



International
Edition

Surveying with Construction Applications

Seventh Edition

Barry F. Kavanagh



PEARSON

Contents

PART I SURVEYING PRINCIPLES 1

1 *Surveying Fundamentals* 2

- 1.1 Surveying Defined 2
- 1.2 Surveying: General Background 4
- 1.3 Control Surveys 4
- 1.4 Preliminary Surveys 4
- 1.5 Surveying Instruments 5
- 1.6 Construction Surveys 6
- 1.7 Distance Measurement 7
- 1.8 Angle Measurement 9
- 1.9 Position Measurement 9
- 1.10 Units of Measurement 11
- 1.11 Stationing 11
- 1.12 Types of Construction Projects 13
- 1.13 Random and Systematic Errors 13
- 1.14 Accuracy and Precision 14
- 1.15 Mistakes 15
- 1.16 Field Notes 15
- Review Questions 17*

2 *Leveling* 18

- 2.1 General Background 18
- 2.2 Theory of Differential Leveling 19
- 2.3 Curvature and Refraction 20

2.4	Types of Surveying Levels	25
2.5	Leveling Rods	31
2.6	Definitions for Differential Leveling	34
2.7	Techniques of Leveling	35
2.8	Benchmark Leveling (Vertical Control Surveys)	39
2.9	Profile and Cross-Section Leveling	41
2.10	Reciprocal Leveling	46
2.11	Peg Test	47
2.12	Three-Wire Leveling	49
2.13	Trigonometric Leveling	50
2.14	Level Loop Adjustments	51
2.15	Suggestions for Rod Work	52
2.16	Suggestions for Instrument Work	53
2.17	Mistakes in Leveling	54
	<i>Problems</i>	55

3 Distance Measurement 61

3.1	Methods of Linear Measurement	61
3.2	Gunter's Chain	63
3.3	Tapes	63
3.4	Steel Tapes	64
3.5	Taping Accessories and Their Use	67
3.6	Taping Techniques	71
3.7	Taping Corrections	74
3.8	Systematic Taping Errors and Corrections	75
3.9	Random Taping Errors	79
3.10	Techniques for "Ordinary" Taping Precision	80
3.11	Mistakes in Taping	81
3.12	Field Notes for Taping	82
3.13	Electronic Distance Measurement	84
3.14	Electronic Angle Measurement	84
3.15	Principles of EDM	86
3.16	EDM Characteristics	88
3.17	Prisms	89
3.18	EDM Instrument Accuracies	90
3.19	EDM Without Reflecting Prisms	91
	<i>Problems</i>	93

4 Introduction to Total Stations and Theodolites 96

4.1	General Background	96
4.2	Reference Directions for Vertical Angles	96
4.3	Meridians	96
4.4	Horizontal Angles	98

4.5	Theodolites	99
4.6	Electronic Theodolites	100
4.7	Total Station	103
4.8	Theodolite/Total Station Setup	104
4.9	Geometry of the Theodolite and Total Station	105
4.10	Adjustment of the Theodolite and Total Station	105
4.11	Laying Off Angles	111
4.12	Prolonging a Straight Line (Double Centering)	112
4.13	Bucking-in (Interlining)	112
4.14	Intersection of Two Straight Lines	113
4.15	Prolonging a Measured Line by Triangulation over an Obstacle	114
4.16	Prolonging a Line Past an Obstacle	116
	<i>Review Questions</i>	<i>117</i>

5 Total Station Operations 118

5.1	General Background	118
5.2	Total Station Capabilities	118
5.3	Total Station Field Techniques	124
5.4	Field Procedures for Total Stations in Topographic Surveys	132
5.5	Field-Generated Graphics	138
5.6	Construction Layout Using Total Stations	140
5.7	Motorized Total Stations	145
5.8	Summary of Modern Total Station Characteristics and Capabilities	152
5.9	Instruments Combining Total Station Capabilities and GPS Receiver Capabilities	153
5.10	Portable/Handheld Total Stations	154
	<i>Review Questions</i>	<i>156</i>

6 Traverse Surveys and Computations 157

6.1	General Background	157
6.2	Balancing Field Angles	160
6.3	Meridians	161
6.4	Bearings	162
6.5	Azimuths	165
6.6	Latitudes and Departures	169
6.7	Traverse Precision and Accuracy	175
6.8	Compass Rule Adjustment	177
6.9	Effects of Traverse Adjustments on Measured Angles and Distances	178
6.10	Omitted Measurement Computations	179
6.11	Rectangular Coordinates of Traverse Stations	181
6.12	Area of a Closed Traverse by the Coordinate Method	184
	<i>Review Questions</i>	<i>186</i>
	<i>Problems</i>	<i>187</i>

7	<i>Satellite Positioning</i>	190
7.1	General Background	190
7.2	U.S. Global Positioning System	194
7.3	Receivers	196
7.4	Satellite Constellations	198
7.5	GPS Satellite Signals	200
7.6	GPS Position Measurements	202
7.7	Errors	210
7.8	Continuously Operating Reference Stations	211
7.9	Canadian Active Control System	213
7.10	Survey Planning	213
7.11	GPS Field Procedures	218
7.12	GPS Applications	224
7.13	Vertical Positioning	231
7.14	Conclusion	235
7.15	GPS Glossary	235
7.16	Recommended Readings	238
	<i>Review Questions</i>	239
8	<i>An Introduction to Geomatics</i>	240
8.1	Geomatics Defined	240
8.2	Branches of Geomatics	240
8.3	Data Collection Branch	242
8.4	Design and Plotting	248
8.5	Contours	258
8.6	Aerial Photography	265
8.7	Airborne and Satellite Imagery	276
8.8	Remote-Sensing Satellites	287
8.9	Geographic Information System	289
8.10	Database Management	294
8.11	Metadata	295
8.12	Spatial Entities or Features	296
8.13	Typical Data Representation	298
8.14	Spatial Data Models	298
8.15	GIS Data Structures	300
8.16	Topology	303
8.17	Remote Sensing Internet Websites and Further Reading	304
	<i>Review Questions</i>	306
	<i>Problems</i>	307
9	<i>Horizontal Control Surveys</i>	311
9.1	General Background	311
9.2	Plane Coordinate Grids	320
9.3	Lambert Projection Grid	326
9.4	Transverse Mercator Grid	327

9.5	UTM Grid	329
9.6	Use of Grid Coordinates	336
9.7	Illustrative Examples	344
9.8	Horizontal Control Techniques	351
9.9	Project Control	353
	<i>Review Questions</i>	361
	<i>Problems</i>	363

PART II CONSTRUCTION APPLICATIONS 365

II.1	Introduction	365
II.2	General Background	365
II.3	Grade	367

10 Machine Guidance and Control 368

10.1	General Background	368
10.2	Motorized Total Station Guidance and Control	371
10.3	Satellite Positioning Guidance and Control	373
10.4	Three-Dimensional Data Files	375
10.5	Summary of the 3D Design Process	377
10.6	Website References for Data Collection, DTM, and Civil Design	379
	<i>Review Questions</i>	379

11 Highway Curves 380

11.1	Route Surveys	380
11.2	Circular Curves: General Background	381
11.3	Circular Curve Geometry	382
11.4	Circular Curve Deflections	388
11.5	Chord Calculations	390
11.6	Metric Considerations	391
11.7	Field Procedure (Steel Tape and Theodolite)	391
11.8	Moving up on the Curve	392
11.9	Offset Curves	393
11.10	Compound Circular Curves	401
11.11	Reverse Curves	402
11.12	Vertical Curves: General Background	403
11.13	Geometric Properties of the Parabola	405
11.14	Computation of the High or the Low Point on a Vertical Curve	406
11.15	Computing a Vertical Curve	406
11.16	Design Considerations	409
11.17	Spiral Curves: General Background	411
11.18	Spiral Curve Computations	413
11.19	Spiral Layout Procedure Summary	421
11.20	Approximate Solution for Spiral Problems	428

- 11.21 Superelevation: General Background 429
- 11.22 Superelevation Design 430
 - Review Questions* 436
 - Problems* 437

12 Highway Construction Surveys 442

- 12.1 Preliminary (Preengineering) Surveys 442
- 12.2 Highway Design 446
- 12.3 Highway Construction Layout 448
- 12.4 Clearing, Grubbing, and Stripping Topsoil 452
- 12.5 Placement of Slope Stakes 453
- 12.6 Layout for Line and Grade 457
- 12.7 Grade Transfer 460
- 12.8 Ditch Construction 462
 - Review Questions* 463

13 Municipal Street Construction Surveys 464

- 13.1 General Background 464
- 13.2 Classification of Roads and Streets 465
- 13.3 Road Allowances 466
- 13.4 Road Cross Sections 466
- 13.5 Plan and Profile 466
- 13.6 Establishing Centerline (C) 469
- 13.7 Establishing Offset Lines and Construction Control 471
- 13.8 Construction Grades for a Curbed Street 474
- 13.9 Street Intersections 478
- 13.10 Sidewalk Construction 480
- 13.11 Site Grading 481
 - Problems* 483

14 Pipeline and Tunnel Construction Surveys 489

- 14.1 Pipeline Construction 489
- 14.2 Sewer Construction 491
- 14.3 Layout for Line and Grade 493
- 14.4 Catch-Basin Construction Layout 502
- 14.5 Tunnel Construction Layout 503
 - Problems* 508

15 Culvert and Bridge Construction Surveys 514

- 15.1 Culvert Construction 514
- 15.2 Culvert Reconstruction 514
- 15.3 Bridge Construction: General Background 517
- 15.4 Contract Drawings 521
- 15.5 Layout Computations 526

- 15.6 Offset Distance Computations 526
- 15.7 Dimension Verification 527
- 15.8 Vertical Control 529
- 15.9 Cross Sections for Footing Excavations 530
- Review Questions* 531

16 Building Construction Surveys 532

- 16.1 Building Construction: General Background 532
- 16.2 Single-Story Construction 532
- 16.3 Multistory Construction 544
- Review Questions* 551

17 Quantity and Final Surveys 552

- 17.1 Construction Quantity Measurements: General Background 552
- 17.2 Area Computations 553
- 17.3 Area by Graphical Analysis 560
- 17.4 Construction Volumes 566
- 17.5 Cross Sections, End Areas, and Volumes 568
- 17.6 Prismoīdal Formula 573
- 17.7 Volume Computations by Geometric Formulas 574
- 17.8 Final (As-Built) Surveys 574
- Problems* 576

Appendix A Trigonometry and Coordinate Geometry Review 579

- A.1 Trigonometric Definitions and Identities 579
- A.2 Coordinate Geometry 583

Appendix B Surveying and Mapping Websites 592

Appendix C Glossary 594

Appendix D Typical Field Projects 605

- D.1 Field Notes 605
- D.2 Project 1: Building Measurements 606
- D.3 Project 2: Experiment to Determine “Normal Tension” 608
- D.4 Project 3: Field Traverse Measurements with a Steel Tape 609
- D.5 Project 4: Differential Leveling 610
- D.6 Project 5: Traverse Angle Measurements and Closure Computations 612
- D.7 Project 6: Topographic Survey 613
- D.8 Project 7: Building Layout 620
- D.9 Project 8: Horizontal Curve 621
- D.10 Project 9: Pipeline Layout 622

Appendix E Answers to Selected Problems 624

Appendix F Steel Tape Corrections 630

- F.1 Erroneous Tape-Length correction 630
 - F.2 Temperature Corrections 631
 - F.3 Tension and Sag Corrections 633
- Problems 636*

Appendix G Early Surveying 637

- G.1 Evolution of Surveying 637
 - G.2 Dumpy Level 643
 - G.3 The Engineers' Vernier Transit 645
 - G.4 Optical Theodolite 653
 - G.5 Stadia 659
- Problems 671*

***Appendix H Illustrations of Machine Control and of Various
Data-Capture Techniques 673***

Index 675