


American Concrete Institute, 1978: "Cold Weather Concreting," ACI 306R-78.


Associated General Contractors and House Builders of Sweden, 1963: Road Construction Year Round (in Swedish), Byggindustriens Förlags AB.


Esch, D. C., 1983: “Evaluation of Experimental Design Features for Roadway Construc-


Bibliography


Länsiuluoto, J., 1977: "Fabrication and Qualities of Steel and Steel Products," in Steel Structures (in Finnish), Finnish Ass. for Civil Eng., RIL 113, chap. 2.


———., 1978: Ice Mechanics, University of Laval Press, Quebec.


Price, W. I. J., 1961: “The Effect of the Characteristics of Snow Fences on the Quality and
Shape of the Deposited Snow,” General Assembly of International Union of Geodesy and Geophysics, Publ. 54.


Räsänen, E., 1980: “Steel Structures for Low Application Temperatures” (in Finnish), Insinöörijärjestöjen Kouluutuskeskus, INSKO 124-80 I.


516 Bibliography


Save, S., 1975: “Properties of Wood and Strength of Glued Joints at Low Temperatures” (in Finnish), Technical University of Helsinki, Dept. of Wood Processing, Otaniemi.


Thunell, B., 1942: “Quality and Strength in Practice” (in Swedish), Statens Provningsanst., Stockholm, Medd. 89.


# UNIT CONVERSION TABLE

<table>
<thead>
<tr>
<th>Metric units</th>
<th>U.S. customary units</th>
<th>U.S. customary units</th>
<th>Metric units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 km = 1000 m</td>
<td>= 0.6214 mi</td>
<td>1 mi = 1760 yd</td>
<td>= 1.60934 km</td>
</tr>
<tr>
<td>1 m = 1000 mm</td>
<td>= 1.0936 yd</td>
<td>1 yd = 3 ft</td>
<td>= 0.91440 m</td>
</tr>
<tr>
<td></td>
<td>= 3.2808 ft</td>
<td>1 ft = 12 in</td>
<td>= 0.3048 m</td>
</tr>
<tr>
<td>1 mm</td>
<td>= 0.0394 in</td>
<td>1 in</td>
<td>= 25.4 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Area</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 km² = 100 ha</td>
<td>= 0.3861 mi²</td>
<td>1 mi² = 640 acres</td>
<td>= 2.58999 km²</td>
</tr>
<tr>
<td>1 ha = 10,000 m²</td>
<td>= 2.47105 acre</td>
<td>1 acre = 4840 yd²</td>
<td>= 0.40469 ha</td>
</tr>
<tr>
<td>1 m² = 1,000,000 mm²</td>
<td>= 1.1960 yd²</td>
<td>1 yd² = 83613 m²</td>
<td>= 0.09290 m²</td>
</tr>
<tr>
<td></td>
<td>= 10.7639 ft²</td>
<td>1 ft² = 0.09290 m²</td>
<td></td>
</tr>
<tr>
<td>1 mm²</td>
<td>= 0.00155 in²</td>
<td>1 in² = 645.160 mm²</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Volume</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m³ = 1000 L</td>
<td>= 1.30795 yd³</td>
<td>1 yd³ = 0.76456 m³</td>
<td>= 28.3168 L</td>
</tr>
<tr>
<td></td>
<td>= 35.3147 ft³</td>
<td>1 ft³ = 0.02832 m³</td>
<td></td>
</tr>
<tr>
<td>1 L = 1 dm³</td>
<td>= 0.03532 ft³</td>
<td>1 in³ = 16.3871 cm³</td>
<td></td>
</tr>
<tr>
<td>1 cm³ = 1 mL</td>
<td>= 0.06102 in³</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Mass</strong></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 tonne = 1000 kg</td>
<td>= 0.98421 long ton</td>
<td>1 long ton = 2240 lb</td>
<td>= 1.01605 tonne</td>
</tr>
<tr>
<td></td>
<td>= 1.10231 short ton</td>
<td>1 short ton = 2000 lb</td>
<td>= 0.90718 tonne</td>
</tr>
<tr>
<td>1 kg</td>
<td>= 2.20462 lb</td>
<td>1 lb</td>
<td>= 0.45359 kg</td>
</tr>
</tbody>
</table>
## Unit Conversion Table (continued)

<table>
<thead>
<tr>
<th>Metric units</th>
<th>U.S. customary units</th>
<th>U.S. customary units</th>
<th>Metric units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1 \text{ kg/m}^3 = 0.001 \text{ g/cm}^3$</td>
<td>$= 1.68556 \text{ lb/yd}^3$</td>
<td>$1 \text{ lb/yd}^3$</td>
<td>$= 0.59328 \text{ kg/m}^3$</td>
</tr>
<tr>
<td></td>
<td>$= 0.06243 \text{ lb/ft}^3$</td>
<td>$1 \text{ lb/ft}^3$</td>
<td>$= 16.0185 \text{ kg/m}^3$</td>
</tr>
<tr>
<td>Force</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1 \text{ MN} = 1000 \text{ kN}$</td>
<td>$= 100.361 \text{ long tons}$</td>
<td>1 long ton</td>
<td>$= 9.96402 \text{ kN}$</td>
</tr>
<tr>
<td></td>
<td>$= 112.404 \text{ short tons}$</td>
<td>1 short ton</td>
<td>$= 8.89644 \text{ kN}$</td>
</tr>
<tr>
<td>$1 \text{ kN} = 1000 \text{ N}$</td>
<td>$= 0.22481 \text{ kip}$</td>
<td>1 kip $= 1000 \text{ lb}$</td>
<td>$= 4.44822 \text{ kN}$</td>
</tr>
<tr>
<td></td>
<td>$= 224.809 \text{ lb}$</td>
<td>1 lb</td>
<td>$= 4.44822 \text{ N}$</td>
</tr>
<tr>
<td>Pressure, stress</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1 \text{ MPa} = 1 \text{ MN/m}^2$</td>
<td>$= 0.14504 \text{ kip/in}^2$</td>
<td></td>
<td>$= 15.4443 \text{ MPa}$</td>
</tr>
<tr>
<td>$1 \text{ kPa} = 1 \text{ kN/m}^2$</td>
<td>$= 0.14504 \text{ lb/in}^2$</td>
<td></td>
<td>$= 107.252 \text{ kPa}$</td>
</tr>
<tr>
<td>$1 \text{ Pa} = 1 \text{ N/m}^2$</td>
<td>$= 0.02089 \text{ lb/ft}^2$</td>
<td></td>
<td>$= 6.89476 \text{ MPa}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 kip/in$^2 = 1000 \text{ lb/in}^2$</td>
<td>$= 6.89476 \text{ kPa}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 lb/in$^2$</td>
<td>$= 47.8803 \text{ kPa}$</td>
</tr>
<tr>
<td>Velocity, speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1 \text{ km/h} = 0.278 \text{ m/s}$</td>
<td>$= 0.62137 \text{ mi/h}$</td>
<td>1 mi/h $= 1.466 \text{ ft/s}$</td>
<td>$= 1.6093 \text{ km/h}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$= 0.4470 \text{ m/s}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$= 1.853 \text{ km/h}$</td>
</tr>
<tr>
<td>$1 \text{ m/s}$</td>
<td>$= 3.28084 \text{ ft/s}$</td>
<td>1 ft/s</td>
<td>$= 0.3048 \text{ m/h}$</td>
</tr>
<tr>
<td>$1 \text{ cm/s}$</td>
<td>$= 0.39370 \text{ in/s}$</td>
<td>1 in/s</td>
<td>$= 2.540 \text{ cm/s}$</td>
</tr>
<tr>
<td>Volume rate of flow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1 \text{ m}^3/\text{s} = 1000 \text{ L/s}$</td>
<td>$= 35.3147 \text{ ft}^3/\text{s}$</td>
<td>1 ft$^3/\text{s}$</td>
<td>$= 0.02832 \text{ m}^3/\text{s}$</td>
</tr>
<tr>
<td>$1 \text{ L/s}$</td>
<td>$= 2.11888 \text{ ft}^3/\text{min}$</td>
<td>1 ft$^3/\text{min}$</td>
<td>$= 0.47195 \text{ L/s}$</td>
</tr>
<tr>
<td>Work, energy, heat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1 \text{ MJ} = 10^6 \text{ Nm}$</td>
<td>$= 0.27778 \text{ kWh}$</td>
<td>1 kWh</td>
<td>$= 3.6 \text{ MJ}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 Btu</td>
<td>$= 1.0551 \text{ kJ}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 ft·lb = 0.3238 cal</td>
<td>$= 1.3558 \text{ J}$</td>
</tr>
<tr>
<td>Metric units</td>
<td>U.S. customary units</td>
<td>U.S. customary units</td>
<td>Metric units</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------</td>
<td>----------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>1 kJ = 1000 J</td>
<td>= 0.94782 Btu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 J = 0.2388 cal</td>
<td>= 0.73756 ft · lb</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Power, heat flow rate**

| 1 kW | = 1.34102 hp |
| 1 W = 1 J/s | = 3.41214 Btu/h |

| 1 hp = 550 ft · lb/s |
| 1 Btu/h | = 0.74570 kW |
| 0.29307 W |

**Calorific value**

| 1 kJ/kg = 1 J/g | = 0.42992 Btu/lb |
| 1 kJ/m³ | = 0.02684 Btu/ft³ |
| 1 Btu/lb | = 2.326 kJ/kg |
| 1 Btu/ft³ | = 37.2589 kJ/m³ |

**Heat flux**

| 1 W/m² | = 0.316998 Btu/(ft² · h) |
| 1 Btu/(ft² · h) | = 3.15459 W/m² |

**Thermal conductance**

| 1 W/(m² · °C) | = 0.17611 Btu/(ft² · h · °F) |
| 1 Btu/(ft² · h · °F) | = 5.6783 W/(m² · °C) |

**Thermal resistance**

| 1 (m² · °C)/W | = 5.678 (ft² · h · °F)/Btu |
| 1 (ft² · h · °F)/Btu | = 0.17611 (m² · °C) |

**Thermal conductivity**

| 1 W/(m · °C) | = 0.57779 Btu/(ft · h · °F) |
| 1 Btu/(ft · h · °F) | = 6.93347 Btu · in/(ft² · h · °F) |
| 1 Btu · in/(ft² · h · °F) | = 1.73073 W/(m · °C) |
| 0.14423 W/(m · °C) |

**Heat capacity**

| 1 kJ/(kg · °C) | = 0.23885 Btu/(lb · °F) |
| 1 kJ/(m³ · °C) | = 0.01491 Btu/(ft³ · °F) |
| 1 Btu/(lb · °F) | = 4.18680 kJ/(kg · °C) |
| 1 Btu/(ft³ · °F) | = 67.0661 kJ/(m³ · °C) |

**Thermal diffusivity**

| 1 m²/s = 10⁶ mm²/s | = 10.7639 ft²/s |
| 1 mm²/s | = 0.03875 ft²/h |
| 1 ft²/s | = 0.0929 m²/s |
| 1 ft²/h | = 25.806 mm²/s |
INDEX

Accelerated ice growth, 159–165
Active layer, 10, 186, 188, 215–224, 251–252, 256
Adfreeze bond:
  frozen ground, 236–238, 253–257, 438–439
  ice cover, 74–76, 93
Adfreeze condition, 119, 127
Adfreeze strength:
  frozen ground, 236–238, 253–257
  ice cover, 76, 93
Admixtures, 366–370
Air bubbling, 150–158, 163–166
Air friction force, 105–109, 127
Air temperatures, 4–6
  effects on work efficiency, 474–475
Air transportation network, 481
Alpine permafrost, 187
Aluminum, 379–381
Anchors, 257–258
Angle of friction:
  frozen soil, 203–205, 261
  between ice and soil, 135, 137, 174
  between ice and structure, 125
  between ice accumulation and shore, 108
  between ice blocks in a ridge, 129–130
  ice rubble, dynamic, 135
Antifreeze, 366–370, 463
Apparent specific heat capacity, 214
Arctic region, 1–2
Arctic surveying, 198, 234–235, 489–491
Arctic transportation, 479–486
Artificial gravel island, 170–171, 174–185, 317, 320, 326, 435
Artificial ice island, 170–171, 178, 180–182
Artificial thickening of ice cover, 89–91
Artificially thickened floating ice pad, 90–91
Artificially thickened ice bridge, 89–90
Aspect ratio effect, 112–113
Asphalt concrete pavements, 383
Atmospheric icing, 37–43
Aufeis, 9, 193, 291–296
Augering, 439, 441, 444
Avalanche, 32–36
Avalanche control, 34–37
Backfilling, 237, 256, 296–297, 309, 316, 437, 439, 441–446
Balanced moisture condition, 470
Basal plane, 50
Beaded stream, 10, 193, 315
Bearing capacity:
  footing, 29–30, 260–265
  frozen marshy ground, 411
  ice cover, 77–91
  pile, 30–31, 253–257
  snow, 29–31
Berggren equation, 217
Borrow pit, 423–425, 448
Brine, 53–57
Brittle zone, 72
Buckling failure, ice, 115, 117, 133–134

c axis, 50–53
Capillary rise, 226
Carbon equivalent, 347–348
Casagrande frost criteria, 226
CAT curve, 345–346, 358
Characteristic length, 78
Charpy V-notch test, 344, 358
Chezy coefficient, 62
Classification system:
  frost design, 227, 277
Classification system (Cont.):
- frozen soil, 190–192
- ice, 50–53

Climatological zones, 2
COD test, 346–347, 351, 353, 357

Coefficient:
- of compressibility, 231–232
- of consolidation, 232
- of thermal expansion, ice, 99

Cohesion:
- frozen soil, 203–205, 207, 261–262
- ridge keel, 129–130

Cold region, 1–2

Cold weather construction:
- concreting, 360–366, 370–371, 446–464
- costs, 422, 473–479, 488–489
- earth handling, 425, 432–435
- excavation, 414–431
- feasibility, 409–413, 473–475
- foundation construction, 437–446
- frost protection, 420, 422, 437–439
- interior work, 469–472
- masonry work, 465–468
- roofing, 468–469
- soil compaction, 425, 432–435
- steel work, 465
- work efficiency, 474, 486

Columnar grained ice, 51–53

Compressional wave velocities in soils, 205, 209

Compressive strength:
- frozen soils, 201–203, 265
- ice, 72–74
- wood, 378–379

Concrete:
- admixtures, 366–370
- early freezing, 361–366
- freeze-thaw effects, 373–375
- ice abrasion, 140–141, 375–377
- low temperature effects, 371–373
- strength development, 363–365

Concrete construction, winter conditions:
- cooling during delivery, 450–452
- cooling during pouring, 450–452
- curing, 370–371, 453, 460–461
- heating, 452–463
- manufacturing in cold weather, 446–449
- thermal protection, 452–464

Condensation, 393–400


Consolidation:
- frozen ground, 206
- ice ridge, 127–129
- thawing ground, 196, 229–231
- Constant-strain-rate test, 70–72, 204–205
- Construction moisture, 399, 469–472
- Continuous permafrost zone, 187

Convection:
- air, 387, 391–394
- ground water, 215, 218, 312, 322–331
- water, 150–164

Cooling ducts, 249, 267–268

Crack propagation, 353–357

Creep:
- frozen ground, 195, 203–212, 265
- ice, 69–72, 99–100
- primary, 69, 205–206, 209–211
- secondary, 69–70, 205–206, 210, 265
- strength, 203, 212
- tertiary, 69, 210, 212

Critical velocity, 83–85

Culverts, 289–291

Cuts, 252–286

Dams on permafrost, 311–315, 319–321

Darcy’s law, 323

Daylight duration, 7, 9

Deflection rate, ice cover, 86

Deformation properties:
- frozen ground, 203–212
- ice, 67–72

Density:
- air, 105, 109
- construction materials, 389, 395
- glaze, 39
- icing, 39
- rime, 39
- snow, 17–18

Depth of frost, 10, 188, 215–224

Depth of thaw, 10, 215–224

Discontinuous permafrost zone, 187

Dissipation of kinetic energy, 137–139

Ditches, 288–291

Drag coefficient, 105–106

Drainage, 288–296, 437

Drifting ice, 158–159
Frozen soil (Cont.):
  unfrozen water content, 198–200
Fusion parameter, 217

Geothermal gradient, 186, 188
Glacier, 59
Glaze, 39
Gravel island, 170–171, 174–185, 317, 320, 326, 435
Ground icing, 291, 293–296
Ground snow load, 19–21
Ground thermal regime, 188, 215–224
Growth rate of ice, 52–54, 160–161

Harbor design, 149–164
Hard frozen soil, 199
Heat of hydration, 452–453
Heat capacity:
  air, 267
  apparent, 214
  concrete, 452
  frozen soil, 214
  specific, 214
  unfrozen soil, 214
  volumetric, 214
  water, 155, 214
Heat flow, 215
Heat flux, 388
Heat pipe, 26–27, 29
Heat tracing, 295, 301
Heat transfer:
  radiation, 100–101, 216, 218, 388–390, 458–460
Heat-transfer coefficient, 64
Heating cables, 21, 26–27, 405, 418, 421
Heave rate, 226–228, 329–330
Heaving forces, 236–238, 253–257, 438–439
High-flow air screen, 164–166
Hot concreting, 463–464
Hummocked ice, 57–59, 172

Ice:
  buildup rate, 89–90
  deformation properties, 67–72
  growth, 52–55
  model tests, 47–50
  salinity, 53–57
  strength, 72–76
  structure, 50–53, 60, 67
  thawing, 54–55, 65, 67
Ice abrasion, 140–141, 376–377
Ice accumulation, 42, 43, 60–63, 107–111, 145, 147, 149, 159
Ice boom, 108, 111, 141–147, 159, 165, 168
Ice classification:
  ice cover, 50–55
  permafrost, 188–192
Ice content, 190, 202
Ice control, 47, 141–168, 176–181
Ice cover, 9, 50–65, 171–173
  bearing capacity, 76–91
  breakup, 54–55, 57, 65, 144–145, 147–148, 185
  drag coefficients, 105–107
  dynamics, 59–60, 171–173
  formation, 50–53, 60–62
Ice crystal, 50–53, 192
Ice forces, 47–48, 91–140, 174–175, 184–185
  buckling failure, 115, 117, 133–134
  dynamic, 117–124
  local, 139–141
  multiyear ice features, 136–139
  pressure ridges, 127–131
  sloping structures, 124–127
  static, 105–117
  thermal, 98–105
  vertical, 91–98
  wide structures, 130–136, 184–185
Ice islands, 57, 59, 136–139
Ice jams, 61–66, 142–146, 165
Ice lens, 190–192, 226–229
Ice maps, 46, 171–173
Ice monitoring, 178–179
Ice movement, 116, 151, 172, 173, 177
Ice pileup, 176, 178
Ice profiles, 173
Ice saturation, 202, 226
Ice scouring, 137–139, 176
Ice segregation, 190–192, 226–229, 329–331
Ice spillways, 145
Ice survey, 171–174
Ice wedge, 10, 159, 194–195
Icebergs, 57, 59, 136–139
Icing:
  atmospheric, 37–43
  ground, 291, 293–296
  river, 291–293
  sea, 37–44
  spring, 291, 293–294
Icing efficiency, 42–43
Indentation factor, 119
Infrared heating of concrete, 455, 458–460
Insulation:
  buildings, 388–394
  during construction, 420, 435–438, 449, 451–466
  foundations, 237–242, 246–250, 267–270
  pipelines, 219–223, 305, 309, 316
  roads, 274–284, 286, 294
  utility lines, 295–304, 306–310
Insulation materials:
  freeze-thaw effects, 383–386
  thermal properties, 383–386, 389

Land-fast ice, 56–57, 172
Landslides, 193
Latent heat:
  ice, 155
  soil, 214
Linear elastic fracture design, 350–351
Local ice pressures, 139–141
Lowest air temperatures, 6

Masonry, 383, 465–468
Maturity factor, 364–365
Mean air temperatures, 5
Minimum and maximum extents of sea ice, 45–46
Model tests:
  ice, 47–50
  snow, 24–25
Module construction, 491–493, 498–501
Modulus of elasticity:
  frozen ground, 208
  ice, 67–68
Modulus of rigidity:
  frozen ground, 208
  ice, 68
Moisture control, 399–400, 469–472
Multimodal ice failure, 133–135
Multiyear ice, 9, 57, 59, 136–139, 172–173
Multizonal ice failure, 131–133

n factor, 217–218
Navigation aids, 167–170
Navigation routes, 482–483
NDT temperature, 345, 346, 348, 358
Neoprene, 386
Non-frost-susceptible soil, 188, 190–192, 195–198
Numerical methods for frost problems, 320–341

Offshore permafrost, 10, 187, 305, 317, 320, 326
Offshore structures, 12, 90–91, 170–171, 174–185, 501

Pack ice, 53–55, 172
Paints, 386, 472
Palsa, 10, 193–195
Pavement:
  construction of, 284–287, 383, 425, 432–435
  design of, 270–295, 383
Permafrost, 10, 186–188
  alpine, 187
  continuous, 10, 187
  definition of, 10
  degradation, 270, 287, 289–290, 303, 305
  discontinuous, 10, 187
  sporadic, 10
  subsea, 10, 187
  surface features, 188–189, 193–195
  thickness, 10, 188
Permeability, 226, 228, 232
Piles:
  construction of, 438–448
  freeze back, 441–443, 446
  in permafrost, 249–260
  in seasonal frost, 236–238
  in snow, 30–32
  thermal, 249, 257–260, 314–317
Pingo, 10, 193–195
Pipelines:
  construction of, 14, 465–466, 487
Pipelines (Cont.):
  frost design of, 305, 309, 314–318, 331–337
Placement, earth materials, 425, 432–435
Plastic frozen soil, 199
Plastics, 381–382
Plate rigidity, 77, 92
Poisson's ratio:
  frozen ground, 208
  ice, 68, 103
Polygon ground, 189, 194–195
Pore water pressure, 196, 231–233, 271, 323, 329–337
Pressure ridges, 9, 56–59, 127–131, 171–173
Primary creep:
  frozen ground, 205–206, 209–211
  ice, 69
Primary ice, 51
Pseudoelastic stress, 351, 353

Radiation, 100–101, 216, 218, 388–390, 458–460
Rafted ice, 59, 172
Refrigeration systems, 249, 257–260, 268–269, 282, 305, 311, 316, 319
Residual stresses:
  soil, 234
  steel, 348–351, 353
Resilient modulus, 231–232
Resins, 386
Ridged ice, 57, 59, 172
Rime, 39, 41
River ice cover, 60–65
River icing, 291–294
Roads:
  design of, 270–296, 383
temporary, 483–485
Roof design, 404–405
Roofing, 468–469
Route selection, 198, 234–235, 489–490
Rubble dynamics, 136, 176–177
Rubble formation, 133–136, 139

Saline permafrost, 199, 210
Screw anchor, 257–258
Sea ice cover, 53–60, 172–173
Sea icing, 37–44
Seasonal frost, 10, 186–188
Secondary creep:
  frozen ground, 205–206, 210
  ice, 69–70
Secondary ice, 51
Seepage, 288, 301, 305, 312, 314
Segregated ice, 190–192
Settlement analysis, 255–256, 261–265, 331–341
Shallow foundations:
  permafrost, 265–270
  seasonal frost, 237–250
Shear modulus:
  frozen ground, 208
  ice, 68
Shear strength:
  frozen ground, 203–205, 414
  ice, 71–75, 93
Shelters, 412–413, 436, 465–468, 475, 496
Site investigation, 198, 234–235, 489–490
Slides, 193
Slope stability, 193, 234
Slurry, 249, 441–446
Snow accumulation, 9, 19–25, 31–33, 490
Snow control, 23–29, 31–35, 37, 407
Snow cover, 17
Snow creep, 24, 28–31, 35
Snow density, 16–18, 20–21
Snow drifting, 17–18, 23–25, 27, 31–33
Snow fences, 25–27
Snow ice, 51–53
Snow loads, 18–24
Snow transport, 16–18
Snowfields, construction on, 27–33
Solifluction, 10, 193
Space heating, 453–456, 461
Specific heat capacity:
  concrete, 452
  soil, 214
  water, 155
Specific surface area, 200
Spring icing, 291, 293–294
Steel:
  construction with, 465–466
design based on fracture mechanics, 350–357
fracture toughness, 343–351, 355, 357
grade selection, 357–360
heat treatment, 348–350
manufacturing effects, 347–350
preloading, 348–349
Stefan's equation, 53, 217
Strain rate, indentation, 112
Subarctic region, 2
Subgrade modulus, 276
Subgrade reaction, 77
Subsea permafrost, 10, 187
Superimposed ice, 51

Talik, 188
Temperate zone, 2
Tensile strength:
  aluminum, 379
  concrete, 372
  ice, 73–74
Tertiary creep:
  frozen ground, 205, 210
  ice, 69
Thaw bulb, 10, 215–216
Thaw consolidation, 196, 229–231, 320–341
Thaw consolidation ratio, 232–234
Thaw penetration, 10, 215–224, 320–341
Thaw-stable soils, 190–192
Thaw-unstable soils, 190–192
Thaw weakening, 10, 196, 224, 231–234,
  270–272, 288–289, 320, 485
Thermal conductance, 387–388, 391
Thermal conductivity:
  construction materials, 389
  foundation soil, 245
  frozen soil, 212–213
  ice, 214
  insulation, 385
  unfrozen soil, 212–213
  water, 214
Thermal contraction cracking, 271–273, 383
Thermal diffusivity, 219
Thermal ice pressure, 98–105
Thermal resistance, 245, 387–390
Thermal stresses, 400–401, 403
Thermoerosion, 189, 193, 270, 284–285, 301, 305, 485
Thermokarst, 193–196, 290, 305
Thermopiles, 249, 257–260, 314–317
Thermopipes, 249, 268–269, 282, 312, 316
Transition temperature, 345, 381
Transition zone, 72
Transverse cracking, 271–273, 383
Trenching, 419, 424

Tundra vegetation, 12
Tunnels, 309–311, 318–319

Unfrozen water content, 199–200
Utilidors, 301, 303, 310, 312
Utility lines:
  design in permafrost, 295–296, 301, 303, 310, 312–313
  design in seasonal frost, 295–304, 306–309

Vapor barrier, 394, 399–400
Vapor condensation, 393–401
Vapor diffusion, 393–398
Vapor pressure, 395–396
Vapor resistivity, 395
Vegetation zones, 11–12
Velocity flux, 323
Vertical ice forces, 91–98
Viscoelastic behavior:
  frozen ground, 203–211
  ice, 69–72
Volumetric heat capacity:
  air, 267
  frozen soil, 214
  unfrozen soil, 214
Vyalov's equation, 209
Vyalov's long-term strength, 203

Water friction force, 105–109
Water intakes, 145–149
Waterway transportation routes, 482–483
Weldability, 343, 347–348, 465
Welding residual stress, 348–351, 353
Whiteout, 7
Wind deflectors, 25–26, 37
Wind drag, 105–107
Windchill factor, 8, 480
Winter navigation, 9, 158–167, 178–180, 479
Winter roads, 479, 481–482
Wood, 377–380

Yield strength:
  aluminum, 379
  steel, 343
Young's modulus:
  frozen ground, 208
  ice, 67–68
ABOUT THE AUTHORS

Esa M. Eranti, an arctic engineering specialist at Finn-Stroi Oy in Finland, has considerable experience in a variety of structural design and development projects. A native of Finland, he is a member of several Finnish boards and working groups managing and promoting cold region engineering research. Mr. Eranti received an undergraduate degree in civil engineering at Helsinki University of Technology and a master’s degree in civil engineering from the State University of New York at Buffalo.

George C. Lee, Ph.D., is Professor and Dean, Faculty of Engineering and Applied Sciences, State University of New York at Buffalo. He is also the founder and associate director of the Calspan-UB Research Center in Buffalo, a structural engineering consultant, and the coauthor of Structural Analysis and Design (with R.L. Ketter and S.P. Prawel) and Design of Single Story Rigid Frames (with R.L. Ketter and T.L. Hsu). Dr. Lee received his B.S. degree in civil engineering from National Taiwan University and his master’s and doctor’s degrees from Lehigh University.