### Index

**A**
- Aalto, Alvar, 71
- Abbey church of St-Philibert (Tournus, France), 6
- Access flooring systems, 325
- Active damping mechanisms, 302–303
- Adams Kara Taylor, 250
- Aerodynamic damping mechanisms, 304
- Air Force Academy Chapel (Colorado Springs, USA), 18
- Air-handling units, 312
- Air-inflated structures, 267
- Air-supported structures, 267
- Air-water HVAC systems, 314–315
- All-air HVAC systems, 313, 315
- All-water HVAC systems, 313, 315
- Alvastra (Sweden), 3
- American Society for Testing and Materials (ASTM), 35
- Anchorage, defined, 97
- Ando, Tadao, 151
- Angus Glen Community Center and Library (Markham, Canada), 161
- Arched frames, 257
- Arches, 254–259
  - Concrete, 240–241
  - Corbeled, 3
  - Fixed, 254
  - Funicular, 254
  - Glue-laminated, 240–241, 256, 258
  - Masonry, 4
  - Rigid, 255
  - Steel, 240–241
  - Three-hinged, 244, 256, 258, 264
  - Trussed, 9, 239, 257
  - Two-hinged, 265
- Architectural structures
  - Celebrating the structure, 18–19
  - Concealing the structure, 17
  - Correspondence between structural form and spatial composition, 20
- Arena Minore, Yoyogi National Gymnasium (Tokyo, Japan), 265
- Arup, 300–301
- Aspdin, Joseph, 9
- Asplund, Erik Gunnar, 63
- ASTM (American Society for Testing and Materials), 35
- Auer + Weber Associates, 63
- Austria, 71
- Axial loads, 158–160, 283

**B**
- Banff Community Recreation Center (Banff, Canada), 245
- Bank of China Building (Hong Kong, China), 295
- Banpo (China), 2
- Barlow, William, 9
- Barnes House (Nanaimo, Canada), 151
- Base isolation, 232, 302
- Bauerfeld, Walter, 11
- Beach House (Victoria, Australia), 138
- Beam-and-girder system, steel, 116, 119
- Beams, 90–91
- Bending moments, 90–91
- Bending stress, 90–91
- Cantilevered buildings, 137
- Castellated, 323
- Collector, 51–53, 56
- Column supports for, 168
- Column-beam connections, 168
- Deflection, 90–91
- Feeder, 51–53, 56
- High-rise structures, 281
- Lateral buckling, 91
- Load tracing, 97
- Load-bearing structures, 90
- Roof, 192
- Shear walls, 42, 48, 79, 97, 152
- Columns, 169
- Concrete, 153, 170–171
- Masonry, 153, 172–173
- Belgian trusses, 246
- Bell, Alexander Graham, 11
- Belt trusses, 293
- Bending moments, 136
- Corner bays, 144
- High-rise structures, 290
- Horizontal spans, 90–91, 96, 102, 111, 157
- Lateral stability, 199, 212–213
- Roof structures, 195
- Systems integration strategies, 323
- Wind loads, 202

- Bending stress, 90–91
- Berg, Max, 11
- Bernoulli, Daniel, 8
- Bessemer, Henry, 9
- Bibliotheca Alexandrina (Alexandrian Library) (Alexandria, Egypt), 62
- Blowers, 312
- Boilers, 312
- Bolted connections, 28
- Bowstring trusses, 246
- Box girders, 263
- Braced core structures, 283, 286, 291
- Braced frames, 207–209, 218–220, 222
- Chevron bracing, 209
- Diagonal bracing, 208
- Diagonal tension-counter systems, 209
- Eccentric bracing, 210
- High-rise structures, 287–288
- Horizontal, 231
- K-bracing, 209
- Knee braces, 208
- Multi-bay arrangements, 211
braced frames (continued)
  stabilizing, 292
  V-bracing, 209
  X-bracing, 209
braced tube structures, 294
bracketing, 146
Bramah, Joseph, 8
Bramante, Donato, 7
Brunelleschi, Filippo, 6–7
building traps, 308
bulk-active structures, 26
bundled tube structures, 287–288, 295
Burj Dubai (United Arab Emirates), 13
butt joints, 28, 162
cable net systems, 185
cable structures, 237, 260–265
cable-restrained pneumatic structures, 267
cable-stayed structures, 263–264
caissons, 84
Calatrava, Santiago, 259, 273
Can Lis (Majorca, Spain), 75
Candela, Felix, 18
cantilevers, 136–139
cantilevered buildings, 137–139, 300–301
high-rise structures, 281
overhanging beams, 136, 138
Cappadocia (Turkey), 2
cap-truss structures, 283
Casa del Fascio (Como, Italy), 20
cast iron, 4, 6, 8, 10
castellated beams, 323, 338
Catal Hüyük (Turkey), 2
catenary, defined, 260
Cathedral of Florence (Florence, Italy), 7
CATIA (Computer Aided Design, Engineering, and Manufacturing), 17
cave dwellings, 2–5
ceiling plane, 150, 152
celebrating the structure, 18–19
cellular decking, 122, 322
cement
  hydraulic, 8
  Portland, 9
Centra at Metropark (Iselin, USA), 161
Centraal Beheer Insurance Offices (Apeldoorn, Netherlands), 52
central heating, 8
Centre Le Corbusier/Heidi Weber Pavilion (Zurich, Switzerland), 16
Chan Chan (Peru), 6
chevron bracing, 209
Chile, 62–63
chimneys, 312
China Central Television (CCTV) Headquarters (Beijing, China), 300–301
Chrysler Building (New York, USA), 10
circuitous load paths, 38
CMU (concrete masonry units), 172–173
code requirements, 29
coffered concrete domes, 5
collector beams
  defined, 51
  modifying grid proportions, 56
  radial grids, 53
  rectangular grids, 51
  tartan grids, 52
 collector elements, 233
Colosseum (Rome, Italy), 4
column-and-beam (trabeated) stone structures, 3
columns, 158–169
  base supports, 168
  bearing walls, 169
  column-and-beam frames, 42, 48–49
  column-beam connections, 168
  composite, 164
  concrete, 162–163
  earthquake resistance, 164
  effective length, 159
  high-rise structures, 281, 283–284, 290
  inclined, 160–161
  loads, 158
  reinforcement of, 162–163
  slenderness ratio, 158
  steel, 164–165
  stone, 3
  struts, 160
  supports for beams, 168
  tributary area, 154
  tributary load, 154
  vertical continuity, 156
  wind loads, 164
  wood, 166–168
  composite columns, 164
  composite decking, 122–123
  compound steel columns, 164
Computer Aided Design, Engineering, and Manufacturing (CATIA), 17
concealing the structure, 17
concentrated loading, 96
beams and girders, 91
bearing walls, 169
bracketing, 146
columns, 42, 155, 158, 160
long-span structures, 237, 260, 271
masonry walls, 173
mat foundations, 84
parking structures, 87
roof structures, 194
scale, 47
shear walls, 214
steel spanning systems, 117, 124
studding, 214–215
transverse beams, 156–157
wood spanning systems, 92, 128–131
concrete, 4
  corner structural bays, 144
  flat plates, 108–107, 236
  hydraulic, 9
  joists, 104–105
  prestressed, 100, 114–115, 329
  reinforced, 11, 243
  reinforced, 9–12, 179
concrete arches, 240–241
concrete beams, 91, 102–103, 243
  precast, 115
  slabs with, 110–111
  spanning ranges, 100, 240–241
concrete domes, 5, 11–12, 240–241
concrete masonry units (CMU), 172–173
concrete planks, 92, 94, 115, 329
concrete roof vaults, 10
concrete slabs, 92
  with beams, 100, 110–111
  diaphragms, 217
  flat, 100, 108–109, 115, 280
  hollow core, 115
  joist, 100, 104–105, 328
  one-way spanning systems, 100, 102–103
  precast, 100, 114–115
  spanning ranges, 98, 100
  two-way spanning systems, 99–100, 110–111
  waffle, 100, 112–113, 240–241, 328
concrete support systems, 152
  bearing walls, 153, 170–171
  columns, 162–163
  moment frames, 213
  reinforced frames for curtain walls, 179
  shear walls, 214
  structural frames, 153
concrete walls, 170–171
  bearing, 153, 170–171
  curtain walls, 179
  shear, 214
contextual patterns, defined, 40
continuity, 38
continuous load paths, 38
contrasting geometry, 54, 60–63, 82
contrasting orientation, 64–67, 82
Cook, Peter, 71
cooling towers, 312
corbel brackets, 3, 5
corbeled arches, 3
corners, 80–83
curved, 80, 83
  emphasized, 80, 82
  with equivalent sides, 80–81
  with one side dominant, 80–81
  reentrant, 226–227
  as void, 80, 83
  coupled shear walls, 292
crescent trusses, 246
Crystal Palace (London, England), 9
curtain walls, 176–183
  corners, 144
  curvilinear, 77
  fire resistance, 177
  loads, 176–183
  structural frames, 179–183
  sunlight exposure, 177
  temperature, 177
  water, 177
  wind loads, 176
D
Daly Genik Architects, 67
damping mechanisms, 206, 302–304
active, 302–303
aerodynamic, 304
passive, 304
Darby, Abraham, 8
INDEX

David Chipperfield Architects, 73
dead loads
  building scale, 149
defined, 97
earthquake resistance, 204
lateral stability, 198
long-span structures, 243, 261, 263
shear walls, 214
decking
  cellular, 122, 322
  composite, 122–123
  form, 122–123
  load tracing, 97
  roof, 122–123
  steel, 92, 100, 122–123, 217
  structural layers, 94
  wood, 100, 130–131
deflection, 90–91
  base isolation, 232
  cantilevers, 136, 138
  concrete spanning systems, 107
  diaphragms, 216
  distributed loading, 96
  high-rise structures, 278–279, 282–284, 302–303
  long-span structures, 236–237, 243, 252, 256
  moment frames, 212, 219
  overhanging beams, 136
  reentrant corners, 226
  shear walls, 219
  steel spanning systems, 116
  walls, 176, 182
  wind loads, 202
  wood spanning systems, 126, 131
Della Porta, Giacomo, 7
deluge sprinkler systems, 309
detailing of building components, 233–234
determinate structures, 36
diagonal bracing, 38
  braced frames, 208
  columns, 164
  corner bays, 146
  curtain walls, 183
  high-rise structures, 292
  long-span structures, 247, 255, 263
  steel spanning systems, 116
  walls, 153, 180
  wood spanning systems, 126, 128
diagonal tension-counter systems, 209
diagrids, 186–187, 287–288, 297–300
diaphragms, 207, 216–218, 223
  concrete slabs, 217
  discontinuities in, 228
  flexible, 216
  light-frame construction, 217
  metal decking, 217
  rigid, 216
direct load paths, 38
The Discourses and Mathematical Demonstrations Relating to Two New Sciences (Galileo), 7
distributed loading, 42, 96
  bearing walls, 169
  cantilevers, 136
  concrete spanning systems, 104
  load tracing, 97
  long-span structures, 237, 260
  overhanging beams, 136
  regular structural grids, 51
  steel spanning systems, 117
  structural layers, 94
  walls, 99, 174
  wood spanning systems, 128, 132
distribution ribs, 104
Ditherington Flax Mill (Shrewsbury, England), 8
domes, 274–276
  concrete, 5, 11–12, 240–241
defined, 274
diastrophes, 11, 275–276
  lattice, 275
  loading, 237
  ribbed steel, 240–241
  Schwedler, 275
double-curve structures, 261
drag, 198, 200, 304
drift
  eccentric bracing, 210
  high-rise structures, 278–279, 283, 290, 292, 297
  reentrant corners, 227
  story, 232
torsional irregularity, 224
dry-pipe sprinkler systems, 309
eccentric loads, 158
Eden Project Bio Domes (Cornwall, England), 276
  effective length, 159
effective length factor, 159
Eiffel, Gustave, 10
Eiffel Tower (Paris, France), 10
electrical circuits, 311
electrical systems, 306, 310–311
electrical wiring, 311
elevators (lifts), 9, 306
Empire State Building (New York, USA), 11
energy conservation, 12
Willis, Faber & Dumas Headquarters, 77
EOS Housing (Helsingborg, Sweden), 75
ESO (European Southern Observatory) Hotel (Chile), 62–63
  exposing the structural system, 16
text
  exterior high-rise structures, 286–289

F
Factory Mutual, 35
fan cable-stayed structures, 263
fan rooms, 312, 316
fan-coil units, 313, 315
feeder beams
  defined, 51
  modifying grid proportions, 56
  radial grids, 53
  rectangular grids, 51
  tartan grids, 52
Fink trusses, 248
Finland, 71
fire protection systems, 309
fire resistance
  floor systems, 95
  horizontal span materials, 93
  long-span structures, 238
  parking structures, 87
  precast concrete slabs, 114
  ratings, 31–32, 34–35
  steel columns, 184
  steel joist structures, 117
  vertical support systems, 152–153
  walls, 169–170, 174, 177
  wood construction, 126
fire-baked brick structures, 3
Fitzpatrick + Partners, 187
fixed arches, 254
flat plates, 156–157, 326
flat roofs, 189
flat slabs, 100, 108–109, 115, 280
flat trusses, 240–241, 246
flexing buttresses, 6
folded plate structures, 240–241, 269
form decking, 122–123
form-active structures, 26
Foster, Norman, 19, 77, 298–299
Foster + Partners, 77, 185, 298–299
foundation grids, 84
foundations, 23
Fourier, Colin, 71
Fox, Kohn Pedersen, 77
Freyssinet, Eugène, 11
friction dampers, 304
Fuller, Buckminster, 11
fundamental period of vibration, 205
funicular arches, 254

G
gable roofs, 193
Galileo, 7
GEC Architecture, 245
Gehry, Frank, 17, 251
Gehry Partners, 251
galvanized domes, 11, 275–276
irregular building configurations, 224–230
moment frames, 212–213, 219
regular building configuration, 220–223
shear walls, 214–215, 219
wind loads, 198–202
lateral-force-resisting systems, 207–234
braced frames, 208–211, 219, 231
continuity in, 38
detailing of building components, 233–234
diaphragms, 216–217
irregular building configurations, 224–230
moment frames, 212–213, 219
pattern of, 41
redundancy in, 36
regular building configuration, 220–223
shear walls, 214–215, 219
lattice domes, 275
Le Corbusier, 14, 16, 59, 69
Lee, C.Y., 13
Leatherdale, J., 12
Los Manantiales (Xochimilco, Mexico), 18
London City Hall (London, England), 185
London County Hall (London, England), 185
...
structural patterns, 39–88. See also structural grids
assembling structural units, 44

vertical distribution, 316–319
water supply systems, 307

T
Taipei 101 (Taiwan), 13
Taiwan, 13
Taj Mahal (Agra, India), 8
Tange, Kenzo, 12, 73, 265
tartan grids, 52
temperature differential
high-rise structures, 279
long-span structures, 255
walls, 173, 177, 179, 183
Temple of Amun (Karnak, Egypt), 3
tendon damping systems, 303
Tenerife Concert Hall (Santa Cruz de Tenerife, Spain),
273
tent structures, 266
terminal reheat systems, 313, 315
Terragni, Giuseppe, 20
30 St. Mary Axe (The Gherkin; Swiss Re Building)
(London, England), 299
tensional irregularity, 224–225
torsional moments, 222, 225, 284
Tower Verre (New York, USA), 300
Toyo Ito and Associates, 187
trabeated (column-and-beam) stone structures, 3
transformers, 310–311
transitional (interstitial) spaces
to mediate between structures of contrasting
grid, 60–63
to mediate between structures of contrasting
orientation, 64–67
to mediate between structures of sheared grids,
79
transitional structural patterns, 80–83
translational shell surfaces, 271
transverse shear, 50
tributary area, 97, 154, 171
tributary loads
defined, 97
long-span structures, 237
vertical support systems, 154
triple-layer system, 121
trussed arches, 9, 239, 257
trussed joists
high-rise structures, 280
wood, 100, 134–135
trussed tube structures, 287–288
trusses
Belgian, 246
belt, 293
bowstring, 246
bracing, 247
cabled, 185
cantilevered buildings, 137, 139
crescent, 246
Fink, 246
flat, 240–241, 246
Howe, 246
long-span structures, 239–241, 244–253
mast, 185
open-web, 249
INDEX

trusses (continued)
  parallel-chord, 249
  planar, 184–185
  Pratt, 246
  scissors, 246
  shaped, 240–241
  spacing, 247
  steel, 120, 240–241, 249
  structural layers, 94
  transfer, 156–157
  vertical, 141
  Vierendeel, 252
  Warren, 246
  wood, 134–135, 240–241, 249
  tube structures, 287–288, 291, 293
  tube-in-tube structures, 287, 294
  tuned liquid dampers, 302–303
  tuned mass dampers, 302–303
  vertical support systems. See supports
  vertical transportation systems, 9, 306
  Vierendeel frames, 137
  Vierendeel trusses, 252
  Vincent James Associates, 245
  viscoelastic and viscous dampers, 304
  vortices, 201

W
  Wachsmann, Konrad, 11
  waffle slabs, 100, 112–113, 240–241, 328
  walls, 150, 170–187
  concrete, 153, 170–171, 179, 214
  curtain walls, 77, 144, 176–183
  diagrids, 186–187
  masonry, 152–153, 172–173
  platform framing, 175
  shear, 207, 214–215, 218–222, 233, 284, 286,
  288, 290–292
  steel, 153, 174–175
  structural glass facades, 184–185
  wood, 153, 174–175
  Walt Disney Concert Hall (Los Angeles, USA), 251
  Warren trusses, 246
  water heaters, 307
  water supply systems, 306–307
  Waterman, Henry, 9
  watt-hour meters, 310
  weak stories, 229
  welded connections, 28
  Western Wood Structures, 258
  wet-pipe sprinkler systems, 309
  wide-flange steel beams, 100, 116, 164, 240–241,
  243
  Wilhelmson, Anders, 75
  Willis, Faber & Dumas Headquarters (Ipswich,
  England), 77

wind loads
  bearing walls, 169
  building scale, 149
  cable structures, 260, 262, 264
  columns, 164
  curtain walls, 176, 178–179
  direct pressure, 200
  distributed loading, 96
  drag, 200
  eddies, 201
  high-rise structures, 280, 282, 290, 300, 302–303
  lateral stability, 198–202
  long-span structures, 237, 253
  overturning, 200
  roof structures, 188, 190
  sliding, 200
  steel beams and girders, 116

substructure, 22
  suction, 200
  tall, slender structures, 202
  turbulence, 201
  vertical support systems, 152
  vortices, 201
  wiring chases, 317
  wood
    heavy timber framing, 34, 93, 126, 128, 153, 242
    light wood framing, 126, 132, 175
    timber framework structures, 5–6
  wood beams, 91–92
    glue-laminated timber, 100, 126–127, 240–242
    laminated veneer lumber, 100, 126–127
    parallel strand lumber, 100, 126–127
    plank-and-beam systems, 128–129
    solid sawn lumber, 100, 126–127
    spanning ranges, 100
  wood spanning systems, 92–93, 98, 100, 126–135
    beams, 126–127
    construction depth, 95
    corner bays, 146
    decking, 130–131
    heavy timber framing, 126
    joists, 132–133
    light wood framing, 126
    plank-and-beam systems, 128–129
    prefabricated joists and trusses, 134–135
    structural layers, 94–95
  wood stilt structures, 3
  wood trusses, 134–135, 240–241, 249
  wood vertical support systems
    columns, 166–168
    moment frames, 213
    shear walls, 214
    stud walls, 153
  wood walls
    platform framing, 175
    structural frames, 153
    stud walls, 153, 174
  World Trade Center Towers (New York, USA), 293
  Wright, Frank Lloyd, 12
  wrought iron structures, 9

X
  X-bracing, 209

Y
  Yeang, Ken, 151
  Young, Thomas, 8
  Yoyogi National Gymnasium (Tokyo, Japan), 73
  Yungang Grottoes (China), 5

Z
  Zaha Hadid Architects, 67, 251
  zoning ordinances, 30–31
  Züblin, Eduard, 10