

2 Loads

2.1 BACKGROUND

The loads to be considered in the design of portal frame buildings are dead, live, wind, seismic and occasionally snow loads, and combinations of these. Live loads generally represent peak loads which have a 95% probability of not being exceeded over a 50 year return period, while for wind and earthquake loads, different return periods are used for the strength and serviceability limit states.

The relevant loading codes are:

- AS/NZS 1170.0:2002 Part 0: *General principles* [1]
- AS/NZS 1170.1:2002 Part 1: *Permanent, imposed and other actions* [2]
- AS/NZS 1170.2:2011 Part 2: *Wind actions* [3]
- AS/NZS 1170.3:2003 Part 3: *Snow and ice actions* [4]
- AS 1170.4-2007 Part 4: *Earthquake actions in Australia* [5]

The determination of dead loads G , live loads Q , wind loads W and seismic loads E is discussed in Sections 2.2, 2.3, 2.4 and 2.5 respectively. Snow loads S are not treated in any detail in this book. Overhead travelling crane loads are treated in Chapter 8 and the calculation of monorail crane loads is presented in Chapter 9.

The load combinations stipulated in AS/NZS 1170 Part 0 to obtain the factored design loads for the strength and serviceability limit states have also been determined on a probabilistic basis, and these combinations are discussed in Section 2.6.

2.2 DEAD LOADS

The dead (or permanent) loads acting on a portal framed industrial building arise from its self-weight including finishes, and from any other permanent construction or equipment. The dead load will vary during construction, but will remain constant thereafter, unless significant modifications are made to the structure or its permanent equipment.

As a guide for preliminary analysis, a dead load of 0.1 kPa can be allowed for the roof sheeting and purlins. An allowance of say 0.05 kPa for roof bracing and miscellaneous items such as insulation and light roof vents is advisable for preliminary design, and this allowance can be refined up or down as the design develops. The presence of mechanical equipment, suspended ceilings and any acoustic insulation layers should, of course, be specifically allowed for. The self-weight of the rafter needs to be included, but the weight of cleats and connections is not usually considered as being significant.

2.3 LIVE LOADS

The live (or imposed) loads acting on the roof of a portal frame building arise mainly from maintenance loads where new or old roof sheeting may be stacked in concentrated areas.

The roof live loads for cladding, purlins and rafters are specified in the loading code AS/NZS 1170.1, the roofs of industrial buildings generally being of the non-trafficable category. Roof cladding must be designed to support a concentrated load of 1.1 kN in any position, but this is usually taken account of by the sheeting manufacturer who nominates the maximum spans that will sustain this load.

For purlins and rafters, the code provides for a distributed load of 0.25 kPa where the supported area A is greater than 14 m^2 , the area A being the plan projection of the inclined roof surface area. For areas A less than 14 m^2 , the code specifies the distributed load w_Q to be

$$w_Q = \left(\frac{1.8}{A} + 0.12 \right) \text{ kPa} \quad (2.1)$$

This formula is equivalent to a distributed load of 0.12 kPa plus a load of 1.8 kN distributed over the span of the member, and ensures that the minimum load to be supported by short members such as purlin cantilevers and end wall fascia members is at least 1.8 kN. Presumably, such a load would cater for the case of a heavy worker standing on the edge of the roof or at the edge of an opening, and lifting materials on to the roof.

Some industrial buildings, particularly those with large roof catchments, have eave gutters with bases or sole widths greater than 200 mm. The rainwater goods code AS/NZS 2179.1 [6] requires these gutters to be able to support a concentrated load of 1.1 kN plus its water load. This requirement is not widely known and is relevant for the design of gutter brackets, fascia purlins and any special bridging which might be required between the fascia purlin and its adjacent purlin to support each gutter bracket.

In addition to the distributed live load, the loading code also specifies that structural elements be designed for a concentrated load of 1.4 kN. The concentrated load of 4.5 kN that was required at any point in the previous code AS 1170.1-1989 is no longer required.

It should be noted that the distributed live load given in Equation 2.1 need not be considered acting simultaneously with any wind load (see Section 2.6). The load combinations in AS/NZS 1170.0 effectively require that a portal frame building with a non-trafficable roof be designed to support either the roof live load or the wind load, whichever produces the worse effect. Note that the distributed live load of 0.25 kPa is significantly less than the live load in parts of Australia, New Zealand and in other countries where snow loads must be considered.

2.4 WIND LOADS

2.4.1 Regional Wind Speed

The wind loading specified in AS/NZS 1170.2 is generally the major loading influence in the design of industrial buildings, even in low wind areas. It is therefore important to evaluate the wind loading carefully. The *regional three second gust wind speeds* V_R are clearly specified

Design of Portal Frame Buildings

including
Crane Runway Beams and Monorails

Fourth Edition

S.T. Woolcock

*Director, Bonacci Group
Consulting Engineers*

S. Kitipornchai

*Honorary Professor, School of Civil Engineering
The University of Queensland*

M.A. Bradford

*Scientia Professor of Civil Engineering
The University of New South Wales*

G.A. Haddad

*Associate, Bonacci Group
Consulting Engineers*

Published by
Australian Steel Institute
Level 13, 99 Mount Street
North Sydney NSW 2060
www.steel.org.au



AUSTRALIAN STEEL INSTITUTE
(ABN)/ACN (94) 000 973 839

**DESIGN OF PORTAL FRAME BUILDINGS
including Crane Runway Beams and Monorails**

Published by
AUSTRALIAN STEEL INSTITUTE

Enquiries should be addressed to the publisher:

Business address – Level 13, 99 Mount Street, North Sydney, NSW 2060 Australia
Postal address – P.O. Box 6366, North Sydney, NSW 2059 Australia
Email address – enquiries@steel.org.au
Website – www.steel.org.au

© Copyright 2011 Australian Steel Institute

All rights reserved. This book or any part thereof must not be reproduced in any form without the written permission of the Australian Steel Institute.

Previously published as:

Design of Portal Frame Buildings, 1st edition, 1987 (to AS 1250)
Limit State Design of Portal Frame Buildings, 1st edition, 1991 (to AS 4100)
Limit State Design of Portal Frame Buildings, 2nd edition, 1993 (to AS 4100)
Design of Portal Frame Buildings, 3rd edition, 1999 (to AS 4100)
Design of Portal Frame Buildings, 3rd edition, 2003 (reprint with ASI)

National Library of Australia Cataloguing-in-Publication entry:

Design of portal frame buildings: including crane runway beams and monorails/ S.T. Woolcock ... [et al.]

4th ed.

ISBN 9781921476266 (pbk.)

Includes bibliographical references and index.

Industrial buildings – Design and construction.
Building, Iron and steel – Design and construction.
Woolcock, S.T.
Australian Steel Institute.

693.71

DISCLAIMER

Every effort has been made and all reasonable care taken to ensure the accuracy of the material contained in the Publication. However, to the extent permitted by law, the Authors, Editors and Publishers of the Publication:

- (a) will not be held liable or responsible in any way; and
- (b) expressly disclaim any liability or responsibility,

for any loss, damage, costs or expenses incurred in connection with this Publication by any person, whether that person is the purchaser of this Publication or not. Without limitation, this includes loss, damage, costs and expenses incurred if any person wholly or partially relies on any part of this Publication, and loss, damage, costs and expenses incurred as a result of the negligence of the Authors, Editors or Publishers.

WARNING

This Publication should not be used without the services of a competent professional person with expert knowledge in the relevant field, and under no circumstances should this Publication be relied upon to replace any or all of the knowledge and expertise of such a person.

Contents

CONTENTS	i
PREFACE.....	ix
NOTATION	xi
1 INTRODUCTION	1
1.1 Key Features of Portal Framed Buildings	1
1.2 Design Issues	3
1.2.1 General Design Criteria	3
1.2.2 Structural Design	3
1.2.2.1 Introduction	3
1.2.2.2 Grey Areas in Design	4
1.2.2.3 Aims of This Book	7
1.3 Limit States Design	7
1.3.1 Background	7
1.3.2 Design for the Strength Limit State	8
1.3.3 Design for the Serviceability Limit State	9
1.4 Design Examples	9
1.4.1 Building	9
1.4.2 Crane Runway Beams	11
1.4.3 Monorails	11
1.5 References	12
2 LOADS	15
2.1 Background	15
2.2 Dead Loads	15
2.3 Live Loads	16
2.4 Wind Loads	16
2.4.1 Regional Wind Speed	16
2.4.2 Site Wind Speeds	17
2.4.3 Terrain Category	18
2.4.4 Design Wind Speeds and Pressures	19
2.4.5 External Pressures	21
2.4.6 Internal Pressures	21
2.4.7 Area Reduction Factor (K_a)	24
2.4.8 Action Combination Factor (K_c)	24
2.4.9 Local Pressure Factors (K_l)	25
2.5 Seismic Loads	26
2.6 Load Combinations	27
2.6.1 Strength Limit State	27
2.6.2 Serviceability Limit State	28
2.7 Design Example - Loads	28
2.7.1 Dead Loads	28
2.7.2 Live Loads	29
2.7.3 Wind Loads	29
2.7.3.1 Basic Wind Data	29
2.7.3.2 External Wind Pressures	31
2.7.3.3 Internal Wind Pressures	33
2.7.3.4 Peak Local Pressures	35
2.7.4 Seismic Loads	36
2.7.5 Load Cases for Portal Frames	37
2.7.6 Load Combinations	41
2.8 References	42

3	PURLINS & GIRTS	43
3.1	General	43
3.2	Roof and Wall Sheeting	44
3.2.1	Rainwater and Temperature	44
3.2.2	Cladding Capacity	44
3.3	Purlin Spans or Frame Spacing	45
3.4	Loads	45
3.4.1	Base Loads	45
3.4.2	Peak Local Pressures	46
3.4.2.1	Summary of Code Provisions	46
3.4.2.2	Aspect Ratio of Patches	47
3.4.2.3	Contributing Widths	53
3.4.3	Equivalent UDL's For Peak Pressure	54
3.5	Member Capacities	57
3.5.1	Manufacturers' Brochures	57
3.5.1.1	Design Capacity Tables	57
3.5.1.2	Bridging	57
3.5.2	Manufacturers' Software	58
3.5.3	R-Factor Method	58
3.5.4	Stramit Method	58
3.6	Deflections	59
3.7	Axial Loads	59
3.8	Purlin and Girt Cleats	59
3.9	Purlin and Girt Bolts	60
3.10	Design Example – Purlins	60
3.10.1	Methodology	60
3.10.2	Select Purlin Spacing	61
3.10.3	Outward Purlin Loading – Transverse Wind	62
3.10.3.1	General	62
3.10.3.2	Edge Zone 0 to 2600 mm from Eaves (TW- Excluding Fascia purlin)	62
3.10.3.3	Fascia Purlin (Edge Zone 0 to 2600 mm from Eaves - TW)	69
3.10.3.4	Edge Zone 2600 mm to 5200 mm from Eaves (TW)	72
3.10.3.5	Zone 5200 mm to 8350 mm from Eaves (TW)	72
3.10.3.6	Zone between 8350 mm from Eaves and the Ridge (TW)	73
3.10.4	Outward Purlin Loading – Longitudinal Wind	73
3.10.4.1	Edge Zone 0 to 5200 mm from Eaves (LW)	73
3.10.4.2	Zone between 5200 mm from Eaves and the Ridge (LW)	76
3.10.5	Check Inward Loading	80
3.10.5.1	Zone 0 to 5200 mm from Eaves (LW)	80
3.10.5.2	Zone between 5200 mm from Eaves and the Ridge (LW)	80
3.10.6	Using Manufacturers' Software	81
3.10.7	R-Factor Method	81
3.10.8	Purlin Summary	83
3.11	Design Example – Girts	84
3.11.1	Long Wall Girts	84
3.11.1.1	Coefficients & Girt Spacing	84
3.11.1.2	Outward Loading	84
3.11.1.3	Inward Loading	88
3.11.2	End Wall Girts with Span of 6250 mm	90
3.11.2.1	Coefficients and Girt Spacing	90
3.11.2.2	Outward Loading	90
3.11.2.3	Inward Loading with 1700 mm Spacing	91
3.11.3	Girt Summary	93
3.12	References	94

4	FRAME DESIGN	95
4.1	Frame Design by Elastic Analysis	95
4.2	Computer Analysis	95
4.2.1	Load Cases	95
4.2.2	Methods of Analysis	96
4.2.3	Moment Amplification for First Order Elastic Analysis	97
4.3	Rafters	98
4.3.1	Nominal Bending Capacity M_{bx} in Rafters	98
4.3.1.1	Simplified Procedure	98
4.3.1.2	Alternative Procedure	99
4.3.2	Effective Length and Moment Modification Factors for Bending Capacity	100
4.3.2.1	General	100
4.3.2.2	Top Flange in Compression	100
4.3.2.3	Bottom Flange in Compression	101
4.3.3	Major Axis Compression Capacity N_{cx}	103
4.3.4	Minor Axis Compression Capacity N_{cy}	104
4.3.5	Combined Actions for Rafters	104
4.3.6	Haunches for Rafters	104
4.4	Portal Columns	104
4.4.1	General	104
4.4.2	Major Axis Compression Capacity N_{cx}	105
4.4.3	Minor Axis Compression Capacity N_{cy}	105
4.4.4	Nominal Bending Capacity M_{bx} in Columns	105
4.4.4.1	General	105
4.4.4.2	Inside Flange in Compression	105
4.4.4.3	Outside Flange in Compression	106
4.5	Combined Actions	106
4.5.1	General	106
4.5.2	In-Plane Capacity	106
4.5.2.1	In-Plane Section Capacity	106
4.5.2.2	In-Plane Member Capacity	107
4.5.3	Out-of-Plane Capacity	108
4.5.3.1	Compression Members	108
4.5.3.2	Tension Members	108
4.6	Central Columns	108
4.6.1	General	108
4.6.2	Effective Lengths for Axial Compression	109
4.6.2.1	Top Connection Pinned	109
4.6.2.2	Top Connection Rigid	110
4.6.3	Combined Actions with First Order Elastic Analysis	110
4.6.4	Combined Actions with Second Order Elastic Analysis	110
4.7	End Wall Frames	110
4.7.1	General	110
4.7.2	End Wall Columns	111
4.7.3	End Wall Columns to Rafter Connection	111
4.7.3.1	General	111
4.7.3.2	Continuous Rafter	111
4.7.3.3	Discontinuous Rafter	112
4.8	Rafter Bracing Design	113
4.8.1	General	113
4.8.2	Purlins as Braces	113
4.8.2.1	AS 4100 Approach	113
4.8.2.2	Eurocode Approach	114
4.8.2.3	Conclusions	117
4.8.3	Fly Braces	117
4.8.3.1	General	117
4.8.3.2	AS 4100 Approach	119
4.8.3.3	Eurocode Approach	120

4.9	Deflections	120
4.9.1	General	120
4.9.2	Problems of Excessive Deflection	121
4.10	Design Example – Frame Design	124
4.10.1	Frame Analysis	124
4.10.1.1	Preliminary Design	124
4.10.1.2	Haunch Properties	125
4.10.1.3	Methods of Analysis	126
4.10.2	Frame Deflections	127
4.10.2.1	Sidesway Deflection	127
4.10.2.2	Rafter Deflection	127
4.10.3	Columns (460UB74)	127
4.10.3.1	Column Section Capacities	127
4.10.3.2	Column Member Capacities	128
4.10.3.3	Column Combined Actions	128
4.10.4	Rafters (360UB45)	132
4.10.4.1	Rafter Section Capacities	132
4.10.4.2	Rafter Member Capacities	133
4.10.4.3	Rafter Combined Actions	134
4.10.5	LIMSTEEL Results	145
4.10.6	End Wall Frames	145
4.10.7	End Wall Columns	145
4.10.7.1	Inside Flange in Tension (Inward Loading)	145
4.10.7.2	Inside Flange in Compression (Outward Loading)	147
4.10.7.3	Axial Compression Under Gravity Loads	148
4.10	References	149
5	FRAME CONNECTIONS	151
5.1	General	151
5.2	Bolted Knee and Ridge Joints	152
5.3	Column Bases	154
5.3.1	Holding Down Bolts	154
5.3.2	Base Plates	155
5.4	Design Example - Frame Connections	155
5.4.1	General	155
5.4.2	Knee Joint	156
5.4.2.1	General	156
5.4.2.2	Calculate Design Actions	157
5.4.2.3	Bottom Flange Connection	163
5.4.2.4	Top Flange Connection	185
5.4.2.5	Summary of Adopted Knee Connection Details	197
5.4.3	Ridge Connection	197
5.4.3.1	General	197
5.4.3.2	Calculate Design Actions	198
5.4.3.3	Carry Out Design Checks	200
5.4.3.4	Summary of Adopted Ridge Joint Details	205
5.4.4	Base Plates	206
5.4.5	End Wall Column Connections	211
5.4.5.1	General	211
5.4.5.2	Centre Column - Top Connection	211
5.4.5.3	Quarter-Point Columns – Top Connection	213
5.5	References	214
6	ROOF & WALL BRACING	215
6.1	General	215
6.2	Erection Procedure	216

6.3	Roof and Wall Bracing Forces	216
6.3.1	Longitudinal Wind Forces	216
6.3.2	Rafter or Truss Bracing Forces	216
6.3.2.1	General	216
6.3.2.2	Quantifying Bracing Forces	217
6.4	Bracing Plane	219
6.5	Bracing Layout	221
6.6	Tension Rods	223
6.7	Tubes and Angles in Tension	226
6.8	Tubes in Compression	229
6.9	End Connections for Struts and Ties	231
6.9.1	Tubes	231
6.9.1.1	Tubes in Tension	231
6.9.1.2	Tubes in Compression	233
6.9.2	Angles	235
6.10	In-plane Eccentricity of Connection	235
6.11	Design Example - Roof and Wall Bracing	235
6.11.1	Longitudinal Forces	235
6.11.1.1	General	235
6.11.1.2	Forces due to Longitudinal Wind	236
6.11.1.3	Forces due to Rafter Bracing	238
6.11.1.4	Forces in Roof Bracing Members	238
6.11.2	Ties or Tension Diagonals	238
6.11.3	Struts	241
6.11.4	Connections	244
6.11.4.1	End Connections for Struts	244
6.11.4.2	Bolts	246
6.11.5	Side Wall Bracing	247
6.12	References	268
7	FOOTINGS & SLABS	269
7.1	General	269
7.2	Design Uplift Forces	270
7.3	Pad Footings	270
7.4	Bored Piers	271
7.4.1	General	271
7.4.2	Resistance to Vertical Loads	273
7.4.3	Resistance to Lateral Loads	274
7.5	Holding Down Bolts	275
7.5.1	General	275
7.5.2	Design Criteria	276
7.5.3	Grouting or Bedding	277
7.5.4	Bolts in Tension	277
7.5.4.1	Anchorage of Straight or Cogged Bars	277
7.5.4.2	Cone Failure	278
7.5.4.3	Embedment Lengths	279
7.5.4.4	Minimum Edge Distance for Tensile Loads	280
7.5.5	Bolts in Shear	282
7.5.6	Corrosion	283
7.6	Slab Design	283
7.6.1	Design Principles	283
7.6.2	Slab Thickness	284
7.6.3	Joints	284
7.6.3.1	General	284
7.6.3.2	Sawn Joints	284
7.6.3.3	Cast-In Crack Initiators	285
7.6.3.4	Keyed Joints	286
7.6.3.5	Dowelled Joints	287
7.6.3.6	Joint Spacing and Reinforcement	287

7.7	Design Example – Footings	288
7.7.1	Typical Portal Footings	288
	7.7.1.1 Bored Piers	288
	7.7.1.2 Compare Pad Footings	290
7.7.2	End Wall Column Footings	291
7.7.3	Main Portal Footings in Bracing Bays	292
	7.7.3.1 Corner Columns	292
	7.7.3.2 Column on Grid B2	292
	7.7.3.3 Columns on Grids A2, A8 and B8	293
7.7.4	Holding Down Bolts for Portal Columns	293
7.7.5	Holding Down Bolts for End Wall Columns	294
7.8	Design Example - Slab	294
7.8.1	Design Criteria	294
7.8.2	Slab Thickness Design	294
7.8.3	Joints	295
7.8.4	Reinforcement	296
7.9	References	296
8	CRANE RUNWAY BEAMS	297
8.1	General	297
8.2	Design Procedure for Crane Runways and Supporting Structure	299
8.3	Design of Crane Runway Beams	300
	8.3.1 General	300
	8.3.2 Design Loads and Moments	300
	8.3.3 Member Capacity in Major Axis Bending ϕM_{bx}	301
	8.3.3.1 AS 4100 Beam Design Rules	301
	8.3.3.2 Proposed Monosymmetric Beam Design Rules	302
	8.3.4 Crane Runway Beam Deflections	305
8.4	Design of Supporting Structure	305
	8.4.1 Portal Frame Structure	305
	8.4.2 Portal Frame Loads	306
	8.4.2.1 General	306
	8.4.2.2 Serviceability Wind Speeds	306
	8.4.3 Portal Frame Deflection Limits	307
8.5	Design Example – Crane Runway Beams and Supporting Structure	308
	8.5.1 General	308
	8.5.2 Load Cases	309
	8.5.3 Crane Runway Beams	311
	8.5.3.1 Major Axis Bending Moments	311
	8.5.3.2 Minor Axis Bending Moments	312
	8.5.3.3 Combined Actions	315
	8.5.3.4 Check Major Axis Compound Section Moment Capacity ϕM_{sy}	315
	8.5.3.5 Deflections	315
	8.5.3.6 Vertical Shear Capacity	316
	8.5.3.7 Shear Buckling Capacity	316
	8.5.3.8 Shear and Bending Interaction	317
	8.5.3.9 Bearing Capacity of Crane Runway Beam	317
	8.5.3.10 Check Local Transverse Bending of Compression Flange	319
	8.5.3.11 Check Effect of Vertical Loads on Web	321
	8.5.3.12 Check Effect of Eccentric Rail Loading on Crane Runway Beam Web	321
	8.5.3.13 Check Effect of Web Buckling Under Vertical Loads	324
	8.5.3.14 Fatigue	325
	8.5.3.15 Check Effect of Eccentric Corbel Loading on Column	325
8.5.4	Check Portal Frame	327
	8.5.4.1 General	327
	8.5.4.2 Loads	327
	8.5.4.3 Load Combinations	329
	8.5.4.4 Columns	329

8.6	References	334
Appendix 8.1	Design Capacity Tables	335
Appendix 8.2	Background to Design Capacity Tables	342
9	MONORAILS	349
9.1	Introduction	349
9.2	Structural Design	350
9.2.1	General	350
9.2.2	Loads	350
9.2.2.1	General	350
9.2.2.2	Vertical Loads	351
9.2.2.3	Lateral Loads	352
9.2.2.4	Dynamic Factors	352
9.2.3	Member Capacity in Major Axis Bending ϕM_{bx}	353
9.2.3.1	General	353
9.2.3.2	Segments Restrained at Both Ends	353
9.2.3.3	Cantilevers	354
9.2.4	Elastic Buckling Moment M_{oa} - Effective Length Approach	354
9.2.4.1	General	354
9.2.4.2	Typical Values of k_t , k_r and k_l	355
9.2.5	Elastic Buckling Moment M_{ob} – Design by Buckling Analysis	357
9.2.5.1	Advantages of Using Design by Buckling analysis	357
9.2.5.2	Single and Continuous Spans	357
9.2.5.3	Cantilevers	358
9.2.6	Member Capacity in Major Axis Bending ϕM_{bxc} for Curved Monorails	360
9.2.7	Local Bottom Flange Bending	361
9.2.8	Web Thickness	365
9.2.9	Deflections	365
9.3	Design Example I – 2 Tonne Single Span Monorail	366
9.3.1	Description	366
9.3.2	Design Loads	367
9.3.3	Preliminary Sizing	367
9.3.4	Check Flange Thickness	368
9.3.5	Check Member Bending Capacity	369
9.3.5.1	Design by Buckling Analysis	369
9.3.5.2	Effective Length Method	370
9.3.5.3	Comparison of Methods	370
9.3.6	Web Thickness	371
9.3.7	Deflections	371
9.3.7.1	Vertical	371
9.3.7.2	Horizontal	371
9.3.8	Summary	372
9.4	Design Example II – 1 Tonne Cantilever Monorail	372
9.4.1	Description	372
9.4.2	Design Load	373
9.4.3	Preliminary Sizing	374
9.4.4	Check Flange Thickness	374
9.4.5	Check Member Bending Capacity	375
9.4.5.1	Cantilever	375
9.4.5.2	Back Span	379
9.4.6	Check Web Thickness	380
9.4.7	Deflections	380
9.4.7.1	Vertical	380
9.4.7.2	Horizontal	381
9.4.8	Summary	381
9.5	Design Example III – 5 Tonne Single Span Monorail	381
9.5.1	Description	381
9.5.2	Design Loads	382
9.5.3	Preliminary Sizing	383
9.5.4	Check Flange Thickness	383

9.5.5	Check Member Bending Capacity	385
9.5.6	Check Web Thickness	385
9.5.7	Deflections	386
	9.5.7.1 Vertical	386
	9.5.7.2 Horizontal	386
9.5.8	Summary	386
9.6	References	386
Appendix 9.1	Design Capacity Tables	389
Appendix 9.2	Background to Design Capacity Tables	398
Appendix 9.3	Effective Length Factors	401
Appendix 9.4	Hoist & Trolley Data	404
APPENDIX I	DRAWINGS.....	409
APPENDIX II	FRAME ANALYSIS OUTPUT.....	419
APPENDIX III	LIMSTEEL OUTPUT.....	439
APPENDIX IV	LIMCON OUTPUT.....	444
APPENDIX V	OUTPUT FOR PORTAL FRAME WITH CRANE.....	461
SUBJECT INDEX	467