

Contents

	<i>Preface to the Fifth Edition</i>	xv
	<i>Preface</i>	xvii
	<i>Acknowledgements</i>	xx
1	Portland cement	1
	Historical note	1
	Manufacture of Portland cement	2
	Chemical composition of Portland cement	8
	Hydration of cement	13
	Calcium silicate hydrates	14
	Tricalcium aluminate hydrate and the action of gypsum	17
	Setting	19
	False set	20
	Fineness of cement	20
	Structure of hydrated cement	25
	Volume of products of hydration	26
	Capillary pores	31
	Gel pores	32
	Mechanical strength of cement gel	34
	Water held in hydrated cement paste	35
	Heat of hydration of cement	37
	Influence of the compound composition on properties of cement	41
	Effects of alkalis	46
	Effects of glass in clinker	48
	Tests on properties of cement	49
	Consistency of standard paste	49
	Setting time	49
	Soundness	51
	Strength of cement	53
	References	56
2	Cementitious materials of different types	62
	Categorization of cementitious materials	62
	Different cements	65
	Ordinary Portland cement	69

Rapid-hardening Portland cement	71
Special very rapid-hardening Portland cements	72
Low heat Portland cement	75
Sulfate-resisting cement	76
White cement and pigments	77
Portland blastfurnace cement	79
Supersulfated cement	81
Pozzolanas	83
Fly ash	84
Pozzolanic cements	86
Silica fume	86
Fillers	88
Other cements	88
Which cement to use	90
High-alumina cement	91
Manufacture	91
Composition and hydration	92
Resistance to chemical attack	92
Physical properties of high-alumina cement	93
Conversion of high-alumina cement	95
Refractory properties of high-alumina cement	102
References	103
3 Properties of aggregate	108
General classification of aggregates	108
Classification of natural aggregates	109
Sampling	111
Particle shape and texture	112
Bond of aggregate	118
Strength of aggregate	119
Other mechanical properties of aggregate	123
Specific gravity	125
Bulk density	127
Porosity and absorption of aggregate	128
Moisture content of aggregate	132
Bulking of fine aggregate	134
Deleterious substances in aggregate	136
Organic impurities	136
Clay and other fine material	137
Salt contamination	139
Unsound particles	140
Soundness of aggregate	142
Alkali-silica reaction	144
Tests for aggregate reactivity	145
Alkali-carbonate reaction	147
Thermal properties of aggregate	148

Sieve analysis	149
Grading curves	154
Fineness modulus	154
Grading requirements	155
Practical gradings	163
Grading of fine and coarse aggregates	166
Oversize and undersize	170
Gap-graded aggregate	171
Maximum aggregate size	174
Use of 'plums'	175
Handling of aggregate	175
Special aggregates	176
Recycled concrete aggregate	176
References	178
4 Fresh concrete	183
Quality of mixing water	183
Density of fresh concrete	186
Definition of workability	186
The need for sufficient workability	187
Factors affecting workability	188
Measurement of workability	191
Slump test	191
Compacting factor test	193
ASTM flow test	194
Remoulding test	195
Vebe test	196
Flow table test	197
Ball penetration test and compactability test	197
Nasser's K-tester	199
Two-point test	199
Comparison of tests	200
Stiffening time of concrete	203
Effect of time and temperature on workability	203
Segregation	205
Bleeding	207
The mixing of concrete	209
Concrete mixers	209
Uniformity of mixing	211
Mixing time	213
Hand mixing	216
Ready-mixed concrete	216
Retempering	217
Pumped concrete	219
Concrete pumps	219
Use of pumping	220

149	Requirements for pumped concrete	221
151	Pumping lightweight aggregate concrete	225
151	Shotcrete	225
152	Underwater concrete	228
153	Preplaced aggregate concrete	228
161	Vibration of concrete	230
170	Internal vibrators	230
171	External vibrators	231
174	Vibrating tables	232
175	Other vibrators	233
175	Revibration	233
176	Vacuum-dewatered concrete	234
176	Permeable formwork	236
178	Analysis of fresh concrete	236
181	Self-compacting (self-consolidating) concrete	238
181	References	238
5	Admixtures	245
180	Benefits of admixtures	245
182	Types of admixtures	245
183	Accelerating admixtures	247
188	Retarding admixtures	251
191	Water-reducing admixtures	254
191	Superplasticizers	257
192	Nature of superplasticizers	258
194	Effects of superplasticizers	258
195	Dosage of superplasticizers	261
196	Loss of workability	261
197	Superplasticizer-cement compatibility	263
197	Use of superplasticizers	264
199	Special admixtures	265
199	Waterproofing admixtures	265
200	Anti-bacterial and similar admixtures	266
203	Remarks about the use of admixtures	267
203	References	267
6	Strength of concrete	271
209	Water/cement ratio	271
211	Effective water in the mix	275
213	Gel/space ratio	276
216	Porosity	279
216	Cement compacts	286
217	Influence of properties of coarse aggregate on strength	286
219	Influence of aggregate/cement ratio on strength	289
219	Nature of strength of concrete	291

Strength in tension	291
Cracking and failure in compression	293
Failure under multiaxial stress	295
Microcracking	300
Aggregate-cement paste interface	302
Effect of age on strength of concrete	304
Maturity of concrete	306
Relation between compressive and tensile strengths	310
Bond between concrete and reinforcement	313
References	313
7 Further aspects of hardened concrete	320
Curing of concrete	320
Methods of curing	325
Tests on curing compounds	328
Length of curing	329
Autogenous healing	330
Variability of strength of cement	330
Changes in the properties of cement	334
Fatigue strength of concrete	337
Impact strength	345
Electrical properties of concrete	348
Acoustic properties	353
References	355
8 Temperature effects in concrete	361
Influence of early temperature on strength of concrete	361
Steam curing at atmospheric pressure	368
High-pressure steam curing (autoclaving)	372
Other thermal curing methods	375
Thermal properties of concrete	376
Thermal conductivity	376
Thermal diffusivity	379
Specific heat	379
Coefficient of thermal expansion	379
Strength of concrete at high temperatures and resistance to fire	386
Modulus of elasticity at high temperatures	389
Behaviour of concrete in fire	389
Strength of concrete at very low temperatures	392
Mass concrete	395
Concreting in hot weather	399
Concreting in cold weather	402
Concreting operations	404
References	407

9	Elasticity, shrinkage, and creep	413
	Stress-strain relation and modulus of elasticity	413
	Expressions for stress-strain curve	418
	Expressions for modulus of elasticity	419
	Dynamic modulus of elasticity	421
	Poisson's ratio	422
	Early volume changes	424
	Autogenous shrinkage	426
	Swelling	426
	Drying shrinkage	427
	Mechanism of shrinkage	427
	Factors influencing shrinkage	430
	Influence of curing and storage conditions	436
	Prediction of shrinkage	438
	Differential shrinkage	439
	Shrinkage-induced cracking	442
	Moisture movement	443
	Carbonation shrinkage	444
	Shrinkage compensation by the use of expansive cements	447
	Types of expansive cements	447
	Shrinkage-compensating concrete	449
	Creep of concrete	450
	Factors influencing creep	453
	Influence of stress and strength	455
	Influence of properties of cement	457
	Influence of ambient relative humidity	458
	Other influences	461
	Relation between creep and time	466
	Nature of creep	470
	Effects of creep	473
	References	475
10	Durability of concrete	483
	Causes of inadequate durability	483
	Transport of fluids in concrete	484
	Influence of the pore system	485
	Flow, diffusion, and sorption	485
	Coefficient of permeability	486
	Diffusion	487
	Diffusion coefficient	487
	Diffusion through air and water	487
	Absorption	488
	Surface absorption tests	489
	Sorptivity	490
	Water permeability of concrete	491
	Permeability testing	495
	Water penetration test	496

496	Air and vapour permeability	496
498	Carbonation	498
499	Effects of carbonation	499
500	Rate of carbonation	500
502	Factors influencing carbonation	502
504	Carbonation of concrete containing blended cements	504
505	Measurement of carbonation	505
506	Further aspects of carbonation	506
507	Acid attack on concrete	507
509	Sulfate attack on concrete	509
510	Thaumasite form of sulfate attack	510
510	Mechanisms of attack	510
512	Factors mitigating the attack	512
514	Tests on sulfate resistance	514
515	Delayed ettringite formation	515
515	Efflorescence	515
516	Effects of sea water on concrete	516
518	Salt weathering	518
519	Selection of concrete for exposure to sea water	519
519	Disruption by alkali-silica reaction	519
521	Preventive measures	521
523	Abrasion of concrete	523
523	Tests for abrasion resistance	523
525	Factors influencing abrasion resistance	525
525	Erosion resistance	525
526	Cavitation resistance	526
527	Types of cracking	527
531	References	531
539	11 Effects of freezing and thawing and of chlorides	539
539	Action of frost	539
544	Behaviour of coarse aggregate particles	544
546	Air entrainment	546
548	Air-void system characteristics	548
550	Entrained-air requirements	550
552	Factors influencing air entrainment	552
554	Stability of entrained air	554
555	Air entrainment by microspheres	555
556	Measurement of air content	556
558	Tests of resistance of concrete to freezing and thawing	558
560	Further effects of air entrainment	560
563	Effects of de-icing agents	563
565	Chloride attack	565
565	Mechanism of chloride-induced corrosion	565
567	Chlorides in the mix	567
568	Ingress of chlorides	568

Threshold content of chloride ions	571
Binding of chloride ions	571
Influence of blended cements on corrosion	573
Further factors influencing corrosion	573
Thickness of cover to reinforcement	575
Tests for penetrability of concrete to chlorides	576
Stopping corrosion	576
References	577
12 Testing of hardened concrete	583
Tests for strength in compression	583
Cube test	584
Cylinder test	585
Equivalent cube test	586
Effect of end condition of specimen and capping	586
Non-bonded caps	588
Testing of compression specimens	590
Failure of compression specimens	592
Effect of height/diameter ratio on strength of cylinders	593
Comparison of strengths of cubes and cylinders	596
Tests for strength in tension	597
Flexural strength tests	598
Splitting tension test	600
Influence on strength of moisture condition during test	602
Influence of size of specimen on strength	603
Size effects in tensile strength tests	605
Size effects in compressive strength tests	608
Specimen size and aggregate size	611
Test cores	613
Use of small cores	614
Factors influencing strength of cores	614
Relation of core strength to strength in situ	618
Cast-in-place cylinder test	619
Influence of rate of application of load on strength	620
Accelerated-curing test	621
Direct use of accelerated-curing strength	624
Non-destructive tests	625
Rebound hammer test	626
Penetration resistance test	629
Pull-out test	630
Post-installed tests	632
Ultrasonic pulse velocity test	632
Further possibilities in non-destructive testing	635
Resonant frequency method	636
Tests on the composition of hardened concrete	637

	Cement content	637
	Determination of the original water/cement ratio	638
	Physical methods	638
	Variability of test results	638
	Distribution of strength	639
	Standard deviation	642
	References	643
13	Concretes with particular properties	651
	Concretes with different cementitious materials	651
	General features of use of fly ash, ggbs, and silica fume	652
	Durability aspects	653
	Variability of materials	654
	Concrete containing fly ash	655
	Influence of fly ash on properties of fresh concrete	656
	Hydration of fly ash	657
	Strength development of fly ash concrete	659
	Durability of fly ash concrete	662
	Concretes containing ground granulated blastfurnace slag (ggbs)	663
	Influence of ggbs on properties of fresh concrete	664
	Hydration and strength development of concrete containing ggbs	664
	Durability aspects of concrete containing ggbs	667
	Concrete containing silica fume	668
	Influence of silica fume on properties of fresh concrete	669
	Hydration and strength development of the Portland cement-silica fume system	671
	Durability of concrete containing silica fume	674
	High performance concrete	676
	Properties of aggregate in high performance concrete	678
	Aspects of high performance concrete in the fresh state	679
	Compatibility of Portland cement and superplasticizer	680
	Aspects of hardened high performance concrete	682
	Testing of high performance concrete	686
	Durability of high performance concrete	687
	The future of high performance concrete	689
	Lightweight concrete	690
	Classification of lightweight concretes	690
	Lightweight aggregates	691
	Natural aggregates	691
	Manufactured aggregates	694
	Requirements for aggregates for structural concrete	696
	Effects of water absorption by lightweight aggregate	698
	Lightweight aggregate concrete	700
	Aspects of the fresh state	700
	Strength of lightweight aggregate concrete	701
	Lightweight aggregate-matrix bond	704

Elastic properties of lightweight aggregate concrete	705
Durability of lightweight aggregate concrete	706
Thermal properties of lightweight aggregate concrete	708
Cellular concrete	710
Autoclaved aerated concrete	711
No-fines concrete	713
Nailing concrete	716
Remark about specialized concretes	717
References	717
14 Selection of concrete mix proportions (mix design)	726
Cost considerations	727
Specifications	727
The process of mix selection	729
Mean strength and 'minimum' strength	731
Variability of strength	734
Quality control	740
Factors governing the selection of mix proportions	741
Durability	741
Workability	745
Maximum size of aggregate	745
Grading and type of aggregate	746
Cement content	747
Mix proportions and quantities per batch	747
Calculation by absolute volume	749
Combining aggregates to obtain a type grading	750
American method of selection of mix proportions	754
Example	757
Mix selection for no-slump concrete	758
Mix selection for flowing concrete	758
Mix selection for high performance concrete	760
Mix selection for lightweight aggregate concrete	761
Example	762
British method of mix selection (mix design)	764
Example	769
Other methods of mix selection	770
Concluding remarks	771
References	772
Appendix I: Relevant ASTM Standards	774
Appendix II: Relevant British and European Standards	778
Name index	783
Subject index	799