

Table of Contents

Preface

Notation

Chapter 1: Behaviour of Semirigid Frames

1.1	Introduction	1
1.2	Frame classification	2
1.3	Influence of joint behaviour on unbraced frame response	6
1.3.1	Simplified model	6
1.3.2	Period of vibration	8
1.3.3	Frame sensitivity to second-order effects	9
1.3.4	Inelastic behaviour	11
1.4	Influence of joint behaviour on braced frame response	19
1.5	Classification of joints	21
1.6	References	35

Chapter 2: Modelling of Joint Behaviour

2.1	Introduction	38
2.2	Methods for modelling rotational behaviour	41
2.3	Mathematical representation of moment-rotation curve	44
2.3.1	Generality	44
2.3.2	Stiffness, resistance and shape factor based formulations	45
2.3.3	Curve fitting by regression analysis	56
2.4	Methods for predicting moment-rotation curves	58
2.4.1	Generality	58
2.4.2	Empirical models	58
2.4.3	Analytical models	67
2.4.4	Mechanical models	73
2.4.5	Finite element analysis	77
2.4.6	Experimental testing	78
2.5	References	79

Chapter 3: Welded Connections

3.1	Introduction	84
3.2	Column web in shear	88
3.3	Column web in compression	96
	3.3.1 Crushing resistance	96
	3.3.2 Buckling resistance	100
	3.3.3 Initial stiffness	103
3.4	Column web in tension	104
	3.4.1 Resistance	104
	3.4.2 Initial Stiffness	106
3.5	Considerations on local stress interaction	106
3.6	Column flange in bending	110
3.7	Beam flange and web in compression	114
3.8	Comparison with experimental data	114
3.9	Influence of strain-hardening	119
3.10	Worked examples	125
	3.10.1 Unstiffened external joint	125
	3.10.2 Stiffened external joint	130
3.11	References	132

Chapter 4: Basic Component of Bolted Connections

4.1	Introduction	135
4.2	Axial strength of bolted T-stubs	137
	4.2.1 Basic formulations	137
	4.2.2 The influence of moment-shear interaction	143
4.3	Axial stiffness of bolted T-stubs	149
	4.3.1 Basic principles	149
	4.3.2 Description of specimens and testing devices	152
	4.3.3 Experimental results	157
	4.3.4 Axial stiffness prediction of non-preloaded T-stubs	160
	4.3.5 Axial stiffness prediction of preloaded T-stubs	164
4.4	References	170

Chapter 5: Bolted End-Plate Connections

5.1	Introduction	172
5.2	Prediction of flexural resistance	177
	5.2.1 Column web in shear	177

Table of Contents

5.2.2	Column web in compression	177
5.2.3	Column flange in bending	177
5.2.4	End plate in bending	182
5.2.5	Column web in tension	184
5.2.6	Beam flange and web in compression	185
5.2.7	Beam web in tension	185
5.2.8	Procedure for evaluating the joint flexural resistance	185
5.2.9	Comparison with experimental results	189
5.3	Prediction of initial rotational stiffness	190
5.3.1	Generality	190
5.3.2	Column web in shear	192
5.3.3	Column web in compression	192
5.3.4	Column web in tension	192
5.3.5	Column flange in bending and end plate in bending	195
5.3.6	Bolt row in tension	195
5.3.7	Comparison with experimental data	196
5.3.8	The influence of the bolt preloading	199
5.4	Moment-rotation curve	200
5.5	Worked examples	206
5.5.1	Geometrical and mechanical properties	206
5.5.2	Initial rotational stiffness	207
5.5.3	Flexural resistance	212
5.6	References	219

Chapter 6: Bolted Connections with Angles

6.1	Introduction	222
6.2	Prediction of the flexural resistance	223
6.2.1	Component identification	223
6.2.2	Column web in shear	225
6.2.3	Column web in compression	226
6.2.4	Column web in tension and column flange in bending	227
6.2.5	Top angle in bending	227
6.2.6	Web angles in bending	234
6.2.7	Bolts in tension	242
6.2.8	Bolts in shear	242
6.2.9	Plates in bearing	243
6.2.10	Plate in tension	243
6.2.11	Plate in compression	245
6.2.12	Beam web in tension	245
6.2.13	Beam flange and web in compression	245
6.3	Operative steps	246

6.4	Comparison with experimental data	248
6.5	Simplified procedure	253
6.6	Prediction of rotational stiffness	254
	6.6.1 Identification of deformation sources	254
	6.6.2 Column web in shear	258
	6.6.3 Column web in compression	258
	6.6.4 Column web in tension	259
	6.6.5 Column flange in bending	259
	6.6.6 Bolt row in tension	259
	6.6.7 Angle in bending	260
	6.6.8 Bolts in shear	263
	6.6.9 Plate in bearing	263
	6.6.10 The influence of bolt preloading	263
	6.6.11 Comparison with experimental data	265
6.7	Worked example	267
	6.7.1 Flexural resistance	267
	6.7.2 Rotational stiffness	279
6.8	References	286

Chapter 7: JMRC - Computer Program for Evaluating the Joint Moment Rotation Curve

7.1	Analysed joint typologies	288
7.2	Description of input data	288
	7.2.1 Generality	288
	7.2.2 Basic joint data	289
	7.2.3 Data for connecting elements of welded connections	296
	7.2.4 Data for connecting elements of end-plate connections	297
	7.2.5 Data for connecting elements of angle connections	298
7.3	Examples of input data files	301
	7.3.1 Welded connections	301
	7.3.2 End plate connections	301
	7.3.3 Connections with angles	302
7.4	Adopted formulations	303
7.5	References	308

Chapter 8: Design of Extended End-Plate Connections for Braced Frames

8.1	Introduction	309
8.2	Behaviour and design of end-plate connections	312

Table of Contents

8.2.1 Parametric analysis	312
8.2.2 Flexural resistance versus rotational stiffness relation	315
8.2.3 End-plate thickness versus rotational stiffness relation	319
8.2.4 Design abaci	326
8.3 Design procedure for braced frames	332
8.3.1 Design conditions	332
8.3.2 Design algorithm	334
8.4 Applications	338
8.5 References	340

Chapter 9: Ductility of Connections

9.1 Introduction	342
9.2 Plastic rotation supply of the beam-joint system	344
9.3 Welded connections	349
9.4 Bolted connections	351
9.4.1 Generality	351
9.4.2 Basis of the theoretical approach	352
9.4.3 Material constitutive law	354
9.4.4 Moment-curvature relationship	355
9.4.5 Failure modes	357
9.4.6 Ultimate plastic displacement for type-1 mechanism	357
9.4.7 Ultimate plastic displacement for type-2 mechanism	361
9.4.8 Ultimate plastic displacement for type-3 mechanism	370
9.4.9 Bolt plastic deformation	371
9.4.10 Prediction of the force-displacement curve	371
9.4.11 Comparison with experimental evidence	380
9.5 Parameters affecting ductility	384
9.6 Ultimate plastic rotation of connections with angles	385
9.7 Ultimate plastic rotation of end-plate connections	392
9.8 References	395

Chapter 10: Cyclic Behaviour of Beam-to-Column Joints

10.1 Introduction	399
10.2 Experimental evidence	402
10.3 Low cycle fatigue	412
10.4 Modelling of cyclic response	426
10.4.1 Model classification	426
10.4.2 Mathematical models	427
10.4.3 Mechanical models	433

10.4.4 Cyclic behaviour of bolted T-stubs	438
10.5 References	444

Chapter 11: Seismic Design of Semirigid Frames

11.1 Introduction	449
11.2 Connection and panel zone design	453
11.2.1 Connection design	453
11.2.2 Panel zone design	454
11.3 Second-order plastic design of moment resisting frames	457
11.3.1 Background on capacity design	457
11.3.2 Location of plastic hinges	460
11.3.3 Notation	463
11.3.4 Mechanism equilibrium curves	466
11.3.5 Global type mechanism	468
11.3.6 Type-1 mechanisms	468
11.3.7 Type-2 mechanisms	469
11.3.8 Type-3 mechanisms	469
11.3.9 Design conditions for failure mode control	470
11.3.10 Conditions to avoid type-1 mechanisms	471
11.3.11 Conditions to avoid type-2 mechanisms	474
11.3.12 Conditions to avoid type-3 mechanisms	476
11.3.13 Technological conditions	477
11.3.14 Evaluation of the axial load in the columns at the collapse state	478
11.3.15 Design algorithm	478
11.4 The influence of beam-to-column joints	481
11.4.1 Preliminary remarks	481
11.4.2 Evaluation of joint rotational stiffness	482
11.4.3 Checking serviceability requirements	483
11.4.4 Design procedure	486
11.5 Parametric analyses	491
11.6 Dynamic inelastic analyses	492
11.7 References	494