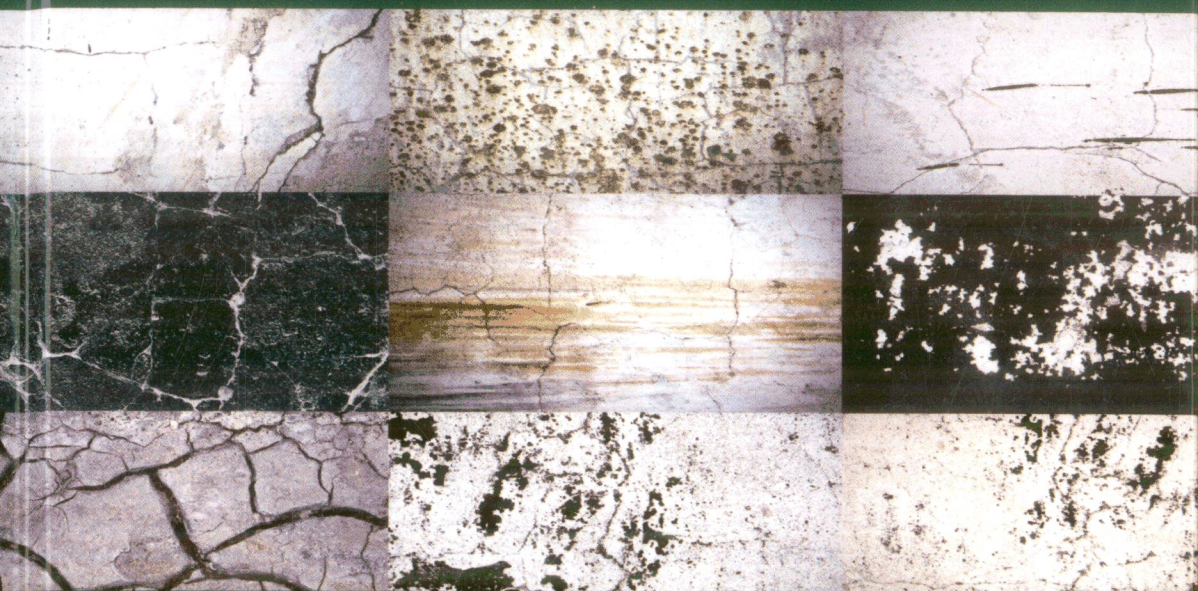




Physical Properties of Concrete and Concrete Constituents

**Jean-Pierre Ollivier
Jean-Michel Torrenti
Myriam Carcassès**

ISTE

 **WILEY**

Table of Contents

Introduction	xi
Chapter 1. Description of Granular Materials, Definitions	1
1.1. Introduction	1
1.2. Density	2
1.2.1. At the grain scale	2
1.2.2. At the granular material scale	4
1.3. Porosity of granular material	4
1.4. Compactness	4
1.5. Void ratio	5
1.6. Relative compactness	6
1.7. Saturation point	7
1.8. Moisture content	7
1.8.1. Measurement of moisture content	7
1.8.2. Comparison of methods of measurement	10
1.9. Ratio between the different densities	12
1.10. Absorption of water	12
1.11. Bibliography	13
1.12. Exercises	13
Chapter 2. Granulometry	19
2.1. Introduction	19
2.2. Characterization of the shape of grains	21
2.3. Methods of granulometric analysis	22
2.3.1. Sieving	23
2.3.2. Granulometric methods based on sedimentation	30
2.3.3. Coulter counter	37

2.3.4. Laser granulometer (NF ISO 13320-1)	38
2.3.5. Analysis of images coupled by microscopic observations	39
2.4. Granularity: presentation of results	40
2.4.1. Granular cumulative curves	40
2.4.2. Granular frequency curves	43
2.4.3. Other presentations of granularity	43
2.5. Granularity of a mixture of aggregate	46
2.6. Bibliography	47
2.7. Exercises.	48
Chapter 3. Specific Surface Area of Materials	55
3.1. Definition	55
3.1.1. The importance of this parameter: Portland cement hydration	56
3.2. Calculating the specific surface area of a granular material.	57
3.2.1. Powder consisting of identical grains of known shape	57
3.2.2. Homogeneous powder containing grains of non-uniform size	58
3.3. Methods based on permeability and porosity measurements	59
3.3.1. Kozeny-Carman equation.	59
3.3.2. Lea and Nurse apparatus	65
3.3.3. Blaine apparatus	67
3.4. Methods based on the adsorption of a gas	70
3.4.1. Adsorption kinetics.	70
3.4.2. Adsorption isotherms	71
3.4.3. Determination of specific surface area from isotherm adsorption.	75
3.4.4. Determination of the specific surface area from an isotherm point	77
3.4.5. Comparison of techniques	78
3.5. Methylene blue test for the characterization of fine particles	78
3.6. Bibliography	79
3.7. Exercises.	79
Chapter 4. Voids in Granular Materials and the Arrangement of Grains	87
4.1. Introduction.	87

4.2. Sphere packing (one-dimensional: $\Phi = 2R$): theoretical approach and experimental data	88
4.2.1. 3D packing of square-based layers	88
4.2.2. 3D packing of rhombic-based layers	90
4.2.3. Porosity of identical spherical packing	90
4.3. Experimental data	95
4.4. Influence of grain shape	97
4.5. Search for maximum compactness	98
4.5.1. Mixture of two one-dimensional aggregates	100
4.5.2. Theoretical analysis of the variation of compactness with volume fractions of grains of different sizes	102
4.5.3. Model with interaction	106
4.5.4. Consideration of the vibration, compressible packing model	109
4.5.5. Mixture of three one-dimensional aggregates	113
4.6. Bibliography	121
4.7. Exercises.	121
Chapter 5. Voids in Concrete	129
5.1. Definitions	129
5.2. Characterization of heterogeneous materials	133
5.3. Specific surface area of porous solids	136
5.4. Measurements of the porosity of consolidated materials	139
5.4.1. Measurement of total porosity	139
5.4.2. Measurement of open porosity	142
5.4.3. Determination of closed porosity	144
5.5. Porometry	145
5.5.1. Mercury porosimetry (or Purcell porosimetry)	145
5.5.2. Image analysis	164
5.5.3. Method based on the adsorption of a gas	165
5.5.4. Dynamic porosimeter: the Brémont porosimeter	172
5.5.5. Thermoporometry	172
5.5.6. Small angle X-ray scattering and small angle neutron scattering	174
5.5.7. Innovative techniques in development	175
5.6. Bibliography	175
5.7. Exercises.	177
Chapter 6. The Fundamentals of Diffusion	195
6.1. The basics of diffusion	195
6.1.1. Microscopic approach to diffusion	195

6.1.2. Diffusion and transport of matter at the macroscopic level: Fick's first law	201
6.1.3. A thermodynamic approach to molecular diffusion	203
6.1.4. The diffusion of ions in solution	205
6.1.5. Fick's second law.	210
6.1.6. The concentration profile of diffusing species.	211
6.2. Diffusion in porous media.	219
6.2.1. Molecular diffusion	219
6.2.2. Ionic diffusion.	222
6.2.3. The penetration kinetic of a species by diffusion: Fick's second law.	222
6.3. Measurement of the effective diffusion coefficient in porous matter	228
6.3.1. Diffusion cell method	228
6.3.2. Electric field migration tests	233
6.3.3. Measurement of the apparent diffusion coefficient by immersion	240
6.3.4. Principle of methods of measuring the effective diffusion coefficient based on measurements of conductivity	241
6.3.5. Orders of magnitude of the diffusion coefficient in concrete	243
6.4. The relationship between the effective diffusion coefficient and porous structure	245
6.4.1. Empirical models	246
6.4.2. Polyphasic models	249
6.5. Gaseous diffusion	256
6.5.1. The diffusion of a gas in an infinite medium.	256
6.5.2. The diffusion of a gas in a pore	258
6.5.3. The diffusion of a gas in a porous material.	259
6.5.4. The diffusion of a gas in a reactive porous environment . .	261
6.6. Bibliography	262
6.7. Exercises.	266
Chapter 7. Permeability	279
7.1. Introduction.	279
7.2. Definition of the permeability of a material.	280
7.3. Measurement of permeability.	282
7.3.1. Constant head permeameters.	282
7.3.2. Analysis of results: validity of Darcy's law	286
7.3.3. Methods of measuring gas permeability.	294
7.3.4. Variable head permeameters.	295

7.4. The relationship between permeability and porous structure . .	296
7.4.1. Empirical models	297
7.4.2. Physical models	297
7.5. The drying of concrete	303
7.5.1. Physical mechanisms	304
7.5.2. Simplified modeling of drying.	305
7.6. Physical parameters and performance-based approach	307
7.7. Bibliography	309
7.8. Exercises.	312
Index	333