

- AASHTO See American Association for State Highway and Transportation Officials
- ABC Supply Co., Inc., 173, **173**, **174**
- Abrasion, boiler slag, 23, **23**; bottom ash, **22**, 43, **44-45**; concrete, 72-77, **76-77**, 97, **105**; metal-matrix composites, 196; mixture design, 72, **73**; testing procedure, **39**, 72-74
- Abrasives/traction See Anti-skid material
- ACI 229 (Controlled Low Strength Materials), **136**, **137**, 244, 246
- ACI 301 (Structural Concrete for Buildings), 231, 232, 238
- ACI 304 (Guide for Measuring, Mixing, Transporting and Placing Concrete), 244
- ACI 305 (Hot Weather Concreting), 231, 236
- ACI 306 (Cold Weather Concreting), 231, 236
- ACI 309 (Recommended Practice for Consolidation of Concrete), 231, 236, 237
- ACI 318 (Standard Building Code), 68
- Activated carbon injection, 16-17, 223
- Admixtures, 15, 16-17, 49-50, 121, 233
- Aggregates, 25, 38, 43, 45-46, 54, 159-161, 169, 179-184, 233; base course, 43, 108-112, **111**, **112**, 159-165, **165**, 189-191; hot mix asphalt, 23-24, 38, 43; lightweight, 47, 229-230, 262-263; Minergy LWA, 229-230, 262-263; seal coat, 24
- Agriculture, 169-170
- Air content, concrete, **56**, **57**, **73**, 74, **79**, **81**, **82**, **84**, 88, **95**, **96**, **110**, 111, **112**, 119, **119**, **125**, 232; controlled low strength material, 130, **131**, **135**, 143, **144**, 147, **148**
- Air emission quality, 3-5, 6, 202, 223-227
- Air permeability See *under* Permeability
- Alkali-aggregate reactions, 51-52
- Alkali-silica reactions, 51-52
- Aluminum ash alloy See *under* Metal-matrix composites
- American Association for State Highway and Transportation Officials, specifications, **44-45**, **104**, 187; testing procedures, **39**
- American Coal Ash Association, 2, 217
- American Concrete Institute, 72, 129 See *also* ACI...
- American Society for Testing and Materials See ASTM...
- Amine enhanced lean gas reburn, 226
- Ammonia, 4, 226-227, **227**
- Angle of internal friction See Friction angle
- Angularity, **44**
- Anti-skid material, 159, 168
- Ash See Bottom ash; Coal combustion products; Fly ash
- Ash recovery See Recovery
- Asphalt, boiler slag, 23-24; bottom ash, 38, 159, 169; cold-in-place recycling, 18, 47, 185-192, **188**, **192**, 249-254, 275-277; cost comparison, 169; hot mix asphalt aggregates, 23-24, 38, 43; specifications, 43, 249-254
- ASTM C31 (Standard Practice for Making and Curing Concrete Test Specimens in the Field), 72, 232
- ASTM C33 (Standard Specification for Concrete Aggregates), 72, 124, 232, 233, 234, 245
- ASTM C39 (Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens), 78, 106, 119, 126, 140, 232
- ASTM C42 (Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete), **98**
- ASTM C55 (Standard Specification for Concrete Brick), 116
- ASTM C90 (Standard Specification for Load Bearing Concrete Masonry Units), **183**
- ASTM C94 (Standard Specification for Ready-Mixed Concrete), 117, 234
- ASTM C109 (Standard Test Method for Compressive Strength of Hydraulic Cement Mortars), 126
- ASTM C138 (Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete), 119
- ASTM C140 (Standard Test Methods of Sampling and Testing Concrete Masonry Units and Related Units), 115
- ASTM C143 (Standard Test Method for Slump of Hydraulic Cement Concrete), **65**, 119, 232
- ASTM C150 (Standard Specification for Portland Cement), **16**, 72, 89, **110**, 233, 245
- ASTM C157 (Standard Test Method for Length Change of Hardened Hydraulic-Cement, Mortar, and Concrete), 69
- ASTM C171 (Standard Specification for Sheet Materials for Curing Concrete), 233
- ASTM C192 (Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory), 78, 114, 118, 119, 124

- ASTM C231 (Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method), **65**, 111, 119, 232
- ASTM C260 (Standard Specification for Air-Entraining Admixtures for Concrete), 233
- ASTM C309 (Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete), 233
- ASTM C403 (Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance), **66**, 129, 245
- ASTM C469 (Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression), **67**, **68**
- ASTM C494 (Standard Specification for Chemical Admixtures for Concrete), 233
- ASTM C593 (Standard Specification for Fly Ash and Other Pozzolans for Use With Lime), 190
- ASTM C618 (Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete), 15, **16**, 34, **34**, 35, **36**, **55**, 89, **110**, **135**, **138**, **177**, 233, 246, 249
- ASTM C642 (Standard Test Method for Density, Absorption, and Voids in Hardened Concrete), 106, 114
- ASTM C666 (Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing), 70, **70**, **71**, **99-101**
- ASTM C672 (Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals), **103**
- ASTM C779 (Standard Test Method for Abrasion Resistance of Horizontal Concrete Surfaces), **105**
- ASTM C944 (Standard Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating-Cutter Method), 73
- ASTM C1064 (Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete), 111, 119
- ASTM C1202 (Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration), 78, 85, 106, 107
- ASTM D422 (Standard Test Method for Particle-Size Analysis of Soils), 160, **161**, 242
- ASTM D698 (Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort), 160, 249
- ASTM D1557 (Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort), 38, 190, 241, 243
- ASTM D1633 (Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders), 190
- ASTM D1751 (Standard Specification for Prefomed Expansion Joint Filler for Concrete Paving and Structural Construction), 233
- ASTM D1883 (Standard Test Method for California Bearing Ratio of Laboratory-Compacted Soils) 160
- ASTM D2234 (Standard Practice for Collection of a Gross Sample of Coal), 176, 177
- ASTM D2434 (Standard Test Method for Permeability of Granular Soils), 160
- ASTM D3080 (Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions), 160
- ASTM D3987 (Standard Test Method for Shake Extraction of Solid Waste with Water), **172**, 203, **206-207**, **210-211**, 212, **213**
- ASTM D4832 (Standard Test Method for Preparation and Testing of Controlled Low Strength Material Test Cylinders), 119, 143, 147, 245
- ASTM D5239 (Standard Practice for Characterizing Fly Ash for Use in Soil Stabilization), 249
- ASTM D6023 (Standard Test Method for Unit Weight, Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low Strength Material), 143, 147
- ASTM D6024 (Standard Test Method for Ball Drop on Controlled Low Strength Material to Determine Suitability for Load Application), 143
- ASTM D6103 (Standard Test Method for Flow Consistency of Controlled Low Strength Material), 143, 147, **153**, 245
- ASTM E1861 (Standard Guide for Use of Coal Combustion By-Products in Structural Fills), 240
- Atterberg limits, 43, **44-45**; testing procedure, **39**
- Autoclave expansion, **110**, **138**
- Average particle size See Size

- Backfill material, 6, 43, 138, 143, 156-157, 159, 165-168, **166**, **167**, **168**; Minergy LWA, 230; specifications, 240-243  
See also Controlled low strength material
- Baghouses, 10, 30, 223-224
- Base course aggregates *See under* Aggregates
- Beneficiation process, 4, 223-227
- Best Block Company, 179
- Bike trails, 169
- Boiler slag, 2, 11, 14, **22-23**, 22-24
- Bottom ash, 2, 11, 14, 37-46, 159-184; abrasion, **22**, 43, **44-45**; California Bearing Ratio, **21**, **22**, 160, **162**; chemical composition, 19, **19**, 37, **37**, 201-203, **202**; color, 37; compressive strength, **21**; corrosion potential, 37; defined, 2; density, **21**, **22**, 38, **38**, 160, 164, 167; effects of coal type, **19**, 19-20; elemental analysis, **171**, **208-209**; expansion, 161; freeze-thaw resistance, **44-45**, 160, 161, 163; friction angle, **22**, 160, 161, 167-168, **168**; gradation, 20, **20**, 43, **44-45**, 160, 166; leaching, **172**, 201, 203, **210-211**; marketing agents, 28, 29; mineralogical composition, 201; moisture content, 21, **22**, **38**, 160; permeability, **21**, **22**, 160, 161, 166, **167**; physical properties, 19-20, **20-22**, 37-39, **38-42**, 160-161, **161-162**  
See also *specific properties*; pilot projects, 163-165, **165**, 169-170, **170**, 173, **173**, **174**; plastic limit, **21**; plasticity, **22**; reburning, 177-179; recovery, 174-177, **175**; research, 37-46, 113, 159-164, 179-184; shrinkage, **21**; size, **39**, **40-42**, 160, **161**; soundness, **44-45**, 45; specific gravity, **22**; specifications, **44-45**; staining potential, 37; statistics, 2, **26**, 26-30, 37; stress, **162**; utilization, 19, 26, 38, 159-184, **165**, **166**, **170**, **173**, **174**  
See also *specific products*; weight, **22**
- Bulk density *See* Density
- C<sup>2</sup>P<sup>2</sup>, 216-217
- Calcium sulfate *See* Gypsum
- Calcium sulfite, 11, 24, **24**
- California Bearing Ratio, 18, **21**, **22**, 23, **23**, 160, **162**
- California Test Method for Estimating the Service Life of Steel Culverts, 140
- Carbon fibers, 123-128, 146-151
- CCP *See* Coal combustion products
- Cement, 6, **16**, 17, 25, 26, 34, 48, 49, 50, 72, **110**, 202, 216, 233
- Cenospheres, 196, **197**, **198**, 199; defined, 199
- Center for By-Products Utilization (UWM), 54, 77, 105, 112, 130, 138, 147, 179, 180
- Center for Highway and Traffic Engineering (Marquette University), 185
- Chemical composition, ASTM C150 specification, **110**; ASTM C618 specifications, **110**; boiler slag, 23, **23**; bottom ash, 19, **19**, 37, **37**, 201-203, **202**; cement, **16**, **110**; fly ash, 15, **15**, **16**, **34**, 34-35, **55**, **110**, **114**, **135**, 201-203, **202**; gypsum, **25**
- Chloride ion permeability *See under* Permeability
- Concrete, 6-7
- Cinders, 1-2, **2**, 6-7, 179; defined, 1 *See also* Bottom ash
- Class C fly ash *See under* Fly ash
- Class F fly ash *See under* Fly ash
- Class N mineral admixture, 15
- Clean Air Act, 3, 4
- Coal, effect on boiler slag, 22, **23**; effect on bottom ash, **19**, 19-20; effect on fly ash, 3, **15**, 33, 35; effect on gypsum, 25; low sulfur, 3; lump, 1; pulverized, 2, 7, 9, 177; super-critical pulverized, 31; Wyoming Powder River Basin, 35
- Coal combustion products, 1-7, 9-11, **14**, 47; cinders, 1-2, **2**, 6-7, 179; defined, 1, 9; elemental analysis, **202**, 202-203; generation process, 10-11, **14**; material safety data sheet, 264-266; radioactivity, 213-214, 267-273; reburning, 177-179; recovery, 174-177, **175**; statistics, 2-3, **3**, **26**  
See also Bottom ash; Fly ash; Utilization
- Coal Combustion Products Partnership, 216-217
- Cohesion, **18**, **25**
- Cold-in-place recycling, 18, 47, 185-192, **188**, **192**, 249-254, 275-277
- Color, bottom ash, 37; concrete, **93**, 94; controlled low strength material, **155**
- Combustion control technology, 3-5, 223-227
- Commerce Street Power Plant, 6
- Commercial use *See* Utilization
- Compressibility, **25**
- Compressive strength, asphalt, 191; base course, 111, **112**; bottom ash, **21**; cement, **110**; concrete, 54-64, **56-61**, 67-68, **67-68**, 72-74, **75**, **77**, 78, **80-81**, 96, **97-98**, 106, 107, **107**, 111, **112**, 117, 119, 121, **122**, 126, **127**, 232; controlled low strength material, 129-140, **131-133**, **136-137**, **139-140**, 144-145, **145**, 147, 149, **149**, 244-

- Compressive strength (cont.) 245;  
 gypsum, **25**; masonry products, 113-116, **115, 116**, 179-180, **182-184**;  
 mixture design, 54-58, **56-57, 95-96, 114, 116, 119, 180-181**; testing  
 procedures, 54-58, 232, 245
- Concrete, 7, 16-17, 26, 47-128, **131**, 169,  
 229; abrasion, 72-77, **76-77**, 97, **105**;  
 admixtures, 16-17, 49-50, 121, 233;  
 air content, **56, 57, 73, 74, 79, 81, 82, 84, 88, 95, 96, 110, 111, 112, 119, 119, 125**, 232; alkali-aggregate  
 reactions, 51-52; alkali-silica  
 reactions, 51-52; carbon fibers, 123-  
 128; color, **93, 94**; compressive  
 strength, 54-64, **56-61, 67-68, 67-68, 72-74, 75, 77, 78, 80-81, 96, 97-98, 106, 107, 107, 111, 112, 117, 119, 121, 122, 126, 127, 232**; conductive,  
 118-128; cost comparison, 90, **90, 118**;  
 cracking, 53; deicing salt scaling,  
 97, **103**; density, 50, **56, 57, 73, 79, 95, 96, 106, 107, 119, 125, 131**;  
 durability, 49, 50, 52-53, 70, **70-71, 77**;  
 elasticity, 67-68, **67-68, 70, 71**;  
 expansion, 51-52, 68, **69, 70, 102**;  
 flexural strength, **99, 102**; freeze-thaw  
 resistance, 49, 54, 70-71, **70-71, 96, 99-102**;  
 hydration reaction, 48-49, 50;  
 leaching, 212; moisture content, **110, 180, 181**;  
 no-fines, 108-112;  
 permeability, 50, 77-88, **82-87, 97, 104, 106, 107, 120, 122, 123, 124, 127, 128**;  
 pilot projects, 88-105, 108-112;  
 Poisson's ratio, 67-68, **67-68, 71**;  
 porosity, 49, 50, 54;  
 precast/prestressed, 117-118;  
 pumping, 108; regulation, 53, 216;  
 research, 54-88, 105-107, 117-128, **131**;  
 shrinkage, 52-53, 68, **69, 96, 102**;  
 slump, **56, 57, 62-64, 73, 79, 94, 95, 96, 110, 112, 117, 119, 119, 125, 131, 232**;  
 specifications, 231-239, 249-254;  
 sulphate resistance, 50-51;  
 temperature, 111, **112, 119, 232**;  
 tensile strength, **99**;  
 thermal contraction 52;  
 time of set, 64-67, **66, 71, 126**;  
 ultrasonic pulse velocity, **101**;  
 water demand, 62-63, **62-63**;  
 workability, 50, 59, 64, 117, 118  
*See also* Masonry products; Pavement;  
 Testing procedures
- Conductivity, electric, 118-128, 143-151;  
 hydraulic, 38; thermal, 140-143, **142**
- Consistency, 34, **35, 36**
- Controlled density fill *See* Controlled low  
 strength material
- Controlled low strength material, 47, 129-  
 157, **140, 141, 153-157**;  
 air content, 130, **131, 135, 143, 144, 147, 148**;
- color, **155**;  
 compressive strength, 129-140, **131-133, 136-137, 139-140, 144-145, 145, 147, 149, 149, 244-245**;  
 conductive, 143-151;  
 cost comparison, 157;  
 defined, 129;  
 density, 131, 135, 147, **148**;  
 electric resistivity, 140-151, **141, 142, 146, 150**;  
 elemental analysis, **212**;  
 excavatability, 130, 134, 137, **141, 145, 147, 149, 154, 156**;  
 expansion, 130;  
 flowability, 129, 130, 131, 137, 143, **144, 147, 148, 149, 245**;  
 leaching, 212, **213**;  
 mixture design, 130-131, **131, 134, 135, 138, 139, 143, 144, 147-148, 148**;  
 permeability, 130, 145, **146, 150, 151, 152, 155**;  
 pilot projects, 153-154;  
 plastics compatibility, 140-143;  
 precautions, 155-156, 247-248;  
 research, 130-152, 155;  
 shrinkage, 130, 134, 137;  
 slump, 131, **131, 133, 133, 135, 136, 137, 139**;  
 specifications, 244-248;  
 thermal conductivity, 140-143, **142**;  
 utilization, 138, **140, 153-157, 153-157**;  
 Wisconsin Department of  
 Transportation, 155;  
 workability, 137
- Corrosion potential, 37, 140-143, **141**
- Cost comparisons, asphalt, 169;  
 bike trails, 169;  
 concrete 90, **90, 118**;  
 controlled low strength material, 157;  
 masonry products, 230;  
 metal-matrix composites, 193-194, 199;  
 Minergy LWA, 230
- County highway JK *See under* Pilot  
 projects
- Dairyland Power Corporation, 113
- Definitions, boiler slag, 11;  
 bottom ash, 2;  
 cenospheres, 199;  
 cinders, 1;  
 Class C, 15, 35;  
 Class F, 15, 35;  
 Class N, 15;  
 coal combustion products, 1, 9;  
 cold-in-place recycling, 18;  
 controlled low strength material, 129;  
 flue gas desulfurization material, 11;  
 fly ash, 2, 10, 15;  
 green roofs, 173;  
 incinerator ash, 5;  
 metal-matrix composites, 193;  
 pozzolans, 48
- De-icing salt scaling, 97, **103**
- Demonstration projects *See* Pilot projects
- Density, asphalt, 190;  
 backfill, 167;  
 boiler slag, **23**;  
 bottom ash, **21, 22, 38, 38, 160, 164, 167**;  
 concrete, 50, **56, 57, 73, 79, 95, 96, 106, 107, 119, 125, 131**;  
 controlled low strength material, **131, 135, 147, 148**;  
 fly ash, **18**;  
 gypsum, **25**;  
 masonry products, 114-116, **115, 116**
- Dewatering bins, 11
- Dimensional stability, 115-116
- Direct shear test, 160, 161

- Disposal costs, 5 *See also* Landfills
- Drainage, 166, **167**
- Drainage media, 26, 159
- Dry cast vibration process, 113, 179
- Dry unloaders, 10-11
- Drying shrinkage *See* Shrinkage
- Durability, 49, 50, 52-53, 70, **70-71**, 77
- East Wells Power Plant, 2, 6
- Elasticity, 67-68, **67-68**, **70**, 71
- Electric conductivity *See under* Conductivity
- Electric power generation, 9-10, **12-13**; power plants, 27-31; service area, **32**
- Electric Power Research Institute, 51, 52, 199
- Electric resistivity *See under* Resistivity
- Electrostatic precipitators, 10, 30
- Elemental analysis, bottom ash, **171**, **208-209**; coal combustion products, **202**, 202-203; controlled low strength material, **212**; fly ash, **171**, **204-205**
- Elm Road Generating Station, 5, 31
- Emissions *See* Air emission quality
- Engineering properties *See* Properties
- Environmental considerations, 2, 3-7, 31, 157, 170, 173, 175-176, 199-227; exemptions, 203, 214; material safety data sheets, 261-266; Minergy LWA, 229-230
- Excavatability, 130, 134, 137, **141**, 145, 147, 149, 154, 156
- Expansion, bottom ash, 161; concrete, 51-52, 68, **69**, **70**, **102**; controlled low strength material, 130
- Figg Method, 78
- Fineness, 17, **35**, **36**, **55**, **110**, **135**, **138**
- Flexural strength, **99**, **102**
- Flo-Pac, 129, 152, **154**; mixture design, **152**; specifications, 246 *See also* Controlled low strength material
- Flowability, 129, 130, 131, 137, 143, **144**, 147, **148**, 149, 245
- Flowable fill *See* Controlled low strength material
- Flue gas desulfurization, 2, 4-5, 11, 24-25
- Fly ash, 2, 3, 10-11, **14**, **33**, 33-36, 47-157, 185-200, **227**; ammonia contamination, 4, 226-227; beneficiation process, 4, 223-227; cenospheres, 196, **197**, **198**, 199; chemical composition, 15, **15**, **16**, **34**, 34-35, **55**, **110**, **114**, **135**, 201-203, **202**; Class C, 15, **16**, **34**, 34-35, **36**, 49, 50, 54-117, 130-134, 185-191; Class F, 15, **16**, **34**, 34-35, **36**, 49, 50, 91-117, 134-140, 191-192; defined, 2, 10, 15; density, 18; effects of coal type, 3, **15**, 33, 35; elemental analysis, **171**, **204-205**; friction angle, **18**; health risks, 201-202; heavy metals, **215**; high calcium *See* Class C; leaching, **172**, 201, 203, **206-207**; low calcium *See* Class F; marketing agents, 28, 34-35; mercury contamination, 223-226; mineralogical composition, 5, 201; moisture content, **16**, **34**, **110**; permeability, **18**; physical properties, 15-19, **18**, 34-36, **36**, 49, 50, **55**, **110**, **135**, **138** *See also specific properties*; pilot projects, 88-105, 108-112, 153-154, 185-192; radioactivity, 213-214, 267-273; reburning, 177-179; recovery, 174-177, **175**; research, 51-52, 54-88, 105-107, 112-116, 130-151, 179-184, 194-198, 214, 223-227; size, 15; soundness, **36**, **55**; specific gravity, 17, **36**, **55**, **110**, **138**; statistics, 2, **26**, 26-30; utilization, 6-7, 17-19, 26, 47-157, 185-200 *See also specific products*
- Fog rooms, 113, 114, 115
- Forging characteristics, 196-198, **197**, **198**
- Foundation sub-base material *See* Sub-base material
- Freeze-thaw resistance, bottom ash, **44-45**, 160, 161, 163; concrete, 49, 54, 70-71, **70-71**, 96, **99-102**; masonry products, 116; testing procedure, **39**
- Friction angle, **18**, **22**, 23, **23**, **25**, 160, 161, 167-168, **168**
- Full depth reclamation *See* Cold-in-place recycling
- Generating process *See* Electric power generation
- Geotechnical properties *See* Properties
- Gradation, 20, **20**, **22**, 43, **44-45**, 160, 166, **176**
- Green building materials, 31 *See also* Environmental considerations; Utilization
- Green roofs, 173, **173**, **174**, 230
- Greenhouse gases, 200, 202
- Gypsum, 4, 11, 24-25
- Haxo, Henry E., Jr., 141
- Heavy metals, 169, **215**
- High volume fly ash concrete *See* Concrete
- Highland Avenue pilot project *See under* Pilot projects
- History, 1-2, 6-7, 19, 47, 229-230
- Hot mix asphalt aggregate *See under* Aggregates
- Hydration reaction, 48-49, 50
- Hydraulic conductivity *See under* Conductivity

- Hydraulic removal systems, 30
- Incinerator ash, 5
- Integrated gasification combined cycle technology, 10, 11, **13**
- Internal friction angle *See* Friction angle
- Johansen, Kjell, "Radioactivity in Coal and Fly Ash," 267
- Ladish Co., Inc., 197
- Lafarge North America, 28
- Lakeside Power Plant, 1
- Lakeview Corporate Park, 163-164
- Landfills, 5, **5**, **6**, 174-177, **175**, 191-192, 201
- Leaching, 176-177, 203-213; bottom ash, **172**, 201, 203, **210-211**; concrete, 212; controlled low strength material, 212, **213**; fly ash, **172**, 201, 203, **206-207**; testing procedures, 203
- Length change *See* Shrinkage
- Lightweight aggregates *See under* Aggregates
- Liquid limit, **21**, 43
- Liquid waste stabilization, 26, 47
- Los Angeles Abrasion Test *See* Abrasion
- Loss on ignition, 16, **16**, **34**, 35, **36**, **110**, 177-179
- Manufactured soil products, bottom ash, 159, 169-170, **170**; Minergy LWA, 230 *See also* Green roofs
- Maple Avenue pilot project *See under* Pilot projects
- Marketing agents, 28, 29, 34-35
- Marquette University Center for Highway and Traffic Engineering, 185
- Masonry products, bottom ash, 38, 113, 159, 179-184; cinders, 1, 179; compressive strength, 113-116, **115**, **116**, 179-180, **182-184**; cost comparison, 230; density, 114-116, **115**, **116**; fly ash, 112-116, **180**; freeze-thaw resistance, 116; Minergy LWA, 229-230; mixture design, **114**, **116**, 180, **180-181**; research, 112-116, 179-184
- Material safety data sheets, coal combustion products, 264-266; Minergy LWA, 262-263
- Matrecon, Inc. 141
- Maximum dry density *See* Density
- MCPP *See* Milwaukee County Power Plant
- Mercury, 223-226, **224-226**
- Metal-matrix composites, 193-200; aluminum ash alloy, **193**, 193-200, **195**; cost comparison, 193-194, 199; defined, 193
- Michigan Department of Environmental Quality, 4, 216
- Michigan Department of Transportation, 39, 43, 45, **45**, 166
- Military Standard 621A (Standard Test Method for Determining the Modulus of Soil Reaction), 163
- Milwaukee County Power Plant, 27, **27**, **170**; map, **32**; statistics, **26**, 27
- Milwaukee County Power Plant (bottom ash), chemical composition, **37**; density, **38**; gradation, **20**, 46; hydraulic conductivity, **38**; moisture content, **38**; physical properties, **38**; research, 170; size, **39**, **40**
- Milwaukee County Power Plant (mixed ash), elemental analysis, **208**; leaching, **210**
- Minergy LWA, 229-230; safety data sheet, 262-263
- Mixture design *See under* Testing procedures
- Modified proctor values, **39**
- Modulus of elasticity *See* Elasticity
- Moisture content, boiler slag, **23**; bottom ash, **21**, **22**, **38**, 160; concrete, **110**, **180**, **181**; fly ash, **16**, **34**, **110**; gypsum, 24
- Nitrogen oxide, 3-4, 226
- NR 428 *See* Wisconsin Department of Natural Resources
- NR 538 *See* Wisconsin Department of Natural Resources
- Oak Creek Power Plant, 5, 28, **28**, 31, **31**; map, **32**; statistics, **26**, 28
- Oak Creek Power Plant (bottom ash), chemical composition, **37**; density, **38**; drainage, **167**; elemental analysis, **209**; gradation, 46, 166; hydraulic conductivity, **38**; leaching, **211**; moisture content, **38**; permeability, **167**; physical properties, **38**; research, 169, 179-184; size, **39**, **40**
- Oak Creek Power Plant (fly ash), chemical composition, **34**; elemental analysis, **205**; fineness, **36**; leaching, **207**; loss on ignition, **34**; moisture content, **34**; physical properties, **36**; pilot projects, 91-105; research, **180**; soundness, **36**; specific gravity, **36**; strength, **36**; water demand, **36**
- Oak Creek (Wis.), landfill, **5**
- Oakes (A. W.) & Son, 28, 29, 164, 169
- OCPP *See* Oak Creek Power Plant
- Patents, 118, 123, 143, 146, 174, 177, 199, 223, 226

- Pavement, 26, **109**, **187**; bottom ash, 38, 159-165, 169; cold-in-place recycling, 18, 47, 185-192, **188**, **192**, 275-277; County highway JK (Waukesha county, Wis.), 189-191, **191**; Maple Avenue (Sussex, Wis.), **91**, **92**; pilot projects, **88**, 88-105, **90-93**, 108-112, **111**, 163-165, 185-192, **188**, **192**; specifications, 249-254; West Highland Avenue (Mequon, Wis.), 185-189, **188**
- Permeability, air, 81-82, **82-83**, 87-88; backfill, 166, **167**; boiler slag, **23**; bottom ash, **21**, **22**, 160, 161, 166, **167**; chloride ion, 77-78, 85-88, **86-87**, **97**, **104**, 106, 107; concrete, 50, 77-88, **82-87**, **97**, **104**, 106, 107, 120, 122, **123**, **124**, 127, **128**; controlled low strength material, 130, 145, **146**, 150, **151**, **152**, 155; fly ash, **18**; gypsum, **25**; electrical, 120, 122, **123**, **124**, **128**, **146**, 150, **151**, **152**; mixture design, 78, **79**; testing procedures, 81; water, 83-84, **84-86**, 87-88
- Pilot projects, A. W. Oakes & Son, 164-165, **165**; base course, 108-112, 163-165, **165**; bottom ash, 163-165, **165**, 169-170, **170**, 173, **173**, **174**; cold-in-place recycling, 185-191, **188**; concrete, 88-105, 108-112; controlled low strength material, 153-154; County highway JK (Waukesha county, Wis.), 189-191, **191**; fly ash, 88-105, 108-112, 153-154, 185-192; green roofs, 173, **173**, **174**; Lakeview Corporate Park, 163-164; landscaping, 169-170, 173, **173**, **174**; manufactured soil products, 169-170, **170**; Maple Avenue (Sussex, Wis.), **91**, **92**; parking lot, 191-192, **192**; pavement, **88**, 88-105, **90-93**, 111, 163-165, 185-192, **188**, **192**; Pleasant Prairie Power Plant, 91-105, **93**, 174-177, **175**; Port Washington Power Plant, 108-112, **111**; recovery, 174-177, **175**; Sussex Corporate Center, **88**, 88-90, **90**; West Highland Avenue (Mequon, Wis.), 185-189, **188**
- PIPP See Presque Isle Power Plant
- PIXE See Proton Induced X-ray Emission Spectroscopy
- Plastic limit, **21**, 43
- Plastic soil-cement See Controlled low strength material
- Plasticity, **22**, **23**, **25**
- Plastics compatibility, 140-143
- Pleasant Prairie Power Plant, 4, 5, 28-29, **29**; ash reburning, 179; ash recovery, 174-177, **175**; landfill, 174-177, **175**; map, **32**; pilot project, 91-105, **93**, 174-177, **175**; statistics, **26**, 28
- Pleasant Prairie Power Plant (bottom ash), abrasion, 43, **44-45**; Atterberg limits, 43, **44-45**; chemical composition, **37**; density, **38**, 45, 167; drainage, **167**; elemental analysis, **209**; freeze-thaw resistance, **44-45**; gradation, **20**, 43, **44-45**, 166; hydraulic conductivity, **38**; leaching, **211**; moisture content, **38**; permeability, **167**; physical properties, **38**, 159-161, **161-162**; research, 159-164, 169; size, **39**, **41**; soundness, **44-45**, 45
- Pleasant Prairie Power Plant (fly ash), chemical composition, **34**, **55**; consistency, 34, **35-36**; elemental analysis, **205**; fineness, **35**, **36**, **55**; leaching, **207**; loss on ignition, **34**, **36**; mercury, 224-225, **225-226**; moisture content, **34**; physical properties, **36**, **55**; pilot projects, 88-105, 185-189; pozzolanic activity index, **55**; research, 54-88, 117-118, 130-134, 155; soundness, **36**, **55**; specific gravity, **36**, **55**; strength, **36**, 54-64, **56-61**; water demand, **36**, **55**, 62-63, **62-63**
- Poisson's ratio, 67-68, **67-68**, 71
- Pollution See Environmental considerations
- Porosity, 49, 50, 54
- Port Washington Power Plant, 27, **29**, 29-30; map, **32**; pilot project, 108-112, **111**; statistics, **26**, 29
- Port Washington Power Plant (bottom ash), density, **38**; drainage, **167**; elemental analysis, **208**; hydraulic conductivity, **38**; leaching, **210**; moisture content, **38**; permeability, **167**; physical properties, **38**; research, 170
- Port Washington Power Plant (CLSM), elemental analysis, **212**; leaching, **213**
- Port Washington Power Plant (fly ash), chemical composition, 138; elemental analysis, **204**; fineness, **138**; leaching, **206**; physical properties, **138**; pozzolanic activity index, **138**; research, 118-122, 138-140, 143-146; specific gravity, **138**; water demand, **138**
- Portland cement See Cement
- Post-combustion controls, 4, 223-227
- Powder Metallurgy, 194-195
- Power plants, 9-10, **12-13**; ash generation process, 10-11, **14**; base loaded, 33; map, **32**; pulverized coal fired, 2, 9-10, **12**, 28-31; stoker-fired, 1-2, 9, 27;

- Power plants (cont.), We Energies, **1**, 1-2, **2**, 6, 26-32, **27-31** *See also names of individual plants*
- Pozzolan activity index, **55**, **110**, **138**
- Pozzolans, 15, 19, 50-52; defined, 48
- PPPP *See* Pleasant Prairie Power Plant
- Presque Isle Power Plant, 4, 30, **30**, 35; ash reburning, 179; map, **32**; statistics, **26**, 30
- Presque Isle Power Plant (bottom ash), abrasion, 43, **44-45**; Atterberg limits, 43, **44-45**; chemical composition, **37**; density, **38**, 45, drainage, **167**; elemental analysis, **208**; freeze-thaw resistance, **44-45**; gradation, 43, **44-45**, 166; hydraulic conductivity, **38**; leaching, **210**; moisture content, **38**; permeability, **167**; physical properties, **38**; size, **39**, **41-42**; soundness, **44-45**, 45
- Presque Isle Power Plant (fly ash), chemical composition, **34**, 35; elemental analysis, **204**; fineness, **36**; leaching, **206-207**; loss on ignition, **34**; mercury, 223-225, **224-226**; moisture content, **34**; physical properties, **36**; research, 123-128, 146-151, 223-225, **224-226**; soundness, **36**; specific gravity, **36**; strength, **36**; water demand, **36**
- Pressure infiltration, 195-196
- Production statistics *See* Statistics
- Properties, ASTM C150 specification, **110**; ASTM C618 specification, **110**, **138**; boiler slag, **22-23**, 22-24; bottom ash, 19-20, **20-22**, 37-39, **38-42**, 160-161, **161-162**; cement, **110**; fly ash, 15-19, **18**, 34-36, **36**, 49, 50, **55**, **110**, **135**, **138**; gypsum, 24-25, **24-25**; metal-matrix composites, 196-198 *See also specific properties*
- Proton Induced X-ray Emission Spectroscopy, 203, **212**
- Pulvaxmixers, 18
- Pulverized coal *See under* Coal
- Pumping, 108
- PWPP *See* Port Washington Power Plant
- Pyrites, 37
- Radioactivity, 213-214, 267-273
- Reburning, 177-179
- Recovery, 174-177, **175**
- Regulation, 159; ACI 318 building code, 68; air emission quality, 3-5, 6, 202, 223-227; Clean Air Act, 3, 4; concrete, 53, 216; exemptions, 203, 214; landfills, 5, **201**; Michigan Department of Environmental Quality, 4, 216; Michigan Department of Transportation, 39, 43, 45, **45**, 166; U. S. Environmental Protection Agency, 4, 201, 216-217; Wisconsin Department of Natural Resources, 3-4, 6, 170, **171-172**, 175, 177, 203, **204-213**, 214, 215, **218-222**, 240, 242, 244, 247, 249; Wisconsin Department of Transportation, 39, 43, **44**, 45-46, 89, **90**, 91, 108, 161, 166, 168, 240, 242, 249
- Research, 47; bottom ash, 37-46, 113, 159-164, 179-184; Center for By-Products Utilization, 54, 77, 105, 112, 130, 138, 147, 179, 180; Center for Highway and Traffic Engineering, 185; cold-in-place recycling, 185-192; concrete, 54-88, 105-107, 117-128, **131**; controlled low strength material, 130-152, 155; Electric Power Research Institute, 51-52, 199; emissions, 223-227; fly ash, 51-52, 54-88, 105-107, 112-116, 130-151, 179-184, 194-198, 213-214, 223-227; manufactured soil products, 169-170; Marquette University, 185; masonry products, 112-116, 179-184; metal-matrix composites, 193-198; radioactivity, 213-214; U. S. Army Corps of Engineers, 51; University of Wisconsin-Madison, 169; University of Wisconsin-Milwaukee, 54, 77, 105, 112, 130, 138, 147, 179, 180, 194; We Energies, 54-88, 112-128, 130-151, 159-164, 179-184, 199; Wisconsin Department of Transportation, 155 *See also* Pilot projects
- Resistivity, electric, 118-128, **123**, **128**, 140-151, **141**, **142**, **146**, **150**; thermal, 230
- Road base *See* Aggregates
- Rule 801 *See* Michigan Department of Environmental Quality
- Safety, bottom ash, 201-202, 264-266; controlled low strength material, 155-156, 247-248; fly ash, 201-202, 213-214, 264-266; Minergy LWA, 262-263
- Scott's Company, 169-170
- Seal coat aggregates *See under* Aggregates
- Selective catalytic reduction, 4, 226
- Selective non-catalytic reduction, 4, 226
- Setting time *See* Time of set
- Sewage sludge stabilization *See* Liquid waste stabilization
- Shrinkage, bottom ash, **21**; concrete, 52-53, 68, **69**, 96, **102**; controlled low strength material, 130, 134, 137

- Size, boiler slag, 22; bottom ash, **39, 40-42, 160, 161**; fly ash, 15; gypsum, 24, **24**; recovered ash, 176, **176**; testing procedure, **39, 160**
- Slump, base course, 110, **112**; concrete, **56, 57, 62-64, 73, 79, 94, 95, 96, 110, 112, 117, 119, 119, 125, 131, 232**; controlled low strength material, 131, **131, 133, 133, 135, 136, 137, 139**; testing procedures, 232
- Slurry *See* Controlled low strength material
- Sodium bicarbonate sorbent injection systems, 29
- Soil-cement slurry *See* Controlled low strength material
- Soil corrosivity, **141**
- Soil stabilization, 17, 47
- Solid waste disposal sites *See* Landfills
- Soundness, 52; bottom ash, **44-45, 45**; fly ash, **36, 55**; testing procedure, **39**
- Specific gravity, boiler slag, **23**; bottom ash, **22**; cement, 17, **110**; fly ash, 17, **36, 55, 110, 138**; gypsum, **24**
- Specifications, AASHTO, **44-45, 104, 187**; asphalt, 43, 249-254; backfill, 240-243; bottom ash, **44-45**; concrete, 231-239, 249-254; controlled low strength material, 244-248; Flo-Pac, 246; gravel, 161; Michigan Department of Transportation, 39, 43, 45, **45, 166**; pavement, 249-254; We Energies, 231-254; Wisconsin Department of Transportation, 39, 43, **44, 45-46, 90, 91, 108, 161, 166, 168, 240, 242, 249** *See also* ACl...; ASTM...
- Staining potential, 37
- Standards *See* Specifications
- Statistics, boiler slag, 2; bottom ash, 2, **26, 26-30, 37**; coal combustion products, 2-3, **3, 26**; flue gas desulfurization material, 2; fly ash, 2, **26, 26-30**; Milwaukee County Power Plant, **26, 27**; nitrogen oxide, 4; Oak Creek Power Plant, **26, 28**; Pleasant Prairie Power Plant, **26, 28**; Port Washington Power Plant, **26, 29**; Presque Isle Power Plant, **26, 30**; production, 2, 3, **3, 26, 26-30, 37**; sulphur dioxide, 4; utilization, 2-3, **3, 5**; Valley Power Plant, **26, 30**; We Energies, **3, 5, 26, 26-30, 37**
- Stir-casting process, 194
- Storage, 10-11; Milwaukee County Power Plant, 27; Oak Creek Power Plant, 28; Pleasant Prairie Power Plant, 28-29; Presque Isle Power Plant, 30
- Strength, **36, 50, 156-157** *See also* Compressive strength, Flexural strength, Tensile strength
- Stress, **18, 162**
- Structural fill, 159, 161, 163-164, 240-241
- STS Consultants, Ltd., 159, 164-165
- Sub-base material, 26, 159-164
- Subgrade reactions, **18**
- Sulphate resistance, 50-51
- Sulfur, 11
- Sulfur dioxide, 4-5, 11
- Sulfuric acid, 11
- Sussex (Wis.), corporate center, **88, 88-90, 90**; Maple Avenue, **91-92**
- Sustainable development, 3, 157, 202
- SW-846 *See* Test Method for Evaluating Solid Waste
- Synthetic gas, 10
- Synthetic gypsum *See* Gypsum
- Tax Incremental Financing, 89
- Temperature, 111, **112, 119, 232**
- Tensile strength, **99**
- Test Method for Evaluating Solid Waste, 203, **212**
- Testing procedures, 39, 54-58, 72-74, 110-111, 113-115, 118-120, 124, 134, 138, 143, 147, 160, 163, 203, 223; AASHTO, **39**; California Test 643, 140; Figg method, 78; Military Standard 621A, 163; mixture design, 54-58, **56-57, 64, 65, 67, 72, 73, 78, 79, 89, 91, 95-96, 108, 114, 116, 117, 118-119, 119, 124-125, 125, 130-131, 131, 134, 135, 138, 139, 143, 144, 147-148, 148, 180, 180-181**; Proton Induced X-ray Emission Spectroscopy, 203, **212**; Test Method for Evaluating Solid Waste, 203, **212**; thermal needle test, 141 *See also* ASTM...; Research
- Thermal conductivity *See under* Conductivity
- Thermal contraction, 52
- Thermal resistivity *See under* Resistivity
- Time of set, 64-67, **66, 71, 110, 126, 143**
- Traction *See* Anti-skid material
- Ultrasonic pulse velocity, **101**
- Unified Soil Classifications System, 17
- Uniformity, fly ash, 17
- U. S. Army Corps of Engineers, 51
- U. S. Department of Energy, 200
- U. S. Environmental Protection Agency, 4, 201, 216-217; Coal Combustion Products Partnership program, 216-217
- U. S. patents *See* Patents
- University of Wisconsin-Madison, 169

- University of Wisconsin-Milwaukee, 54, 77, 105, 112, 130, 138, 147, 179, 180, 194
- Unshrinkable fill *See* Controlled low strength material
- Utilization, 5, 18-26; agriculture, 169-170; anti-skid material, 159, 168; asphalt, 23-24, 38, 159, 169; backfill material, 6, 138, 143, 156-157, 159, 165-168, **166**, 240-243; base course, 43, 108-112, 159-165; bike trails, 169; boiler slag, 23-24; bottom ash, 19, 26, 38, 159-184, **165**, **166**, **170**, **173**, **174**; calcium sulfite, 24; cenospheres, 199; Concrete, 6, cinders, 1, 2, 6-7; Coal Combustion Products Partnership program, 216-217; cold-in-place recycling, 18, 47, 185-192, **188**, **192**; concrete, 6-7, 16, 19, 26, 47-128, **131**, 169, 231-239; construction, 6, 47, 50, **165**, **166**, 229; controlled low strength material, 129-157, **153-157**; drainage media, 26, 159; drying agent, 17; Flo-Pac, 129, 152, **154**, 246; fly ash, 6-7, 17-19, 26, 47-157, 185-200; green roofs, 173, **173**, **174**, 230; gypsum, 24, 25; lightweight aggregates, 47, 229-230, 262-263; liquid waste stabilization, 26, 47; manufactured soil products, 159, 169-170, **170**, 230; masonry products, 1, 38, 112-116, 159, 179-184, 229-230; metal-matrix composites, 193-200; Minergy LWA, 229-230, 262-263; pavement, 26, **88**, 88-112, **90-93**, 159-165, 185-192, **188**, **192**; reburning, 177-179; soil stabilization, 17, 47; statistics, 2-3, **3**, 5; structural fill, 159, 161, 163-164, 240-241; sub-base material, 26, 159-164; sulfur, 11; sulfuric acid, 11; wallboard, 24
- Valley Power Plant, 30, **30**, **141**; map, **32**; statistics, **26**, 30
- Valley Power Plant (bottom ash), chemical composition, **37**; density, **38**, 167; drainage, **167**; elemental analysis, **208**; hydraulic conductivity, **38**; leaching, **210**; moisture content, **38**; permeability, **167**; physical properties, **38**; research, 170; size, **39**, **42**
- Valley Power Plant (fly ash), chemical composition, **34**, **135**; elemental analysis, **204**; fineness, **36**, **135**; leaching, **206**; loss on ignition, **34**; mercury, 224, **225**; moisture content, **34**; physical properties, **36**, **135**; research, 134-137, 140-143, 224, **225**; soundness, **36**; specific gravity, **36**; strength, **36**; water demand, **36**
- VAPP *See* Valley Power Plant
- Wallboard, 24
- Water absorption, 115-116, **116**
- Water demand, **36**, **55**, 59, 62-63, **62-63**, **110**, **138**
- Water permeability *See under* Permeability
- We Energies, map, **32**; pilot projects, **88**, 88-105, **90-93**, 153-154, **153-154**, 163-165, **165**, 169-170, **170**, 174-175, **175**, 185-192, **188**, **192**; power plants, **1**, **2**, 6, 26-31, **27-31** *See also names of individual plants*; recovery project, 174-175, **175**; research on bottom ash, 37-46, 113, 159-164, 179-184; research on cenospheres, 199; research on cold-in place recycling, 185-192; research on concrete, 54-88, 105-107, 117-128; research on controlled low strength material, 130-152; research on emissions, 223-227; research on fly ash, 51-52, 54-88, 130-152, 179-184, 194-198, 213-214, 223-227; research on masonry products, 112-116, 179-184; research on metal-matrix composites, 194-198; sample specifications, 231-254; service area, **32**; statistics, **3**, 5, **26**, 26-30, 37
- Weight, boiler slag, **23**; bottom ash, **22**; concrete, 119, **119**, **125**, **131**, **180**, **181**; controlled low strength material, **131**, **135**, 143, **144**, 147, **148**
- Wells Street Power Plant, **2**, 6
- West Highland Avenue pilot project *See under* Pilot projects
- West Virginia Department of Transportation, 169
- Wet unloaders, 11
- Wisconsin Administrative Code, NR 428 *See under* Wisconsin Department of Natural Resources
- Wisconsin Administrative Code, NR 538 *See under* Wisconsin Department of Natural Resources
- Wisconsin Department of Natural Resources, NR 428, 3-4; NR 538, 6, 170, **171-172**, 175, 177, 203, **204-213**, 214, 215, **218-222**, 240, 242, 244, 247, 249
- Wisconsin Department of Transportation, 39, 43, **44**, 45-46, 89, **90**, 91, 108, 155, 161, 166, 168, 240, 242, 249
- Wisconsin Electric Power Company, 229-230 *See also* We Energies
- Workability, concrete, 50, 59, 64, 117, 118; controlled low strength material, 137