



# INDEX

## A

- Abrams' law, 212–213
- Abrasion, 25
- Absolute viscosity procedure, 338
- Absorption, 167–168
  - defined, 167
- Accelerators, 225–227
- Accuracy, 27
- Additives, asphalt:
  - plastics, 385
  - rubber, 385
- Adhesives, 1
- Admixtures, 219–230, 296
  - requirements, concrete mix, 247
- Aesthetic characteristics of materials, 26–27
- Aggregates, 3, 159–200
  - abrasion resistance, 166–167
  - absorption, 167–168
  - affinity for asphalt, 191–192
  - alkali–aggregate reactivity, 190–191
  - angular, 163
  - blended, 185–187
    - properties of, 187–189
  - bulk unit weight and voids in
    - (experiment), 493–495
    - analysis and results, 495
    - apparatus, 493
    - test procedure, 493–494
  - deleterious substances in, 189–190
  - durability, 165–166
  - evaluation of suitability of, 161
  - gap-graded, 179
  - geological classification, 160–161
  - gradation and maximum size, 172–189
    - blended aggregate properties, 187–189
    - blending aggregates to meet
      - specifications, 185–187
    - fineness modulus, 184
    - gap-graded aggregates, 179
    - maximum density gradation, 175–179
    - one-sized graded aggregates, 179
    - open-graded aggregates, 179
    - sieve analysis, 174–175
    - specifications, 180–183
  - handling, 192–194
  - hardness, 166–167
  - hydrophilic, 191
  - hydrophobic, 191
  - igneous rocks, 160
  - lightweight synthetic, 2
  - Los Angeles abrasion test, 167
  - manufactured, 159
  - maximum size of aggregate particles,
    - 174, 193
  - metamorphic rocks, 161
  - modulus of elasticity of, 172
  - moist, 168
  - moisture condition states, 168
  - natural sources for, 159
  - nominal maximum aggregate size,
    - 174, 193
  - One-sized graded, 179
  - open-graded, 179
  - particle shape, 163–165
  - and portland cement concrete, 162
  - properties, 163–192
  - resilient modulus test, 172
  - rounded, 163
  - sampling, 192–193
    - from stockpiles, 192
  - sedimentary rocks, 160–161
  - sieve analysis of (experiment), 482–483
    - analysis and results, 484
    - apparatus, 482
    - test procedure, 483–484
    - test specimens, 482
  - soundness, 165–166

- Aggregates (*Continued*)
- sources, 159–160
    - evaluation of, 160
  - specific gravity, 169–170
  - stockpiles of, 192
  - stockpiling, 160
  - strength and modulus, 172
  - surface texture, 163–165
  - toughness, 166–167
  - underlying materials (base courses), 162
  - uses, 162–163
- Air drying wood, 405
- Air entrainment, 244–245
- agents, and permeability, 276
  - concrete, 211, 452
  - requirements, concrete mix, 244–245
- Aliphatic, 329
- Alloy atoms, arrangement of, 68
- Alloys, 67–68
- Aluminum, 55, 138–158
- advantages of, 140
  - alloying elements, 142
  - aluminum-copper phase diagram, 144
  - arc welding, 153
  - and bauxite, 140
  - brake forming, 143
  - casting and forming methods, 143
  - coefficient of thermal expansion, 153
  - corrosion, 154
  - cutting operations, 143
  - die casting, 143
  - drawing, 143
  - embossing, 143
  - extrusion, 143
  - fastening, 153–154
  - galvanic corrosion, 154
  - gas metal arc welding (GMAW), 153–154
  - gas tungsten arc welding (GTAW), 153–154
  - ingots, 142
  - metallurgy, 142–146
    - alloy designation system, 144–145
    - temper treatments, 145–146
  - molten, 142
  - production, 140–142
  - production of, 138
  - properties, 146–153
  - pure, 138
  - recycling, 142
  - roll forming, 143
  - rolling, 143
  - sand casting, 143
  - as steel alloying agent, 97
  - strengths of, 153
  - structures, 138
  - superplastic forming, 143
  - tensile strength of, 153
  - tension test of (experiment), 470–473
    - analysis and results, 472–473
    - apparatus, 470
    - replacement of specimens, 473
    - test procedure, 470–472
    - test specimens, 470
  - testing, 146–153
  - torsion test of (experiment), 474–476
    - analysis and results, 476
    - apparatus, 474
    - test procedure, 474–476
    - test specimens, 474
  - welding, 153–154
- Aluminum alloys, 140, 142, 145–146, 449
- properties of, 149–152
  - temper designations for, 147–148
  - in tension, 5
- American Association of State Highway and Transportation Officials (AASHTO), 27
- American Concrete Institute (ACI), 237, 296
- American Material Reference Laboratory (AMRL), 28
- American Society for Testing and Materials (ASTM), 27
- Angular aggregates, 163
- Angularity, aggregate particle shape, 163
- Anionic emulsion, 323
- Annealing, 67
- steel, 94–95
- Annual rings, trees, 396
- Anode, 128
- Antistripping agents, as asphalt additive, 385
- Apparent specific gravity, 169
- Appearance grades, glued–laminated wood, 434
- Aramid (Kevlar), 447
- Arc welding, 125
- Architectural grade, glued–laminated wood, 434
- Area defects, 64–65
- Arithmetic mean, 28–29
- Asbestos, 447

- Asphalt, 319–393
  - absolute viscosity test of (experiment), 533–534
    - analysis and results, 534
    - apparatus, 533
    - test procedure, 533–534
  - additives, 384–385
    - antistripping agents, 385
    - extenders, 384
    - fillers, 384
    - plastics, 385
    - rubber, 385
  - asphalt binders, 340–346
  - asphalt concrete, 348
    - characterization of, 377–381
    - diametral tensile resilient modulus test, 378–380
    - freeze and thaw test, 381
    - indirect tensile strength, 378
    - production, 381–382
    - recycling of, 382–384
    - rheological models, 381
    - specimen preparation in the laboratory, 349–351
  - asphalt concrete mix design, 348–377
  - asphalt emulsions, 322, 346–347
  - asphalt pavements, loads subjected to, 377–378
  - characterization of, 331–339
    - characterization of emulsion and cutback, 338–339
    - Performance Grade binder
      - characterization, 332–337
    - Performance Grade characterization approach, 331
    - traditional asphalt characterization tests, 338
  - chemical properties of, 328–329
  - classification of, 340–347
  - component fractionation schemes, 329
  - consistency of, 326
  - cutbacks, 322, 346
  - density and voids analysis, 351–355
  - dispersing in water as emulsion, 322–323
  - dissolving in a solvent, 322
  - emulsified, 322–323
  - liquid, 322–323
  - molecules, 329
  - paving applications of, 326
  - Performance Grade asphalt binder
    - specifications, 322
    - quantity/quality of, 319
    - separating, based on the molecular size, 329
  - Superpave mix design, 322
  - temperature susceptibility of, 326–328
  - Trinidad Lake asphalt, 319
  - types of products, 322–323
  - uses of, 323–326
- Asphalt binders, 330, 340–346
  - dynamic shear rheometer test of (experiment), 528–530
    - apparatus, 528
    - test procedure, 528–530
  - grading methods, 344–345
  - performance grade specifications and selection, 340–343
  - viscosity of by rotational viscometer (experiment), 526–527
    - apparatus, 526
    - test procedure, 526–527
- Asphalt cement, 322, 329
  - penetration test of (experiment), 531–532
    - apparatus, 531
    - test procedure, 532
- Asphalt concrete, 348, 452, 456
  - and aggregates, 162–163
  - characterization of, 377–381
  - diametral tensile resilient modulus test, 378–380
  - freeze and thaw test, 381
  - indirect tensile strength, 378
  - Marshall method of design, 349–351, 367–375
    - aggregate evaluation, 368
    - asphalt cement evaluation, 368
    - density and voids analysis, 369
    - design asphalt content determination, 369
    - job mix formula (JMF), 371
    - Marshall stability and flow measurement, 369–371
    - specimen preparation, 368–369
  - production, 381–382
  - recycling of, 382–384
  - rheological models, 381
  - specimen preparation in the laboratory, 349–351
  - specimens prepared using the Marshall compactor (experiment), 539–542
    - apparatus, 539
    - test procedure, 539–541

Asphalt concrete mix design, 348–377  
 objective of, 348  
 Asphalt cutbacks, 322, 346  
 Asphalt emulsions, 322, 346–347  
 Asphaltenes, 329  
 Atactic structures, 78–79  
 ASTM, 27  
 Atomic mass, 52  
 Atomic number, 52  
 Atomic packing factor (APF), 61–62

**B**

Bacteria, and wood, 419  
 Bark pockets, as lumber defect, 410  
 Bark, trees, 396  
 Barrier coatings, 128  
 Basic materials:  
 atomic mass, 52  
 atomic number, 52  
 bonding, 55–58  
 concepts, 52–59  
 electron configuration, 52–55  
 electrons, 52  
 elements, 52  
 inorganic solids, 74–77  
 isotopes, 52  
 metallic materials, 59–74  
 neutrons, 52  
 organic solids, 77–82  
 protons, 52  
 Basic oxygen furnaces, 88  
 Batching concrete, 256  
 Bauxite, 140  
 Beetles, and wood, 419  
 Behavior of materials, 52–85  
 Bend test, 122  
 Bending beam rheometer test, 336  
 Bias, 27  
 Bituminous materials, 319  
 Black heartwood, 419  
 Blaine fineness, 214  
 Bleeding, 377  
 Blended aggregates, 187–189  
 properties of, 187–189  
 Blended hydraulic cements, 216  
 Blunder, 27  
 Body center cubic (BCC) structure, 60, 63  
 Bolting, steel, 107  
 Bolts, aluminum, 153–154

Bonding, 55–58  
 covalent bonds, 56–57  
 interatomic bonds, 57  
 ionic bonds, 56–57  
 material classification by bond type, 58–59  
 metallic bonds, 56–58  
 primary bonds, 56–58  
 secondary bonds, 56, 58  
 Bone dry, use of term, 168  
 Bound water, 400  
 Box beams, 438  
 Brake forming, aluminum, 143  
 Breaking, emulsion, 323–326  
 Brick, 74–75, 305  
 Brittle materials, 10  
 and fractures, 20  
 Buckling, 20  
 Building bricks (common bricks), 311–312  
 Bulk-dry gravity, 169  
 Bulk-saturated surface–dry specific  
 gravity, 169  
 Burgers model, 17–18, 381

**C**

Calcium, 55  
 Calcium chloride, 225  
 alternatives to use of, 226–227  
 Calcium silicates, 205  
 Calcium-silicate-hydrate (C-S-H), 205  
 California kneading compactor method,  
 350–351  
 Cambium, trees, 396  
 Capillary voids, 209  
 Carbon-content steels, 115  
 Cast iron, 86  
 Catastrophic failure of a structural member, 3  
 Cathode, 128  
 Cathodic protection, 129  
 Cationic emulsion, 323  
 Cavities, 64  
 Cement, 75  
 inorganic, 74  
 Cement mortar, 314  
 Cement paste, 205  
 soundness of, 211  
 structure development in, 207  
 Cementing materials content requirements,  
 concrete mix, 247  
 Cementite, 96

- Cement–lime mortar, 314
- Cenistokes (cSt), 338
- Central plant recycling, 383–384
- Central tendency, 28
- Central-mixed concrete, 256
- Ceramic materials, 74–76
  - classes of, 75
  - high-performance ceramics, 75
  - tensile strength, 76
- Chace air indicator test, 264
- Chalk, 5
- Charpy V Notch impact test, 119–122
- Checks, as lumber defect, 410
- Chipped grain, as lumber defect, 410
- Chord modulus, 8, 277
- Chromium, 55
  - as steel alloying agent, 97
- Cinder blocks, 306
- Civil and construction engineers,
  - responsibilities of, 1
- Civil engineering materials:
  - advances in the technology of, 1
  - nature and behavior of, 2
- Civil engineering, predominant materials
  - used in, 58–59
- Civil engineers, and the quality control of
  - portland cement concrete, 235
- Clay bricks, 305–306, 311–313
  - absorption, 311
  - characteristics of, 311
  - compressive strength of, 312
  - defined, 311
  - nominal dimension, 313
  - specified (modular) dimension, 313
  - types of, 311
- Clay products, 75
- Cleveland open cup method, 334
- Coarse aggregate:
  - specific gravity and absorption of
    - (experiment), 487–489
    - analysis and results, 488
    - apparatus, 487
    - test procedure, 488
    - test specimens, 488
- Coarse aggregate requirements, concrete mix,
  - 241–244
- Coatings, 1
- Coefficient of thermal expansion, wood, 412
- Coherent boundary, 66–67
- Coherent strain boundary, 66–67
- Cold-formed metals, 1
- Common bricks, 311
- Compacted bituminous mixtures:
  - bulk specific gravity of (experiment),
    - 543–545
    - analysis and results, 543
    - apparatus, 543
    - test procedure, 543–545
    - test specimens, 543
- Composite panels, 457
- Composite structural members, 438
- Composites, 1–2, 445–464
  - classification scheme, 446
  - defined, 445
  - macroscopic composites, 446, 452–457
    - asphalt concrete, 456
    - engineered wood, 457
    - plain portland cement concrete, 455
    - reinforced portland cement concrete,
      - 455–456
  - microscopic composites, 446–452
    - civil and construction engineering
      - applications, 449–452
    - dispersed phase (reinforcing phase), 446
    - fabrication, 449
    - fiber-reinforced composites, 446,
      - 447–448
    - matrix phase, 446, 449
    - particle-reinforced composites, 446, 448
    - properties of, 457–462
      - loading parallel to fibers, 457–459
      - loading perpendicular to fibers, 459–460
    - particle-reinforced composites, 461
    - randomly oriented fiber composites, 461
- Compression, 55
- Compression parallel to the grain test, wood,
  - 550–551
- Compression perpendicular to grain test,
  - wood, 551–552
- Compression tests, wood, 416–417
- Compressive strength test, concrete, 279–281
- Compressive stress–strain curves, 5
- Concrete, 5, 75, *See also* Asphalt concrete;
  - Concrete masonry units; Concrete mix
    - proportioning; Conventional concrete
      - alternatives; Cylindrical concrete
        - specimens; Fiber-reinforced concrete;
        - Freshly mixed concrete; Hardened
          - concrete; Portland cement concrete
            - creep, 13–14

- Concrete (*Continued*)
  - flexural strength of (experiment), 515–517
    - analysis and results, 516–517
    - apparatus, 515
    - test procedure, 515–516
    - test specimens, 515
- Concrete blocks, 306
- Concrete bricks, 310
- Concrete cylinders and beam, making/curing (experiment), 506–509
  - apparatus, 506
  - precautions, 509
  - test procedure, 506–508
- Concrete masonry unit testing (experiment), 523–525
  - analysis and results, 525
  - apparatus, 523
  - test procedure for absorption, 524
  - test procedure for compressive strength, 523
- Concrete masonry units, 305–310
  - classes of, 306–307
  - concrete mixture used in manufacturing, 307
  - load-bearing units, 307
  - nominal dimension, 309–310
  - non-load-bearing units, 307
  - solid, 310
  - specified (modular) dimension, 309–310
  - water absorption in, 308–309
- Concrete mix proportioning, 235–255
  - basic steps, 236–237
    - admixture requirements, 247
    - air entrainment requirements, 244–245
    - cementing materials content requirements, 247
    - coarse aggregate requirements, 241–244
    - fine aggregate requirements, 247–250
    - moisture corrections, 250
    - strength requirements, 237–239
    - trial mixes, 250
    - water content requirements, 247
    - water-cementitious materials ratio requirements, 239–241
    - workability requirements, 245–247
  - mixing concrete for small jobs, 254–255
- Conductor, 128
- Conifers, 396
- Construction, 25–26
- Construction engineers, and the quality control of portland cement concrete, 235
- Consumer Product Safety Commission (CPSC), 422
- Control charts, 29–32
  - benefits of, 29–30
  - statistical, 30–32
  - types of, 30
- Control limits, 30
- Controlled density fill (CDF), 288
- Controlled low-strength material (CLSM), 288
- Conventional concrete alternatives, 287–297
  - fiber-reinforced concrete, 295–296
  - flowable fill, 288–290
  - heavyweight concrete, 292–293
  - high-performance concrete (HPC), 296–297
  - high-strength concrete, 293–294
  - lightweight concrete, 291–292
  - polymers and concrete, 294–295
  - roller-compacted concrete (RCC), 296
  - self-consolidating concrete (SCC), 287–288
  - shotcrete, 290–291
  - shrinkage-compensating concrete, 294
- Coordination number, 60–61
- Copper, 55
  - as steel alloying agent, 97
- Corrosion, 25
  - aluminum, 154
  - defined, 128
  - steel, 127–129
- Covalent bonds, 56–57
- Cracking, shrinkage-induced, 274–275
- Creep, 13–14, 275
  - wood, 413
- Crude petroleum, fractional distillation
  - process of, 319
- Crushed stones, 159
- Crystalline structure, metals/inorganic solids, 58
- C-S-H, 205
- Cupping, 410
- Curing, 211
  - concrete, 267–273
    - portland cement concrete, 267–273
      - curing period, 273
      - electrical, 273
      - fogging, 268
      - forms left in place, 273
      - hot oil, 273
      - immersion, 268
      - impervious papers/plastic sheets, 270
      - infrared, 273

- insulating blankets/covers, 273
  - membrane-forming compounds, 271–272
  - ponding, 268
  - spraying, 268
  - steam curing, 273
  - wet coverings, 268–270
  - Cutting operations, aluminum, 143
  - Cylindrical concrete specimens:
    - capping with sulfur or capping compound (experiment), 510–514
    - analysis and results, 514
    - apparatus, 510
    - capping procedure, 510–514
- D**
- Damping capacity, wood, 413–414
  - Dashpot, 15–18
  - Dead loads, 4
  - Decay damage, wood, 419
  - Deciduous trees, 396
  - Deformation–time diagram, 18
  - Deformed bars, steel, 109
  - Degradation, 25
  - Deleterious substances, in aggregates, 189–190
  - Density, 22–23
    - metallic materials, 63
    - and specific gravity, 169
    - wood, 410–411
  - Density and voids analysis, asphalt concrete, 351–355
  - Depositing concrete, 257–260
  - Deterioration rate, 3
  - Dial gauges, 33–34, 113, 466
  - Diametral tensile resilient modulus test,
    - asphalt concrete, 378–380
  - Diamond, 76
  - Die casting, aluminum, 143
  - Diffusivity, 459
  - Dimensional lumber, 402
  - Direct tension test, asphalt, 337
  - Disposal of waste water, concrete, 217–219
  - Distillation test:
    - of cutback asphalt, 339
    - of emulsified asphalt, 339
  - Drawing, aluminum, 143
  - Dried lumber products, 424
  - Drying shrinkage, 267, 274
  - Ductile materials, 10
  - Dynamic loads, 4–5
  - Dynamic shear rheometer test, 334–336
- E**
- Economic factors, material selection process, 2–3
  - Edge dislocation, 64
  - Effective specific gravity, aggregate, 170
  - E-Glass, 447
  - Elastic behavior, 6–8
  - Elastic limit, 8, 11
  - Elastic materials, 7
  - Elasticity, 7
  - Elastomers, 78–79
  - Elastoplastic behavior, 8–12
  - Electric arc furnaces, 88–89
  - Electrical conductivity, 459
  - Electrical curing, concrete, 273
  - Electrical properties, wood, 412
  - Electrolyte, 128
  - Electrons, 52
    - behavior of, 52
    - configuration, 52–55
      - samples, 54
    - distance between nucleus and, 52
    - energy level of, 53–54
    - shell, 53–55
    - subshells, 53–55
    - valence, 55
  - Elements, 52
  - Embossing, aluminum, 143
  - Emulsified asphalts, 322–323
  - Emulsifying agents, 323
  - Emulsion:
    - anionic, 323
    - asphalt, 322, 346–347
    - cationic, 323
  - Emulsion viscosity, 339
  - Endogenous trees, 394
  - Endurance limit, 20
  - Energy, 12–13
  - Engineered wood, 402–403, 422–438, 452, 457
    - composite structural members, 437–438
    - structural composite lumber (SCL), 425–426
    - structural panel products/sheets, 424–425
    - structural shapes, 425–438
      - glued–laminated timbers, 432–438
      - laminated strand lumber (LSL), 430, 432
      - laminated veneer lumber (LVL), 427–430
      - oriented strand lumber (OSL), 430, 432
      - parallel strand lumber, 430–431

- Engineering stress–strain curve, 114  
 Entraining air, 209  
 Environmental Protection Agency (EPA),  
   limits to water-soluble chloride ion  
   content, 226  
 Equilibrium moisture content (EMC), 401  
 Equilibrium spacing, 55  
 Error, 27  
 Eutectoid reaction, phase diagrams, 73–74  
 Exactness of measurements, 38  
 Excessive deformation, 20–21  
 Exogenous trees, 394–395  
 Expansive cements (type K), 216  
 Experimental error, 32  
 Extenders, as asphalt additive, 384  
 Extension yield stress, 11–12  
 Extensometers, 34, 113, 467–468  
 External vibrators, 261  
 Extractives, 400  
 Extrusion, aluminum, 143  
 Extrusive igneous rocks, 160
- F**
- Face center cubic (FCC) structure, 60  
 Facing bricks, 311, 313  
 Factor of safety (FS), 21  
 Failure, 19–22  
   buckling, 20  
   excessive deformation, 20–21  
   fatigue, 20  
   fracture, 20  
   functional, 3  
   general yielding, 20  
 False set, concrete, 211  
 Fastening products, steel, 86  
 Fatigue, 20  
 Fatigue cracking, pavement, 377  
 FBA (face brick architecture), 313  
 FBS (face brick standard), 313  
 FBX (face brick extra), 313  
 Ferrite, 91–93, 96  
 Ferrous metals, 86  
 Fiber composite materials, 2  
 Fiber saturation point (FSP), 400–401  
 Fiberglass, 448, 450–452  
 Fiber-reinforced composites, 446, 447–448  
 Fiber-reinforced concrete, 2, 295–296, 445,  
   450  
 Fiber-reinforced plastics, 445  
 Fiber-reinforced polymer (fiberglass), 448,  
   450–452
- Fibers, 447–448  
 Fibrils, 400  
 Fillers, as asphalt additive, 384  
 Fine aggregate:  
   requirements, concrete mix, 247–250  
   specific gravity and absorption of  
     (experiment), 490–492  
   analysis and results, 492  
   apparatus, 490  
   test procedure, 490–491  
 Fineness modulus, 184  
 Finishing concrete, 264–266  
 Flakeboard, 438  
 Flakiness, aggregate particle shape, 163  
 Flash point test, asphalt, 333–334  
 Flash set, concrete, 205  
 Flat-sawn boards, 404  
 Flexure strength test, concrete, 282–283  
 Floor bricks, 311  
 Flow mortar, 288  
 Flowable fill, concrete, 288–290  
 Flushing, pavement, 377  
 Fly ash, 291  
 Fly ash flow, 288  
 Fogging, concrete, 268  
 Foil–plastic strain gauges, 38  
 Force–displacement diagram, 12  
 Fracture, 20  
 Framing grade, glued–laminated wood, 433  
 Free moisture, aggregate, 168  
 Free water, wood, 400  
 Freeze and thaw test, asphalt concrete,  
   381  
 Freshly mixed concrete:  
   air content of, by pressure method  
     (experiment), 502–503,  
     apparatus, 502  
     test procedure, 502–503  
   air content of, by volumetric method  
     (experiment), 504–505  
     apparatus, 504  
     calibration, 504  
     test procedure, 504–505  
   slump of (experiment), 496–498  
   unit weight and yield of (experiment),  
     499–501  
   analysis and results, 500–501  
   apparatus, 499  
   test procedure, 499–500  
   apparatus, 496  
   test procedure, 496–498  
 Functional failures, 3



Fungi, and wood, 419  
Fuzzy grain, as lumber defect, 410

## G

Galvanic corrosion, aluminum, 154  
Gap-graded aggregates, 179  
Gas metal arc welding (GMAW), 153–154  
Gas tungsten arc welding (GTAW), 153–154  
Gas welding, 125–126  
General yielding, 20  
Generalized Hooke's law, 7  
Geotechnical engineers, responsibilities of, 1  
Geotextiles, 1  
GGBF slag, 228  
Gillmore test, 210  
Glass, 5, 74–75, 77  
Glass blocks, 305  
Glass fibers, 447–448  
Glued-laminated timbers, 457  
Glued-laminated wood, 432–438  
  defined, 432  
  grades, 433–434  
  stress classes of, 434  
Glulams, *See* Glued-laminated wood  
  defined, 432  
Gradation, aggregates, 172–189  
Grades, structural steel, 98–101  
Grain boundaries, 64, 66–67  
  effect on behavior of materials, 67  
Grain size, 67  
Grain structure, 64–67  
Graphite, 447  
Gravel, 159  
Gravimetric method, 263  
Gross area compressive strength, 307  
Ground granulated blast furnace slag  
  (GGBF slag), 228  
Grout, 314–315  
  defined, 314  
  use of, 314–315  
Gypsum, 205, 210–211  
Gyratory compaction devices, 349–350

## H

Hall-Hérault process, 140  
Hardened concrete:  
  penetration resistance of (experiment),  
    520–522  
  apparatus, 520  
  test procedure, 520–522

  properties, 274–278  
    creep, 275  
    early volume change, 274–275  
    permeability, 275–276  
    stress-strain relationship, 276–278  
  rebound number of (experiment), 518–519  
    apparatus, 518  
    test conditions, 519  
    test procedure, 519  
  testing, concrete, 278–287  
    compressive strength test, 279–281  
    flexure strength test, 282–283  
    maturity test, 285–286  
    penetration resistance test, 284  
    rebound hammer test, 283–284  
    split-tension test, 281–282  
    ultrasonic pulse velocity test, 285  
Hardening, 67  
  setting compared to, 209  
  steel, 95–96  
Hardness test, 122–124  
  Rockwell hardness test, 123  
  Rockwell superficial hardness test,  
    123–124  
Hardwood, 394–395  
Heartwood, 396–398  
Heat-affected zone (HAZ), 127  
Heavy timber, 402  
Heavyweight concrete, 292–293  
Hemicelluloses, 400  
Hexagonal close pack (HCP) structure, 60, 63  
Highly ordered polymers, 79  
High-performance ceramics, 75  
High-performance concrete (HPC), 296–297  
High-performance materials, 1  
High-performance steels (HPS), 102–104  
High-strength bolts, 107  
High-strength concrete, 293–294  
High-strength materials, 12–13  
High-toughness materials, 12–13  
HMA, *See* Hot-mix asphalt (HMA)  
Hollow blocks, 306  
Hooke, Robert, 5  
Hookean element, 15, 17  
Hooke's law, 5, 14  
Hot oil curing, 273  
Hot-mix asphalt (HMA), 348  
  specimen density by Superpave gyratory  
    compactor (experiment), 535–538  
  analysis and results, 537–538  
  apparatus, 535  
  test procedure, 535–537

HPC, 296–297  
 HPS, 102–104  
 Hume–Rothery rules, 68  
 Hveem method of asphalt concrete design,  
   349, 351, 375–376  
   moisture susceptibility, evaluation of,  
     376–377  
   steps in, 375  
 Hydrated cement:  
   properties of, 209–212  
     compressive strength, 212  
     setting, 209–211  
     soundness, 211  
     voids in, 207–209  
 Hydration-control admixtures, portlan  
   cement, 225  
 Hydrophilic aggregates, 191  
 Hydrophobic aggregates, 191  
 Hypoeutectoid alloys, 91–92

**I**

I-beams, 438  
 Igneous rocks, 160  
 I-joists, 438  
   wood, 457  
 Immersion, 268  
 Impervious papers/plastic sheets, 270  
 Incoherent boundary, 66–67  
 Indirect tensile strength, 378  
 Industrial grade, glued–laminated wood, 433  
 Infrared curing, 273  
 Inhabitive primer coatings, 128  
 Initial tangent modulus, 8  
 Inorganic solids, 74–77  
   ceramics, 74–76  
   defined, 74  
   glass, 77  
 In-place recycling, 384  
 Insects, and wood, 419–420  
 Insoluble materials, phase diagrams, 71–73  
 Insulating blankets/covers, 273  
 Interatomic bonds, 57  
 Interlayer hydration space, 208–209  
 Internal vibrators, 261  
 Interstitial atoms, solubility limit of, 68  
 Intrusive igneous rocks, 160  
 Ionic bonds, 56–57  
 Iron, 86, 88  
   cast, 86  
   pig, 87–88

Iron carbide, 91–93  
 Iron–carbon phase diagram, 90–94  
 Isocyanate, in structural panel  
   products/sheets, 425  
 Isostrain condition, 457  
 Isotactic structures, 78–79  
 Isotopes, 52

**J**

Joints, 24

**K**

Kelvin model, 17–18  
 Kevlar, 447  
 Killed steels, 90  
 Kiln drying wood, 405  
 Kinematic viscosity test procedure, 338  
 Knots, as lumber defects, 407  
 Kraft papers, 270

**L**

Laboratory manual, 465–555  
   aggregates, sieve analysis of, 482–483  
   air content of freshly mixed concrete:  
     by pressure method, 502–503  
     by volumetric method (experiment),  
       504–505  
   asphalt, absolute viscosity test of, 533–534  
   asphalt binder:  
     dynamic shear rheometer test of 528–530  
     viscosity of by rotational viscometer,  
       526–527  
   asphalt cement, penetration test of,  
     531–532  
   asphalt concrete specimens prepared using  
     the Marshall compactor, 539–542  
   bulk specific gravity of compacted  
     bituminous mixtures, 543–545  
   bulk unit weight and voids in aggregate,  
     493–495  
   concrete cylinders and beams, making and  
     curing, 506–509  
   concrete, flexural strength of, 515–517  
   concrete masonry units, testing of,  
     523–525  
   cylindrical concrete specimens, capping  
     with sulfur or capping compound,  
     510–514

- freshly mixed portland cement concrete, slump of, 496–498
  - hardened concrete:
    - penetration resistance of, 520–522
    - rebound number of, 518–519
  - hot-mix asphalt (HMA) specimen density
    - by Superpave gyratory compactor, 535–538
  - Marshall stability and flow of asphalt concrete, 546–547
  - measuring devices, 466–469
  - microscopic inspection of materials, 480–481
  - plastics, tensile properties of, 553–555
  - specific gravity and absorption:
    - of coarse aggregate, 487–489
    - of fine aggregate, 490–492
  - steel, impact test of, 477–479
  - tension test of steel and aluminum, 470–473
  - torsion test of steel and aluminum, 474–476
  - unit weight and yield of freshly mixed concrete, 499
  - wood, bending and compression tests of, 548–552
  - Laboratory measuring devices, 32–40
    - dial gauges, 33–34
    - linear variable differential transformer (LVDT), 34–37
    - load cells, 39–40
    - measurement accuracy, 33
    - proving rings, 38–39
    - sensitivity of, 33
    - strain gauges, 37–38
  - Laminated strand lumber (LSL), 430, 432
  - Laminated veneer lumber (LVL), 427–430, 457
  - Lattice defects, 64–65
  - Lattice structure, 59–64
    - atomic packing factor (APF), 61–62
    - body center cubic (BCC) structure, 60, 63
    - coordination number, 60–61
    - face center cubic (FCC) structure, 60
    - hexagonal close pack (HCP) structure, 60, 63
    - of metals (table), 61
    - space lattice, 60
  - Lean fill, 288
  - Lightweight concrete, 291–292
  - Lightweight synthetic aggregates, 2
  - Lightweight units, 306–307
  - Lignin, 400
  - Lime mortar, 314
  - Limestone, 88
  - Line defects, 64
  - Linear chain polymers, 78–79
  - Linear materials, 7
  - Linear variable differential transformer (LVDT), 34–37, 467–469
  - Linearity, 7
  - Liquid asphalts, 322–323
  - Liquid dirt, 288
  - Lithium-based admixtures, 190
  - Load cells, 39–40, 467–468
  - Loading conditions, 4–5
  - Logs, 402
  - Loosened grain, as lumber defect, 410
  - Los Angeles abrasion test, 167
  - Lot, 28
  - Low-relaxation steels, 110
  - LSL, 430, 432
  - Lumber grades, 405–407
  - LVDT, 34–37, 467–469
  - LVDT extensometer, 113
  - LVL, 427–430, 457
- M**
- Machine burn, as lumber defect, 410
  - Macroscopic composites, 446, 452–457
    - asphalt concrete, 452, 456
    - engineered wood, 452, 457
    - plain portland cement concrete, 452, 455
    - reinforced portland cement concrete, 455–456
  - Maltenes, 329
  - Manganese, as steel alloying agent, 97
  - Manufactured aggregates, 159
  - Marine boring organisms, and wood, 420
  - Marshall method of asphalt concrete design, 349–351, 367–375
    - aggregate evaluation, 368
    - asphalt cement evaluation, 368
    - density and voids analysis, 369
    - design asphalt content determination, 369
    - job mix formula (JMF), 371
    - Marshall stability and flow measurement, 369–371
    - specimen preparation, 368–369

- Marshall stability and flow of asphalt
  - concrete (experiment), 546–547
  - apparatus, 546
  - test procedure, 546–547
- Martensite, 96
- Masonry, 305–318
  - masonry units, 305–306
- Masonry cements, 216
- Material selection process, economics of, 2–3
- Material variability, 27–32
  - accuracy, 27
  - bias, 27
  - blunder, 27
  - control charts, 29–32
  - error, 27
  - experimental error, 32
  - normal distribution, 29
  - precision, 27
  - sampling, 28–29
- Materials engineering, concepts, 1–51
- Materials engineers, responsibilities of, 1
- Maturity meters, concrete, 286–287
- Maturity test, concrete, 285–286
- Maximum density gradation, aggregate, 175–179
- Maximum pavement temperatures, 331
- Maxwell model, 16
- Mean, 28–29
- Measuring devices (experiment), 466–469
  - apparatus, 466–467
  - calibration, 467–469
  - requirements, 469
- Mechanical engineering:
  - aesthetic characteristics of materials, 26–27
  - construction, 25–26
  - laboratory measuring devices, 32–40
    - dial gauges, 33–34
    - linear variable differential transformer (LVDT), 34–37, 467–469
    - load cells, 39–40
    - measurement accuracy, 33
    - proving rings, 38–39
    - sensitivity of, 33
    - strain gauges, 37–38
  - material variability, 27–32
    - accuracy, 27
    - bias, 27
    - blunder, 27
    - control charts, 29–32
    - error, 27
    - experimental error, 32
    - normal distribution, 29
    - precision, 27
    - sampling, 28–29
  - nonmechanical properties of materials, 22–25
  - production, 25–26
- Mechanical properties of materials, 3–22
  - elastic behavior, 6–8
  - elastoplastic behavior, 8–12
  - failure, 19–22
  - loading conditions, 4–5
  - rheological models, 14, 15–18
  - safety, 19–22
  - stress–strain relations, 5
  - temperature and time effects, 18–19
  - time-dependent response, 13–14
  - work and energy, 12–13
- Mechanical testing of steel, 110–124
  - bend test, 122
  - Charpy V Notch impact test, 119–122
  - hardness test, 122–124
  - tension test, 110–117
  - torsion test, 117–119
  - ultrasonic testing, 124
- Medium-curing (MC) cutbacks, 346
- Medium-weight units, 306–307
- Melamine–formaldehyde (MF), in structural panel products/sheets, 425
- Membrane-forming compounds, 271–272
- Metallic bonds, 56–58
- Metallic materials, 59–74
  - alloys, 67–68
  - combined effects, 74
  - density, 63
  - grain structure, 64–67
  - lattice defects, 64–65
  - lattice structure, 59–64
  - phase diagrams, 68–74
  - unit cell, 59
- Metallic solids, 59
- Metallurgy, 142–146
  - alloy designation system, 144–145
  - temper treatments, 145–146
- Metals, 449
  - cold-formed, 1
  - creep, 13
  - density, 63
  - ferrous, 86
  - gas metal arc welding (GMAW), 153–154
  - shielded metal arc welding (stick welding), 125

- Metamorphic rocks, 161
- Microscopic composites, 446–452
  - civil and construction engineering applications, 449–452
  - dispersed phase (reinforcing phase), 446
  - fabrication, 449
  - fiber-reinforced composites, 446, 447–448
  - matrix phase, 446, 449
  - particle-reinforced composites, 446, 448
- Microscopic inspection of materials (experiment), 480–481
  - apparatus, 480
  - materials, 480
- Mig welding, 125–126
- Mild steel, 10
- Minerals, 75
- Minimum pavement temperatures, 331
- Mixing concrete, 256
- Mobile batcher mixed concrete, 257
- Modular bricks, 313
- Modulus of elasticity, 6
  - of concrete, 277–278
  - wood, 412–413
- Modulus of resilience, 12–13
- Moist aggregates, 168
- Moisture corrections, concrete mix, 250
- Moisture-induced damage, 191
- Molybdenum, as steel alloying agent, 97
- Mortar, 314
  - cement, 314
  - compressive strength of, 212, 314
  - flow, 288
  - lime, 314
  - tensile bond strength, 314
- MW grade, building bricks, 312–313
- N**
- N grade, solid concrete masonry units, 312
- National Asphalt Paving Association, 371
- National Hardwood Lumber Association, 406
- National Institute of Standards and Technology (NIST), 425
- National Lumber Grader Authority (NLGA), 405
- National Standard Institute (NSI), 414
- Natural pozzolans, 228–229
- Natural sources for aggregates, 159
- Nature of materials, 52–85
- NELMA, 405
- Neoprene, 78
- Net area compressive strength, 307
- Neutrons, 52
- Newtonian element, 15
- Newtonian fluids, 14
- NHPMA, 405
- Nickel, as steel alloying agent, 97
- NIST, 425
- NLGA, 405
- Noncontact extensometer, 337
- Nonmechanical properties of materials, 22–25
  - density, 22–23
  - specific gravity, 22–23
  - surface properties of materials, 25
  - thermal expansion, 23–24
  - unit rate, 22–23
- Non-modular bricks, 313
- Normal distribution, 29
- Normalizing, steel, 95
- Normal-weight units, 306–307
- Northeastern Timber Manufacturer Association (NELMA), 405
- Northern Hardwood and Pine Manufacturer Association (NHPMA), 405
- NSI, 414
- NW grade, building bricks, 312
- Nylon, 447
- O**
- Offset yield stress, 11
- One-sized graded aggregates, 179
- Open hearth furnaces, 88–89
- Open-graded aggregates, 179
- Organic solids, 77–82
  - defined, 77
  - elastomers, 78–79
  - mechanical properties, 80–82
  - melting and glass transition temperature, 79–81
  - natural materials, 78
  - polymers, 78–79
  - rubbers, 78
  - thermoplastics, 77, 79
  - thermosets, 77, 79
- Oriented strand board (OSB), 424, 457
- Oriented strand lumber (OSL), 430, 432, 457
- P**
- Parallel strand lumber, 430–431, 457
- Parraffinic, use of term, 329

- Partially soluble materials, phase diagrams, 71
- Particle-reinforced composites, 446, 448, 461
- Particle-reinforced plastics, 445
- PAV, 333
- Pavement materials, recycling of, 382–384
  - central plant recycling, 383–384
  - in-place recycling, 384
  - surface recycling, 383
- Paving bricks, 311
- Pearlite, 91–93
- Penetration resistance test, 284
- Penetration test, 338
- Performance Grade asphalt binder
  - characterization, 332–337
    - bending beam rheometer test, 336
    - direct tension test, 337
    - dynamic shear rheometer test, 334–336
    - flash point test, 333–334
    - pressure-aging vessel (PAV), 333
    - rolling thin-film oven (RTFO) procedure, 332–333
    - rotational (Brookfield) viscometer test, 334
- Performance Grade characterization
  - approach, asphalt, 331
- Performance Grade specifications, 330
- Periodic loads, 4–5
- Permeable concrete, 275–276
- Petrolenes, 329
- Petroleum-based wood preservation
  - solutions, 420
- Phase diagrams, 68–74
  - eutectoid reaction, 73–74
  - insoluble materials, 71–73
  - lever rule for the analysis of, 92
  - partially soluble materials, 71
  - soluble materials, 69–71
- Phases, 68
- Phenol–formaldehyde (PF), in structural
  - panel products/sheets, 424
- Pig iron:
  - materials used to produce, 87–88
  - refining to steel, 88
- Pitch pockets, as lumber defect, 410
- Pith, trees, 396–398
- Plain and deformed wire fabrics, 109
- Plain bars, 109
- Plain portland cement concrete, 452, 455
- Plaster, 315
- Plastic deformation, 64–65
- Plastic shrinkage, concrete, 274
- Plastics:
  - as asphalt additive, 385
  - tensile properties of (experiment), 553–555
    - analysis and results, 554–555
    - apparatus, 553
    - test procedure, 553–554
    - test specimens, 553
- Plexiglas, 78
- Plywood, 457
  - mechanical properties of, 425
- Point defects, 64
- Poisson's ratio, 6, 9, 459
  - of concrete, 277
- Polybutadiene (synthetic rubber), 78
- Polychloroprene (Neoprene), 78
- Polyethylene film, 270
- Polyisoprene (natural rubber), 78
- Polymer concrete, 294–295
- Polymer-impregnated concrete, 294
- Polymer–portland cement concrete, 294
- Polymers, 1–2, 449
  - and cross-linking, 78–79
  - mechanical behavior of, 81–82
  - modulus of, 81–82
- Polymers and concrete, 294–295
- Polymethylmethacrylate (Plexiglas), 78
- Ponding, 268
- Population, 28
- Portland blast furnace slag cement (Type IS), 216
- Portland cement, 201–230, *See also* Portland
  - cement concrete
    - admixtures, 219–230
      - accelerators, 225–227
      - air entrainers, 220–221
      - hydration-control admixtures, 225
      - retarders, 224–225
      - specialty, 229–230
      - supplementary, 227
      - water reducers, 221–224
    - chemical composition of, 202–203
    - defined, 201
    - fineness of, 203–204
    - hydrated cement:
      - compressive strength, 212
      - properties of, 209–212
      - setting, 209–211
      - soundness, 211
      - voids in, 207–209
    - hydration process, 205–207
      - evaluation of, 207

- through-solution mechanism, 205
- topochemical, 205
- mixing water, 216–219
  - acceptance criteria, 217
  - disposal of waste water, 217–219
  - reuse of concrete wash water, 217–219
- production, 201–202
- specific gravity of, 204
- structure development in cement paste, 207
- types of, 213–216
- Portland cement concrete, 10, 74, 76, 235–297, 445, *See also* Portland cement
  - and aggregates, 162
  - air content, measuring in fresh concrete, 262–264
  - batching, 256
  - conventional concrete alternatives, 287–297
    - fiber-reinforced concrete, 295–296
    - flowable fill, 288–290
    - heavyweight concrete, 292–293
    - high-performance concrete (HPC), 296–297
    - high-strength concrete, 293–294
    - lightweight concrete, 291–292
    - polymers and concrete, 294–295
    - roller-compacted concrete (RCC), 296
    - self-consolidating concrete (SCC), 287–288
    - shotcrete, 290–291
    - shrinkage-compensating concrete, 294
  - curing, 267–273
    - curing period, 273
    - electrical, 273
    - fogging, 268
    - forms left in place, 273
    - hot oil, 273
    - immersion, 268
    - impervious papers/plastic sheets, 270
    - infrared, 273
    - insulating blankets/covers, 273
    - membrane-forming compounds, 271–272
    - ponding, 268
    - spraying, 268
    - steam curing, 273
    - wet coverings, 268–270
  - depositing concrete, 257–260
  - hardened concrete properties, 274–278
    - creep properties, 275
    - early volume change, 274–275
    - permeability, 275–276
    - stress–strain relationship, 276–278
  - hardened concrete testing, 278–287
    - compressive strength test, 279–281
    - flexure strength test, 282–283
    - maturity test, 285–286
    - penetration resistance test, 284
    - rebound hammer test, 283–284
    - split-tension test, 281–282
    - ultrasonic pulse velocity test, 285
  - hydration, 267
  - mixing, 256
  - mixing/placing/handling fresh concrete, 256–265
  - mobile batcher mixed concrete, 257
  - pitfalls/precautions for mixing water, 261–262
  - proportioning of concrete mixes, 235–255
    - pumped concrete, 260
    - ready-mixed concrete, 256–257
    - spreading/finishing, 264–266
    - vibration, 260–261
  - Portland-pozzolan cement (Type IP and Type P), 216
  - Pottery, 74
  - Pozzolan-modified portland cement (Type I(PM)), 216
  - Pozzolans, 228–229
  - Prandtl model, 17
  - Precision, 27
  - Premium grade, glued–laminated wood, 434
  - Preservation of wood, 420–422
    - application techniques, 421
    - construction precautions, 422
    - petroleum-based solutions, 420
    - waterborne preservatives, 420–421
  - Pressure-aging vessel (PAV), 333
  - Pressure-treated wood, 422
  - Pretensioned joints, 107
  - Primary bonds, 56–58
  - Production, 25–26
  - Proportional limit, 11
  - Proportioning of concrete mixes, 235–255
  - Protons, 52
  - Proving ring, calibrating, 467–469
  - Proving rings, 38–39
  - Pultrusion, 449
  - Pumped concrete, 260
  - Pycnometer, 170

## Q

Quick set, 205

## R

Raised grain, as lumber defect, 410  
 Random loads, 4–5  
 Random sampling, 28  
 Randomly oriented fiber composites, 461  
 Rapid-curing cutbacks, asphalt, 346  
 Rapid-curing (RC) cutbacks, asphalt, 346  
 Raveling, pavement, 377  
 Reaction wood, as lumber defect, 409  
 Ready-mixed concrete, 256–257  
 Rebound hammer, 284  
 Rebound hammer test, 283–284  
 Recycling of pavement materials,  
   382–384  
   central plant recycling, 383–384  
   in-place recycling, 384  
   surface recycling, 383  
 Redwood Inspection Service (RIS), 405  
 Regional preferences, for materials, 26  
 Reinforcing steel, 86, 107–110  
   forms of manufacture, 109  
   standard sizes, 110  
 Relaxation, 14, 110  
 Resins, 329  
 Resistance to abrasion and wear, 25  
 Retarders, 224–225, 257  
 Rheological elements, 14  
 Rheological models, 14, 15–18  
 Rivet fasteners, aluminum, 154  
 Riveting, steel, 107  
 Rocks, 75  
 Rockwell hardness test, 123  
 Rockwell superficial hardness test,  
   123–124  
 Roll forming, aluminum, 143  
 Roller-compacted concrete (RCC), 296  
 Rolling, aluminum, 143  
 Rolling thin-film oven (RTFO) procedure,  
   332–333  
 Rotational (Brookfield) viscometer test,  
   334  
 Round stock, 402  
 Rounded aggregates, 163  
 Rubber, as asphalt additive, 385  
 Rubbers, 78  
 Rutting, 377

## S

S grade, solid concrete masonry units, 312  
 Sacrificial primers, 129  
 Safety, 19–22  
 Salt, and corrosion, 128  
 Sampling, 28–29  
 Sampling aggregates, 192–193  
 Sand casting, aluminum, 143  
 Sap streak, as lumber defect, 407  
 Sapwood, 396  
 Saturated rings, 329  
 Saturated surface–dry (SSD) condition, 168  
 Sawing patterns, 403–404  
 Saybolt–Furol viscosity, 347  
   tests, 338–339  
 Schmidt hammer test, 283  
 Seasoning, wood, 404–405  
 Secant modulus, 8  
 Secondary bonds, 56, 58  
 Sectional shapes, in structural steel,  
   101–102  
 Sedimentary rocks, 160–161  
 Self-consolidating concrete (SCC), 287–288  
 Semicohesive boundary, 66–67  
 Semiguided bend test, 122  
 Setting:  
   emulsion, 323  
   hardness compared to, 209  
 Shakes, as lumber defect, 407  
 Shells, 53–55  
 Shielded metal arc welding (stick welding),  
   125  
 Shock absorber, 15  
 Shotcrete, 290–291  
 Shrinkage, 274  
 Shrinkage-compensating concrete, 294  
 Shrink-mixed concrete, 256  
 SHRP, *See* Strategic Highway Research  
   Program (SHRP)  
 Sieve analysis, 174–175  
 Silica fume, 228, 291  
 Silicon, as steel alloying agent, 97  
 Silicon atoms, 76  
 Syndiotactic structures, 78–79  
 Slag cement (Type S), 216  
 Slag-modified portland cement (Type I(SM)),  
   216  
 Slip-critical joints, bolts in, 107  
 Slow-curing (SC) cutbacks, 346  
 Small jobs, mixing concrete for, 254



- Snug-tightened joints, 107
- Soft rubber in tension, 5
- Softwoods, 394–395
- Soil, 1
- Solid concrete masonry units, 310
- Soluble materials, phase diagrams, 69–71
- Southern Pine Inspection Bureau (SPIB), 405
- Space lattice, 60
- Specialty admixtures, 229–230
- Specialty cements, 216
- Specialty items, wood, 403
- Specialty Steel Industry of North America (SSINA), 98
- Specialty steels in structural applications, 102–106
- Specific gravity, 22–23, 169–170
  - of GGBF slag, 227
  - of portland cement, 204
  - wood, 410–411
- Specific heat, wood, 411–412
- Specifications, aggregates, 180–183
- SPIB, 405
- Splits, as lumber defect, 410
- Split-tension test, 281–282
- Spraying, 268
- Spreading concrete, 264–266
- SSINA, 98
- St. Venant element, 15–17
- Stability of SCC, 287
- Stainless steel, 98
  - properties of, 106
- Stains, wood, 419
- Standard deviation, 28–29
- Static bending test, 548–550
  - wood, 415–416
- Static loading, 4
- Statistical control charts, 30–32
- Steam curing, 273
- Steel, 68, 86–137
  - corrosion, 127–129
    - methods for corrosion resistance, 128–129
  - fastening products, 107
  - heat treatment of, 94–96
    - annealing, 94–95
    - example of, 96
    - hardening, 95–96
    - normalizing, 95
    - tempering, 96
  - impact test of (experiment), 477–479
    - apparatus, 477
    - test conditions, 477
    - test procedure, 477–478
    - test specimens, 477
  - iron–carbon phase diagram, 90–94
  - killed, 90
  - low-relaxation, 110
  - mechanical testing of, 110–124
    - bend test, 122
    - Charpy V Notch impact test, 119–122
    - hardness test, 122–124
    - tension test, 110–117
    - torsion test, 117–119
    - ultrasonic testing, 124
  - for prestressed concrete reinforcement, 110
  - reinforcing, 86, 107–110
    - forms of manufacture, 109
    - standard sizes, 110
  - steel alloys, 96–98
    - alloying agents, 96–97
    - characteristics, 98
  - steel production, 87–90
    - phases of, 87
  - stress-relieved steels, 110
  - structural, 86, 98–107
    - grades, 98–101
    - sectional shapes, 101–102
    - specialty steels in structural applications, 102–106
  - tension test of (experiment), 470–473
    - analysis and results, 472–473
    - apparatus, 470
    - replacement of specimens, 473
    - test procedure, 470–472
    - test specimens, 470
  - torsion test of (experiment), 474–476
    - analysis and results, 476
    - apparatus, 474
    - test procedure, 474–476
    - test specimens, 474
  - welding, 107, 125–127
    - arc welding, 125
    - gas welding, 125–126
    - methods, 125
    - welding zone classification of steel, 126–127
- Steel alloys, 86, 96–98
- Steel production, 87–90
- Steel rebars, 455–456
- Steel-reinforced concrete, 452, 455–456
- Stick welding, 125
- Stone, 305

- Strain gauges, 37–38, 467
  - Strain hardening, 10
  - Strain softening, 10
  - Strategic Highway Research Program (SHRP), 297, 329–330, 385
  - Straw, 445
  - Strength requirements, concrete mix, 237–239
  - Strength-versus-water-cementitious materials ratio curve, 240
  - Stressed skinned panels, 438
  - Stresses, 24
  - Stress-relieved steels, 110
  - Stress-strain diagram, 12
  - Stress-strain relations, 5
  - Stripping, 191
  - Structural clay tiles, 305–306
  - Structural composite lumber (SCL), 425–426
  - Structural insulated panels, 438
  - Structural steel, 86, 98–107
    - grades, 98–101
    - sectional shapes, 101–102
    - specialty steels in structural applications, 102–106
  - Stucco, 315
  - Subangular particles, 163
  - Submerged arc welding, 125
  - Subshells, 53–55
  - Substitutional atoms, 68
  - Sulfur, as steel alloying agent, 97
  - Superpave gyratory compactor, 351
  - Superpave mix design method, 322, 330, 349
  - Superpave mix-design process:
    - aggregate selection, 356
    - binder selection, 356
    - design aggregate structure, 357–362
    - design binder content, 362–364
    - moisture sensitivity evaluation, 364
    - steps in, 355–363
    - Superpave simple performance tests (SPT), 364–367
      - dynamic modulus test, 364–366
      - triaxial repeated load permanent deformation test, 367
      - triaxial static creep test, 366–367
  - Superplastic forming, aluminum, 143
  - Superplasticizers, 2
  - Supplementary cementitious admixtures, 227–229
    - effect on freshly mixed concrete, 229
    - effect on hardened concrete, 229
    - fly ash, 227
    - ground granulated blast furnace slag (GGBF slag), 228
    - natural pozzolans, 228–229
    - silica fume, 228
  - Surface properties of materials, 25
  - Surface recycling, 383
  - Surface texture, 25
  - Surface vibrators, 261
  - Sustained (dead) loads, 4
  - SW grade, building bricks, 312–313
  - Swelling, concrete, 275
- T**
- Tangent modulus, 8
  - Tar, 319
  - Temperature, and materials, 18–19
  - Tempering, steel, 96
  - Tensile bond strength, mortar, 314
  - Tension, 55
  - Tension stress-strain diagram, steel, 115
  - Tension test, steel, 110–117
  - Termites, 419–420
  - Testing, aluminum, 146–153
  - Thermal conductivity, 459
  - Thermal diffusivity, wood, 412
  - Thermal expansion, 23–24
    - coefficient of, 24
  - Thermal properties, wood, 411
  - Thermoplastics, 77, 79
  - Thermosets, 77, 79
  - Through-solution mechanism, hydration, 205
  - Time, and materials, 18–19
  - Time-dependent response, 13–14
  - Time-dependent strain or creep, 14
  - Time-temperature shift factor, 19
  - Time-temperature transformation diagrams, 94
  - Titanium alloys, 449
  - Topochemical hydration, 205
  - Torn grain, as lumber defect, 410
  - Torsiometer, 119
  - Torsion test, 117–119
  - Toughness of a material, 12–13
  - Traditional asphalt characterization tests, 338
  - Trained work force, and construction, 26
  - Transient loads, 4–5
  - Transition temperature, 19
  - Trapped air, 209
  - Tree rings, 396

## Trees:

- annual rings, 396
- bark, 396
- cambium, 396
- deciduous, 396
- endogenous, 394
- exogenous, 394–395
- pith, 396–398
- tree rings, 396

## Trial mixes:

- concrete, 257
- concrete mix, 250

Trinidad Lake asphalt, 319

Truck-mixed concrete, 256

True stress–strain curve, 114

Twisting, 410

**U**

Ultrasonic pulse velocity test, 285

Ultrasonic testing, 124

Uniaxial tensile stress–strain curves, 5

Unit cell, 59

Unit rate, 22–23

Unsaturated rings, 329

Unshrinkable fill, 288

Urea–formaldehyde (UF), in structural panel products/sheets, 424

U-tube, 338

**V**

Valence electrons, 55

Van der Waals forces, 58

Vanadium, as steel alloying agent, 97

Veneer-based materials, 422–423

Vibrating tables, 261

Vibration of concrete, 260–261

Vibratory rollers, 261

Vicat test, 209–210

Viscoelastic materials, 14, 19

## Viscosity:

- absolute, 338
- emulsion, 339
- kinematic, 338
- Saybolt–Furol, 338–339, 374

Viscous flow, 13–14

Visual stability index (VSI), 288

Vitreous ceramics, 75

Volume defects, 64–65

**W**

Wane, as lumber defect, 407

Warping, as lumber defect, 410

Water content requirements, concrete mix, 247

Waterborne preservatives, wood, 420–421

Water–cementitious materials ratio (water–cement ratio), 212, 236

Wear resistance, 25

Weight and absolute volume methods, basic steps for, 236–237

Welded wire fabrics, 109

Welding, 107, 125–127

aluminum, 153–154

arc welding, 125

gas welding, 125–126

methods, 125

steel, 107, 125–127

welding zone classification of steel, 126–127

West Coast Lumber Inspection Bureau (WCLIB), 405

Western Wood Products Association (WWPA), 405–406, 414

Wet coverings, 268–270

Wet wood, 419

White portland cement, 216

Windsor Probe test, 284–285

Wire fabrics, 109

Wire strain gauges, 38

Wiskers, 447

Wood, 394–444

air drying, 405

anisotropic nature of, 398–399

bending and compression tests of (experiment), 548–552

compression parallel to the grain test, 550–551

compression perpendicular to grain test, 551–552

static bending test, 548–550

chemical composition, 399–400

coefficient of thermal expansion, 412

combination sawing, 403

compression tests, 416–417

conifers, 396

creep, 413

cutting techniques, 403–404

damping capacity, 413–414

deciduous trees, 396

Wood (Continued)

- defined, 394, 396–397
- degradation of, 418–420
  - bacteria, 419
  - fungi, 419
  - insects, 419–420
  - marine boring organisms, 420
- density, 410–411
- design considerations, 417–418
- electrical properties, 412
- endogenous trees, 394
- engineered wood products, 422–438
  - composite structural members, 437–438
  - structural composite lumber (SCL), 425–426
  - structural panel products/sheets, 424–425
  - structural shapes, 425–438
- exogenous trees, 394–395
- growth rings, 396–398
- hardwoods, 394–395
  - grades, 406
- heat flow in, 411
- kiln drying, 405
- lumber defects, 407–410
- lumber grades, 405–407
- mechanical properties, 412–414
  - testing to determine, 414–417
- modulus of elasticity, 412–413
- moisture content of, 400–402, 411
- physical properties, 410–412
- plain sawing, 403
- preservation of, 420–422
  - application techniques, 421
  - construction precautions, 422
  - petroleum-based solutions, 420
  - waterborne preservatives, 420–421
- production, 402–405
- quarter sawing, 403
- seasoning, 404–405
- softwoods, 394–395
  - grades, 406
- specific gravity, 410–411
- specific heat, 411–412
- static bending test, 415–416
- strength properties, 413
- structural engineered wood products, 403
- structure of, 396–399
- surfacing (planing) of wood surfaces, 403
- thermal diffusivity, 412
- thermal properties, 411
- tree classifications, 394

Wood I-joists, 457

Work, 12–13

Work hardening, 10

Workability, defined, 245

requirements, concrete mix, 245–247

**Y**

Yield strength, 11

Yield stress, 11

Young's modulus, 6, 277

**Z**

Zinc, 129