sections or plate thicker than 3 mm (or 2.5 mm for fillet welds), failure of the weld must be checked according to AS 4100 (Ref. 1.10) or NZS 3404 (Ref. 1.11).

Bolted connections in cold-formed construction are commonly used, though the ratio of the bolt diameter to plate thickness is usually much larger than for hot-rolled construction. Design provisions developed for this case are given in Clause 5.3 of AS/NZS 4600 and their experimental basis is discussed in Chapter 9 of this book.

Screws and blind rivets are often used to join cold-formed steel sections. Specific design provisions are included in Clauses 5.4 and 5.5 of AS/NZS 4600. Screws are discussed in detail in Chapter 9 of this book.

1.4.7 Corrosion Protection

The main factor governing the corrosion resistance of cold-formed steel sections is the type and thickness of the protective treatment applied to the steel and not the base metal thickness. Cold-formed steel has the advantage that the protective coatings can be applied to the strip during manufacture and before roll forming. Consequently, galvanised strip can be passed through the rolls and requires no further treatment.

Material which is coated with Zinc or Aluminium-Zinc must satisfy the requirements of AS 1397 (Ref. 1.25). AS 1397 defines coating classes based on the coating type and the coating mass determined by the triple spot test. The commonly used coating classes are Zinc (Designated Z), Zinc converted to a Zinc/Iron alloy (ZF), and Aluminium-Zinc Alloy (Designated AZ). The defined weights for zinc coating (Z) are 100, 200, 275, 350, 450 and 600 grams per square metre, zinc/iron alloy (ZF) are 80 and 100 grams per square metre and for aluminium-zinc alloy (AZ) are 150 and 200 grams per square metre. Common applications of the different coating classes are given in Table 1.1.

Table 1.1 Coating classes for corrosion conditions

Coating Class	Application
Z100	A very thin, smooth and ductile coating for higher finishes in internal, protected environments, eg for refrigerators and dryers (in conjunction with paints).
Z200	A light coating for internal protected environments such as ducting and washing machines
Z275, Z350	General purpose coatings.
Z450, AZ150	Recommended coatings for typical exterior protection, eg roofing and accessories, and cladding.
Z600, AZ200	Heavy duty coatings designed for culverts and box gutters.

Appendix C of AS/NZS 4600 provides general guidance on corrosion protection and repair of damaged coatings.

1.4.8 Inelastic Reserve Capacity

A section to allow for the inelastic reserve capacity of flexural members is included in Clause 3.3.2.3 of AS/NZS 4600 where compressive strains up to 3 times the yield strain are permitted for sections satisfying certain slenderness limits and other requirements. In this case, the design moment may not exceed the yield moment by more than 25 percent. A detailed summary of these requirements is given in Section 5.7 of this book.

1.4.9 Fatigue

Fatigue in a cold-formed steel member or connection is the process of initiation and subsequent crack growth under the action of a cyclic or repetitive load. Fatigue commonly occurs at stress

Design of Cold-Formed Steel Structures
(To Australian/New Zealand Standard AS/NZS 4600:2005)

by

Gregory J. Hancock BSc BE PhD DEng

Bluescope Steel Professor of Steel Structures
Dean
Faculty of Engineering & Information Technologies
University of Sydney

fourth edition - 2007

CONTENTS

		Page
PREFACE TO THE 4th EDITION		viii
CHAPTER 1	INTRODUCTION	1
1.1	Design Standards and Specifications for Cold-Formed Steel	1
1.1.1	General	1
1.1.2	History of Australian Cold-Formed Steel Structures Standards and USA Specifications	1
1.1.3	New Developments in the 2005 Edition	2
1.2	Common Section Profiles and Applications of Cold-Formed Steel	4
1.3	Manufacturing Processes	10
1.4	Special Problems in the Design of Cold-Formed Sections	12
1.4.1	Local Buckling and Post-local Buckling of Thin Plate Elements	12
1.4.2	Propensity for Twisting	13
1.4.3	Distortional Buckling	14
1.4.4	Cold Work of Forming	14
1.4.5	Web Crippling under Bearing	15
1.4.6	Connections	15
1.4.7	Corrosion Protection	16
1.4.8	Inelastic Reserve Capacity	16
1.4.9	Fatigue	16
1.5	Loading Combinations	17
1.6	Limit States Design	17
1.7	Computer Analysis	19
1.8	References	20
CHAPTER 2	MATERIALS AND COLD WORK OF FORMING	22
2.1	Steel Standards	22
2.2	Typical Stress-Strain Curves	23
2.3	Ductility	25
2.4	Effects of Cold Work on Structural Steels	29
2.5	Corner Properties of Cold-Formed Sections	30
2.6	Fracture Toughness	32
2.6.1	Background	32
2.6.2	Measurement of Critical Stress Intensity Factors	32
2.6.3	Evaluation of the Critical Stress Intensity Factors for Perforated Coupon Specimens	34
2.6.4	Evaluation of the Critical Stress Intensity Factors for Triple Bolted Specimens	35
2.7	References	36
CHAPTER 3	BUCKLING MODES OF THIN-WALLED MEMBERS IN COMPRESSION AND BENDING	37
3.1	Introduction to the Finite Strip Method	37
3.2	Monosymmetric Column Study	38
3.2.1	Unlipped Channel	38
3.2.2	Lipped Channel	41
3.2.3	Lipped Channel (Fixed Ended)	44
3.3	Purlin Section Study	45
3.3.1	Channel Section	45
3.3.2	Z-Section	46

3.4 Tubular Flange Sections 47
3.4.1 Hollow Flange Beam in Bending 47
3.4.2 LiteSteel Beam Section in Bending 48
3.5 References 49

CHAPTER 4 STIFFENED AND UNSTIFFENED COMPRESSION ELEMENTS 50

4.1 Local Buckling 50
4.2 Postbuckling of Plate Elements in Compression 51
4.3 Effective Width Formulae for Imperfect Elements in Pure Compression 52
4.4 Effective Width Formulae for Imperfect Elements under Stress Gradient 56
4.4.1 Stiffened Elements 56
4.4.2 Unstiffened Elements 56
4.5 Effective Width Formulae for Elements with Stiffeners 57
4.5.1 Edge Stiffened Elements 57
4.5.2 Intermediate Stiffened Elements with One Intermediate Stiffener 58
4.5.3 Edge Stiffened Elements with Intermediate Stiffeners, and Stiffened Elements with more than One Intermediate Stiffener 58
4.5.4 Uniformly Compressed Edge Stiffened Elements with Intermediate Stiffeners 59
4.6 Examples 59
4.6.1 Hat Section in Bending 59
4.6.2 Hat Section in Bending with Intermediate Stiffener in Compression Flange 63
4.6.3 C-Section Purlin in Bending 68
4.7 References 75

CHAPTER 5 BEAMS, PURLINS AND BRACING 76

5.1 General 76
5.2 Flexural-Torsional (Lateral) Buckling 77
5.2.1 Elastic Buckling of Unbraced Simply Supported Beams 77
5.2.2 Continuous Beams and Braced Simply Supported Beams 81
5.2.3 Bending Strength Design Equations 85
5.3 Distortional Buckling 86
5.3.1 Flange Distortional Buckling 86
5.3.2 Lateral-Distortional Buckling 89
5.4 Basic Behaviour of Purlins 89
5.4.1 Linear Response of Channel and Z-sections 89
5.4.2 Stability Considerations 92
5.4.3 Sheeting and Connection Types 94
5.5 Design Methods for Purlins 95
5.5.1 No Lateral and Torsional Restraint Provided by the Sheeting 95
5.5.2 Lateral Restraint but No Torsional Restraint 95
5.5.3 Lateral and Torsional Restraint 96
5.6 Bracing 98
5.7 Inelastic Reserve Capacity 101
5.7.1 Sections with Flat Elements 101
5.7.2 Cylindrical Tubular Members 102
5.8 Examples 102
5.8.1 Simply Supported C-Section Purlin 102
5.8.2 Distortional Buckling Stress for C-Section 107
5.8.3 Continuous Lapped Z-Section Purlin 108
5.8.4 Z-Section Purlin in Bending 116
5.9 References 122

CHAPTER 6 WEBS 125

6.1 General 125

6.2 Webs in Shear 125
6.2.1 Shear Buckling 125
6.2.2 Shear Yielding 127

6.3 Webs in Bending 127

6.4 Webs in Combined Bending and Shear 129

6.5 Web Stiffeners 130

6.6 Web Crippling (Bearing) of Open Sections 130
6.6.1 Edge Loading Alone 130
6.6.2 Combined Bending and Edge Loading 133

6.7 Webs with Holes 134

6.8 Examples 136
6.8.1 Combined Bending and Shear at the End of the Lap of a Continuous Z-Section Purlin 136
6.8.2 Combined Bearing and Bending of Hat Section 138

6.9 References 139

CHAPTER 7 COMPRESSION MEMBERS 141

7.1 General 141

7.2 Elastic Member Buckling 141
7.2.1 Flexural, Torsional and Flexural-Torsional Buckling 141
7.2.2 Distortional Buckling 143

7.3 Section Capacity in Compression 143

7.4 Member Capacity in Compression 144
7.4.1 Flexural, Torsional and Flexural-Torsional Buckling 144
7.4.2 Distortional Buckling 146

7.5 Effect of Local Buckling 147
7.5.1 Monosymmetric Sections 147
7.5.2 High Strength Steel Box Sections 149

7.6 Examples 151
7.6.1 Square Hollow Section Column 151
7.6.2 Unlipped Channel Column 153
7.6.3 Lipped Channel Column 157

7.7 References 164

CHAPTER 8 MEMBERS IN COMBINED AXIAL LOAD AND BENDING 165

8.1 Combined Axial Compressive Load and Bending - General 165

8.2 Interaction Equations for Combined Axial Compressive Load and Bending 166

8.3 Monosymmetric Sections under Combined Axial Compressive Load and Bending 167
8.3.1 Sections Bent in a Plane of Symmetry 167
8.3.2 Sections Bent about an Axis of Symmetry 169

8.4 Combined Axial Tensile Load and Bending 170

8.5 Examples 171
8.5.1 Unlipped Channel Section Beam-Column Bent in Plane of Symmetry 171
8.5.2 Unlipped Channel Section Beam-Column Bent about Plane of Symmetry 174
8.5.3 Lipped Channel Section Beam-Column Bent in Plane of Symmetry 176

8.6 References 180

CHAPTER 9 CONNECTIONS 182

9.1 Introduction to Welded Connections 182

9.2 Fusion Welds 184
9.2.1 Butt Welds 184
9.2.2 Fillet Welds subject to Transverse Loading 184
9.2.3 Fillet Welds subject to Longitudinal Loading 185
9.2.4 Combined Longitudinal and Transverse Fillet Welds 186
9.2.5 Flare Welds 186
9.2.6 Arc Spot Welds (Puddle Welds) 187
9.2.7 Arc Seam Welds 190

9.3 Resistance Welds 190

9.4 Introduction to Bolted Connections 190

9.5 Design Formulae and Failure Modes for Bolted Connections 192
9.5.1 Tearout Failure of Sheet (Type I) 193
9.5.2 Bearing Failure of Sheet (Type II) 193
9.5.3 Net Section Tension Failure (Type III) 194
9.5.4 Shear Failure of Bolt (Type IV) 196

9.6 Screw Fasteners and Blind Rivets 196

9.7 Rupture 200

9.8 Examples 201
9.8.1 Welded Connection Design Example 201
9.8.2 Bolted Connection Design Example 205

9.9 References 208

CHAPTER 10 DIRECT STRENGTH METHOD 209

10.1 Introduction 209

10.2 Elastic Buckling Solutions 209

10.3 Strength Design Curves 210
10.3.1 Local Buckling 210
10.3.2 Flange-distortional buckling 212
10.3.3 Overall buckling 213

10.4 Direct Strength Equations 213

10.5 Examples 215
10.5.1 Lipped Channel Column (Direct Strength Method) 215
10.5.2 Simply Supported C-Section Beam 216

10.6 References 218

CHAPTER 11 STEEL STORAGE RACKING 219

11.1 Introduction 219

11.2 Loads 220

11.3 Methods of Structural Analysis 221
11.3.1 Upright Frames - First Order 222
11.3.2 Upright Frames - Second Order 223
11.3.3 Beams 223

11.4 Effects of Perforations (Slots) 224
11.4.1 Section Modulus of Net Section 224
11.4.2 Minimum Net Cross-Sectional Area 225
11.4.3 Form Factor (Q) 225

11.5 Member Design Rules 225
11.5.1 Flexural Design Curves 225
11.5.2 Column Design Curves 226

11.5.3 Distortional Buckling 227
11.6 Example 227
11.7 References 235
SUBJECT INDEX BY SECTION 236