ECONOMICAL CARPARKS
A Design Guide
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FOREWORD

In 1998, BHP Integrated Steel published the First Edition of Economical Carparks – A Design Guide. Since its release countless developers and designers have utilised the publication to assist in the design and construction of carparks. Over the last seven years there have been some significant changes in design, construction techniques and in supply of the materials required to construct these carparks.

This Edition of the Design Guide is now published by OneSteel Market Mills who are the largest manufacturer of the structural steel beams referenced in this Guide. The standard base material for the decking profiles have changed, as has the number of different decking profiles available. The Australian Design Standards have also changed making it necessary to amend some of the design drawings. Also two new schemes offering column free parking spaces have been included in this Edition taking the total number of schemes to eleven.

This Edition includes the aforementioned changes as well as a new layout adopted to reflect the comments made by the users of the First Edition.

OneSteel Market Mills wishes to thank the many people who have contributed to the production of the First Edition and this Second Edition, in particular:

Ian Bennetts
Chong Chee Goh
John Cottam
Spiros Dallas
Anthony Ng
Nick van der Kreek
Imran Saeed
Ken Watson
Gary Yum
1. INTRODUCTION

This Design Guide has been prepared to assist engineers, architects, quantity surveyors, builders and developers produce and cost preliminary designs for steel carparks.

Eleven carpark schemes utilising re-entrant profiled steel decking on structural steel are presented with extensive information given for each scheme including:

- slab details;
- beam and column sizes;
- number of shear connectors;
- connection details;
- corrosion protection details; and
- cost indicators

These schemes can be used to produce designs for most carpark building layouts. Over the last two years there have been a number of new profiled steel decks launched into the Australian market which has provided many new alternative layouts. Nonetheless the schemes presented in this Guide provide an excellent starting point for the preliminary design, which may then be fine-tuned as required and in some cases, utilise the new profiled steel decks.

The use of the above information is illustrated by means of some worked examples, demonstrating some of the advantages associated with steel construction for carpark buildings.

The Appendices in this Design Guide give the detailed structural design criteria adopted for design solutions, information on designing for durability, costing data, a survey of existing carparks and examples of ramp configurations.

1.1 Steel Carparks

Since 1985 well in excess of 100 carparks have been constructed in Australia and New Zealand using structural steelwork. Advantages associated with steel carpark construction include:

Earlier Occupation: Repetition from bay to bay and floor to floor leads to reduced time in the production of shop drawings, fabrication of connections and the erection of steelwork. The time-savings offered by a steel solution results in reduced financial holding costs and hence provides an earlier return on investment.

Reduced Exposure to on-site risks: Off-site fabrication reduces the on-site labour, which reduces the cost of amenities and the amount of on-site supervision. The reduction in the on-site workforce, delays due to weather and the on-site congestion reduces the exposure to on-site risk.

Greater Space Utilisation: The sizes of steel columns are small compared with other forms of carpark construction and this results in a more functional carpark. The column free space offered by the long spanning capability of structural steel reduces the number of columns required and in some of the schemes eliminates all internal columns.

Future Proof Investment: Columns are easily strengthened and additional connections can be site welded to the existing steel structure providing flexibility for vertical or horizontal extension.

Reduced Foundation Costs: The reduced dead load associated with structural steel results in smaller foundations.
1.2 Layouts

The Australian/New Zealand Standard AS/NZS 2890.1:2004 provides guidance and minimum requirements for the design and layout of off-street parking facilities including multi-storey carparks. It classifies car parking facilities according to the type of use as shown in Table 1. Parking space and aisle widths are also given for each class. The nominal length of a parking space is 5.4m.

The following discussion covers some of the major requirements of the code which have a significant impact on the design of a multi-storey carpark.

1.2.1 Column Location

The location of the columns is one of the most critical decisions in achieving an economical and functional carpark.

Construction using large clear spans offers the following benefits:

- improved visibility;
- increased interior lighting efficiency;
- ease of cleaning and maintenance;
- better security; and
- greater number of cars per unit area of available floor space.

<table>
<thead>
<tr>
<th>User Class</th>
<th>Examples of Uses</th>
<th>Space Width (m)</th>
<th>Aisle Width (m) (Parking at 90°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Generally all day parking</td>
<td>2.4</td>
<td>6.2</td>
</tr>
<tr>
<td>1A</td>
<td>Residential, domestic and employee parking - 3 point turn entry &amp; exit</td>
<td>2.4</td>
<td>5.8</td>
</tr>
<tr>
<td>2</td>
<td>Generally medium term parking</td>
<td>2.5</td>
<td>5.8</td>
</tr>
<tr>
<td>3</td>
<td>Generally short term city and town centre parking, shopping centres, hospitals and medical centres</td>
<td>2.6</td>
<td>5.8</td>
</tr>
<tr>
<td>3A</td>
<td>Short term, high turnover parking generally at shopping centres</td>
<td>2.6</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.7</td>
<td>6.2</td>
</tr>
<tr>
<td>4</td>
<td>Parking for people with disabilities</td>
<td>2.4 ( + 2.4 Shared area)</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Table 1 - Carpark Classifications and Dimensions
1.2.2 Headroom

The minimum height clearance for cars and light vans is 2.2m. Car spaces for people with disabilities require a clearance of 2.3m from the carpark entrance/exit to their designated space and 2.5m above the designated car space.

With a steel carpark, sprinklers, lights, etc. can be placed within the depth of the steel beams. This not only protects these items, but also means that these items do not control the floor-to-floor height. Therefore, the critical height clearance dimension is to the bottom of the steel beams.

1.2.3 Ramps & Circulation

Ramps play a major role in the efficient circulation of traffic through a carpark allowing traffic to flow from one level to the next. Ramps can be designed in various configurations to facilitate the required circulation of traffic. A typical example of a ramp arrangement and circulation for a split system carpark is shown in Figure 2. Additional common ramp configurations for both one-way and two-way traffic flow are presented in Appendix F.

The Australian/New Zealand Standard AS/NZS 2890.1:2004, Clause 2.5.3 provides details on allowable gradients on ramps. For straight ramps in public carparks, not part of a parking module, from one level to the next, the maximum gradient is:
- Ramps longer than 20m - 1 in 6
- Ramps up to 20m - 1 in 5

For further details refer to Clause 2.5.3 of AS/NZS 2890.1:2004.

1.2.4 Gradients (Excluding Ramps)

The maximum gradient within a parking module is:
- Measured parallel to the angle of parking - 1 in 20
- Measured in any other direction - 1 in 16

Parking spaces for people with disabilities the maximum gradient should not exceed - 1 in 40

The minimum recommended gradients to allow the floor to drain adequately are:
- Outdoor area floor - 1 in 100
- Covered area floor - 1 in 200
1.3 Parking Modules

A parking module is defined in AS/NZS 2890.1:2004 as a parking aisle together with a single row of parking spaces on one or both sides. In this document only parking on both sides of the aisle is considered. The parking module excludes any ramps or circulation roadways which take off within the module.

Many variations could be developed for the different classes of carpark to cover all situations. In this document, a user Class 3 module for parking at the preferred angle of 90° to the aisle is considered. The standard module in this publication consists of:

- Parking space width: 2.6m
- Parking space length: 5.4m
- Aisle width: 5.8m
- Parking module length: 16.6m (2x5.4 + 5.8)

This configuration is considered to cover most practical cases, and allows the designs and costs given in Section 2 to be quickly and accurately adopted at an early stage of a project. It is noted that the new Class 3A in the latest edition of AS/NZS 2890.1:2004 exceeds the dimensions of this adopted module, and the designs should be adjusted accordingly. As the design progresses, the beams and columns would of course be designed for the actual layout of the project. The costs per square metre are generally not very sensitive to small changes in dimensions.

The other major simplifying assumption is a standard allowance for a column width of 300mm. Whilst this is usually adequate, a small number of columns exceed this dimension at the bottom of an eight level carpark and this would need to be allowed for in the final design. Alternatively, the columns could be redesigned to fit within the 300mm width.

<table>
<thead>
<tr>
<th>Module Type</th>
<th>Scheme Description</th>
<th>SCHEME NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Bay Width</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 car</td>
</tr>
<tr>
<td>SINGLE</td>
<td>Internal and edge columns, Figure 3(a)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Internal columns and cantilever edges, Figure 3(b)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Clear span with edge columns, Figure 3(c)</td>
<td>S3A</td>
</tr>
<tr>
<td>MULTIPLE</td>
<td>Internal and edge columns, Figure 5(a)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Internal columns and cantilever edges, Figure 5(b)</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: Refer to Section 2 for full details of each of the schemes.
Carpark layouts can be divided into single and multiple module designs:

1.3.1 Single Module Schemes

Three different single module schemes have been developed, viz:

- Scheme S1 - Internal columns with edge columns, see Figure 3(a);
- Scheme S2 - Internal columns with cantilevers, see Figure 3(b); and
- Scheme S3 - Clear span with edge columns, see Figure 3(c).

These schemes were developed for various bay widths as shown in Table 2.

A carpark may consist of a number of single modules as shown in Figure 4, each module consisting of an aisle and a row of parking each side. These modules can either be horizontal; see Figure 4(a), or sloped to form a long ramp between the different levels; see Figure 4(b) & 4(c). The single modules provide considerable flexibility in achieving different layouts.
1.3.2 Multiple Module Schemes

Multiple module schemes are used when there are a number of aisles in the same plane. They are often used at shopping centres, hospitals and educational institutions where the carparks are relatively large in plan compared to their height.

Two different multiple module schemes have been developed viz:

- Scheme S4 - Internal columns with edge columns, see Figure 5(a); and
- Scheme S5 - Internal columns with cantilevers, see Figure 5(b).

1.3.3 Carpark Space Utilisation Efficiency

Table 3 gives the square metres per car space together with their relative module efficiency, for each of the schemes. It can be seen that Schemes S3A, S3B and S3C provide up to 4% more car space in a given area. This is the most efficient scheme as the columns do not impinge on the design envelope (see Figure 1).

Reference


<table>
<thead>
<tr>
<th>Scheme</th>
<th>Square metres per car space</th>
<th>Relative module efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1A</td>
<td>22.4</td>
<td>96%</td>
</tr>
<tr>
<td>S1B</td>
<td>22.2</td>
<td>97%</td>
</tr>
<tr>
<td>S1C</td>
<td>22.1</td>
<td>98%</td>
</tr>
<tr>
<td>S2</td>
<td>22.4</td>
<td>96%</td>
</tr>
<tr>
<td>S3A</td>
<td>21.6</td>
<td>100%</td>
</tr>
<tr>
<td>S3B</td>
<td>21.6</td>
<td>100%</td>
</tr>
<tr>
<td>S3C</td>
<td>21.6</td>
<td>100%</td>
</tr>
<tr>
<td>S4A</td>
<td>22.4</td>
<td>96%</td>
</tr>
<tr>
<td>S4B</td>
<td>22.2</td>
<td>97%</td>
</tr>
<tr>
<td>S4C</td>
<td>22.1</td>
<td>98%</td>
</tr>
<tr>
<td>S5</td>
<td>22.4</td>
<td>96%</td>
</tr>
</tbody>
</table>

Table 3 - Relative Layout Efficiency Of Different Schemes
2. CARPARK SCHEMES AND COSTING

2.1 Schemes

Eleven carpark schemes, as shown in Figure 6, have been designed and costed. The engineering drawings for each of these schemes are given in Section 2.3.
### Scheme 1: Single Module

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1A</td>
<td>3 car spaces per module width</td>
<td>Drawing 1A (page 11)</td>
</tr>
<tr>
<td>S1B</td>
<td>4 car spaces per module width</td>
<td>Drawing 1B (page 12)</td>
</tr>
<tr>
<td>S1C</td>
<td>5 car spaces per module width</td>
<td>Drawing 1C (page 13)</td>
</tr>
</tbody>
</table>

### Scheme 2: Single Module - Cantilever

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2</td>
<td>3 car spaces per module width</td>
<td>Drawing 2 (page 14)</td>
</tr>
</tbody>
</table>

---

**Figure 6 - The Eleven Carpark Schemes**

(Contd. on next page)
<table>
<thead>
<tr>
<th>SCHEME 3: SINGLE MODULE</th>
<th>SCHEME 4: MULTIPLE MODULE</th>
<th>SCHEME 5: MULTIPLE MODULE - CANTILEVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheme <strong>S3A</strong>:</td>
<td>Scheme <strong>S4A</strong>:</td>
<td>Scheme <strong>S5</strong>:</td>
</tr>
<tr>
<td>2 car spaces per module width</td>
<td>3 car spaces per module width</td>
<td>3 car spaces per module width</td>
</tr>
<tr>
<td>Refer to Drawing 3A (page 15)</td>
<td>Refer to Drawing 4A (page 18)</td>
<td>Refer to Drawing 5 (page 21)</td>
</tr>
<tr>
<td>Scheme <strong>S3B</strong>:</td>
<td>Scheme <strong>S4B</strong>:</td>
<td></td>
</tr>
<tr>
<td>3 car spaces per module width</td>
<td>4 car spaces per module width</td>
<td></td>
</tr>
<tr>
<td>Refer to Drawing 3B (page 16)</td>
<td>Refer to Drawing 4B (page 19)</td>
<td></td>
</tr>
<tr>
<td>Scheme <strong>S3C</strong>:</td>
<td>Scheme <strong>S4C</strong>:</td>
<td></td>
</tr>
<tr>
<td>4 car spaces per module width</td>
<td>5 car spaces per module width</td>
<td></td>
</tr>
<tr>
<td>Refer to Drawing 3C (page 17)</td>
<td>Refer to Drawing 4C (page 20)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6 (Contd.) - The Eleven Carpark Schemes
### 2.2 Costing

The cost of each of the eleven schemes has been calculated on a square metre rate for 2, 4, 6 and 8 storey high carparks. The results are presented in Table 4.

The costing has been done on the basis of using BONDEK® profiled steel decking.

### Table 4 - Cost Summary

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Description</th>
<th>Floor Costs $/m²</th>
<th>Column Costs $/m² for No. of Storeys</th>
<th>TOTAL COST (Floor and Columns) $/m² for No. of Storeys</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Beams</td>
<td>Decking</td>
<td>Slab</td>
</tr>
<tr>
<td>SINGLE MODULES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1A</td>
<td>3 Spaces/Bay</td>
<td>83</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>S1B</td>
<td>4 Spaces/Bay</td>
<td>81</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>S1C</td>
<td>5 Spaces/Bay</td>
<td>101</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>S2</td>
<td>Cantilever 3 Spaces/Bay</td>
<td>94</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>S3A</td>
<td>2 Spaces/Bay</td>
<td>73</td>
<td>49</td>
<td>58</td>
</tr>
<tr>
<td>S3B</td>
<td>3 Spaces/Bay</td>
<td>132</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>S3C</td>
<td>4 Spaces/Bay</td>
<td>135</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>MULTIPLE MODULES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4A</td>
<td>3 Spaces/Bay</td>
<td>84</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>S4B</td>
<td>4 Spaces/Bay</td>
<td>80</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>S4C</td>
<td>5 Spaces/Bay</td>
<td>97</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>S5</td>
<td>Cantilever 3 Spaces/Bay</td>
<td>87</td>
<td>39</td>
<td>55</td>
</tr>
</tbody>
</table>

**Notes:**
1. The values in the table have been rounded to the nearest dollar prior to totalling
2. Costs for all schemes are based on the use of the coating system specified in Table B2 for the Atmospheric Corrosivity Category C

### 2.3 Engineering Drawings

The schemes have been designed in accordance with the criteria given in Appendix A.
Economical Carparks
A Design Guide - 2nd Edition

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Notes
2. Design Loads:
   - Superimposed Dead Loads - 0.5kPa
   - Live Loads - Carpark 3.0kPa (non-reducible)
Construction Loads in accordance with Appendix F - AS2327.1-1996.
3. The designs have been based on 1.2mm Bondi II as the steel decking. Conloc HP and other profiles may also be used, however a qualified Structural Engineer shall be required to design the alternative steel decking, associated slab and variations to studs. Refer Appendix E of this guide.
4. Construction of the carpark structure, including fabrication and erection of steelwork shall comply with Section 11 of AS2327.1-1996.
   - All shear studs shall be placed in the central region of the Bondi II panels where the cross beams intersect. Only straightforward welded studs shall be applied through the Bondi II.
   - The top surface of the beam shall not be treated with any material that does not allow satisfactory welding of shear studs through the steel decking.
   - The beams and slabs shall not be propped.
5. All beams, columns and web side plates to be standard Steel, base & cap plates to columns to be grade 250 AS/NZS3679-1985.
6. All welding shall be category SP in accordance with AS/NZS1554.1-1995 unless noted otherwise.
   - Welds shall be 6mm continuous fillet welds unless noted otherwise. Welding consumables shall be E6010XNHSX.
7. Lateral stability and resistance to be provided by bracing, cores and ramps.
8. Refer to Drawings C1, C2 & C3 for column details. Refer to Drawings D1 & D2 for slab details.

<table>
<thead>
<tr>
<th>Beam Mark</th>
<th>Beam Size</th>
<th>No. Studs</th>
<th>Camber (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>310UB40.4</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>B2</td>
<td>250UB37.3</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>PB1</td>
<td>460UB67.1</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>PB2</td>
<td>560UB44.7</td>
<td>0</td>
<td>ncu</td>
</tr>
</tbody>
</table>

ncu - natural camber up

<table>
<thead>
<tr>
<th>Level</th>
<th>Column C1</th>
<th>Column C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>200UC46.2</td>
<td>150UC37.2</td>
</tr>
<tr>
<td>7</td>
<td>250UC72.9</td>
<td>200UC46.2</td>
</tr>
<tr>
<td>6</td>
<td>250UC72.9</td>
<td>250UC37.2</td>
</tr>
<tr>
<td>4</td>
<td>250UC89.5</td>
<td>250UC89.5</td>
</tr>
<tr>
<td>3</td>
<td>310UC118</td>
<td>250UC89.5</td>
</tr>
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<td>2</td>
<td>310UC118</td>
<td>250UC89.5</td>
</tr>
<tr>
<td>1</td>
<td>310UC118</td>
<td>250UC89.5</td>
</tr>
</tbody>
</table>

Steel Carpark Design
Single Module
Scheme 1A - 3 car spaces / bay

ABN 42 004 651 325

Copyright 2002 OneSteel Manufacturing Pty Limited
2. Design loads:
   - Superimposed Dead loads - 0.16kPa
   - Live loads - Carpark 2.9kPa (non-reducible)
3. These design have been based on 1.2mm Bondex as the steel decking. Condeck HP, KFS7 and other profiles may be used, however it is recommended that the alternative steel decking be selected by a qualified Structural Engineer.
4. All stud numbers for profiles with 300mm spans are provided on the schedule for the case where studs are located in the middle of the span only. Other arrangements are possible. Refer to manufacturers recommendations.
5. The beams shall be category SP in accordance with AS/NZS 1554.1:2004 unless otherwise noted.
6. Welds shall be 6mm continuous fillet welds unless noted otherwise. Welding consumables shall be E460X/W6X0.
7. The top surface of the beam shall not be treated with any material that does not allow satisfactory welding of shear studs through the steel decking.
8. Refer to Drawings C1, C2, C3 for column details. Refer to Drawing S1 for slab details.
2. Design Loads:
   - Superimposed Dead Loads = 0.15kPa
   - Live Loads - Carpark 3.0kPa (non-abrasive)
   - Construction Loads in accordance with Appendix F - AS2327.1-1996.
3. These designs have been based on 1.6mm Bondel II as the steel decking.  Bondel HF and other profiles may also be used, however a qualified Structural Engineer shall be required to design the alternative steel decking, associated slab and variation to studs. Refer to Appendix E of this guide.
4. Construction of the carpark structure, including fabrication and erection of work shall comply with Section 11 of AS2327.1-1996.
5. All shear studs shall be placed in the centre of the Bondel II panels where they cross these beams. Only automatically welded studs shall be applied through the Bondel II. The top surface of the beam shall not be treated with any material that does not allow satisfactory welding of shear studs through the steel decking.
6. All welding shall be category SP in accordance with AS/NZS1546.1:1995 unless noted otherwise.
7. Lateral stability and resistance to be provided by bracing, core and rence.
8. Refer to Drawings C1, C2 and C3 for column details. Refer to Drawings S1, S2 & S3 for slab details.

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ncu - natural camber up

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Steel Carpark Design
Single Module
Scheme 1C - 5 car spaces / bay

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FRAMING PLAN - TYPICAL MODULE

20 PLATE 8CFW
4M20 8.8/S BOLTS

20 PLATE CPBW TO FLANGES
GRIND FLUSH 8CFW TO WEB

ENDS OF BEAM TO BE COLD SAW CUT
OR EQUIV.
CPBW BEAM TOP FLANGE TO COLUMN CAP PLATE
6CFW REMAINDER OF BEAM

ENDS OF COLUMNS TO BE COLD SAW CUT
OR EQUIV.
20 THICK END PLATE
8CFW
4M20 8.8/S BOLTS
Refer to DRG C1

SECONDARY BEAM TO PRIMARY BEAM CONNECTION

SECTION 1A
CANTILEVER / COLUMN CONNECTION
OPTION A

SECTION 1B
CANTILEVER / COLUMN CONNECTION
OPTION B
Applies to Carparks of 4 storeys maximum

VIEW X-X

2. Design Loads:
   a) Superimposed Dead Loads - 0.1kPa
   b) Live Loads - Carpark 3.0kPa (non-駐足)
Construction Loads in accordance with Appendix F - AS2327.1-1996.
3. These designs have been based on 1.0mm Bondell II as the
   steel decking. Condor HP and other profiles may also be
   used, however a qualified Structural Engineer shall be required
   to design the alternative steel decking, associated slab and
   variation to studs. Refer to Appendix E of this guide.
4. Construction of the carpark structure, including fabrication
   and erection of steelwork shall comply with Section 11 of
   AS2327.1-1996.
   a) All shear studs shall be placed in the centre of the Bondell II
      panels where they cross the beams. Only automatically welded
      shear stud shall be used through the Bondell II.
      The top surface of the beam shall not be treated with any material
      that does not allow satisfactory welding of shear studs through
      the steel decking.
      The beams and slabs shall not be cropped.
   b) All beams, columns and web side plates to be 300PLUS
      Steel, 8mm cap plates to columns to be grade 250
      AS/NZS2367-1996.
   c) All welding shall be category SP in accordance with
      AS/NZS1554.1-1996 unless noted otherwise.
      Welds shall be 6mm continuous fillet welds unless noted
      otherwise. Welding consumables shall be E6013/ER70S.
   d) 7. Lateral stability and resistance to be provided by bracing,
      cores and ramps.
   e) 10. All welds shall be category SP in accordance with
      AS/NZS1554.1-1996 unless noted otherwise.
      Welding consumables shall be E6013/ER70S.
   f) 9. Costing for the examination of built welds is based on testing in
      accordance with AS 1554.1 - SP for the first two built welds then
      10% at random for the top flange and 5% for stiffeners.

Steel Carpark Design
Single Module - Cantilever edge
Scheme 2 - 3 car spaces / bay

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FRAMING PLAN - TYPICAL MODULE

Notes
2. Design Loads:
   - Superimposed Dead Loads - 0.6kPa
   - Live Loads - Carpark 3.0kPa (non-walkable)
   - Construction Loads in accordance with Appendix F - AS2327.1-1996.
3. These designs have been based on 0.75mm Bonded II steel decking. Condor HP and other profiles may also be used, however a qualified Structural Engineer shall be required to design the alternative steel decking, associated slab and variation to slabs. Refer to Appendix E of this guide.
4. Construction of the carpark structure, including fabrication and erection of steelwork shall comply with Section 11 of AS2327.1-1996.
   - All shear studs shall be placed in the centre of the Bonded II panels where they cross the beams. Only automatically welded studs shall be applied through the Bonded II.
   - The top surface of the beams shall not be treated with any material that does not allow satisfactory welding of shear studs through the steel decking.
   - The beams shall not be prepared.
5. All beams, columns and web side plates shall be 300PLUS Steel. Base & cap plates to columns to be grade 250 AS/NZS 2367.5-1996.
6. All welding shall be category SP in accordance with the Bonded II.
   - Welds shall be from continuous weld filled welds unless noted otherwise. Welding consumables shall be E6015/E6010.
7. The contact surfaces in the friction type connections shall have a minimum coefficient of 0.35.
8. Lateral stability and resistance to be provided by bracing, cores and ramps.
9. Refer to Drawings C1, C2 & C3 for column details. Refer to Drawings S1 & S2 for slab details.
10. Costing for the examination of butt welds is based on testing in accordance with AS 1941 SP. Ultrasonic testing for the first two butt welds shall be 50% of the butt welds to the top flange and 5% of the butt welds to the stiffeners.
11. Provide temporary bracing to columns at every second floor.

Beam Mark | Beam Size | No. Studs | Camber
--- | --- | --- | ---
PB1 | 330 UB 22.0 | 76 | 20
EB1 | 200 UB 25 | 13 | ncu

Level | Column C1
--- | ---
6 | 800WB122
7 | 800WB122
6 | 800WB122
4 | 800WB168
3 | 800WB168
2 | 800WB192
1 | 800WB192

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Steel Carpark Design
Single Module
Scheme 3 - 2 car spaces / bay

Date: Oct 08
Drawn: AN
Approved: 3
Rev: C
Notes


2. Design Loads:
   - Superimposed Dead Loads - 0.1kPa
   - Live Loads - Carpark 2.0kPa (non-expendable)
   - Construction Loads in accordance with Appendix F - AS2327.1-1996

3. These designs have been based on 1.0m Bondell II as the steel decking. Condoek HP and other profiles may also be used, however a qualified Structural Engineer shall be required to design the alternative steel decking, associated slab and variation to studs. Refer to Appendix F of the guide.

4. Construction of the carpark structure, including fabrication and erection of steelwork shall comply with Section 11 of AS2327.1-1996. All shear studs shall be placed in the centre of the Bondell II panels where they cross the beams. Only automatically welded studs shall be applied through the Bondell II. The top surface of the beam shall not be treated with any material that does not allow satisfactory welding of shear studs through the steel decking. The beams shall not to be propped.

5. All beams, columns and web side plates to be 300kN/m ULS Steel. Base & cap plates to columns to be grade 250 AS/NZ3678-1996.

6. All welding shall be category SP in accordance with AS/NZ2155.1-1996. Welds shall be firm continuous filled welds unless noted otherwise. Welding consumables shall be E80XG/W00X.

7. Lateral stability and resistance to be provided by bracing, cores and ramps.

8. Refer to Drawings C1, C2 & C3 for column details. Refer to Drawings S1 & S3 for slab details.
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Notes
2. Design Loads:
   Superimposed Dead Loads - 0.0 n/s
   Live Loads - Carpark 2.04kPa (non-excludable)
   Construction Loads in accordance with Appendix F - AS2327.1-
   1996.
3. These designs have been based on 1.0 mm Bondok II as the
   steel decking. Condex HP and other profiles may also be
   used, however a qualified Structural Engineer shall be required
   to design the alternative steel decking, associated slab and
   variation to studs. Refer to Appendix F of the guide.
4. Construction of the carpark structure, including fabrication
   and erection of steelwork shall comply with Section 11 of
   AS2327.1-1996.
   All shear studs shall be placed in the centre of the Bondok II
   plates where they cross the beams. Only automatically welded
   studs shall be applied through the Bondok II.
   The top surface of the beam shall not be treated with any material
   that does not allow satisfactory welding of shear studs through
   the steel decking.
   The beams shall not be propped.
5. All beams, columns and web side plates to be 300PLUS
   Steel. Base & cap plates to columns to be grade 250
   AS/NZ3875-1996.
6. All welding shall be category SP in accordance with
   AS/NZ2155.1-1996.
   Welds shall be items continuous fillet welds unless noted
   otherwise. Welding consumables shall be E6010/909X.
7. Lateral stability and resistance to be provided by bracing,
   cores and ramps.
8. Refer to Drawings C1, C2 & C3 for column details.
   Refer to Drawings S1 & S3 for slab details.
2. Design Loads:
   Superimposed Dead Loads = 0.5kPa
   Live Loads - Carpark: 3.0kPa (non-reducible)
   Construction Loads in accordance with Appendix F - AS2327.1-1996.
3. These designs have been based on 1.0mm Bonded II as the steel decking. Condorock HP and other profiles may also be used, however a qualiﬁed Structural Engineer shall be required to design the alternative steel decking. Associated slab and variation to studs. Refer to Appendix E of this guide.
4. Construction of the carpark structure, including fabrication and erection of steelwork shall comply with Section 11 of AS2327.1-1996.
   All shear studs shall be placed in the centre of the bonding II series where they cross the beams. Only automatically welded studs shall be applied through the bonding II.
   The top surface of the beam shall not be treated with any material that does not allow satisfactory welding of shear studs through the steel decking. The beams and slabs shall not be propped.
5. All beams, columns and web side plates to be 300PLUS Steel. Base & cap plates to columns to be grade 250 AS/NZS1596:1996.
6. All welding shall be category 5 in accordance with AS/NZS1554.1-1995 unless noted otherwise.
   Welds shall be 6mm continuous ﬁllet welds unless noted otherwise. Welding consumables shall be E6013/EN6015.
7. Lateral stability and resistance to be provided by bracing, cores and ramps.
8. Refer to Drawings C1, C2 & C3 for column details. Refer to Drawings S1 & S2 for slab details.

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ncu - natural camber up

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Steel Carpark Design
Multiple Module
Scheme 4A - 3 car spaces / bay

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Notes
2. Design Loads:
   - Superimposed Dead Loads - 0.5kPa
   - Live Loads - Carpark 3.0kPa (non-redundant)
   - Construction Loads in accordance with Appendix F - AS2327.1-1996.
3. These designs have been based on 1.0mm Bondel II as the steel decking. Corodock HP and other profiles may also be used, however a qualified Structural Engineer shall be required to design the alternative steel decking, associated slab and variation to studs. Refer to Appendix E of this guide.
4. Construction of the carpark structure, including fabrication and erection of steelwork shall comply with Section 11 of AS2327.1-1996.
   - All shear studs shall be placed in the centre of the Bondel II pans where they cross the beams. Only automatically welded studs shall be applied through the Bondel II.
   - The top surface of the beam shall not be treated with any material that does not allow satisfactory welding of shear studs through the steel decking.
   - The beams and slabs shall not be propped.
5. All beams, columns and web side plates to be 300PLUS Steel. Base & cap plates to columns to be grade 250 AS/NZ2579.1-1990.
6. All welding shall be category SP in accordance with AS/NZ2155:1.1995 unless noted otherwise.
   - Welds shall be 6 mm continuous fillet welds unless noted otherwise. Welding consumables shall be E6010-E6013X.
   - Lateral stability and resistance to be provided by bracing, core and nape.
7. Refer to Drawings C1, C2 & C3 for column details.
   - Refer to Drawings S1 & S2 for slab details.

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---

**Beam Mark | Beam Size | No. Studs | Camber (mm)**
---
B1 | 360UB50.7 | 26 | 50
B2 | 360UB44.7 | 0 | 45
PB1 | 530UB42.0 | 36 | 20
PB2 | 360UB50.7 | 0 | ncu

ncu - natural camber up

---

Level | Column C1 | Column C2
---|---|---
6 | 310UC118 | 200UC59.5
7 | 200UC59.5 | 150UC37.2
9 | 350WC197 | 250UC59.5
1 | 350WC230 | 310UC118

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**Steel Carpark Design Multiple Module**
**Scheme 4B - 4 car spaces / bay**

Date Oct 98 | Drawn AN | Drawn By AN | REV
---|---|---|---
--- | | | 1800 1 STEEL

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Notes:
2. Design Loads:
   - Superimposed Dead Load - 0.1 kPa
   - Live Loads - Carpark 3.0 kPa (non-redundant)
   - Construction loads in accordance with Appendix F - AS2327.1-1996.
3. These designs have been based on 1.6m Bondek II as the steel decking.
   - Cordex HP and other profiles may also be used, however a qualified Structural Engineer shall be required to design the alternative steel decking, associated slab, and verification to loads. Refer to Appendix E of this Guide.
4. Construction of the carpark structure, including fabrication and erection of steelwork shall comply with Section 11 of AS2327.1-1996.
   - All shear studs shall be placed in the centre of the Bondek II pans where they cross the beams. Only automatically welded shear studs shall be used through the Bondek II beams. The top surface of the beam will not be treated with any material that does not allow satisfactory welding of the shear studs through the steel decking.
   - The Slabs and beams shall not be pretreated.
5. All beams, columns and web plate sizes to be 360 PLUS Steel. Base & cap plates to columns to be grade 250 AS/NZS 3900-1995.
6. All welding shall be category S9 in accordance with AS/NZS 1554.1-1996 unless noted otherwise.
   - Welds shall be 8 mm continuous fillet webs unless noted otherwise. Welding consumables shall be E4600/005X.
7. Lateral stability and resistance to be provided by bracing, cores and rams.
8. Refer to drawings C1, C2 & C3 for column details. Refer to drawings B1, B2 & B3 for slab details.

Costing for the examination of the butt welds is based on testing in accordance with AS 1554.1 - SP for the first two welds then 10% at random for the top flange and 5% for stiffeners.

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Notes:
1. Columns have been designed for a maximum floor to floor height of 3 metres.
2. Column connection shall be a full contact splice in accordance with AS 4100-1998. The tolerances shall comply with Clause 14.4.2.
3. The columns shall be cut to length with a cold saw or equivalent.
4. All Cap Plates to be grade 250 AS/NZS 3275-1996.
5. All welding shall be category SP in accordance with AS/NZS 1554.1-1995 unless noted otherwise. Welding consumables shall be E4600/W65K.
6. Refer to framing plans for beam details and general notes.

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<th>b₁</th>
<th>CAP PLATE THICKNESS</th>
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* USE DIMENSION IN BRACKETS WHERE THERE IS A SMALLER COLUMN OVER
TYPICAL BASE PLATE DETAILS
REFER TO SCHEDULE BELOW FOR DETAILS

BASE PLATE SCHEDULE

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Notes:

1. Refer to framing plans for beam details and general notes.

2. Decking not shown for clarity.

3. Decking sheets shall not be continuous at the columns. Cut decking locally to fit around column.

Typical Deck Support Detail for Continuous Columns

Typical Deck Support Detail at Column Splice

75 x 50 x 1.0 Galvanised Angle Fillet Weld to Column & Beam

3mm Plate Seal Weld Top & Bottom of Plate to Column

4M20 8.8/S Bolts

1mm Galvanised Sheet Between End Plates

1mm Galvanised Sheet Between End Plates
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Notes:
2. Design Loads
   Superimposed Dead Loads - 0.1 kPa
   Live Loads - 3.0 kPa (non reducible)
   Construction loads in accordance with Appendix F - AS2327.1-1996
3. The slab has been designed for a maximum exposure classification of B1.
4. The slab has been designed for an FRL of 60/60/90 based on a Bonddek II slab.
5. Concrete shall be:
   Grade - N40
   Slump - 60mm
   Max Aggregate size 20mm
   Project Testing to AS3600-1996.
6. The minimum top cover to reinforcement is 40mm.
7. The slab shall be cured to the requirements of AS3600-1996.
8. The slab shall not be propped. The Bonddek II shall not cantilever more than 300mm from the centre line of the beam at the edge. For Condock HP and other steel profiles refer to manufacturers literature.

Additional Reinforcement at Internal Columns

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Reinforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A, 4A, 5</td>
<td>4Y16 - 250 2000 long</td>
</tr>
<tr>
<td>1B, 4B</td>
<td>6Y16 - 150 2000 long</td>
</tr>
<tr>
<td>1C, 4C</td>
<td>6Y16 - 150 2000 long</td>
</tr>
<tr>
<td>2</td>
<td>NONE REQUIRED</td>
</tr>
</tbody>
</table>

Steel Carpark Design  
Typical Slab Details for Schemes 1, 2, 3B, 3C, 4 & 5
3. DESIGN EXAMPLES

Figures 6(a) & (b) show flowcharts outlining the typical steps involved in arriving at suitable preliminary design and costing.

Two design examples are provided in this Section to illustrate how the information in this Design Guide may be used.
STEP 1
Is it a stand alone open-deck* or sprinklered* carpark?

YES

Refer to Appendix C, Section C2
Then use the appropriate sections of the guide & if required determine extent of fire protection

NO

STEP 2
Is it a single module?

YES

STEP 3
Are there edge columns?

YES

STEP 3a
Are there internal columns?

YES

STEP 4
Schemes S1A, S1B, S1C
Schemes S3A, S3B, S3C
Scheme S2
Schemes S4A, S4B, S4C
Scheme S5

NO

STEP 5
Select appropriate drawing provided in Section 2.3. For Schemes S1, S3 and S4 the final selection is also based on spaces/bay requirements

NO

STEP 6
Use Table 4 to price the scheme

STEP 7
Adjust price for penetration and surface treatment (use Tables D2 & D3) and for Fire Protection if required

STEP 8
Design and cost other elements

* Note: Refer to Appendix C, Section C1 for a definition of open-deck carpark

Figure 6(a) - Flow Chart for Design

Figure 6(b) - Flow Chart for Costing
3.1 Example 1

Design Constraints

- The figure above shows diagrammatically the architects requirements for an 8 storey carpark.
- The carpark is to be open deck.
- The surface treatment to be appropriate for atmospheric Category C.
- No penetrations in primary beams required.
- Edge columns are permitted.

Preliminary design (see flow chart in Figure 6a):

<table>
<thead>
<tr>
<th>STEP</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Is this an open deck carpark? - Yes</td>
</tr>
<tr>
<td>2</td>
<td>Is this a single module? - No (2 x 16600 = 33200)</td>
</tr>
<tr>
<td>3</td>
<td>Are there edge columns? - Yes</td>
</tr>
<tr>
<td>4</td>
<td>Possible schemes S4A, S4B and S4C</td>
</tr>
<tr>
<td>5</td>
<td>Based on the information given in the Scheme S4B drawing, the following design information is relevant.</td>
</tr>
</tbody>
</table>

Preliminary costing (see flow chart in Figure 6b):

STEP 6 The cost of 8 suspended levels is obtained from Table 4. A scheme may be selected on the basis of cost and/or preferred layout. Scheme selected in STEP 5 may be revised if cost is the deciding issue. In this case Scheme S4B currently chosen is found to be economical.

STEP 7 Adjust base cost determined in STEP 6 using data from Appendix D. Adjustment for surface treatment (Table D2), Adjustment for beam penetrations (Table D3), Calculate Net Adjustment (Price from STEP 6 + Adjustments).

STEP 8 Design and cost all other elements not covered in this Guide, e.g. stairs, ramps, lateral bracing systems.
A developer requires a carpark to suit the following criteria:-
- 4 suspended levels.
- Site is 34m x 75m with 3% fall across the 34m.
- Facade to be out of light weight steel up to barrier height only -> open deck carpark.
- Surface treatment to be appropriate for atmospheric Category C with top coat varying in colour for each floor.
- 1 circular penetration per primary beam.

Design Constraints

Preliminary design (see flow chart in Figure 6a)

STEP 1 Is it an open deck carpark?
Yes, a requirement of the developer.

STEP 2 Is it a single module carpark?
Since it is 34m wide it could be 2 single modules with a split level or a multiple module of 2. Since a split level carpark will suit the 3% fall across the site and also will result in shorter ramps which will not intrude into the aisle width, adopt the single module option.

STEP 3 Are edge columns allowed?
There is no requirement that the edge beams are to be cantilevered, therefore use scheme with edge columns. Table 4 indicates edge columns result in a more economical structure.

STEP 3a Are internal columns allowed?
Again there are no requirements set. Table 4 indicates that schemes with internal columns are more economical.

However if maximum flexibility is desired then no internal columns would be the preferred option. In this example we are looking for the most economical option therefore the internal column schemes will be considered.

STEP 4 Schemes S1A, S1B and S1C are therefore appropriate.

STEP 5 Design as a 4 suspended level carpark. Refer to drawings 1B, C1 and S1.
STEP 5

Columns for a 4 level carpark.

The table on drawing 1B gives column sizes for an 8 level carpark. For a 4 level carpark use the column sizes for the top 4 levels.

For the C2a which is normally an external column for single module carpark, use the same size as an internal column, ie C1.

This gives:

<table>
<thead>
<tr>
<th>Level</th>
<th>Column C1/C2a</th>
<th>Column C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250UC89.5</td>
<td>200UC59.5</td>
</tr>
<tr>
<td>2</td>
<td>250UC89.5</td>
<td>200UC59.5</td>
</tr>
<tr>
<td>3</td>
<td>200UC46.2</td>
<td>150UC37.2</td>
</tr>
<tr>
<td>4</td>
<td>200UC46.2</td>
<td>150UC37.2</td>
</tr>
</tbody>
</table>

The 10.7m bays can be repeated 7 times.

Preliminary costing (see flow chart in Figure 6b):

STEP 6 The cost of a scheme is obtained from Table 4.

STEP 7 Adjust base cost using information from Appendix D (Table D2 for surface coating and Table D3 for penetrations)

(a) Surface Treatment - Category C plus top coat (Table D2)
(b) 1 circular penetration per primary beam (Table D3).

STEP 8 Design and cost all other elements not covered in this Guide, e.g. stairs, ramps, lateral bracing systems etc.
A. STRUCTURAL DESIGN CRITERIA

The following principles guided the selection of the structural systems given in this publication for the various schemes.

Simple details were adopted wherever possible to minimise fabrication costs and to allow fast erection of the steelwork on-site.

A.1 Building Regulations

The modular carpark designs given in this publication comply with the provisions of the Building Code of Australia (Australian Building Code Board, 2004) for stand alone open-deck and closed carparks with sprinklers. The companion to this document “Economical Carparks - A Guide to Fire Safety” (Bennetts, Poh & Thomas, 2001) explains the fire protection requirements in more detail for both stand alone carparks as well as carparks within mixed occupancy buildings.

A.2 Design Loads

The carparks have been designed for the following loads:

- Superimposed dead loads - 0.1 kPa
- Live load - AS/NZS 1170.1:2002 - 2.5 kPa (with no reduction for tributary area)

A lightweight self-supporting steel facade and guardrail have been assumed to exist along the perimeter of the carpark. If a concrete or other heavy facade is adopted, the edge beams and supporting columns will need to be designed for the heavier loads.

A.3 Floors

A.3.1 Use of Unpropped Construction

It is preferable not to prop the beams or slabs for speed of construction, to keep an open working space and also to minimise concrete cracking problems. Hence, for all cases except Scheme S3A, secondary beams are spaced at about 2.8m centres. This spacing was considered to correspond to the maximum spanning distance for 1.0mm re-entrant profiled steel sheeting (continuous over a minimum of three spans) to achieve aesthetically acceptable deflections. Alternative sheeting profiles can be used in accordance with A.3.3.

With Scheme S3A, where the beams are spaced at 5.2m centres, it was not considered economical to provide intermediate secondary beams. So for this case only, the profiled steel sheeting (0.75mm Bondek) is propped during construction.

A.3.2 Beams

The beams were designed to AS 2327.1-2003 and AS 4100-1998. The beams are cambered for the weight of the wet concrete, except when the camber is less than the straightness tolerance specified in AS 4100 (lesser of length/1000 and 10mm). Vibration in the carparks that have been constructed previously has not been identified as a problem and this was confirmed in checks carried out using the methods proposed by Murray, Allen & Ungar (1997).

The limit state design models proposed by Hogan & Thomas (1994) were generally adopted for the design of connections. The number of bolts is often less than that given in the third edition of the AISC Standardised Structural Connections (Australian...
Institute of Steel Construction, 1985), which was based on the working stress steel code, AS 1250-1981. 8mm steel flat was adopted as the standard web-side-plate in order to avoid the need to stack plates of different thickness. Dimensions such as edge distances, bolt size and pitch are generally in accordance with the recommendations by Hogan & Thomas (1994).

The primary beams have been checked in accordance with Chick, Dayawansa & Patrick (1998) for a 200mm diameter unstiffened circular web penetration. Larger penetrations, either unstiffened or stiffened, and end notches can be provided, but would need to be designed. Pipes should be designed to run under or between the secondary beams.

A.3.3 Profiled Steel Sheeting

The designs in this guide have been developed for Bondek®, which satisfies the design criteria set out in Figure A1. Other re-entrant sheeting profiles conforming to AS 2327.1-2003, such as Condeck HP®, KF57®, RF55® may be used provided these criteria are satisfied, and any other effects that this may have on the building design are taken into account - e.g. beam size and spacing, shear stud numbers and spacing, thickness of slab, etc.

Over the last two years three new types of steel decks have been introduced into the Australian market, which are commonly described as trapezoidal decks. These decks are not covered by AS 2327.1-2003 and are subsequently not utilised in the 11 carpark schemes presented in this Guide. However, literature published by the manufacturers of these decks indicates that they provide a competitive alternative to the re-entrant profiles steel sheeting considered in this Guide. As these trapezoidal decks are not covered by an Australian Standard, designers are left with the option to use the respective manufacturer’s recommendations or an International Standard with design to engineering principles, or a combination of these.

A.3.4 Slabs

The composite slabs have been designed using a partial shear connection strength theory (BlueScope, 2003). Grade 500PLUS® reinforcing bars have been adopted in lieu of mesh as this is believed to be more economical. In addition, no special details are required to avoid overlapping layers of mesh. It should be noted that Scheme S3A utilises moment redistribution, while AS 3600-2001 permits the redistribution of moments with grade N500 bars but not with cold-reduced mesh. Therefore the bar reinforcement specified on the drawings in Section 2.3 cannot be directly substituted with mesh of equivalent area.

Scheme S3A has been designed as simply supported for the strength limit state, with crack width and deflection checked at serviceability load levels. All the other schemes have been designed for the bending moments and shear derived from an elastic analysis.

Reinforcement intensity is typically 6.5-7.5 kg/m² for each of the 11 schemes contained in this Guide.

The criteria listed in this figure were adopted for the design of the profiled steel sheeting acting as formwork. Bondek® with a nominal base metal thickness of 1.0 mm is satisfactory for the largest beam spacing involving unpropped construction, i.e. 2.8 metres. Condeck HP® and other profiled steel sheeting products may also be considered for use, provided a Certified Structural Engineer confirms that these criteria have been met.

1. The minimum nominal loads for construction comply with Appendix F of AS 2327.1-2003, viz.:

(a) Construction Stage 1 (See Notes):

1.2 Gsh + 1.5 Qu

where Qu = 1.0 kPa; OR

1.2 Gsh + 1.5 Qp

where Qp = 1.0 kN in edge pan or 2.0 kN elsewhere.

(b) Construction Stage 2:

1.2 (Gsh + Greo) + 1.5 Qu

where Qu = 2.0 kN elsewhere.

(c) Construction Stage 3:

1.2 (Gsh + Greo + Gconc) + 1.5 Qu

where Qu = 1.0 kPa; OR

1.2 (Gsh + Greo + Gconc) + 1.5 Qheap

where Qheap = 2.0 kPa over 1.6mx1.6m.

2. The maximum deflection of the sheeting does not exceed span/200 under the dead loads (Gsh + Greo + Gconc) corresponding to Construction Stage 3.

3. The strength and stiffness of the profiled steel sheeting are assessed using recognised procedures supported by adequate test data. If further information is required contact deck suppliers.

Notes:

Gconc = dead load of concrete including ponding;
Greo = dead load of steel reinforcement;
Gsh = dead load of steel sheeting;
Qheap = heaped-concrete live load;
Qp = point live load; and
Qu, Qp = uniformly-distributed live load.

Figure A1 - Profiled Steel Sheeting Design
Refer to Appendix B on durability for details of shrinkage-and-temperature and other crack-control reinforcement.

A.4 Columns

The columns have been designed in accordance with AS 4100-1998. Allowance has been made for pattern loading and a maximum floor-to-floor height of 3m when determining their size.

The columns have been designed for the vertical loads of an eight level carpark. The designs can be used for carparks with fewer levels by using size corresponding to the top levels e.g. for a two level carpark, the appropriate columns are those required for levels 7 and 8. Whilst the column size is given in increments of 2 levels, it may be more economical in some cases to remove the column splice(s) and run the heavier column all the way up. The practical limit for this approach is 6 levels. This is discussed in more detail in D.5.

The column splices have been incorporated in the depth of the slab for aesthetic and functional reasons.

Edge columns in single module schemes have only been designed for that situation. Where two modules abut (for example combination single modules - see Figure 4 - for Scheme S1A, S1B & S1C) the columns common to two modules take twice the vertical load. These columns can be conservatively designed as internal columns.

Figure A2 - Steel Stair Options
A.5 Lateral Load Resisting Systems

The designs in this Guide only cover vertical loadings. Lateral load-resisting systems can utilise ramps, shear walls and steel moment or braced frames. Generally, braced frames are more economical than moment frames. Braced frames can be located along the perimeter of a carpark or along the column lines.

A.6 Stairs

To match the speed of construction offered by steel, it is common practice to adopt steel stair systems. These fall into two categories viz.:

• Formwork systems such as Stairmetal Formwork (Aus Iron Industries Pty Ltd, Melbourne - http://www.ausironindustries.com.au).
• Steel stairs as shown in Figure A2. These allow safe access to all floors during construction, as well as providing permanent access. They are often fully assembled in the fabrication shop and lifted directly into place on site.

References

Australian Building Code Board 2004, Building Code of Australia, Volume 1: Class 2 to Class 9 Buildings, ABCB, Canberra

Australian Institute of Steel Construction 1985, AISC Standardized Structural Connections, 3rd edn, AISC, North Sydney


Standards Australia 1981, AS 1250-1981 (superceded) SAA Structural Steel Code, SAI, Sydney

Standards Australia 2003, AS 2327.1-2003 Composite structures - Simply supported beams, SAI, Sydney

Standards Australia 2001, AS 3600-2001 Concrete structures, SAI, Sydney

Standards Australia 1998, AS 4100-1998 Steel structures, SAI, Sydney
B. DURABILITY

B.1 Slabs

The slabs have been designed and detailed for a maximum Exposure Classification of B1 (near coastal) in accordance with AS 3600-2001. Less severe classifications may be appropriate for fully enclosed carparks or for carparks in cities away from the coast.

For durability and aesthetic reasons, the slabs have been designed in accordance with AS 3600-2001 to achieve a strong degree of crack control. Special attention should also be given to the need for additional reinforcement in the vicinity of restraints, openings and discontinuities particularly on the top level, which is subjected to a great deal more moisture in the form of rainfall.

The regions of the slabs in negative bending have been designed for crack control in accordance with Proe, Patrick & Goh (1997). The regions at the ends of the primary and secondary beams have also been checked for crack control in accordance with Adams & Patrick (1998). This has resulted in additional reinforcement being provided around some columns and over some primary beams. Proping of the slabs or beams, where the system has been designed as unpropped, may result in excessive crack widths. Hence, propping should be avoided in all schemes except Scheme S3A.

Movement joints traditionally require high maintenance and should be avoided if possible. When required, they should be detailed so that in the event of leakage through the joint, there will not be any adverse effect on the durability of the structure or damage to the paint on the cars below. Consequently, the joints must not be placed over the flange of a steel beam. A suitable detail is given in Figure B1.

The concrete should be screeded or boxed locally around the steel column so that water will not pond at the column. In addition a sealant with a high modulus of elasticity (e.g. ROADseal) should be provided at the interface of the concrete and the steel column so that water can not penetrate when the concrete shrinks away from the column.

B.2 Profiled Steel Sheeting

It is recommended that the galvanized coating on the profiled steel sheeting complies with Table B1. (BlueScope Steel, 2004) The atmospheric classifications in AS/NZS 2312:2002 are appropriate for steel sheeting and have been adopted herein (refer to Table B3). For exposed edge forms, a drip arrester should be incorporated along the edge (see drawing No S1, Section 2.3, page 25 for a suitable detail), and should be made from Z450 galvanized steel. For edges not exposed to the weather, a standard edge form of Z450 galvanized steel is recommended.
B.3 Structural Steelwork

Considerable care has been taken to avoid details that will lead to premature deterioration of the paint system. The selection of the steelwork finish will often be governed by aesthetics as well as durability. The top flange of the composite steel beams should not be coated with materials that would prevent the satisfactory welding of shear studs through the profiled steel sheeting. Shear studs can be welded through the profiled steel decking and a 25-50µm coating of a zinc phosphate primer onto the steel beam. For atmospheric corrosivity category A it is recommended that this sort of weld through primer be used.

For higher atmospheric corrosivity categories it is recommended that the steelwork be protected as indicated in Table B2. However, a strip wide enough to accommodate the shear studs is to be initially left untreated by masking the appropriate area on the top flange. A special tape is available to accommodate a hot-dip galvanized treatment. This area is latter treated with a 25-50µm coating of a zinc phosphate primer.

Exposed perimeter steelwork is in a more severe environment than the internal steelwork and therefore should have a higher level of protection. Therefore, for perimeter beams with a slab edge exposed to the weather, it is recommended that at the very least, the top flange should be given a complete coat of the protection indicated in Table B2, while the beam should be galvanized in marine and tropical environments. This means that perimeter beams in these cases would need to be non-composite as the whole top flange of the beam would be treated making the welding of shear studs to this surface difficult.

Table B2 gives the minimum recommended surface treatment based on AS/NZS 2312:2002. In some situations, it may be better to adopt a more durable surface coating with a higher initial cost and reduced maintenance. Different systems can be compared by determining the life cycle cost, using the Net Present Value method (AS/NZS 2312:2002) of each alternative including allowances for taxation benefits. Systems alternative to those given in Table B2 that can be considered include:

- Class 2.5 blast clean (AS 1627.0-1997) followed by one coat of inorganic zinc silicate (75µm), a

### Table B2 - Minimum Recommended Surface Treatment options for Various Atmospheric Classifications in Accordance with AS/NZS 2312:2002

<table>
<thead>
<tr>
<th>Atmospheric Corrosivity Category</th>
<th>Preparation</th>
<th>Protection</th>
<th>Top Coats for Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Blast Clean to Class 2</td>
<td>75µm Alkyd Primer (Zinc Phosphate)</td>
<td>Alkyd Gloss</td>
</tr>
<tr>
<td>B</td>
<td>Blast Clean to Class 2</td>
<td>75µm Epoxy Zinc Phosphate Primer</td>
<td>50-75 µm Polyurethane or Catalysed Acrylic</td>
</tr>
<tr>
<td>C</td>
<td>Blast Clean to Class 2½</td>
<td>75µm Epoxy Zinc + 125µm High Build Epoxy</td>
<td>50-75 µm Polyurethane or Catalysed Acrylic</td>
</tr>
<tr>
<td>D</td>
<td>Blast Clean to Class 2½</td>
<td>75µm Epoxy Zinc + 150µm High Build Epoxy or Hot-dip Galvanized</td>
<td>50-75 µm Polyurethane or Catalysed Acrylic</td>
</tr>
<tr>
<td>E</td>
<td>Blast Clean to Class 2½</td>
<td>75µm Epoxy Zinc + 200µm High Build Epoxy or Hot-dip Galvanized</td>
<td>50-75 µm Polyurethane or Catalysed Acrylic</td>
</tr>
<tr>
<td>F</td>
<td>Blast Clean to Class 2½</td>
<td>75µm Epoxy Zinc + 125µm High Build Epoxy</td>
<td>50-75 µm Polyurethane or Catalysed Acrylic</td>
</tr>
</tbody>
</table>

**NOTE:**
1. Masking of top flange is not required. Shear studs to be installed through Zinc Phosphate coating
2. Refer to Table B3 for descriptions of Atmospheric Corrosivity Categories
A functional system where aesthetics are less important;
- Class 2.5 blast clean followed by 50µm epoxy zinc and 50µm 2 pack acrylic (epoxy cross linked catalysed acrylic) to provide an architectural finish in a range of colours

Szokolik & Rapattoni (1997) has shown that a single coat of water borne inorganic zinc silicate will out perform multi-coat systems. However the multi-coat system is given for situations where a different colour top coat is desired.

Table B2 is a guide only. The corrosion protection system should be designed in accordance with AS/NZS 2312:2002. Labour rather than material cost drives the applied cost of coating systems. Often similar corrosion resistance can be achieved independent of aesthetics.

Reference should be made to Appendix D for costs of alternate coating systems

B.4 Monitoring

In accordance with normal practice, an inspection would be undertaken towards the end of the contract defects-liability period. This should identify items which require ongoing monitoring such as expansion joints.

References


BlueScope Steel Limited, Melbourne


BlueScope Steel 2004, Technical Bulletin TB-29,
Atmospheric Corrosivity Category | Description
--- | ---
Category A: Very low | Environments in this category are most commonly found inside heated or air conditioned buildings with clean atmospheres, such as most commercial buildings. They may also be found in semi-sheltered locations remote from marine or industrial influence and in unheated or non-air conditioned buildings. The only external environments in Australia or New Zealand are some alpine regions although, generally these environments will extend into Category B.

Category B: Low | Environments in this category include dry, rural areas as well as other regions remote from the coast or sources of pollution. Most areas of Australia and New Zealand beyond at least 50 kilometres from the sea are in this category, which can however, extend as close as 1 kilometre from seas that are relatively sheltered and quiet. Typical areas occur in arid and rural inland regions, most inland cities and towns such as Canberra, Ballarat, Toowoomba, Alice Springs and Hamilton, NZ and suburbs of cities on sheltered bays, such as Melbourne, Hobart, Brisbane and Adelaide (except areas within 3 to 6 kilometres of the coast near Adelaide). Unheated or non-airconditioned buildings where some condensation may occur, such as warehouses and sports halls, can be in this category. Proximity to the coast is an important factor.

Category C: Medium | This category mainly covers coastal areas with low salinity. The extent of the affected area varies significantly with factors such as winds, topography and vegetation. Around sheltered seas, such as Port Philip Bay, Category C extends beyond about 50 metres from the shoreline to a distance of about one kilometre inland. For a sheltered bay or gulf, such as near Adelaide, this category extends from the shoreline to about 3 to 6 kilometres inland. Along ocean front areas with breaking surf and significant salt spray, it extends from about 1 kilometre inland to between 10 to 50 kilometres inland, depending on the strength of prevailing winds and topography. Much of the metropolitan areas of Wollongong, Sydney, Newcastle, the Gold Coast, Auckland and Wellington are in this category. In South Australia, the whole of the Yorke peninsula falls within this or a more severe category, and in the south-east of the state, from Victor Harbour to the Victorian border, this category extends between 30 and 70 kilometres inland. Such regions are also found in urban and industrial areas with low pollution levels and although uncommon in Australia and New Zealand, exist for several kilometres around major industries, such as smelters and steelworks, and in the geothermal areas of New Zealand. Micro-environmental effects, such as result from proximity to airports and sewage treatment works, may also place a site into this category. Interior environments with Category C corrosivity can occur in humid production rooms, such as food-processing plants, laundries, breweries, printing works and dairies.

Category D: High | This category occurs mainly on the coast. Around sheltered bays, Category D extends up to 50 metres inland from the shoreline. In areas with rough seas and surf, it extends from about several hundred metres inland to about one kilometre inland. As with Categories B and C, the extent depends on winds, wave action and topography. Industrial regions may also be in this category, but in Australia and New Zealand these are only likely to be found within 1.5 kilometres of the plant. This category extends inside the plant where it is best considered as a micro-environment. Damp, contaminated interior environments such as occur with swimming pools, dye works, paper manufacturers, foundries, smelters and chemical processing plants may also extend into this category.

Category E: Very High | This category is common offshore and on the beachfront in regions of rough seas and surf beaches. The region can extend inland for several hundred metres. (In some areas of Newcastle, for example, it extends more than half a kilometre from the coast.) This category may also be found in aggressive industrial areas, where the environment may be acidic with a pH of less than 5. For this reason, Category E is divided into Marine and Industrial for purposes of coating selection. Some of the damp and/or contaminated interior environments in Category D may occasionally extend into this category.

Category F: Inland Tropical | A tropical environment is found in coastal areas of north Queensland, Northern Territory, north-west Western Australia, Papua New Guinea and the Pacific Islands, except where affected by salinity. Corrosivity in inland regions is generally low (similar to that of Category B), but the aggressiveness of the environment to organic coatings means special protection is required.

Note: If a site is considered to be in more than one category, for example an industry on the coast in a tropical region, then a selected coating should be capable of resisting the most severe of the environments involved.

Table B3 - Atmospheric Classification in Accordance with AS/NZS 2312:2002
C. FIRE-RESISTANCE REQUIREMENTS

C.1 Open-deck or Sprinklered Carparks

According to the Building Code of Australia (2004), open-deck and sprinklered carparks can be constructed from bare steel construction provided that the columns and beams achieve certain requirements with respect to their surface-area-to-mass ratio.

The BCA defines an open-deck carpark as a carpark which is cross ventilated using two approximately opposite sides. The sides that provide ventilation must be at least 1/6 of the area of any other side and the opening must be at least 1/2 of the wall area (see Figure C1).

C2 Not Open-deck and Not Sprinklered Carparks

The designs in this publication are also applicable to carparks that are not open-deck or are not sprinklered, however some fire protection of structural elements may be required. The BCA carparks provisions including those for non-sprinklered, non-open deck carparks are described in detail in the OneSteel publication “Economical Carparks – A Guide to Fire Safety” (Bennetts, Poh & Thomas, 2001). This document should be consulted to determine the extent of protection required.

References


Figure C1 - Open-Deck Carpark (Source: Bennetts, Poh & Thomas, 2001)
D. COSTING

D.1 Methodology

The costing of the different carpark schemes is based on a rational costing method, proposed by Watson et al. (1996), which divides the costs up into the following components.

Steel Supply
Steel sections are costed in dollars per lineal metre, whereas plate and profiled sheeting are costed in dollars per square metre.

Fabrication
This item covers shop drawings and transport, as well as the fabrication activity. It is an activity-based costing system. The time to undertake each activity has been derived from a detailed survey of practices within the Australian fabrication industry.

Surface Treatment
Rates per square metre of treated area are used to determine the cost of these activities.

Erection
This item covers all activities carried-out on site such as steel erection, laying and fixing of profiled steel sheeting and welding of shear studs.

The advantages of the above methodology in costing are that it:

• provides more reliable and accurate costs;
• provides continuity of approach from initial project costing through to fabricator’s detailed costing;
• provides a clearer focus on the elements that will have a significant effect on the final cost; and

• allows reliable determination of contract variation costs.

A Microsoft Excel 7.0 spreadsheet program was used to determine the costs of each of the carpark schemes using the above methodology. Each scheme is costed on a separate sheet and this information is brought together on a summary sheet. The costs are based on data given by Watson et al. (1996) with an updated fabrication hourly rate of $60 and 2004 supply costs.

The accuracy of these costs has also been verified independently by a number of fabricators. As significant attention has been given to minimise the cost of the details recommended for use, the cost of the fabrication is sometimes less than the fabricator’s initial approximation. However, a more detailed examination reveals that the costs are realistic.

D.2 Costs

A summary of the base costs is given in Table D1. The base costs are derived for schemes with a Category C exposure classification and no web penetrations. This information has been taken from the summary sheet of the spreadsheet program.

D.2.1 Schemes with Edge Columns (Schemes S1 & S4)

From the base costs in Table D1, it can be seen that, the 4 car space schemes (S1B & S4B) with edge columns are the most economical. The 3 car space schemes (S1A & S4A) are only slightly more expensive. This goes against conventional wisdom since one would expect the 3 car space schemes to be cheaper as there is less steel. The beam
supply cost for Schemes S1A & S4A is $35 per square metre whereas for schemes S1B & S4B it is $40 per square metre. However, with these schemes there is the same amount of fabrication and erection per module. Yet the module area for the 4 car space module is one third larger than the 3 car space module. Therefore, the additional supply cost for the beams in the 4 car space scheme is offset by the reduced fabrication costs and the total cost for the beams is the same. In addition, with the 4 car space schemes there are fewer members to erect for a given carpark and hence construction speed is increased.

The cost for the beams includes allowance for the components of the connections to the columns. Therefore the column costs include only the supply cost of the column, the fabrication costs associated with the end splice, erection costs and surface treatment costs. It can be seen from Table D1, that the column cost per square metre for the 4 car space schemes is less than that for their respective 3 car space scheme.

The 5 car space schemes suffer a significant cost penalty of up to $20 per square metre over the 4 car space schemes. This is largely due to the increase in steel supply cost of $10 per square metre. The remainder is made up of increased fabrication and surface treatment costs due to the larger members and connections.

Schemes S1B, S1C, S4B and S4C offer a small improvement in utilisation of the floor area (see Table 3) which should be taken into account when comparing the different schemes.

### Table D1 - Summary of Indicative Costs (Surface treatment: Refer to Table B2 Category C)

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Floor Costs $/m²</th>
<th>Column Costs $/m² for No. of storeys</th>
<th>TOTAL COSTS $/m² for No. of storeys</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beams</td>
<td>Decking</td>
<td>Slab</td>
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<tr>
<td>1A</td>
<td>83</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>1B</td>
<td>81</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>1C</td>
<td>101</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>2</td>
<td>94</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>3A</td>
<td>73</td>
<td>49</td>
<td>58</td>
</tr>
<tr>
<td>3B</td>
<td>132</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>3C</td>
<td>135</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>4A</td>
<td>84</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>4B</td>
<td>80</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>4C</td>
<td>97</td>
<td>39</td>
<td>55</td>
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<tr>
<td>5</td>
<td>87</td>
<td>39</td>
<td>55</td>
</tr>
</tbody>
</table>

**NOTE:** To obtain the total cost of the carpark floor and columns, multiply the cost for the relevant number of storeys by the total area.

### D.2.2 Schemes with a Cantilever Edge (Schemes S2 & S5)

This layout is only given for a 3 car space scheme as the cantilever size proved uneconomical for larger module widths. The steel supply cost was only slightly more than for the edge column solution. However, the fabrication costs increased considerably with the moment connections. For the multiple module Scheme S5, this additional cost is spread over a greater floor area and hence is not as obvious as the single module Scheme S2 which has two cantilevers in a single module.

### D.2.3 Scheme with a Clear Span (Scheme S3A, S3B & S3C)

Clear span solutions offer a very efficient layout with more car spaces in a given footprint. These schemes are also very appealing to the user as there are no internal columns that are a potential source of damage to cars. For this reason they are popular in carparks with high turnover, particularly in shopping centres.

The total cost of Scheme 3A is very sensitive to the component cost of propping the slab during construction, however if this is well managed the more efficient usage of space almost pays for the additional cost over the schemes that are not clear span.

The additional cost of schemes 3B and 3C are generally accepted by owners on the basis of the additional appeal it offers the users of the carpark.
D.3 Different Surface Treatment Systems

The cost of surface treating or painting the steelwork has a major influence on the initial cost of a carpark. The cost of different paint systems for each of these schemes is given in Table D2. It should be noted that an additional $5/m² allowance to mask the top flange and to later treat with a weld through primer has been included in the costs for all paint systems except for category A. Scheme 3A is significantly less than the other schemes as there are fewer members involved. This makes this scheme more attractive if the more expensive protective systems need to be used.

D4 Penetrations

The cost of large reinforced penetrations in the webs of steel beams can have a significant influence on the cost of a floor. However, in a carpark, such penetrations are usually not required. Circular and rectangular unreinforced penetrations will generally cater for the necessary hydraulic services in a carpark can be economically provided in the primary beams. For example 200 diameter penetrations in each of the primary beams will cost in the order of 25 cents per square metre over the entire carpark. The indicative costs of different types of penetrations that are commonly used are given in Table D3.

D.5 Column Splices

The cost of column splices is quite substantial. The fabrication cost is generally between $240 and $320 per splice. To this the additional cost of shop drawings, transport and erection has to be added. This brings the total cost of a splice to between $520
and $800. Therefore, in general it is better to minimise the number of splices rather than the mass of the column.

The maximum length of column section that is readily available and still easy to handle is 18 metres. Therefore, it is recommended that for carparks less than four levels high, the columns are made from one length (without splices). With a six level carpark, the cost of a non-prismatic column with splices is similar to that of a prismatic continuous column. The choice will depend on the scheme being adopted and the time allowed for fabrication and erection. For an eight level carpark, it is suggested that a splice be provided at mid-length for maximum economy.

**References**

Watson, K. B., Dallas, S., van der Kreek, N. & Main, T. 1996, “Costing of Steelwork from Feasibility through to Completion”, *Journal of Australian Institute of Steel Construction*, vol. 30, no. 2
E. SURVEY OF EXISTING CARPARKS

There have been a significant number of steel carparks constructed in Australia and New Zealand of various configurations in plan and elevation. This appendix lists many of these carparks.

Information on these are presented in tables, for each state of Australia, and one for New Zealand. These tables provide available information on each of the carparks.
<table>
<thead>
<tr>
<th>Name / Location</th>
<th>No of Suspended Steel Carpark Levels</th>
<th>No of Car Spaces</th>
<th>Carpark Type</th>
<th>Year of Construction</th>
<th>Floor System</th>
<th>No of Car Spaces between Columns</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dickson Shopping Centre, Dickson, Canberra</td>
<td>4</td>
<td>326</td>
<td>Open</td>
<td>1996</td>
<td>Precast</td>
<td>3</td>
<td>Scheme S1A</td>
</tr>
<tr>
<td>Woden Valley Hospital, Woden Valley</td>
<td>2</td>
<td>350</td>
<td>Closed</td>
<td>1994</td>
<td>Tensioned slab on steel columns</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Manuka Carpark, Corner Fumeau &amp; Bouganville Road, Manuka</td>
<td>1 ½</td>
<td>170</td>
<td>Standalone</td>
<td>1993</td>
<td>Composite</td>
<td>3</td>
<td>Scheme S1A</td>
</tr>
<tr>
<td>ANU Carpark, ANU, Canberra</td>
<td>3</td>
<td>330</td>
<td>Multiuse</td>
<td>1985</td>
<td>Precast</td>
<td>3</td>
<td>Scheme S1A</td>
</tr>
<tr>
<td>National Gallery of Australia, Parkes Place, Canberra</td>
<td>1</td>
<td>1974</td>
<td>Cast in-situ rc slab</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City West Carpark, Civic, Canberra</td>
<td>5</td>
<td>1100</td>
<td></td>
<td></td>
<td>Composite</td>
<td></td>
<td></td>
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**Northern Territory**

<table>
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<th>Carpark Type</th>
<th>Year of Construction</th>
<th>Floor System</th>
<th>No of Car Spaces between Columns</th>
<th>Comments</th>
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<tbody>
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<td>K- Mart, Palmerston, Darwin</td>
<td></td>
<td>400</td>
<td></td>
<td>1998</td>
<td>Composite</td>
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**Queensland**

<table>
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<th>No of Car Spaces</th>
<th>Carpark Type</th>
<th>Year of Construction</th>
<th>Floor System</th>
<th>No of Car Spaces between Columns</th>
<th>Comments</th>
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<tr>
<td>Gary Crick Auto</td>
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<td>150</td>
<td></td>
<td>2003</td>
<td>Composite</td>
<td></td>
<td>Continuous composite beams</td>
</tr>
<tr>
<td>Capalaba Shopping Centre, Capalaba, Brisbane</td>
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<td>200</td>
<td></td>
<td>1995</td>
<td>Composite</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Petrie Rail Interchange, Petrie</td>
<td>1</td>
<td>270</td>
<td></td>
<td>1993</td>
<td>Precast</td>
<td>3</td>
<td>Scheme S2</td>
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<td>St Andrews Hospital, North St, Spring Hill</td>
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<td>42</td>
<td></td>
<td>1993</td>
<td>Precast</td>
<td>3</td>
<td>Scheme S1A</td>
</tr>
<tr>
<td>City Centre Plaza, Rockhampton</td>
<td>2</td>
<td>330</td>
<td></td>
<td>1990</td>
<td>Composite</td>
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<td></td>
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<tr>
<td>Mal Burke, Southport</td>
<td>1</td>
<td>90</td>
<td></td>
<td>1988</td>
<td>Precast</td>
<td>2</td>
<td></td>
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<td>Rockhampton Shopping Centre</td>
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<td>300</td>
<td></td>
<td>1987</td>
<td>Composite</td>
<td>3</td>
<td></td>
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<tr>
<td>Sunnybank Hills Shoppingtown, Sunnybank Hills</td>
<td>3</td>
<td>1600</td>
<td></td>
<td>1987</td>
<td>Composite</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Valley Centre, Fortitude Valley</td>
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<td>130</td>
<td></td>
<td>1978</td>
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**Table E1 – Survey of Existing Carparks – ACT, Northern Territory and Queensland**
<table>
<thead>
<tr>
<th>Name / Location</th>
<th>No of Suspended Steel Carpark Levels</th>
<th>No of Car Spaces</th>
<th>Year of Construction</th>
<th>Floor System</th>
<th>No of Car Spaces between Columns</th>
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<td></td>
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<td>Nowra Fair Shopping Centre, Haigh St, Nowra</td>
<td>1</td>
<td>80</td>
<td>2000</td>
<td>Composite</td>
<td>3</td>
<td></td>
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<tr>
<td>Cowra Carpark, Busby Place, Cowra</td>
<td>1</td>
<td>70</td>
<td></td>
<td>Composite</td>
<td>3</td>
<td></td>
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<td>Westfields Hornsby Carpark Extension</td>
<td>1</td>
<td>150</td>
<td></td>
<td>Composite</td>
<td>inf</td>
<td></td>
</tr>
<tr>
<td>Albury Commercial Club Carpark, Albury</td>
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<td>160</td>
<td>2001</td>
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<tr>
<td>TNT Office Carpark, Mascot</td>
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<td>200</td>
<td>2000</td>
<td>Composite</td>
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<td>190</td>
<td>2000</td>
<td>Composite</td>
<td>4</td>
<td>Scheme S1B.</td>
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<td>Prince of Wales Carpark, Prince of Wales Hospital, Randwick</td>
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<td>1997</td>
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<td></td>
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<td>King Street Carpark, King Street, Newcastle</td>
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<td>160</td>
<td>1997</td>
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<td>Scheme S4A</td>
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<td>Mascot Airport Carpark - Stage 4, Keith Smith Avenue, Domestic Terminal, Mascot</td>
<td>4</td>
<td></td>
<td>1997</td>
<td>Stressed concrete slab</td>
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</tr>
<tr>
<td>HIA Building &amp; Renovata Supa Centre, Homebush Bay</td>
<td>2</td>
<td>190</td>
<td>1996</td>
<td>Composite</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Liverpool Hospital Carpark, Liverpool</td>
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<td>456</td>
<td>1995</td>
<td>Precast</td>
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<td>Thornleigh Railway Station, Yarrara Street, Thornleigh</td>
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<td>1994</td>
<td>Precast - untopped</td>
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<td>Murwillumbah Hospital Carpark, Murwillumbah</td>
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<td>80</td>
<td>1991</td>
<td>Precast</td>
<td>3</td>
<td>Scheme S1A</td>
</tr>
<tr>
<td>Bankstown City Council Carpark, Brandon Avenue, Bankstown</td>
<td>3</td>
<td>240</td>
<td>1988</td>
<td>Composite</td>
<td>2</td>
<td>Scheme S3</td>
</tr>
<tr>
<td>Blacktown City Council Carpark, Nelson Lane, Blacktown</td>
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<td>500</td>
<td>1987</td>
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<tr>
<td>IBM Carpark, Coonara Avenue, West Pennant Hills</td>
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<td>630</td>
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<td>Novotel Hotel Carpark, Darling Harbour</td>
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<td>1800</td>
<td>1987</td>
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<td>Scheme S3</td>
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<td>Forest Centre Carpark - Stage 3, Forest Way Shopping Centre, Frenchs Forest</td>
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<td>80</td>
<td>1986</td>
<td>Composite</td>
<td>2</td>
<td>Scheme S3</td>
</tr>
<tr>
<td>Pender Place Shopping Centre Carpark, Maitland</td>
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<td>113</td>
<td>1985</td>
<td>Composite</td>
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<td></td>
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<td>West Terrace Carpark, West Terrace, Bankstown</td>
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<td>Stage 1-1978 Stage 2-1984</td>
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Table E2 – Survey of Existing Carparks – New South Wales
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<th>Name / Location</th>
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<th>No of Car Spaces</th>
<th>Carpark Type</th>
<th>Year of Construction</th>
<th>Floor System</th>
<th>No of Car Spaces between Columns</th>
<th>Comments</th>
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<td>Composite</td>
<td>3</td>
<td>W-deck</td>
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<tr>
<td>The Royal Adelaide Hospital Carpark</td>
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<td>1440</td>
<td>2002</td>
<td>Composite</td>
<td>3</td>
<td>W-deck</td>
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<td>Mill Street Auto Park</td>
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<td>Composite &amp; non-composite</td>
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<td>Miller Anderson, Hindley St</td>
<td>3</td>
<td></td>
<td>1986</td>
<td>Composite</td>
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<tr>
<td>Pirie St</td>
<td>4</td>
<td>590</td>
<td>1986</td>
<td>Precast</td>
<td>2 &amp; 3</td>
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<tr>
<td>Central Market, Grote St</td>
<td>2</td>
<td>1090</td>
<td>1982</td>
<td>Precast</td>
<td>3 &amp; 4</td>
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<tr>
<td>Cnr Rundle St &amp; Poulterney St</td>
<td>7</td>
<td>850</td>
<td>1974</td>
<td>Composite</td>
<td>4</td>
<td>Castellated Beams</td>
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**Table E3 – Survey of Existing Carparks – South Australia**
### Victoria

<table>
<thead>
<tr>
<th>Name / Location</th>
<th>No of Suspended Steel Carpark Levels</th>
<th>No of Car Spaces Open</th>
<th>Carpark Type</th>
<th>Year of Construction</th>
<th>Floor System</th>
<th>No of Car Spaces between Columns</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Deakin University, Melbourne Campus, Burwood</td>
<td>3</td>
<td>2003</td>
<td>Composite str. steel</td>
<td>3</td>
<td>Add-a-top West</td>
<td></td>
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<tr>
<td>Federation Square Russell St Extn, Melbourne</td>
<td>3</td>
<td>2003</td>
<td>Composite str. steel</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Little Lonsdale St, Melbourne</td>
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<td>2003</td>
<td>Composite str. steel</td>
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<tr>
<td>Monash University, Clayton Campus North West Section 1</td>
<td>2</td>
<td>2003</td>
<td>Composite str. steel</td>
<td>3</td>
<td>Add-a-Top</td>
<td></td>
<td></td>
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<tr>
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<td>Composite str. steel</td>
<td>3</td>
<td>Add-a-top East</td>
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<tr>
<td>Grocon QV Tentants BHP Billiton, Melbourne</td>
<td>5</td>
<td>2002</td>
<td>Composite str. steel</td>
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<tr>
<td>Klopf &amp; Dobos Waverley Rd, Glen Waverley</td>
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<td>2001</td>
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<td>2001</td>
<td>Composite str. steel</td>
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<tr>
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<td>2</td>
<td>587</td>
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<td>Blessed Sacrament Fathers - St Francis 312, Lonsdale St, Melbourne</td>
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<td>1992</td>
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<td>Composite</td>
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<td>1990</td>
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<td>Chandler Hwy, Northcote</td>
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<td>200</td>
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<td>Non composite</td>
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<tr>
<td>Endeavour Hills Shopping Centre, Mathew Flinders Ave, Endeavour Hills</td>
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<td>1990</td>
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<td>Sprinklered</td>
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<td>1100</td>
<td>1990</td>
<td>Non composite</td>
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<td>50</td>
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Table E4 – Survey of Existing Carparks – Victoria
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<th>Name / Location</th>
<th>No of Suspended Steel Carpark Levels</th>
<th>No of Car Spaces</th>
<th>Carpark Type</th>
<th>Year of Construction</th>
<th>Floor System</th>
<th>No of Car Spaces between Columns</th>
<th>Comments</th>
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<td>Grand Mercure Hotel, 333 Collins St, Melbourne</td>
<td>5</td>
<td>364</td>
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<td>1990</td>
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<td>Sprinklered</td>
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<td>Macedon Square Shopping Centre, Manningham Rd, Templestowe Lower</td>
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<td>1990</td>
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<td>Sprinklered</td>
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<td>17 Burgundy St, Heidelberg</td>
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<td>Composite</td>
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<td>9 Porter St, Dandenong</td>
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<td>Sprinklered</td>
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<td></td>
<td>1989</td>
<td>Composite</td>
<td>Sprinklered</td>
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<td>Jolimont St, East Melbourne</td>
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<td>1987</td>
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<td>20</td>
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<tr>
<td>Hobart City Council, Argyle St Carpark Extension, Hobart</td>
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<td></td>
<td></td>
<td>1994</td>
<td>Composite</td>
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<tr>
<td>Launceston City Council, Paterson St West Carpark, Launceston</td>
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<td>Western Australia</td>
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<td>2003</td>
<td>Composite</td>
<td>2</td>
<td>Clear span, Scheme S3</td>
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<td>Call Centre, Bunbury</td>
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<td>2003</td>
<td>Composite</td>
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<td>Scheme S4A</td>
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<td>Melville Plaza Carpark</td>
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<td>231</td>
<td></td>
<td>2002</td>
<td>Precast</td>
<td>3</td>
<td></td>
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<tr>
<td>Coles Myer, Kalgoorrie</td>
<td>1</td>
<td>142</td>
<td></td>
<td>1997</td>
<td>Ultralow</td>
<td>3</td>
<td>Structure erected in 9-days</td>
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<td>Karrinyup Shopping Centre, Francis St, Karrinyup</td>
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<td>218</td>
<td></td>
<td>1997</td>
<td>Precast</td>
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<tr>
<td>Curtin University - Carpark 2, Dumas St, Bentley</td>
<td>1</td>
<td>290</td>
<td></td>
<td>1996</td>
<td>Precast</td>
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<tr>
<td>48 Mount Street, Perth</td>
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<td>24</td>
<td></td>
<td>1993</td>
<td>Precast</td>
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<td>St Quentins, 337-339 Stirling Hwy, Claremont</td>
<td>2</td>
<td>175</td>
<td></td>
<td>1991</td>
<td>Composite</td>
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Table E5 – Survey of Existing Cararks – Victoria (Contd.), Tasmania and Western Australia
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<th>Name / Location</th>
<th>No of Suspended Steel Carpark Levels</th>
<th>No of Car Spaces</th>
<th>Year of Construction</th>
<th>Floor System</th>
<th>No of Car Spaces between Columns</th>
<th>Comments</th>
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<tr>
<td>St Mathews Carpark, Hobson St, Auckland</td>
<td>4</td>
<td>131</td>
<td>1996</td>
<td>Speedfloor trusses with 90 mm conc</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Teachers College Carpark, Union St East, Dunedin</td>
<td>2</td>
<td>3000</td>
<td>1996</td>
<td>130mm slab on HiBond 0.75 bmt Decking</td>
<td>2</td>
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</tr>
<tr>
<td>Newmarket Carpark, Broadway, Auckland</td>
<td>6</td>
<td>507</td>
<td>1996</td>
<td>130mm slab on HiBond 0.75 bmt Decking</td>
<td>4</td>
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<tr>
<td>Arthur Barnettts, George St, Dunedin</td>
<td>4</td>
<td>456</td>
<td>1996</td>
<td>130 mm topping on 0.95mm HiBond</td>
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<tr>
<td>Watt St Carpark, Watts St, Auckland</td>
<td>3</td>
<td>99</td>
<td>1995</td>
<td>Speedfloor trusses with 90 mm conc</td>
<td>3</td>
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</tr>
<tr>
<td>Great King St Carpark, Great King St, Dunedin</td>
<td>4</td>
<td>360</td>
<td>1994</td>
<td>130 topping on HiBond</td>
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<td>Skycity Carpark, Hob St, Auckland</td>
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<td>1998</td>
<td>1994</td>
<td>130 -200 mm topping on 0.75mm HiBond</td>
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<td>Wakefield Street, Wakefield St, Auckland</td>
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<td>350</td>
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<td>HiBond</td>
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Table E6 – Survey of Existing Carparks – New Zealand
F. EXAMPLES OF RAMP CONFIGURATIONS

Common ramp configurations for both one-way and two-way traffic flow are presented in this appendix.

(a) One way traffic flow - Fast exit

(b) One way traffic flow - Scissor ramp

(c) Two way traffic flow - Two way ramps

Figure F1 - Examples of Ramp Configurations for Combined Single Module Split level carparks (refer to Figure 4a)

Figure F2 - Example of Ramp Configurations for Multiple Module Schemes (refer to Figure 5)
FOR MORE INFORMATION PLEASE CONTACT:

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E-mail: onesteeleldirect@onesteel.com
Website: www.onesteel.com