

Contents

Preface

v

1 | PRESTRESSING METHODS

1-1	Introduction	1
1-2	General Design Principles	2
1-3	Prestressing with Jacks	4
1-4	Pre-tensioning	5
1-5	Post-tensioning with Tendons	6
1-6	Pre-tensioning vs Post-tensioning	7
1-7	Linear vs Circular Prestressing	8
1-8	Application of Prestressed Concrete	8

2 | STEEL FOR PRESTRESSING

2-1	Introduction	10
2-2	Stress-Relieved Wire	12
2-3	Stress-Relieved Strand	13
2-4	High-Tensile Strength Bars	15
2-5	Yield Strength	18
2-6	Plasticity	18
2-7	Relaxation and Creep	19
2-8	Corrosion	23
2-9	Application of Steel Types	25
2-10	Idealized Tendon Material	26
2-11	Allowable Steel Stresses	26

vii

3 | CONCRETE FOR PRESTRESSING

3-1	Introduction	30
3-2	Cement Type	31
3-3	Admixtures	31
3-4	Slump	32
3-5	Curing	32
3-6	Concrete Aggregates	33
3-7	Strength of Concrete	33
3-8	Elastic Modulus	36
3-9	Shrinkage	39
3-10	Estimating Shrinkage	44
3-11	Creep of Concrete	46
3-12	Relaxation of Concrete	55
3-13	Low-Pressure (Atmospheric Pressure) Steam Curing	55
3-14	Cold Weather Concrete	58
3-15	Allowable Concrete Flexural Stresses	59

4 | BASIC PRINCIPLES FOR FLEXURAL DESIGN

4-1	Introduction	66
4-2	Mathematical Relationships for Prestressing Stresses	67
4-3	Pressure Line in a Beam with a Straight Tendon	71
4-4	Variation in Pressure-Line Location	74
4-5	Pressure-Line Location in a Beam with a Curved Tendon	77
4-6	Advantages of Curved or Draped Tendons	81
4-7	Limiting Eccentricities	88
4-8	Cross-Section Efficiency	92
4-9	Selection of Beam Cross Section	94
4-10	Effective Beam Cross Section	96
4-11	Variation in Steel Stress	101

5 | CRACKING LOAD, ULTIMATE MOMENT, SHEAR, AND BOND

5-1	Action Under Overloads—Cracking Load	115
5-2	Principles of Ultimate Moment Capacity for Bonded Members	117
5-3	Principles of Ultimate Moment Capacity for Unbonded Members	127
5-4	Ultimate Moment Code Requirements—Bonded Members	130
5-5	Ultimate Moment Code Requirements—Unbonded Tendons	146
5-6	Strength Reduction Factor	148
5-7	Shear and Shear Reinforcement	149
5-8	Shear Design Expedients	157

5-9	Bond of Prestressing Tendons	166
5-10	Bonded vs Unbonded Post-Tensioning	174
6 	ADDITIONAL DESIGN CONSIDERATIONS	
6-1	Introduction	192
6-2	Losses of Prestress	192
6-3	Deflection	207
6-4	Composite Beams	221
6-5	Beams with Variable Moments of Inertia	224
6-6	Segmental Beams	226
6-7	Partial Prestressing	228
6-8	End Blocks	229
6-9	Spacing of Pre-tensioning Tendons	235
6-10	Pre-tensioning Stresses at Ends of Beams	237
6-11	Bond Prevention in Pre-tensioned Construction	241
6-12	Deflected Pre-tensioned Tendons	244
6-13	Combined Pre-tensioned and Post-tensioned Tendons	245
6-14	Buckling Due to Prestressing	248
6-15	Secondary Stresses Due to Tendon Curvature	251
6-16	Variation in Tendon Stress	252
6-17	Standard vs Custom Prestressed Members	253
6-18	Precision of Elastic Design Computations	254
6-19	Load Balancing	254
7 	DESIGN EXPEDIENTS AND COMPUTATION METHODS	
7-1	Introduction	269
7-2	Computation of Section Properties	270
7-3	Allowable Concrete Stresses to be Used in Design Computations	275
7-4	Limitations of Sections Prestressed with Straight Tendons	277
7-5	Limitations of Sections Prestressed with Curved Tendons	279
7-6	Determination of Minimum Prestressing Force for Straight Tendons	280
7-7	Determination of Minimum Prestressing Force for Curved Tendons	286
7-8	Estimating Prestressing Force and Cross-Sectional Characteristics	292
7-9	Reduction in Shear Force Due to Curvature of Parabolic Tendons	308
7-10	Computing the Location of Pre-tensioning Tendons	309
7-11	Fiber Stresses at Ends of Prismatic Beams	313
7-12	Computing the Effects of Bond Prevention	314

8 | CONTINUITY IN PRESTRESSED CONCRETE FLEXURAL MEMBERS

8-1	Introduction	318
8-2	Disadvantages of Continuity	319
8-3	Methods of Framing Continuous Beams	320
8-4	Continuous Prestressed Slabs	325
8-5	Elastic Analysis of Beams with Straight Tendons	326
8-6	Elastic Analysis of Beams with Curved Tendons	336
8-7	Additional Elastic-Design Considerations	345
8-8	Elastic Design Procedure	347
8-9	Limitations of Elastic Action	352
8-10	Analysis at Design Loads	355
8-11	Additional Considerations	359
8-12	Continuous Beams Utilizing Prestressed Beam Soffits	360
8-13	Continuous Beams Constructed in Cantilever	361

9 | DIRECT STRESS MEMBERS, TEMPERATURE AND FATIGUE

9-1	Introduction	367
9-2	Tension Members or Ties	367
9-3	Columns and Piles	371
9-4	Fire Resistance	384
9-5	Normal Temperature Variation	387
9-6	Fatigue	392

10 | CRACKING AND OTHER DEFECTS—THEIR CAUSE AND REMEDY

10-1	Introduction	395
10-2	Cracking	395
10-3	Restraint of Volume Changes	404
10-4	Honeycombing	406
10-5	Buckling	407
10-6	Deflection	407
10-7	Corrosion of Prestressing Steel	409
10-8	Concrete Crushing at End Anchorages	411
10-9	Deterioration	411
10-10	Grouting of Post-tensioned Tendons	411
10-11	Damage Due to Couplers	412
10-12	Wedge-Type Dead Ends	412
10-13	Looped or Pig Tail Dead Ends	412
10-14	Congested Connections	414
10-15	Inadequate Welding	414
10-16	Dimensional Tolerances	414

11 | ROOF AND FLOOR FRAMING SYSTEMS

11-1	Introduction	416
11-2	Double T Slabs	417
11-3	Single T Beams or Joists	421
11-4	Long-Span Channels	422
11-5	Prestressed Joists	423
11-6	Solid Precast Slabs	425
11-7	Precast Hollow Slabs	426
11-8	Cast-in-Place Prestressed Slabs	426
11-9	Other Types of Framing	440
11-10	Continuity in Precast Construction	442

12 | BRIDGE CONSTRUCTION

12-1	Introduction	444
12-2	Short-Span Bridges	449
12-3	Bridges of Moderate Span	453
12-4	Long-Span Bridges	457
12-5	Bridges of Special Types	458

13 | CONNECTIONS FOR PRECAST MEMBERS

13-1	General	463
13-2	Computation of Horizontal Forces	465
13-3	Corbels	466
13-4	Column Heads	471
13-5	Post-tensioned Connection	475
13-6	Column Base Connections	476
13-7	Elastomeric Bearing Pads	476
13-8	Other Expansion Bearing Pads	480
13-9	Fixed Steel Bearings	480
13-10	Wind/Seismic Connections	480
13-11	Shear-friction Connections	482

14 | PRE-TENSIONING EQUIPMENT AND PROCEDURES

14-1	Introduction	485
14-2	Pre-tensioning with Individual Molds	486
14-3	Pre-tensioning Benches	486
14-4	Stressing Mechanisms and Related Devices	493
14-5	Forms for Pre-tensioned Concrete	498
14-6	Tendon-Deflecting Mechanisms	501

15 | POST-TENSIONING SYSTEMS AND PROCEDURES

15-1	Introduction	508
15-2	Description of Post-tensioning Systems	509
15-3	Sheaths and Ducts for Post-tensioning Tendons	516
15-4	Forms for Post-tensioned Members	517
15-5	Effect of Friction During Stressing	519
15-6	Elastic Deformation of Post-tensioning Anchorages	522
15-7	Computation of Gauge Pressures and Elongations	528
15-8	Construction Procedure in Post-tensioned Concrete	530
15-9	Construction of Multi-element Beams	533

16 | ERECTION OF PRECAST MEMBERS

16-1	General	537
16-2	Truck Cranes	537
16-3	Crawler Cranes	542
16-4	Floating Cranes	542
16-5	Girder Launchers	545
16-6	Falsework	547
16-7	Cable Ways and Highlines	549
16-8	Towers	549
	Appendix A	553
	Appendix B	583
	Appendix C	621
	Index	631