Appendix A

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 stock 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/m^2 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):
   $1.2\,G_{sh} + 1.5\,Q_U$
   where $Q_U =$ 1.0 kPa; OR
   $1.2\,G_{sh} + 1.5\,Q_P$
   where $Q_P =$ 1.0 kN in edge pan or 2.0 kN elsewhere.

   (b) Construction Stage 2:
   $1.2\,(G_{sh} + G_{reo}) + 1.5\,Q_M$
   where $Q_M =$ 5.0 kPa; OR
   $1.2\,G_{sh} + 1.5\,Q_P$
   where $Q_P =$ 1.0 kN in edge pan or 2.0 kN elsewhere.

   (c) Construction Stage 3:
   $1.2\,(G_{sh} + G_{reo} + G_{conc}) + 1.5\,Q_U$
   where $Q_U =$ 1.0 kPa; OR
   $1.2\,(G_{sh} + G_{reo} + G_{conc}) + 1.5\,Q_{Heap}$
   where $Q_{Heap} =$ 2.0 kPa over 1.6mx1.6m.

2. The maximum deflection of the sheeting does not exceed span/200 under the dead loads ($G_{sh} + G_{reo} + G_{conc}$) 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:
G_{conc} = dead load of concrete including ponding;
G_{reo} = dead load of steel reinforcement;
G_{sh} = dead load of steel sheeting;
Q_{Heap} = heaped-concrete live load;
Q_P = point live load; and
Q_U, Q_M = 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.

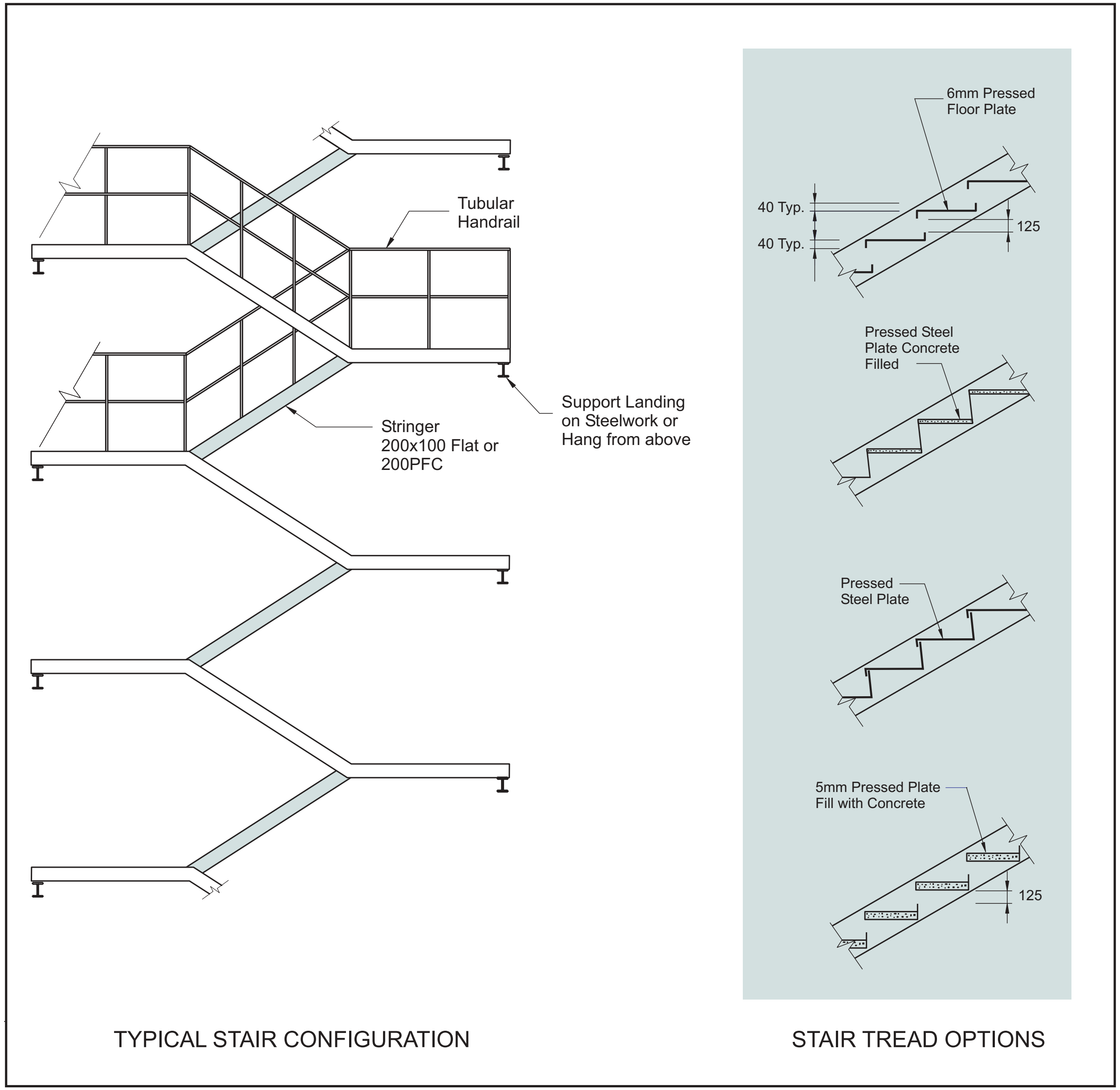

Figure A2 - Steel Stair Options

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.

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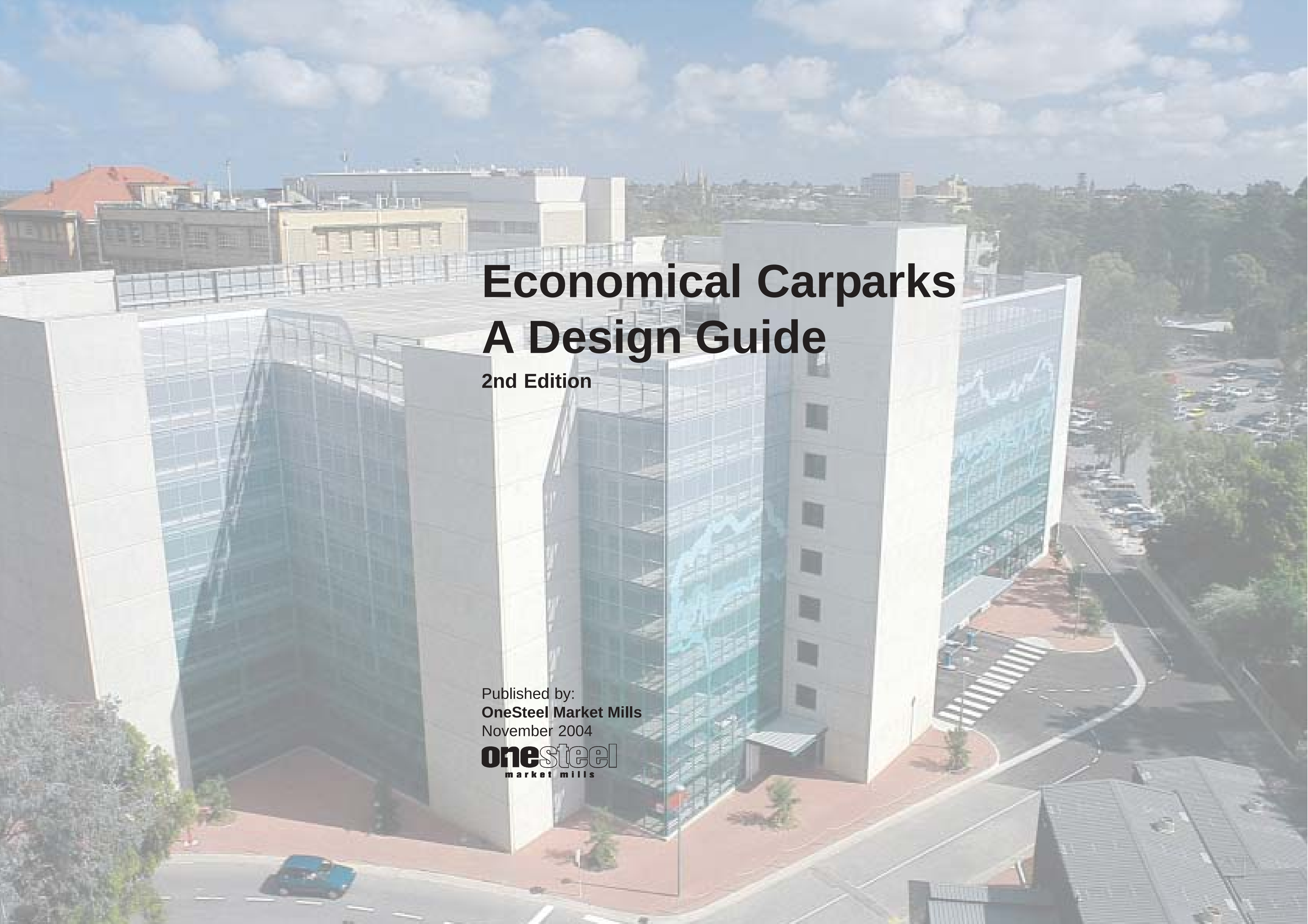

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