

Contents

Preface	xv
Notation	xix
Conversion Factors	xxv
1 Introduction	1
1.1 Structural Concrete	1
1.2 Historical Background	1
1.3 Advantages and Disadvantages of Reinforced Concrete	3
1.4 Codes of Practice	4
1.5 Design Philosophy and Concepts	4
1.6 Units of Measurement	5
1.7 Loads	6
1.8 Safety Provisions	8
1.9 Structural Concrete Elements	9
1.10 Structural Concrete Design	10
1.11 Accuracy of Calculations	10
1.12 Concrete High-Rise Buildings	11
References	14
2 Properties of Reinforced Concrete	15
2.1 Factors Affecting the Strength of Concrete	15
2.2 Compressive Strength	17
2.3 Stress–Strain Curves of Concrete	18
2.4 Tensile Strength of Concrete	20
2.5 Flexural Strength (Modulus of Rupture) of Concrete	21
2.6 Shear Strength	22
2.7 Modulus of Elasticity of Concrete	22
2.8 Poisson’s Ratio	23

2.9	Shear Modulus	23	
2.10	Modular Ratio	24	
2.11	Volume Changes of Concrete	24	
2.12	Creep	26	
2.13	Models for Predicting the Shrinkage and Creep of Concrete	28	
2.14	Unit Weight of Concrete	53	
2.15	Fire Resistance	53	
2.16	High-Performance Concrete	53	
2.17	Lightweight Concrete	54	
2.18	Fibrous Concrete	55	
2.19	Steel Reinforcement	55	
	Summary	59	
	References	61	
	Problems	62	
3	Flexural Analysis of Reinforced Concrete Beams		64
3.1	Introduction	64	
3.2	Assumptions	65	
3.3	Behavior of a Simply Supported Reinforced Concrete Beam Loaded to Failure	65	
3.4	Types of Flexural Failure and Strain Limits	69	
3.5	Load Factors	73	
3.6	Strength-Reduction Factor ϕ	74	
3.7	Significance of Analysis and Design Expressions	76	
3.8	Equivalent Compressive Stress Distribution	77	
3.9	Singly Reinforced Rectangular Section in Bending	79	
3.10	Lower Limit or Minimum Percentage of Steel	90	
3.11	Adequacy of Sections	91	
3.12	Bundled Bars	95	
3.13	Sections in the Transition Region ($\phi < 0.9$)	96	
3.14	Rectangular Sections with Compression Reinforcement	98	
3.15	Analysis of T- and I-Sections	109	
3.16	Dimensions of Isolated T-Shaped Sections	118	
3.17	Inverted L-Shaped Sections	119	
3.18	Sections of Other Shapes	119	
3.19	Analysis of Sections Using Tables	122	
3.20	Additional Examples	122	
3.21	Examples Using SI Units	124	
	Summary	126	
	References	129	
	Problems	130	
4	Flexural Design of Reinforced Concrete Beams		134
4.1	Introduction	134	
4.2	Rectangular Sections with Reinforcement Only	134	
4.3	Spacing of Reinforcement and Concrete Cover	137	
4.4	Rectangular Sections with Compression Reinforcement	145	
4.5	Design of T-sections	152	

Contents	vii
4.6 Additional Examples	157
4.7 Examples Using SI Units	162
Summary	164
Problems	167
5 Alternative Design Methods	172
5.1 Introduction	172
5.2 Load Factors	172
5.3 Strength-Reduction Factor, ϕ	173
5.4 Rectangular Sections with Tension Reinforcement	174
5.5 Rectangular Sections with Compression Reinforcement	178
5.6 Design of T-Sections	180
5.7 Strut and Tie Method	181
References	189
6 Deflection and Control of Cracking	190
6.1 Deflection of Structural Concrete Members	190
6.2 Instantaneous Deflection	191
6.3 Long-Time Deflection	197
6.4 Allowable Deflection	198
6.5 Deflection Due to Combinations of Loads	198
6.6 Cracks in Flexural Members	207
6.7 ACI Code Requirements	211
Summary	216
References	217
Problems	218
7 Development Length of Reinforcing Bars	221
7.1 Introduction	221
7.2 Development of Bond Stresses	222
7.3 Development Length in Tension	225
7.4 Development Length in Compression	228
7.5 Summary for the Computation of l_d in Tension	230
7.6 Critical Sections in Flexural Members	232
7.7 Standard Hooks (ACI Code, Sections 12.5 and 7.1)	235
7.8 Splices of Reinforcement	239
7.9 Moment-Resistance Diagram (Bar Cutoff Points)	242
Summary	245
References	248
Problems	248
8 Shear and Diagonal Tension	251
8.1 Introduction	251
8.2 Shear Stresses in Concrete Beams	251
8.3 Behavior of Beams without Shear Reinforcement	255
8.4 Moment Effect on Shear Strength	256
8.5 Beams with Shear Reinforcement	258
8.6 ACI Code Shear Design Requirements	261

8.7	Design of Vertical Stirrups	266	
8.8	Design Summary	267	
8.9	Shear Force Due to Live Loads	272	
8.10	Shear Stresses in Members of Variable Depth	276	
8.11	Deep Flexural Members	282	
8.12	Examples Using SI Units	293	
	Summary	295	
	References	296	
	Problems	297	
9	One-Way Slabs		300
9.1	Types of Slabs	300	
9.2	Design of One-Way Solid Slabs	302	
9.3	Design Limitations According to the ACI Code	303	
9.4	Temperature and Shrinkage Reinforcement	304	
9.5	Reinforcement Details	305	
9.6	Distribution of Loads from One-Way Slabs to Supporting Beams	306	
*9.7	One-Way Joist Floor System	311	
	Summary	314	
	References	315	
	Problems	315	
10	Axially Loaded Columns		318
10.1	Introduction	318	
10.2	Types of Columns	318	
10.3	Behavior of Axially Loaded Columns	320	
10.4	ACI Code Limitations	320	
10.5	Spiral Reinforcement	323	
10.6	Design Equations	324	
10.7	Axial Tension	325	
10.8	Long Columns	326	
	Summary	328	
	References	329	
	Problems	329	
11	Members in Compression and Bending		331
11.1	Introduction	331	
11.2	Design Assumptions for Columns	333	
11.3	Load-Moment Interaction Diagram	333	
11.4	Safety Provisions	336	
11.5	Balanced Condition—Rectangular Sections	337	
11.6	Column Sections under Eccentric Loading	340	
11.7	Strength of Columns for Tension Failure	342	
11.8	Strength of Columns for Compression Failure	345	
11.9	Interaction Diagram Example	351	
*11.10	Rectangular Columns with Side Bars	352	
*11.11	Load Capacity of Circular Columns	356	
11.12	Analysis and Design of Columns Using Charts	361	

Contents

ix

11.13	Design of Columns under Eccentric Loading	366
*11.14	Biaxial Bending	373
*11.15	Circular Columns with Uniform Reinforcement under Biaxial Bending	375
*11.16	Square and Rectangular Columns under Biaxial Bending	376
*11.17	Parame Load Contour Method	377
*11.18	Equation of Failure Surface	382
11.19	SI Example	385
	Summary	387
	References	388
	Problems	389
12	Slender Columns	394
*12.1	Introduction	394
*12.2	Effective Column Length (Kl_u)	395
*12.3	Effective Length Factor (K)	396
*12.4	Member Stiffness (EI)	397
*12.5	Limitation of the Slenderness Ratio (Kl_u/r)	401
*12.6	Moment-Magnifier Design Method	402
	Summary	412
	References	414
	Problems	414
13	Footings	416
13.1	Introduction	416
13.2	Types of Footings	418
13.3	Distribution of Soil Pressure	421
13.4	Design Considerations	422
13.5	Plain Concrete Footings	431
*13.6	Combined Footings	441
*13.7	Footings under Eccentric Column Loads	448
*13.8	Footings under Biaxial Moment	450
*13.9	Slabs on Ground	453
*13.10	Footings on Piles	453
13.11	SI Equations	454
	Summary	454
	References	457
	Problems	457
14	Retaining Walls	460
14.1	Introduction	460
14.2	Types of Retaining Walls	460
14.3	Forces on Retaining Walls	462
14.4	Active and Passive Soil Pressures	463
14.5	Effect of Surcharge	467
14.6	Friction on the Retaining Wall Base	469
14.7	Stability against Overturning	469
14.8	Proportions of Retaining Walls	470
14.9	Design Requirements	471

x

Contents




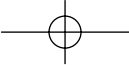
14.10	Drainage	472	
14.11	Basement Walls	483	
	Summary	487	
	References	488	
	Problems	488	
15	Design for Torsion		493
15.1	Introduction	493	
15.2	Torsional Moments in Beams	494	
15.3	Torsional Stresses	495	
15.4	Torsional Moment in Rectangular Sections	498	
15.5	Combined Shear and Torsion	499	
15.6	Torsion Theories for Concrete Members	500	
15.7	Torsional Strength of Plain Concrete Members	504	
15.8	Torsion in Reinforced Concrete Members (ACI Code Procedure)	504	
15.9	Summary of ACI Code Procedures	512	
	Summary	520	
	References	521	
	Problems	522	
16	Continuous Beams and Frames		525
16.1	Introduction	525	
16.2	Maximum Moments in Continuous Beams	526	
16.3	Building Frames	531	
16.4	Portal Frames	533	
16.5	General Frames	535	
16.6	Design of Frame Hinges	537	
16.7	Introduction to Limit Design	549	
16.8	The Collapse Mechanism	551	
16.9	Principles of Limit Design	551	
16.10	Upper and Lower Bounds of Load Factors	553	
16.11	Limit Analysis	553	
16.12	Rotation of Plastic Hinges	557	
16.13	Summary of Limit Design Procedure	564	
16.14	Moment Redistribution of Maximum Negative or Positive Moments in Continuous Beams	568	
	Summary	576	
	References	578	
	Problems	579	
17	Design of Two-Way Slabs		581
17.1	Introduction	581	
17.2	Types of Two-Way Slabs	581	
17.3	Economical Choice of Concrete Floor Systems	585	
17.4	Design Concepts	586	
17.5	Column and Middle Strips	590	
17.6	Minimum Slab Thickness to Control Deflection	592	
17.7	Shear Strength of Slabs	597	

Contents

xi

17.8	Analysis of Two-Way Slabs by the Direct Design Method	602
17.9	Design Moments in Columns	631
17.10	Transfer of Unbalanced Moments to Columns	632
17.11	Waffle Slabs	644
17.12	Equivalent Frame Method	651
	Summary	663
	References	664
	Problems	665
18	Stairs	667
18.1	Introduction	667
18.2	Types of Stairs	669
18.3	Examples	684
	Summary	693
	References	693
	Problems	694
19	Introduction to Prestressed Concrete	696
19.1	Prestressed Concrete	696
19.2	Materials and Serviceability Requirements	707
19.3	Loss of Prestress	709
19.4	Analysis of Flexural Members	717
19.5	Design of Flexural Members	728
19.6	Cracking Moment	734
19.7	Deflection	736
19.8	Design for Shear	739
19.9	Preliminary Design of Prestressed Concrete Flexural Members	747
19.10	End-Block Stresses	749
	Summary	752
	References	754
	Problems	755
20	Seismic Design of Reinforced Concrete Structures	758
20.1	Introduction	758
20.2	Seismic Design Category	758
20.3	Analysis Procedures	775
20.4	Load Combinations	789
20.5	Special Requirements in Design of Structures Subjected to the Earthquake Loads	791
	Code and Design References	826
	Problems	826
21	Beams Curved in Plan	828
21.1	Introduction	828
21.2	Uniformly Loaded Circular Beams	828
21.3	Semicircular Beam Fixed at End Supports	835
21.4	Fixed-End Semicircular Beam under Uniform Loading	839
21.5	Circular Beam Subjected to Uniform Loading	842

21.6	Circular Beam Subjected to a Concentrated Load at Midspan	845
21.7	V-Shape Beams Subjected to Uniform Loading	848
21.8	V-Shape Beams Subjected to a Concentrated Load at the Centerline of the Beam	851
	Summary	854
	References	856
	Problems	856
	Appendix A: Design Tables (U.S. Customary Units)	857
	Appendix B: Design Tables (SI Units)	867
	Appendix C: Structural Aids	875
	Index	895



A companion Web site for the book is available at www.wiley.com/college/hassoun. This Web site contains MSExcel spreadsheets that enable students to evaluate different design aspects of concrete members in an interactive environment, and a solutions manual for instructors.

