

Contents

<i>Preface</i>	v
1. Introduction to Concrete	1
1.1 Concrete Definition and Historical Development	1
1.2 Concrete as a Structural Material	6
1.3 Characteristics of Concrete	7
1.3.1 Advantages of Concrete	7
1.3.2 Limitations	8
1.4 Types of Concrete	9
1.4.1 Classification in Accordance with Unit Weight	9
1.4.2 Classification in Accordance with Compressive Strength	10
1.4.3 Classification in Accordance with Additives	11
1.4.4 Classification in Accordance with Construction Methods	11
1.4.5 Classification in Accordance with Non-structural Functionality	12
1.5 Factors Influencing Concrete Properties	13
1.5.1 w/c Ratio or (w/b or w/p Ratio)	13
1.5.2 Cement Content	13
1.5.3 Aggregate	14
1.5.4 Admixtures	14
1.5.5 Mixing Procedures	15
1.5.6 Curing	15
2. Components of Concrete	17
2.1 Cement	17
2.1.1 Manufacturing Process of Cement	17
2.1.2 Chemical Composition of Portland Cement	20
2.1.3 Hydration of Cement	22
2.1.4 Types of Cement	25
2.1.5 Storage of Cement	27
2.1.6 Testing of Cement	28
2.2 Aggregates	33
2.2.1 Classification of Aggregates	33
2.2.2 Characteristics of Aggregates	34
2.2.3 Alternatives to Aggregates	36
2.2.4 Tests on Aggregates	37
2.3 Mineral Admixtures	39
2.3.1 Fly Ash	39
2.3.2 Ground Granulated Blast Furnace Slag (GGBFS)	39
2.3.3 Silica Fume	39
2.3.4 Metakaolin	39
2.3.5 Natural Pozzolans	40
2.3.6 Rice Husk Ash (RHA)	40
2.4 Water	40
2.4.1 Quantity of Water	41
2.4.2 Water-Cement Ratio	42
2.4.3 Sources of Water	44
2.4.4 Indirect Water—Bulking Quantity Test	45
2.4.5 Water Quality	46
3. Chemical and Mineral Admixtures	48
Chemical Admixture	
3.1 Accelerators	48

- 3.1.1 Set Accelerators 49
 - 3.1.2 Hardening Accelerators 51
- 3.2 Retarders 51
 - 3.2.1 Dosage of Retarders 53
- 3.3 Plasticizers 54
 - 3.3.1 Finely Divided Minerals 55
 - 3.3.2 Air-entraining Agents 56
 - 3.3.3 Synthetic Derivatives 57
- 3.4 Superplasticizers 58
- 3.5 Viscosity Modifying Admixtures 59
- 3.6 Waterproofers 60
- 3.7 Miscellaneous Admixtures 62
 - 3.7.1 Gas-forming and Expansive Chemicals 62
 - 3.7.2 Corrosion-inhibiting Chemicals 63
 - 3.7.3 Pigments 64
 - 3.7.4 Antifungal Admixtures 65
 - 3.7.5 Curing Compounds 66
 - 3.7.6 Sealants 68
- Mineral Admixture**
- 3.8 Fly Ash 68
 - 3.8.1 Characteristics of Fly Ash 70
- 3.9 Silica Fume 71
 - 3.9.1 Characteristics of Silica Fume 71
- 3.10 Ground Granulated Blast Furnace Slag 73
 - 3.10.1 Characteristics of GGBFS 73

4. Properties of Fresh Concrete

76

- 4.1 Workability of Fresh Concrete 76
 - 4.1.1 Factors Affecting Workability 77
 - 4.1.2 Methods to Measure Workability 77
- 4.2 Compactability 83
- 4.3 Mobility 84
- 4.4 Stability 84
- 4.5 Consistency 85
- 4.6 Segregation 86
- 4.7 Bleeding 87
 - 4.7.1 Test for Bleeding 88
- 4.8 Factors Affecting Workability 89
- 4.9 Rheology 90
- 4.10 Factors Affecting Rheology 90
- 4.11 Analysis of Fresh Concrete 91

5. Stages in Concrete Manufacturing

93

- 5.1 Batching of Concrete 93
 - 5.1.1 Volume Batching Method 94
 - 5.1.2 Weigh Batching Method 97
- 5.2 Mixing Concrete 97
 - 5.2.1 Methods of Mixing 98
 - 5.2.2 Mixing Time 99
 - 5.2.3 Performance Attributes of Mixed Concrete 99
 - 5.2.4 Re-tempering of Concrete 100
- 5.3 Transporting Concrete 100
- 5.4 Placing Concrete 100
 - 5.4.1 Site Preparation 101
 - 5.4.2 Conveying Concrete 103

5.5 Compacting Concrete	105
5.6 Curing of Concrete	108
5.6.1 Methods of Curing Concrete	108
5.6.2 Importance of Concrete Curing	109
5.7 Finishing the Concrete Surface	110
5.8 Autogenous Healing of Concrete	111
6. Rheology of Concrete	112
6.1 Introduction	112
6.2 Representation of Rheological Behavior	113
6.3 Measurement of Rheology by the Modified Slump Test	116
6.3.1 Procedure for Measuring the Slump Time	116
6.3.2 A Semi-empirical Model for Evaluation of the Plastic Viscosity	119
6.4 Factors Affecting Rheological Properties	120
6.4.1 Mix Proportions	120
6.4.2 Consistency	121
6.4.3 Hardening and Stiffening	121
6.4.4 Aggregate Shape and Texture	121
6.4.5 Aggregate Grading	121
6.4.6 Maximum Aggregate Size	121
6.4.7 Admixtures	122
6.5 Mixture Adjustments	123
6.6 Rheology Models of Concrete	123
7. Properties of Hardened Concrete	125
7.1 Uniaxial and Multiaxial Strength of Concrete	126
7.1.1 Uniaxial Strength of Concrete	126
7.1.2 Multiaxial Strength of Concrete	127
7.2 Compressive Strength	127
7.2.1 Specimens for Compression	128
7.3 Flexural Strength	129
7.4 Tensile Strength	131
7.5 Factors Impacting the Strength of Concrete	132
7.5.1 Aggregate	134
7.5.2 Hardened Cement Paste or Mortar Matrix	134
7.5.3 Transition Zone	134
7.6 Stress-strain Relationship	137
7.7 Modulus of Elasticity	140
7.8 Dimensional Stability—Shrinkage and Creep	141
7.8.1 Aggregate	141
7.8.2 Autogenous Shrinkage	142
7.8.3 Drying Shrinkage	144
7.8.4 Shrinkage Control	148
7.8.5 Creep of Concrete	149
7.9 Durability	150
7.9.1 Factors Influencing Durability	150
7.9.2 Role of Water-Cement Ratio	150
7.9.3 Permeability	151
7.9.4 Factors Contributing to Durability Issues	152
8. Concrete Mix Design	157
8.1 Mix Design	157
8.2 Principal Requirements for Concrete	157
8.3 Weight Method and Absolute Volume Method	158

8.4 Factors to be Considered in Concrete Mix Design	158
8.4.1 Water/Cement Ratio	159
8.4.2 Durability	160
8.4.3 Workability	161
8.4.4 Cement Type and Content	162
8.4.5 Major Aggregate Properties and Aggregate Content	163
8.5 Approaches for Concrete Mix Design	166
8.5.1 Prescriptive Method	166
8.5.2 Statistical Method	172
8.6 Concrete Mix Proportioning—IS Guidelines	175
8.6.1 Mix Design Procedure	176
9. Durability of Concrete	188
9.1 Why Durability?	188
9.2 Factors Influencing Durability	189
9.3 Transport Properties	189
9.4 Measurement of Transport Properties	191
9.5 Cracking in Concrete	196
9.6 Major Durability Problems	198
9.6.1 Corrosion of Reinforcing Steel	198
9.6.2 Corrosion Mechanisms	201
9.7 Prevention of Steel Corrosion	203
9.8 Deterioration Caused by Freeze-Thaw Cycling	205
9.9 Durability in a Marine Environment	206
9.10 General Methods to Enhance the Durability of Concrete	208
10. Ready-mixed Concrete	210
10.1 Historical Development	210
10.2 Advantages of Ready-mixed Concrete	211
10.3 Production Methods	212
10.3.1 Material Types	212
10.3.2 Storage Capacity	212
10.3.3 Processing Sequence	213
10.3.4 Truck Mixer Capacity and Throughput	214
10.3.5 Planning Requirements	214
10.3.6 Quality Control Requirements	214
10.3.7 Duration of Operations	215
10.3.8 Health and Safety	215
10.4 Organizing Production and Delivery	216
10.5 Delivery	216
10.5.1 Truck Mixers	216
10.5.2 Mixing	216
10.5.3 Delivery	217
10.5.4 Distribution	217
10.5.5 Types of Vehicles	217
10.5.6 Tippers	218
10.5.7 Conveyors	218
10.6 Quality Assurance	219
11. Nondestructive Testing of Concrete	220
11.1 Introduction	220
11.2 Principles and Classifications	222
11.2.1 Direct Measurement NDT Techniques	223
11.2.2 Load-induced Reaction Measurement NDT Techniques	224
11.2.3 Measurement through Inquiring Agent NDT Techniques	224

11.3 Components of NDT	224
11.3.1 Testing Objects	224
11.3.2 Testing Problems	225
11.3.3 Testing Methods	225
11.4 Commonly Used NDT Techniques	231
11.4.1 Ultrasonic Technique	231
11.4.2 Acoustic Emission Technique	238
11.4.3 Impact-echo	240
11.4.4 Penetrative Radar Technique	245
11.4.5 Optical Techniques	247
12. Concreting Machinery and Equipment	250
12.1 Concrete Mixers	250
12.1.1 Freefall Mixers	250
12.1.2 Power Mixers	252
12.2 Placing Concrete	254
12.2.1 Buckets	254
12.2.2 Chutes and Drop Pipes	255
12.2.3 Bell Conveyors	255
12.2.4 Concrete Pumps	255
12.3 Finishing Concrete	257
12.3.1 Floating	258
12.3.2 Troweling	258
13. Future Trends in Concrete Technology	260
13.1 Sustainability of Concrete	260
13.2 Utilizing Eco-friendly Resources in a Scientific Manner	261
13.3 Low Energy and Low CO ₂ Emission Binders	265
13.4 Efficiently Utilizing Materials: HSC and UHSC Applications	268
13.5 Deep Understanding of the Nature of Hydration	268
13.6 Integrated Materials and Structural Design	273
13.6.1 Load-carrying Capability: Durability Unified Service Life Design Theory	274
13.7 High-tensile-strength and High-toughness Cement-based Materials	276
13.8 Application of Nanotechnology in Concrete	279
13.9 Data Science and Artificial Intelligence in Concrete Technology	282
Index	283

