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.

Structural STEEL Casebook

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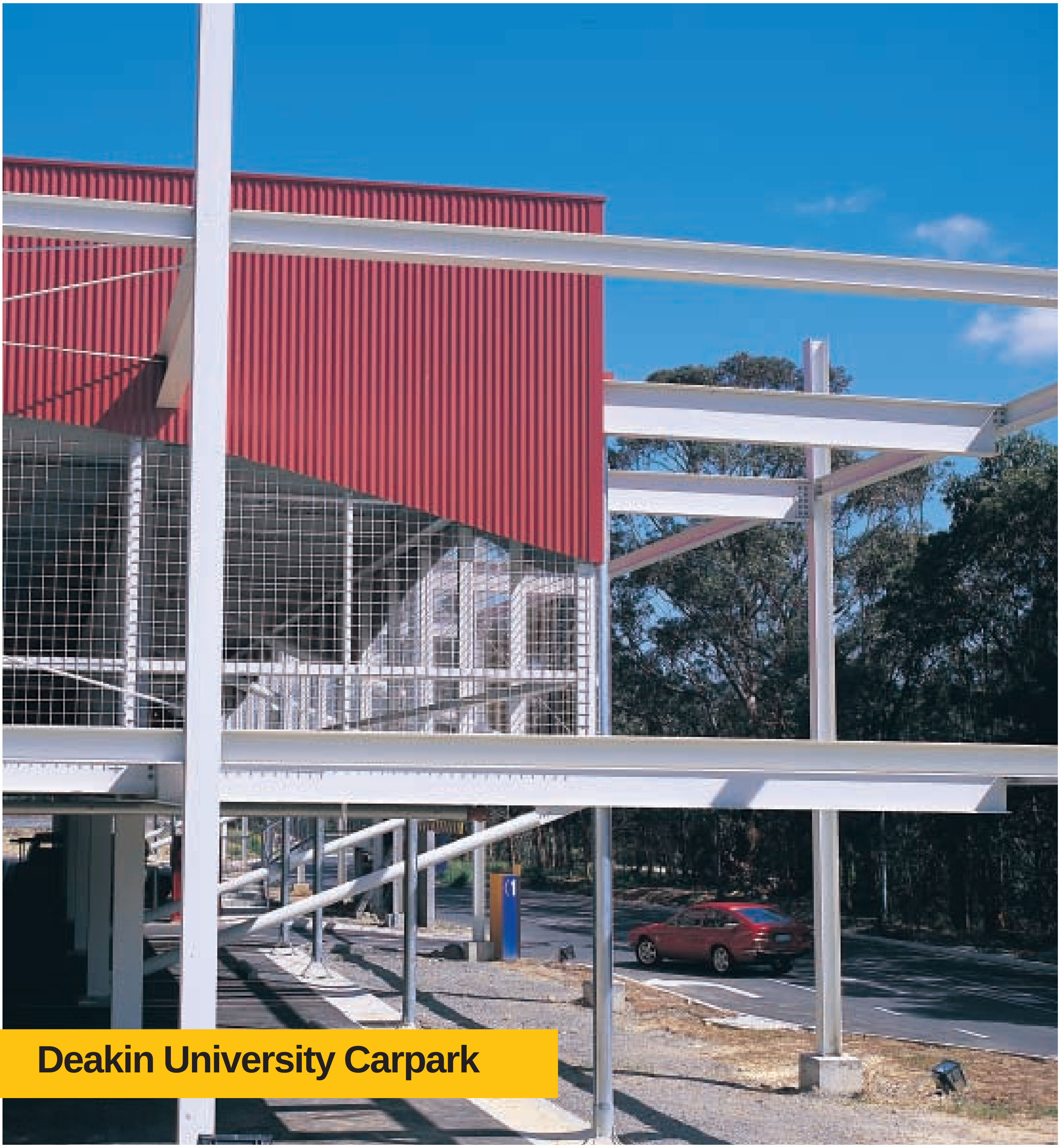


Deakin University Carpark

Deakin University is a multi-campus university in Victoria. Like many universities, hospitals and shopping centres it had a problem with inadequate parking facilities at its Burwood Campus.

Since Deakin University merged with Victoria College in 1992, a major upgrade and expansion programme has been undertaken at its Burwood Campus to bring the facilities into line with those required for a modern university. The number of students has grown to over 5,500. There was growing pressure from the students and staff as well as the wider community to increase the amount of on-site parking. As part of the master plan for the site, an area close to Gardiners Creek currently used for carparking had been identified as a site for a multi-level carpark. As the site is visible to residents across the valley, there was the desire to create an interesting structure that blended with the environment. In addition the design was also required to be functionally and aesthetically pleasing to the user.

Demand for car spaces during the academic term meant it was not possible to close the existing carpark, allowing only 4 months from November 1997 to February 1998 for on-site construction of a new carpark.

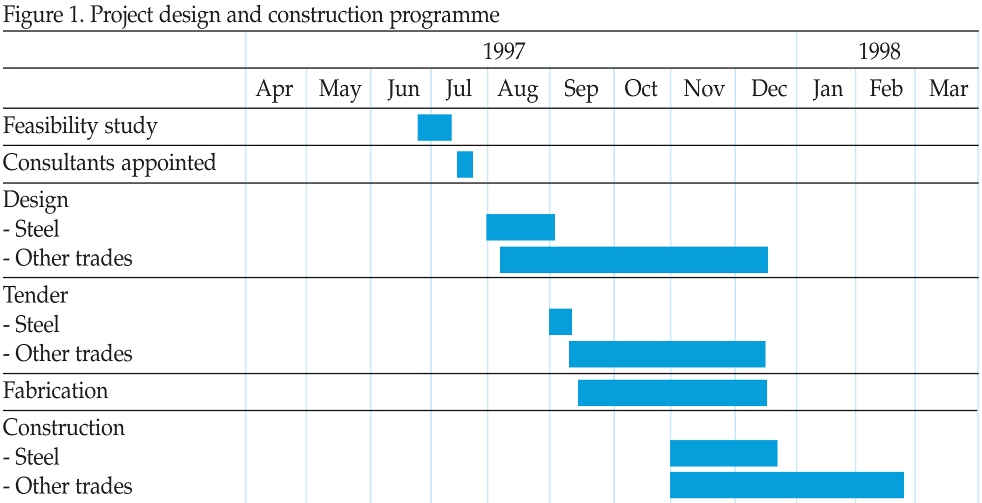
It was decided to construct a three level (two suspended) carpark on approximately half the land allocated in the master plan. This provided a total number of 587 car spaces including 11 spaces for people with disabilities. An allowance was made for two additional levels of suspended parking to be added when funding permitted. The carpark was designed to be self-funding from the parking revenue.

Given the very tight project timetable, it was found that steel offered the inherent benefits of off-site fabrication and speed of construction. Work commenced on the design of the project in early August 1997 and the project was handed over to Deakin University for the use of students in the last week of February 1998. The design and construction programme for the project is given in figure 1.

In addition to steel's inherent construction benefits, the achievement of this tight timetable was facilitated by the great teamwork that developed between all the participants in this project.

Vehicle and pedestrian access is provided at road level, saving costs and lost spaces associated with ramps.

Figure 1. Project design and construction programme



FEASIBILITY STUDY

Decisions made at the feasibility stage have been shown to have the maximum potential to positively influence the cost of a project. Therefore, a detailed feasibility study of the project was undertaken by the Quantity Surveyor, Trevor Main (of Trevor Main and Associates), in conjunction with the Project Manager, Gary Connor of the Wycombe Group, in less than a month. The financial viability of the carpark scheme proposed by Deakin University was initially confirmed.

A comparative analysis of the following four different structural schemes was undertaken:

- Scheme 1 – Insitu reinforced concrete frame and slab
- Scheme 2 – Insitu reinforced concrete frame with precast reinforced concrete slab
- Scheme 3 – Steel frame with composite deck and insitu reinforced concrete slab
- Scheme 4 – Steel frame with precast reinforced concrete slab.

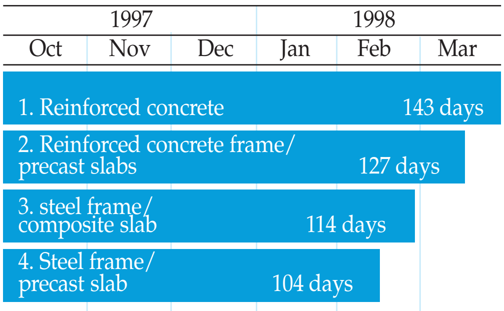
Each scheme was assessed against the following criteria:

- Construction time and capital cost
- Risk analysis
- Appearance
- Early rental income

Construction time and capital cost

The estimated construction period for each of the schemes was determined and are featured in figure 2. This shows that only the steel schemes were able to comply with Deakin University's timetable. No allowance was made in these initial programmes for lead times and scheduling issues, as these were evaluated in the risk analysis.

Figure 2. Feasibility study construction programmes



A comparative cost analysis, using historical data was also undertaken. This showed that scheme 3 was 8% more expensive than scheme 1. Whilst schemes 2 and 4 were respectively 13% and 19% more than scheme 1. Given the preliminary nature of the information there was confidence that the cost of scheme 3 could be reduced with further development.

Risk Analysis

The following risks were evaluated for each scheme and compared.

1. Client

Deakin University's main criteria were:
• programme: the lead times and availability of the materials were assessed.
• student / staff safety
• completion of the carpark prior to the new academic year
• ability to complete the project within budget

2. Material

• Availability, with a preference for local supply
• Authorities requirements, particularly the ability of the materials to meet code requirement and fire safety issues
• The current market conditions were evaluated for precast concrete, steel and formwork. In particular, given the tight construction programme, lead times and scheduling issues were addressed.

3. Construction

Each option was assessed to determine whether there were sufficient players with the:
• capability to handle medium and large tasks
• ability to meet the programme
• ability to provide competitive pricing

Deakin University's timetable was achieved by the adoption of a steel framing scheme, with a composite deck and insitu reinforced slab.

Feasibility Study Outcome

Deakin University decided to proceed with two suspended levels of carparking with an allowance for two additional levels of carparking in the future. Scheme 3 with the steel frame and composite concrete slab was selected as the structural system for its:
• Ability to meet the tight programme even after allowing for the Christmas shut down due to:
Off-site
- availability of fabricators
- reliability of the steel fabrication industry
- ability to commence fabrication early

On-site
- availability of erectors
- safety
- ability to meet the tight programme
- site access

Capital Cost

A competitive capital cost was achieved. The savings envisaged in the feasibility study were realised and scheme 3 ended up costing 6% less than the initial estimate of scheme 1. Some of the items that led to this reduction include:
- The base grade of steel increasing from 250 to 300 MPa with the introduction of 300PLUS® steel
- Limit state steel code (AS4100) providing a reduction in beam and column sizes as well as savings with connections
- Limit state composite code (AS2327.1) with partial shear connection design reducing the number of shear connectors by 35%.
- 30% reduction in loads on foundations due to the lighter mass of scheme 3.

Early rental income

By completing the carpark by February 1998, parking revenue could be collected from the start of the new academic year.

The new carpark fits comfortably into Deakin University's architectural environment.

Appearance

The Burwood Campus of Deakin University has a mixture of steel and concrete buildings. The steel carpark was considered to provide a positive contribution to the architecture of the campus. Attention was also paid to the interior of the carpark to achieve a balanced design which involved selecting the column spacing, head height and beam depth to give the appropriate proportions.

CARPARK LAYOUT

The existing ground level carpark had already been cut into the side of a hill. This meant the new carpark could be built with minimal further excavation. The general slope of the surrounding land allowed each of the levels to be entered directly from the road system. This scheme, devised by Deakin University's Department of Building, saved the costs and lost spaces associated with ramps. In addition, it gave the University greater versatility in operating the carpark. The carpark design allows different levels to be allocated for different users eg staff, short and long term users, visitors.

The carpark's configuration currently allows for parking of staff and people with disabilities on the middle level, with general parking on the other levels. This arrangement can easily be changed in response to changing circumstances.

The top level has 186 car spaces, the middle level 180 including 11 spaces for people with disabilities and the remainder are on the ground floor. The parking spaces and the aisle widths comply with the requirements of the carparking code AS2890.1 for class 3 users.

BUILDING REGULATIONS

The carpark was designed under the *Deemed-to-Satisfy Provisions* of the Building Code of Australia 1996 (BCA). The carpark will eventually have a *rise in storeys* of 4 and hence Type A fire resisting construction is specified in the BCA.

The carpark meets the requirements of an *open-deck carpark* i.e. all parts of the carpark are cross ventilated by permanent unobstructed openings in not fewer than 2 opposite or approximately opposite sides and:

(a) each side that provides ventilation is not less than 1/6 of the area of any other side; and

(b) the openings are not less than $^1/_2$ of the wall area of the side concerned.

Consequently sprinklers and/or mechanical ventilation were not required by the BCA.

The *Deemed-to-Satisfy Provisions* for Type A fire-resisting construction (refer BCA Specification C1.1-Table 3.9) are:

(a) Steel columns have an exposed surface to mass ratio (ESA/M) of not greater than 26 m^2/tonne.

(b) Steel floor beams in continuous contact with a concrete floor slab have an ESA/M of not greater than 30 m^2/tonne.

(c) Slabs to floor and ramps have a fire-resistance level (FRL) of 60/60/60. (*Structural adequacy/ Integrity/Insulation*)

With more than two exits provided to each level, the maximum travel distance to an exit is 40 metres. Consequently a stair was provided on each external face of the carpark.

Fire hydrants and hose reels were required as each floor exceeded 500 square metres. Four sets were provided adjacent to the stairs and passenger ramps at each level. No smoke hazard management systems are required for open-deck carparks.

A minimum of 1% of car parking spaces must comply with the requirements for parking in AS28901.1 for people with disabilities.

STRUCTURAL SYSTEM

Foundations

The soil was clay with an allowable bearing capacity of 200 kPa. Pad footings were generally selected as the most economical solution. Bored piers were adopted locally in the batters to found the foundations at the right level.

Floor System

The floor system consists of a 120 mm concrete slab acting compositely with the steel beams. The system was chosen for simplicity, speed of construction and economy. The typical structural module covered virtually all of the floor plate, apart from the perimeter, so a considerable amount of thought went into optimising this module during the feasibility study.

The secondary steel beams are equally spaced at approximately 2.8 metres maximum centres to suit the typical grid without the need for propping the 1.0 mm steel profiled sheeting. It was decided not to prop the floor system to minimise cracking of the slab and maximise the speed of construction.

The initial steel design was based on three car spaces between columns in one direction and 8.3 metre centres in the other. Secondary beams at a maximum of 2.8 metre centres spanned between the primary beams that in turn were supported on steel columns. It was decided to refine the steel option, increasing the spacing of the columns to four car spaces in one direction whilst leaving the columns at 8.3 metre centres in the other direction (see Fig 3). The four-car scheme was marginally cheaper and had the major advantage that there were 24% fewer members to fabricate and erect, with corresponding time savings. Therefore the 8.3m by 10.7m grid was selected as the best option.

The composite steel beams were designed to the new composite code AS2327.1-1996. The use of partial shear connection design reduced the number of shear studs by 35%. The beams were designed as simply supported and the dead load deflection was cambered out. Details of the beams are given in Table 1.

The connections were designed to AS4100-1996, which reduced the number of bolts when compared to the old working stress code, AS1250.

The beams met the *Deemed-to-Satisfy Provisions* of the BCA and therefore ***no*** passive fire protection was required.

The 1.00 mm Condeck HP steel profiled sheeting provided both the formwork during construction and the positive reinforcement for the concrete slab. The slab reinforcement was initially designed for a high degree of crack control and then checked for strength at both ambient and elevated temperatures. This ensured that a fire rating of 60/60/60 was achieved, negating the need for passive fire protection. The design of the Condeck HP during the formwork stage was based on it being continuous over a minimum of three spans.

As the floor plate is approximately 70m x 70m, consideration was given by the structural engineer, Keith Macklin of Meinhardt, of the need for movement joints. A general observation is that with any form of carpark construction, movement joints generally do not work properly and are a source of ongoing maintenance. As the slab is relatively thin, it was determined that the shrinkage cracking could be controlled with reinforcement. The slab was consequently detailed for a strong degree of crack control in accordance with the concrete code, AS3600. The forces resulting from temperature

Figure 3 Four Car Module

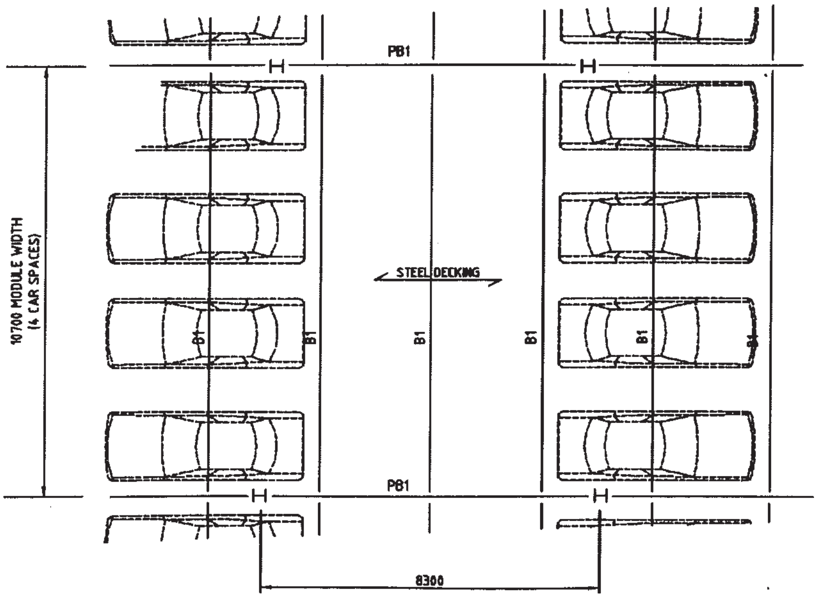


Table 1 - Beam details –Four car module

Beam				Shear Studs	End Connections	
No	Size	Grade	Camber (mm)	No-19dia 95 high	Type	Bolts (Grade 8.8/S)
PB1	460UB82	300PLUS	30	40	Web Side Plate	2x5 M20
B1	410UB54	300PLUS	40	35	Web Side Plate	3M20

Note: Web side plate - 10mm flat with 8mm fillet weld each side

Right: Lighting and signage on the upper level are supported by columns which allow for future extensions.

Stairs provide an attractive visual feature in galvanised steel

Steel framing extends beyond the perimeter of the carpark, providing a striking architectural feature.

effects could be accommodated within the structure. This together with no major points of restraint led to the decision to detail the slab without movement joints.

The floor plate was graded from the centre of the carpark to the east and west. This kept the same concrete slab thickness as well as structural depth across the floor. This greatly simplified the detailing and fabrication of the beams and reduced the number of different types of beams required.

Columns

The columns were designed for an extra 2 levels of carparking to be added in the future. Each column is a single length, as it was more economical than splicing at the first floor. The column extends a minimum of 1000 mm above the 2nd floor level to provide good visibility for parking. The column end was drilled to allow for a future extension. In the interim period they are being used to support lights and signs. The internal columns are typically 310UC118 300PLUS. Meinhardt, using a simple spreadsheet developed in-house, designed them to AS4100.

The columns comply with the surface area to mass ratio requirement of the *Deemed-to-Satisfy Provisions* of the BCA and therefore no passive fire protection was required.

Lateral Resisting System

As the beams are designed as simply supported, bracing was provided in the end bays for lateral stability and to resist lateral wind and other loads. The brace is 219 diameter pipe and three are provided across each end in the north-south direction and four in each end in the east-west direction.

Stairs

The Stairmaster System was adopted for its speed-of-construction. It consists of a permanent steel form with the reinforcement attached in place. The complete form is taken to site, erected and the concrete is placed.

Facade

The Architect, Rod Ball from Deakin University faced the challenge of providing an attractive facade, yet at the same time keeping the costs within a very tight budget. Rod chose to set the external frame 4 metres past the edge of the carpark. This gave depth to the steel facade and allowed integration of landscaping. Around the carpark a galvanised reinforcing mesh was used as a safety screen and scalloped, painted corrugated sheeting complemented this. The screen was supported on a frame of rectangular hollow sections that had been designed chiefly for the purpose of stopping errant vehicles from going over the edge of the carpark. The frame was analysed plastically for the absorption of the energy from an errant vehicle.

Surface Treatment

The carpark is located in a fairly benign environment from a corrosion perspective. It falls into the moderate environment under the classification of AS/NZS2312. Initially it was proposed to adopt an alkyd primer with two coats of alkyd gloss. The topcoats were provided essentially for aesthetic reasons. Page Steel, as part of their tender, offered an abrasive blast clean, 50 microns of inorganic zinc silicate and 40 microns of gloss acrylic top coat. This system offers better corrosion protection and with only two coats provided time, as well as cost savings on this project.

The stair forms were galvanised. However, galvanising was not an option for the beams, as the shear studs needed to be welded through the steel profiled sheeting onto the top flange of the beam. This is not possible where the top flange of the steel beam has been galvanised.

TENDER

The project was let in major trade packages i.e. steel, concrete, electrical, hydraulics/fire services and civil works. The steel package consisted of shop detailing, supply, fabrication, erection, laying the steel profiled sheeting, shear stud welding and the facade supply and installation.

The steel package was put out to six fabricators with four submitting a tender. The tenderers were assessed on price and quality of their work. During the tendering process, a visit was made to each of the tenderers to determine their compliance with the requirements of the welding code, AS/NZS 1554.1. In particular, evidence was sought on the use of qualified welding procedures and qualification of the welding supervisors.

The tender assessment team visited and reviewed the fabrication shop of the preferred tenderer. After this assessment Page Steel was awarded the contract. The steelwork programme developed at tender, which was subsequently achieved, is given in figure 4. The relative cost breakup for the steel contract is given in table 2.

STEELWORK

Shop Drawings

The shop drawings were prepared for Page Steel using a computer program developed on Autocad. This project, for its size, had very few drawings as so many of the members were identical. This reduced the time to prepare the drawings and consequently they were produced very economically. About half of the drawings were for the façade steelwork. On a typical steel project the ratio of fabrication hours to shop drawing hours is of the order of four to one, but for this carpark the ratio was about six to one.

Steel Supply

The steel was supplied by BHP through the steel distributor, Union Steel. As the secondary beams were 10.7 metres long and the wastage was considered too great from twelve metre standard lengths, they were ordered to length from BHP through the steel distributor. The other beams and columns were economically cut from standard lengths.

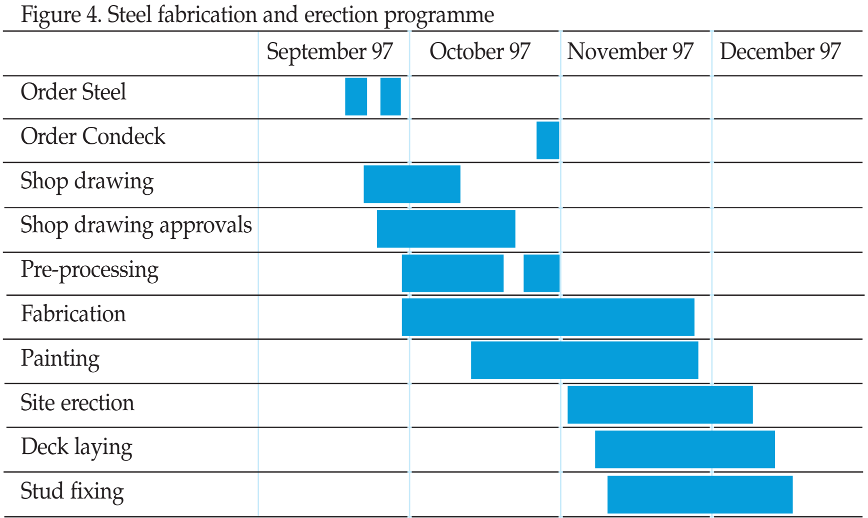
Fabrication

The sections were cut to length, drilled and coped by the steel distributor, Union Steel. Page Steel processed the plate and flats for the connections, which were in turn assembled and welded to the sections. In addition, most of the beams were cambered for dead load. With the large number of identical elements, the process was more like a manufacturing plant than the traditional jobbing shop of a fabricator.

Table 2. Cost Components of Steel Contract

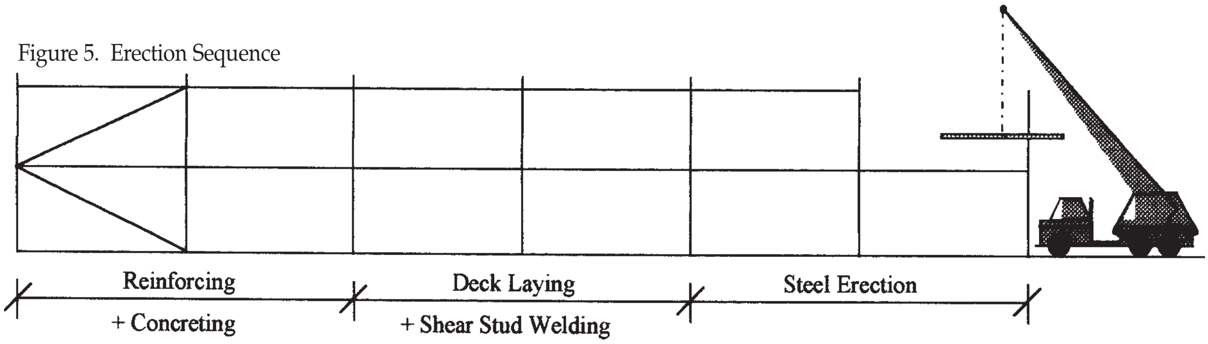
Component	Percentage cost
Steel Supply	38.5%
Bolts	1.1%
Shop Details	1.6%
Fabrication	9.9%
Transport	1.4%
Surface Treatment	12.3%
Façade Cladding	4.1%
Condeck and studs	20.3%
Erection	10.8%

Figure 4. Steel fabrication and erection programme



Page Steel used their own prime mover and two trailers to transport the steel from the fabrication shop to the painter and then on to site. Using two trailers allowed the prime mover to be fully utilised as it did not have to wait for the trailers to be loaded or unloaded.

Figure 5. Erection Sequence



Erection

The work commenced on the eastern side of the project with an erection module of two structural bays, two storeys high and the width of the structure. Once an area was erected, the decking could be placed and the studs welded, then the reinforcement fixed and the concrete placed. This is shown diagrammatically in figure 5, above.

The erector, SES Structural Erectors Pty Ltd (SES), supplied all the plant including cranes and access equipment. The choice of plant depended on the needs of the project, the productivity required and the plant owned by SES.

Two 25 tonne mobile cranes were adopted for this project. One crane was on-site full-time whilst the second was required for about two thirds of the time. A 16 tonne crane would have been adequate for the project according to Rudi Ricanek from SES, but the 25 tonne was more productive and this compensated for the additional charge out cost. A 25 tonne crane is becoming the standard crane used for the lifting of steel members and profiled steel sheeting in this type of structure. Three riggers worked with each crane and were supplemented, when required, by two additional riggers to assist with the follow-up bolting. Each erection crew averaged about 30 steel members per day. In addition to lifting steel members, the cranes lifted the steel profiled sheeting into place as well as the reinforcement for the concreter.

Each crew of riggers operated from two eighteen metre booms. Twelve metre booms would have been sufficient for this project, however SES decided to utilise their own machines. The riggers doing the follow up bolting worked from a twelve metre scissor lift or one of the booms, depending on availability.

For laying the Condeck HP steel profiled sheeting, there were 4 permanent deck fixers supplemented with 2 additional fixers when required. Typical laying rates of 1000 square metres per day were achieved for the project.

Two stud welders were employed on site for welding the shear studs. They each averaged approximately 600 studs per day.

CONCLUSIONS

The decision to use steel as the principal construction material allowed the carpark to be designed and constructed within the very short time frame available. Construction speed was further assisted by the teamwork of all the participants involved. Deakin University now has an attractive, economical carpark that was built for $6,500 per car space. This is equivalent to a payback period of 10 years. Part of the challenge faced by the team was the traditional January shut down in the building industry. Steel helped overcome this challenge by being fabricated off site, hence allowing the structural frame and slabs to be completed by Christmas. Deakin University Carpark is also very versatile due to the clever use made of the natural slope of the land to allow access to each level from the ring road, thus doing away with the need for internal ramps for stage 1.

Building on its success with this project, Deakin University has already elected to duplicate this carpark with the same design and construction team.

Owner	Deakin University
Architect	Deakin University
Project Manager	Wycombe Group
Quantity Surveyor	Trevor Main & Associates Pty Ltd
Structural Engineer	Meinhardt (Vic) Pty Ltd
Fabricator	Page Steel Fabrications Pty Ltd
Painter	Brooklyn Industrial Coating Pty Ltd
Erector	SES Structural Erectors Pty Ltd
Steel Distributor	Union Steel Pty Ltd