CONTENTS

SECTION 1: DESIGN PRINCIPLES & CONSTRUCTION DOCUMENTATION . . . 1

CHAPTER 1 FUNCTIONAL PLANNING  3
Human Factors  4
Anthropometrics and Ergonomics  4
Human Behavior  4
Anthropometric Data  5

Universal and Accessible Design  19
Universal Design  19
Accessible Design  39
Technical Criteria  42
Public Restrooms  67
Theatre and Stage Spaces and Equipment  72
Musical Instrumental Spaces and Equipment  72
Audio-Visual Spaces and Equipment  72

CHAPTER 2 ENVIRONMENT  73
Environmental Factors  74
Solar Radiation and Building Orientation  74
Solar Constant, Solar Angles, and Shadow Construction  75
Orientation and True North  77
Solar Time  78

Solar Path and Solar Angle  79
Solar Angles  79
Solar Path Diagrams  79
Solar Position and Heat Gain  82

Climate Zone  86
Designing for Cold and Permafrost Climates  86
Designing for Cold and Underheated Climates  87
Designing for Hot Arid Climates  88
Designing for Humid, Overheated Climates  88

Thermal Comfort  90
Climate Data  90

Daylighting  92
Daylighting Design  92

Acoustics  95
Sound  95
Frequency  95
Sound Absorption Properties of Materials  95
Sound Energy Absorption Mechanisms  95
Acoustic Measurement Terms  96
Measuring Sound Absorption  96
Measuring Sound Absorption Detail  96
Room Acoustics  96
Properties of Sound  97
Use of Sound-Absorptive Materials  97
Sound Transmission  97
Transmission Loss  97
Noise Reduction  98
Sound Isolation  98
Sound Isolation Detail  98
Sound Transmission Control Regulations  98
Impact Noise  98
Impact Noise Reduction  99
Impact Design Standards  99
Background Noise Criteria Detail  99
Acoustic Partitions  99
Acoustic Partitions Detail  100
More Acoustic Partitions Detail  100
Sound Control Windows  101
Acoustic Applications  101
Open Office Acoustics  101
Blocking Sound  101
Masking Sound  101
Absorbing Sound  102
Other Factors  102
Factors Affecting Acoustic Performance Detail  102
Hotel Acoustics  102
School Acoustics  103
Lecture Hall Acoustics  103
Exterior Noise Control  103
Reverberation  103
Performance Theater and Rehearsal Hall Acoustics  103
Interior Construction  103

Theater Viewing Angle and Acoustics  103
Proscenium Stages  104
Performance Acoustics  105
Spaciousness  105
Reverberation Times  105
Articulation  105
Focusing  105
Upholstered Seats  105
Balconies  105
Orchestra Pit  105
Sound System  105

CHAPTER 3 BUILDING RESILIENCY  107
Overview  108

Components of Building Resilience  109
The 4Rs  109
Asset (Building) Resilience and Community Resilience  110
Resilience Management–Based Building Designs  111
Community Resilience  112

Hazard–Specific Building-Resilience Considerations  113
Overview  113
Durability  113
Long-Term Performance  113
Climate Change  114
Technological Obsolescence  114
Maintainability  114

Safety  115
Gravitational and Lateral Loads  115
Wind  115
Shelter  116
Seismic  118
Flood  119
Fire  120

Security  122
Blast Resistance  122
Chemical and Biological Protection  124
Radiological and Nuclear Protection  125
Ballistic Protection  125
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Sections</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forced Entry/Physical Attack Resistance</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>Cybersecurity</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>Security Planning and Design: Continuing Education</td>
<td>127</td>
<td></td>
</tr>
<tr>
<td>Sustainability</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>Energy and Environmental Impact</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>Interaction with Resilience Strategies</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>Good Practices in Resilience-Based Architectural Designs</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Overview</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Building Function and Tenants</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Building Siting and Layout</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>Passive Design</td>
<td>131</td>
<td></td>
</tr>
<tr>
<td>Active Systems</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>Operational Infrastructure versus Life Safety/Security Infrastructure</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>Multihazards Needs</td>
<td>134</td>
<td></td>
</tr>
<tr>
<td>Continued Operations Goals</td>
<td>136</td>
<td></td>
</tr>
<tr>
<td>Crime Prevention Through Environmental Design</td>
<td>136</td>
<td></td>
</tr>
<tr>
<td>CPTED Concepts</td>
<td>136</td>
<td></td>
</tr>
<tr>
<td>Strategies</td>
<td>137</td>
<td></td>
</tr>
<tr>
<td>Subdivisions and Office Parks</td>
<td>138</td>
<td></td>
</tr>
<tr>
<td>Multi-Family Dwellings</td>
<td>138</td>
<td></td>
</tr>
<tr>
<td>Lifecycle Considerations in Resilience-Based Designs</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>Overview</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>Short-Term versus Long Term Resilience Planning</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>Existing Structures versus New Buildings</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>Chapter Appendices</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>Resilience Assessment</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>Resilience Acceptance</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>CHAPTER 4 ARCHITECTURAL CONSTRUCTION DOCUMENTATION</td>
<td>141</td>
<td></td>
</tr>
<tr>
<td>Drawings</td>
<td>142</td>
<td></td>
</tr>
<tr>
<td>Ideology of Construction Drawings</td>
<td>142</td>
<td></td>
</tr>
<tr>
<td>National CAD Standard</td>
<td>142</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>142</td>
<td></td>
</tr>
<tr>
<td>Drawing Conventions</td>
<td>142</td>
<td></td>
</tr>
<tr>
<td>Symbol Classification Structure</td>
<td>144</td>
<td></td>
</tr>
<tr>
<td>Construction Specifications</td>
<td>146</td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>146</td>
<td></td>
</tr>
<tr>
<td>OmniClass Construction Classification System</td>
<td>147</td>
<td></td>
</tr>
<tr>
<td>UniFormat</td>
<td>148</td>
<td></td>
</tr>
<tr>
<td>MasterFormat</td>
<td>149</td>
<td></td>
</tr>
<tr>
<td>SectionFormat</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Implementing Sustainable Products and Procedures</td>
<td>151</td>
<td></td>
</tr>
<tr>
<td>Building Information Modeling (BIM)</td>
<td>151</td>
<td></td>
</tr>
<tr>
<td>How BIM Overcomes the Limitations of CAD</td>
<td>152</td>
<td></td>
</tr>
<tr>
<td>Procurement Documents</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>SECTION 2: MATERIALS . . . 161</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHAPTER 6 MASONRY</td>
<td>181</td>
<td></td>
</tr>
<tr>
<td>Typical Components Applicable to Masonry Work</td>
<td>182</td>
<td></td>
</tr>
<tr>
<td>Clay Masonry Units</td>
<td>182</td>
<td></td>
</tr>
<tr>
<td>Structural Facing Tile: Wall Sections and Properties</td>
<td>183</td>
<td></td>
</tr>
<tr>
<td>Concrete Masonry Units</td>
<td>184</td>
<td></td>
</tr>
<tr>
<td>Glass Unit Masonry</td>
<td>185</td>
<td></td>
</tr>
<tr>
<td>Glass Block: Design Data</td>
<td>185</td>
<td></td>
</tr>
<tr>
<td>Stone Assemblies</td>
<td>187</td>
<td></td>
</tr>
<tr>
<td>Stone Uses and Properties</td>
<td>187</td>
<td></td>
</tr>
<tr>
<td>Stone Masonry Patterns and Veneer</td>
<td>189</td>
<td></td>
</tr>
<tr>
<td>Stone Details</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>Masonry Mortaring and Grouting</td>
<td>191</td>
<td></td>
</tr>
<tr>
<td>Mortar and Grout</td>
<td>191</td>
<td></td>
</tr>
<tr>
<td>Masonry Anchorage, Reinforcing, and Accessories</td>
<td>194</td>
<td></td>
</tr>
<tr>
<td>Masonry Anchorage and Reinforcing</td>
<td>194</td>
<td></td>
</tr>
<tr>
<td>Masonry Ties</td>
<td>195</td>
<td></td>
</tr>
<tr>
<td>Masonry Accessories</td>
<td>197</td>
<td></td>
</tr>
<tr>
<td>Masonry Movement Joints</td>
<td>198</td>
<td></td>
</tr>
<tr>
<td>Installation Guidelines and Construction Tolerances</td>
<td>199</td>
<td></td>
</tr>
<tr>
<td>Lintels</td>
<td>199</td>
<td></td>
</tr>
<tr>
<td>Unit Masonry</td>
<td>201</td>
<td></td>
</tr>
<tr>
<td>Columns, Pilasters, and Beams</td>
<td>202</td>
<td></td>
</tr>
<tr>
<td>Masonry Arches</td>
<td>204</td>
<td></td>
</tr>
<tr>
<td>Glass Block Installation</td>
<td>206</td>
<td></td>
</tr>
<tr>
<td>CHAPTER 7 METALS</td>
<td>209</td>
<td></td>
</tr>
<tr>
<td>Common Characteristics, Standards, and Practices</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Properties of Metals</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Finishes on Metals</td>
<td>212</td>
<td></td>
</tr>
<tr>
<td>Steel Sheets, Coils, and Plates</td>
<td>214</td>
<td></td>
</tr>
<tr>
<td>Typical Metal Products Incorporated into Applicable Work Results</td>
<td>216</td>
<td></td>
</tr>
<tr>
<td>Structural Metal Framing</td>
<td>216</td>
<td></td>
</tr>
</tbody>
</table>
### Decorative Metal
- Decorative Metal Detailing 224
- Perforated Metals 225
- Perforated and Sheet Metals 227
- CNC Machining for Metalwork 228

### Installation Guidelines and Construction Tolerances
- Metal Fastenings 228

### CHAPTER 8
#### WOOD, PLASTICS, AND COMPOSITES
- Common Characteristics, Standards, and Practices 234
  - Wood Materials 234
  - Wood Classification 236
    - Wood Classification—Softwood and Hardwood 236
    - Wood Sources 236
    - Forest Certification 236
    - Reclaimed Wood 236
  - Wood Treatment 236
    - Wood Preservatives 236
    - Fire-Resistant Construction 238
  - Typical Wood, Plastic, and Composite Products Incorporated into Applicable Work Results 240
    - Plywood Design Data 240
    - Plywood Panel Types 241
    - Wall and Roof Sheathing 244
    - Plywood Subflooring on Wood Framing 245
    - Plywood Sheathing for Roofs and Soffits 246
    - Oriented Strand Board 247
    - Panel Products and Wood Veneers 247
    - Panel Products and Wood Veneers 249

### CHAPTER 9
#### GLASS
- Common Characteristics, Standards, and Practices 260
  - Glass Products 260
  - Thermal Resistance Values of Glazing Materials 263
  - Solar Gain Through Fenestration Systems 263
  - Properties of Glazing Materials Used in Manufactured Window Units 265

### CHAPTER 10
#### ELEMENT A: SUBSTRUCTURE
- Soils and Soils Explorations 274
  - Soils Definitions: Terms and Classifications 274
  - Soil Studies and Reports 275
  - Expansive Soils 278
  - Radon in Soils 279
  - Climatic Foundation Issues 279
- Foundations 283
  - General 283
  - Settlement and Differential Settlement 283
  - Standard Foundations 284
  - Shallow Foundations 285
  - Foundations Details 289
  - Foundation Reinforcing 292
  - Special Foundations 293
  - Seismic Base Isolation 297
- Cast-in-Place Concrete Slab 298
  - General 299
  - Subgrade 299
  - Types of Slabs-on-Grades 301

#### Crawl Space Construction 303
- Crawl Space Insulation and Ventilation 303

#### Basement Construction 304
- Basement Walls 304
- Backfilling Against Basement Walls 308

### CHAPTER 11
#### ELEMENT B: SHELL
- Design Considerations 314
  - Climate and Energy 314
  - Exterior Climatic Influence 314
  - Interior Climatic Influence 315
  - Considerations for Climate Zones 316
  - Thermal Movement 316
- Sustainability and Energy 320
  - Long-Span and Tensile Structures 320

#### Floor Assemblies 322
- Roof Assemblies 326

#### Superstructure 329
- Comparison of Systems 329
- Selected Floor Loads 330
- Concrete 330
- Structural Metal 340
- Balconies and Guardrails 344
- Space Frames 345
- Exterior Wall Construction 347
- Cold-Formed Metal Roof Framing 349
- Metal Roof Decking 350
- Metal Stairs 351
- Wood Framing 356
- Shop-Fabricated Structural Wood 364
- Heavy Timber Construction 365
- Glued-Laminated Construction 370
- Wood Decking 371
- Framing Details for Roofs 374
- Shop-Fabricated Wood Trusses 376
- Glued-Laminated Construction 379
- Timber Frame Roof Decking 382
- Composite Systems 384
- Glass Flooring 386

#### Exterior Vertical Enclosures 387
- Exterior Walls 387
- Exterior Windows 438
- Exterior Doors 459

#### Exterior Horizontal Enclosures 468
- Roofing Design Considerations 468
- Roof Coverings 471
- Roof Openings 516
CHAPTER 12
ELEMENT C: INTERIORS 527
Interior Construction 528
Interior Partitions 528
Finishes 546
Interior Windows and Glazing 566
Interior Doors 570
Interior Hardware 583
Access Panels 589
Interior Floor Construction 590
Floor and Base Finishes 593
Floor Transitions 607
Interior Ceiling Construction 609
Ceiling Finishes 611
Interior Specialties 618
Safety Specialties 637

CHAPTER 13
ELEMENT D: SERVICES 641
Conveying 642
Design Considerations 642
Elevators 642
Escalators and Moving Walks 652
Dumbwaiters 653

Other Conveying Equipment 655
Material Processing and Handling Equipment 655
Chutes 659
Plumbing 659
Design Considerations 659
Accessibility 660
Sustainability 660
Domestic Water Distribution 660
Other Plumbing Systems 661
Sanitary Waste 663
Plumbing Fixtures 674
Rainwater Drainage 682
Graywater Systems 685

Heating, Ventilating, and Air-Conditioning (HVAC) 691
Design Considerations 691
Industry Standards 691
Sustainability 691
Climate and HVAC Systems 691
Design Process 691
Design Coordination 692
HVAC System Types 694
Heating/Cooling Source Components 699
Heat Generation 699
Refrigeration 707
HVAC Distribution Arrangements and Components 711
HVAC Delivery Components 722
HVAC Control Systems 725
Other HVAC Systems and Equipment 726
Economizers 728
Fire Protection 732
Design Considerations 732
Sprinkler Occupancy Hazard Classifications 733
Types of Fires 733
Sprinkler Heads 733
Standpipes 736
FDC Connection 736
Fire-Protection Pumping Systems 738
Rated/Nonrated Cabinets 741
Fire-Protection Specialties 741
Other Fire-Protection Systems 742
Locating Pull Stations and Extinguishers 742
Electrical 744
Industry Standards 744
Sustainability 744
Transformers 744
Lighting and Branch Wiring 746
Electrical Panelboards, Circuit Breakers, Disconnect Switches, and Fuses 752
GFCI 754
Lighting Control 760
Light Trespass and Light Pollution 761
Facility Power Generation: PV 762
Other Electrical Systems 764
Communications 767
Design Considerations 767
Telecommunications Systems 768
Local Area Networks 772
Building Management Systems 773
CHAPTER 14
ELEMENT E: EQUIPMENT AND FURNISHINGS 779
Equipment 780
Vehicular and Pedestrian Equipment 780
Commercial Equipment 785
Institutional Equipment 807
Sight Lines 812
Human Factors and Audiovisual Design 813
Audio Intelligibility 813
Presentation Rooms 814
AV Support Spaces 814
AV Control Rooms 815
AV Equipment Rooms 815
Residential Equipment 817
Entertainment and Recreational Equipment 821
Other Equipment 833
Furnishings 836
Fixed Furnishings 836
Movable Furnishings 849

CHAPTER 15
ELEMENT F: SPECIAL CONSTRUCTION 877
Design Considerations of Integrated Construction 878
Building Modules 878
Integrated Frame 878
External Frame 879
Manufactured—Fabricated Rooms 881
Clean Rooms 881
Cold Storage Rooms 883
Sound-Conditioned Rooms 884
Saunas and Steam Baths 885
Vaults 887
Paint Booths 888

Special Structures 890
Fabric Structures 890
Air-Supported Structures 892
Space Frames 893
Manufactured Engineered Structures 893
Glazed Structures 893
Metal Building Systems 894