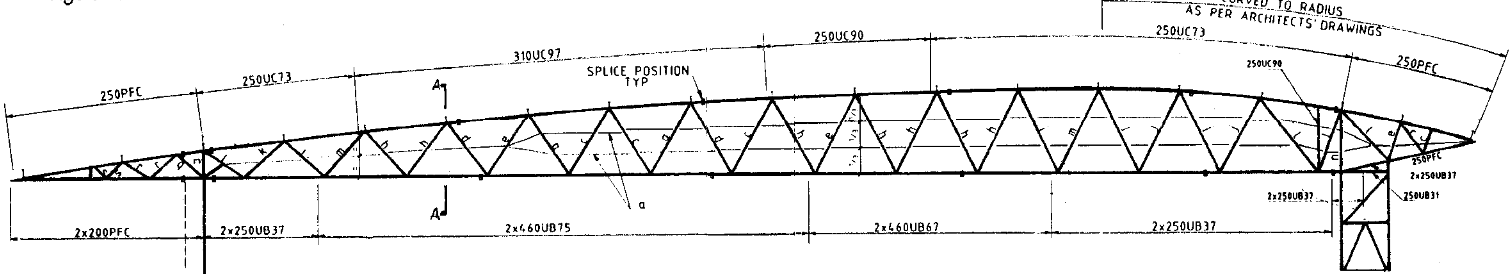
- display loads of 10 tonnes over $400m^2$, with a minimum capacity for a 2 tonne point load placed anywhere.
- the 84m wide by 11m high sliding screen walls. Each of these four massive sliding walls is suspended from the roof trusses and weighs a total of 56 tonnes.
- mechanical services loading from the supply and return air ductwork.

The roof trusses, 7m in height, are triangular in section, providing a form which is laterally stable in its own right. The bottom chord, fabricated from

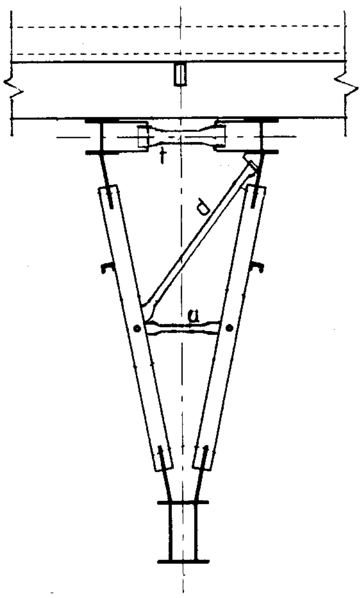
pairs of UB’s welded toe-to-toe, supports the track for the sliding wall panels, while the top chord is curved to the required architectural profile for the aerofoil shaped roof. Since the chord design was governed by strength rather than serviceability, Grade 350 steel was used in both the top chords (250UC73) and bottom chords (2/360UB51) in order to minimise their weight. The webs are fabricated from tube and braced in both directions to enable their weight to be minimised. Each roof truss weighs 45 tonnes and contains 500 individual members excluding side girts.

Monash University undertook detailed wind tunnel tests on the aerofoil shaped roof to accurately determine wind loads and the results led to substantial reduction in uplift pressure compared with pressure predicted using

Figure 1. Truss elevation



Section AA



AS 1170 Part 2. In addition, perforated cladding was introduced on the north and south roof overhangs just behind the solid leading edge to provide a substantial reduction in uplift pressures. Given the large load from the sliding wall panels, the downwards wind loads became the critical design loading condition for the roof.

Trusses are portalised on the structure’s north side where a braced column frame takes out all transverse loads on the building, concentrating the raking piles to one side only. On the south side the trusses are supported on pinned columns which are designed to rotate as the truss flexes up and down.

Plaster panels clad the trusses to provide acoustic insulation. To accommodate truss deflection, cladding consists of a series of individual panels with a vertical joint which allows movement.

Expansion joints divide the roof into four. Roof bracing is provided in each bay to transfer the longitudinal loads to the north and south walls which have been braced to take lateral loads to the ground.

Structural steel intensity for the hall structure was 38 kg/m². AS 4100 was used for the roof design and throughout the project.

Roof Cladding

Total roof area covered by Klip-Lok Colorbond XPD cladding is 48,000m² which is equivalent to 2400 average size house roofs. The Roofing Contractor developed a new lap joint on the cladding to give a lower profile on the joint.

The maximum length of sheets transported to site was 31m, achieved with extendible semi-trailers accompanied by escort vehicles.

Entry Building

The shell of an existing concrete building was remodelled for the main entry structure.

A striking steel canopy has been built at the Clarendon Street entry to act as an icon for the centre. It rises 25m into the air and spans 60m from the entry building to the slender pin jointed support columns. To resist lateral loads, the canopy is provided with a horizontal bracing truss designed to transfer the loads to the building core and specially designed stiffened walls. To resolve the complex geometry of the canopy, particularly the intersection zone where the bracing truss and the canopy join, a full 3-dimensional CAD model was established. Large plate girders were detailed at the end on each truss to enable loads to be redirected between trusses.

A 17m wide concourse runs the full length of the building along the river side. It features a colonnade of inclined SHS columns and a steel pergola providing a transition to the new maritime park. The concourse is covered by a canopy, also running the full length of the building, and is enclosed by a glass wall 8m high.

Sliding wall details

Melbourne Exhibition Centre has an advantage over exhibition centres around Australia in that it can be divided into smaller spaces in increments of 1500m² (compared with divisions of 5000m² in Sydney and Brisbane). This is achieved through the use of four sliding walls which are stored along the northern wall of the main hall when not in use.

Each sliding wall contains 70 panels which are 11m high by 1.2m wide. Panels were manufactured using a robotic welder for the steel frame and cladding. The panels incorporate special insulation to achieve high acoustic performance. They were supplied by Lotus Doors and are the tallest panel of this type ever made by the manufacturer. Panels are top hung and have a spring operated shoe mechanism which is clamped down into place when the door is moved into position.

The base seal of each wall panel is designed to accommodate movements of 100mm up and 50mm down under the combined action of wind and exhibition live load. However, to achieve correct operation of wall panels, the track on the underside of the roof trusses had to be installed to within a ± 12mm vertical tolerance. By accurate combination of pre-camber and running track installation, the vertical tolerance achieved was less than ± 5mm.

Shop detailing

Roof steelwork was detailed by Precision Design using CAD to establish the geometrically intricate set-out for the 500 individually bolted members which made up each truss. Significant features included top chord curvature both horizontally and vertically; truss pre-camber to allow for dead load deflection and bolt slip; girts on truss sides established on a line of best fit to achieve planar sides for the plaster panels. The shop detailers liaised closely with the fabricator, structural engineer, architect, services engineer, construction consultant and cladding contractor to ensure constructability, staged construction and overall geometric and structural requirements within a tight time frame. This attention to detail and a team approach to pre-planning paid dividends in terms of achieving high quality fit-up which assisted the project in achieving its program, budget and safety targets.

The canopy roof structure and bracing truss was another area which required high order detailing skills because of the geometric and structural complexity. This work was detailed in-house by the fabricator, DiFabro Constructions, and it also achieved high quality fit-up during construction.

Paint systems

A high quality paint finish was specified for all steelwork in the project. The following systems were chosen to meet the criteria of a long life with low maintenance:

Concealed Steel

Abrasive blast clean	Class $2^1/_2$
Primer	1 Coat Epoxy- 75µm of two pack zinc rich epoxy primer

Exposed Steel (Interior)

Abrasive blast clean	Class $2^1/_2$
Primer	1 Coat Epoxy- 75µm of two pack zinc rich epoxy primer
Top coat	1 Coat Polyurethane- 50µm

Exposed Steel (Exterior)

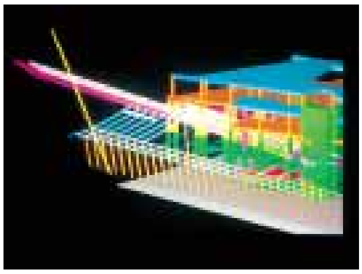
Abrasive blast clean	Class $2^1/_2$
Primer	1 Coat Epoxy- 75µm of two pack zinc rich epoxy primer plus 1 Coat Epoxy High Build Primer- 75µm
Top coat	1 Coat Polyurethane- 50µm

Fabrication and erection

DiFabro Constructions was the Fabricator and Erector for the 3500 tonnes of structural steelwork on this project. Due to extensive repetition, fabrication proceeded as an assembly line operation and required tight program co-ordination with the steel supplier, BHP and its distributor, Union Steel, to integrate with the delivery schedule on site. The Grade 350 steel was pre-ordered for the project. In order to process such a large quantity of steel in the very short available timeframe, DiFabro employed a peak workforce of 60 in the shop, and, in addition, it subcontracted parcels of work to local fabricators.

Distance from the fabrication shop to the site is 150 km and this was taken into account when assessing size of fabricated components. It was decided to transport the entire 84m internal section of each roof truss to site as individual truss members, whereas the overhanging nose and tail sections were fabricated and transported as fully welded assemblies.

DiFabro Constructions achieved transportation to site with a fleet of between 4 and 7 trucks being despatched each day for the 300 km return journey. Longer lengths were easily transported with the use of overdimensional transport permits. These sections included the 23m long secondary beams, the lattice columns on the north wall and lifting frames for panel erection.



Top left: Tower crane and centre crane.

Top: Truss erection operation.

Above: 3d CAD model of the canopy and entry building.

DiFabro used a site crew which peaked at 46 workers to assemble and erect all the steelwork over a six month period. Five cranes were used, including a Favco 1500 tower crane on a travelling base on the north side, an American 200 tonne crawler crane in Skyhorse configuration on the south side, plus three hydraulic cranes with capacities up to 35 tonnes.

The structural steel contract was awarded on 2 September 1994, and fabrication commenced four weeks later. 3500 tonnes of steel was erected in the six month period from February to July 1995.

DiFabro Construction's Director, Tony Di Fabrizio, said: "The main highlights for our company were firstly the achievement of the extremely tight timetable - six months to fabricate 3500 tonnes; secondly the steel erection challenge in working to a four day assembly cycle and a seven day roof panel installation cycle; and finally the quality of our fabrication and assembly work on the complex entrance canopy structure and roof trusses."

Steel erection on site was assisted with the appointment of a Construction Engineering consultant, Keays Engineering and Computing. They performed the key function of construction engineering on the project with input on constructability to Ove Arup. They were responsible for the development of the large range of methods, erection procedures and temporary works required to achieve the planned cycle time of one bay per week and maximise the use of ground assembly. Detailed calculations were carried out for erection stresses in the roof trusses, roof panels and loading on the suspended floor slab from the tower crane travelling base. Construction methods utilised included:

Panel Erection

This allowed effective use of ground assembly. Panel assembly and erection were achieved using a purpose built jig with the following features:

- multiple suspension points to secondary beams
- adjustable location
- lifting beams in two directions
- adjustable webbing slings at each lifting point
- lightweight triangular truss

A multi-steerable wheeled low loader was used for panel transport from assembly location to lifting location. Panel lift was governed by crane capacity for dual crane lifts based on 20% greater than calculated share of load (AS2550.1).

Jig for Truss Assembly

- temporary support stools were designed to cater for camber configuration
- lifting lugs were designed to be bolted onto each truss.

Travelling Base For Tower Crane

- grillage base to distribute loads onto rails.

Top: Truss to column joint assembly.

Above: Entrance canopy steelwork.

Construction method

Extensive pre-planning and coordination were undertaken by the construction team for the detailed procedures and innovative work methods adopted to achieve the planned cycle time of four days for truss assembly, and seven days to complete the whole bay including the roof panels. On this project a "build on the ground" system of pre-assembly of structural steelwork and other components was used extensively. This system achieved efficient steel erection in a safe manner.

1. Roof Truss Assembly and Erection

During the detailed planning it was decided to assemble virtually the whole of each roof truss on the deck below its final position. After assembly on the deck, each truss was lifted with two cranes and positioned at the north where connections were made good before pins were driven home on the south column. The Favco 1500 tower crane with travelling base operated on the north side of the hall, while the 200 tonne crawler crane was used to service the southern end. Steel to the north service corridor proceeded in advance of truss erection. The travelling tower crane utilised
a three section track enabling it to leapfrog its own foundation thus very much reducing the manual work to be carried out by the site riggers.

While the behaviour of the fully assembled truss under crane handling conditions was assessed theoretically as much as possible by the Engineers, a trial off site assembly was carried out at the premises of the fabricator and erector to verify fit-up and camber as well as behaviour during lifting. While confirming the performance of handling the truss, it also allowed riggers and crane crew to become familiar with the site procedures.

2. Panelised Construction

The roof, covering more than 40,000m^2 up to a height of 17 metres above the concrete floor, comprises a metal deck roof, under which is an insulating blanket of synthetic mineral fibres, resting on standard roof safety mesh. Below the roof purlins there is also an acoustic layer held in place by wire mesh. These components are in turn supported by a grid of secondary and tertiary steel roof beams bolted to the roof trusses.

In assessing the amount and type of work which could be done on the ground, it was decided to use panelised construction as much as practicable. This required a joint effort involving the total design and construction team and the builder. The outcome was a system of work where panels of roof up to 700m^2 were fully constructed on the ground. Panels comprised secondary and tertiary beams, purlins, insulation, roof sheeting, fire piping and sprinklers. Roof panel assembly was only 1.5m high which enabled work to proceed at easily accessible heights.

The roofing contractors, Hueston Roofing, and BHP Building Products developed a unique mid-span purlin lap joint to enable assembly and erection of the roof panels. The system used the maximum purlin cantilever for the temporary erection condition based on 80% of the 50 year return wind.

These sections, weighing up to 25 tonnes, were then transported by low loader a short distance across the site. A crane then hoisted them into position using a purpose built frame. Wind conditions were carefully monitored during lifting.

While the north and two south side areas of the roof were installed by this method, for technical reasons (roof shapes overlap in two sections), it was not practicable to fully pre-assemble the centre section, which had the roof deck finished by workers on the roof. This was safely achieved through programming the activity to a full bay behind the pre-assembled installation, resulting in workers being at least 20 metres away from the exposed edge.

3. Painting

Specifications called for a special high quality finish to be applied to all structural steel members. Considering the required on site activities it was decided to apply all coats including finishing coats off site. This resulted in special care handling requirements during delivery, and by erectors during assembly and hoisting to minimise damage to the coated components.

4. Mechanical Services Duct Installation

Part of the air handling system for the exhibition hall comprises large insulated ducts transverse to the building, and against the ceiling in between roof trusses. These sections were raised into position at pre-installed hangers by crane in a purpose built frame which automatically released after the duct had been raised and bolted in position. Bolting was easily carried out by a worker in a boom lift.

5. Installation of Entry Hall Roof Structures

The north side entry hall which extends the full length of the building has a complex structure with steeply angled columns and an unusual roof line. Installation was carried out as a pre-assembly with whole structural roof sections, including purlins, being erected on the ground and craned into position.

Summary

The successful design and construction of the Melbourne Exhibition Centre, a landmark steel structure, has been a major engineering achievement and resulted from close cooperation, innovation and planning from all parties involved.

A feature of the project was the development and widespread use of award winning construction techniques and it was successfully completed within a tight budget and time frame to provide world class facilities for exhibitors and patrons. “Build on the ground” techniques were effectively used on this project. The method was the catalyst for many innovations carried out by the project participants. The technique also demonstrated that steel framing offers builders the opportunity to adopt differing construction systems to achieve economic and safe work practices.

Baulderstone Hornibrook’s Safety Superintendent, Les Lobbe, concluded, “By deciding our overall strategy at tender preparation time, and by extensive ongoing consultation and planning, we developed a system and sub-systems of work designed to efficiently achieve our construction programme and provide a safe working environment.”

The foregoing construction initiatives contributed to the project’s fine safety record. This excellent achievement was recognised when Baulderstone Hornibrook, DiFabro Constructions and Hueston Roofing jointly won the 1995 HSO (Health and Safety Organisation, Victoria) award for excellence and innovation in workplace health and safety in construction.

Project participants

Client:	Department of Business & Employment (Vic)
Constructing Authority:	Office of Major Projects
Architect:	Denton Corker Marshall Pty Ltd
Structural Engineer:	Ove Arup and Partners
Design & Construct Contractor:	Baulderstone Hornibrook Pty Ltd
Fabricator / Erector:	DiFabro Constructions
Roofing Contractor:	Hueston Roofing
Construction Engineering Consultant:	Keays Engineering & Computing Pty Ltd
Shop Detailer:	Precision Design Pty Ltd

Panelised roof construction.


MELBOURNE EXHIBITION CENTRE