

Contents

FOREWORD	vii
PREFACE	ix
1 INTRODUCTION	1
1.1 General	1
1.2 Soil Groups	2
1.3 Preparation of Disturbed Sample	2
1.4 Quantity of Sample	2
2 WATER CONTENT	4
2.1 General	4
2.2 Oven Drying Method	5
2.3 Sand Bath Method	7
2.4 Alcohol Method	8
2.5 Infra-red Lamp and Torsion Balance Method	8
2.6 Calcium Carbide Method	10
2.7 Pycnometer Method	12
3 SPECIFIC GRAVITY	14
3.1 General	14
3.2 Density Bottle Method	16
3.3 Flask Method	18
3.4 Pycnometer Method	18
3.5 Gas Jar Method	18
3.6 Porosimeter Method	20
4 PARTICLE SIZE DISTRIBUTION	24
4.1 General	24
4.2 Wet Sieve Analysis	26
4.3 Dry Sieve Analysis	32
4.4 Calibration of Hydrometer	33
4.5 Hydrometer Method	35
4.6 Pipette Method	41

5	PLASTICITY CHARACTERISTICS	45
5.1	Liquid Limit (Casagrande Method)	45
5.2	Liquid Limit (One Point Method)	49
5.3	Liquid Limit (LCPC Cone Method)	50
5.4	Liquid Limit (Uppal Cone Method)	53
5.5	Plastic Limit	55
5.6	Shrinkage Factors	57
5.7	Linear Shrinkage	61
6	FIELD IDENTIFICATION AND CLASSIFICATION	63
6.1	General	63
6.2	Coarse Grained Soils	63
6.3	Fine Grained Soils	67
6.4	Organic Soils and Peat	74
6.5	Identification by Cone Test	75
7	POROSITY, VOID RATIO AND SUCTION	77
7.1	Total Porosity	77
7.2	Air Porosity (Difference Method)	77
7.3	Air Porosity (Air Space Pycnometer Method)	78
7.4	Pore Size Distribution (Porosity-Suction Relation)	81
7.5	Moisture-Suction Relation (Alternative Test)	89
8	PERMEABILITY AND CONDUCTIVITY	93
8.1	General	93
8.2	Jodhpur Permeameter Method	95
8.3	Tube and Bucket Method	105
8.4	Permeability of Unsaturated Soil	107
8.5	Permeability of Irregular Specimen	110
8.6	Capillarity-Permeability Test	113
8.7	Permeability-Settlement Test	115
8.8	Permeability of Clay	121
9	IN SITU PERMEABILITY	123
9.1	Pumping-in Test (Open End Cased Hole)	123
9.2	Falling Head Packer Test	125
9.3	Constant Head Packer Test	128
9.4	Pumping-out Test (Single Hole)	129
9.5	Pumping-out Test (Test Well with Piezometers)	132
9.6	Pumping-out Test (IS Method)	137
9.7	Pumping-out Test (Open Pit or Unlined Hole)	139
9.8	Cylinder Permeameter Method	140
9.9	Piezometer Method	143

10	IN SITU SUCTION BY TENSIOMETER	145
11	INFILTRATION	150
	11.1 General	150
	11.2 Double Cylinder Infiltrometer	150
	11.3 Rogers Infiltrometer	153
12	ATMOSPHERIC EVAPORATIVITY	157
13	DENSITY MOISTURE RELATIONS	161
	13.1 Light Compaction Test	161
	13.2 Heavy Compaction Test	166
	13.3 Compaction in Large-size Mould	166
	13.4 Jodhpur Mini-Compactor Test	168
	13.5 Compaction by Constant Mass of Soil Method	170
	13.6 Proctor Needle Test	172
14	DENSITY	175
	14.1 General	175
	14.2 Water Displacement Method	175
	14.3 Submerged Mass Method	177
	14.4 Core Cutter Method	179
	14.5 Sand Replacement Method	181
	14.6 South African Density Cone	187
	14.7 Ring and Water Replacement Method	187
15	DENSITY INDEX	189
	15.1 Laboratory Method	189
	15.2 Eggestad Comprimeter	191
	15.3 Density Index by SPT	195
16	RADIATION METHODS	196
	16.1 General	196
	16.2 Typical Density and Moisture Gauges	201
	16.3 Test Procedure for Density and Moisture Gauges	207
	16.4 Density by Double Probe Gauge	209
	16.5 Sediment Density	211
17	CONSOLIDATION	214
18	SOIL EXPANSIVITY	228
	18.1 General	228
	18.2 Swell Pressure (Constant Volume Method)	228

18.3	Swell Potential	231
18.4	Swell Pressure (Consolidometer Method)	232
18.5	Differential Free Swell	234
18.6	In Situ Heave	235
19	CALIFORNIA BEARING RATIO	240
19.1	Laboratory CBR	240
19.2	Field CBR	247
20	NORTH DAKOTA CONE VALUE	249
21	BENKELMAN BEAM REBOUND	252
21.1	Rebound at a Point of Pavement	252
21.2	Design Rebound	255
22	DIRECT SHEAR, UNCONFINED COMPRESSION AND FALL CONE TESTS	256
22.1	Direct Shear Test	256
22.2	Unconfined Compression Test	270
22.3	Fall Cone Test	274
23	VANE SHEAR TESTING	279
23.1	Laboratory Vane	279
23.2	Inspection Vane Borer	281
23.3	SGI Vane Borer	283
23.4	Heave Inspection Vane Borer	285
23.5	Jonell and Nilsson Vane Borer	287
24	IN SITU DIRECT SHEAR AND COMPRESSION TESTS	291
24.1	Wedge Shear Test	291
24.2	Shear Box Tests	295
24.3	Burggraf Shear Test	302
24.4	Compression Test	305
25	TRIAxIAL TESTING	307
25.1	Equipment	307
25.2	Specimen Preparation and Mounting	314
25.3	Types of Tests	321
25.4	Undrained Test	321
25.5	Consolidated Undrained Test	328
25.6	Back Pressure Testing	334
25.7	Drained Test	338
25.8	Self-Compensating Mercury Control	339

CONTENTS

xvii

25.9	Pore Pressure by Mercury Null Indicator	346
25.10	Pore Pressure by Transducer	352
25.11	Volume Change Measurement	353
25.12	Permeability Test in Triaxial Cell	356
26	PLATE LOAD TESTS	358
26.1	General	358
26.2	Apparatus and Setting up	358
26.3	Constant Load and Settlement Rate Method	360
26.4	Constant Load and Time Interval Method	363
26.5	Housel Analysis	364
26.6	Constant Rate of Penetration Method	369
26.7	Repetitive Load Test	373
26.8	Foundation Settlement and Deformation Modulus	379
26.9	Coefficient of Elastic Uniform Compression (Cyclic Load Test)	393
27	PILE LOAD TESTS	397
27.1	General	397
27.2	Apparatus	397
27.3	Constant Load and Settlement Rate Method (Slow ML Test)	398
27.4	Equilibrium Method	399
27.5	Constant Load and Time Interval Method (Housel Method)	401
27.6	CRP Method	401
27.7	Constant Load and Time Interval Method (Quick ML Test—Fellenius Method)	403
27.8	Allowable Load	404
27.9	Cyclic Load Test (CBRI Method)	406
27.10	Cyclic Load Test (Naithani Method)	409
27.11	Pull Out Test	412
27.12	Lateral Resistance	412
28	PENETRATION TESTS	414
28.1	Standard Penetration Test	414
28.2	Dynamic Cone (50 mm) Test	416
28.3	Dynamic Cone (65 mm) Test	417
28.4	Static Cone Test	420
28.5	Pocket Penetrometer	428
28.6	Jodhpur Penetrometer	429
28.7	Compaction Probe	429

28.8	OSK Cone Penetrometer	431
28.9	Swedish Sounding Test	433
29	DEFORMATION MODULUS	436
29.1	General	436
29.2	Modulus by Consolidometer	440
29.3	Modulus by Standard Penetration Test	442
29.4	Modulus by Cone Test	444
29.5	Modulus by Plasticity Test	445
29.6	Field Compressometer	446
29.7	Modulus by Plate Test (Method I)	452
29.8	Modulus by Plate Test (Method II)	457
30	MODULUS OF SUBGRADE REACTION	460
30.1	Vertical Subgrade Modulus (U. S. Army Method)	460
30.2	Vertical Subgrade Modulus (RRL Method)	467
30.3	Subgrade Modulus from Compressibility Modulus	469
30.4	Horizontal Subgrade Modulus (Simon Method)	470
30.5	Horizontal Subgrade Modulus (Plate Test Method)	472
31	PIEZOMETERS	474
31.1	General	474
31.2	Wellpoint Piezometer	474
31.3	Casagrande Open Piezometer	477
31.4	Geonor Open Piezometer	480
31.5	Electric Piezometer	482
31.6	Pneumatic Piezometer	486
31.7	Hydraulic Piezometers	488
32	SETTLEMENT AND DISPLACEMENT MEASURING DEVICES	502
32.1	USBR Vertical Movement Device	502
32.2	USBR Foundation Settlement Device	510
32.3	USBR Surface Settlement Points for Embankment	513
32.4	IS Electrical Vertical Movement Device	514
32.5	Maihak Electrical Settlement and Displacement Gauges	515
32.6	SIL Electrical Settlement Gauge	519
32.7	SIL Electrical Settlement and Displacement Gauge	521
32.8	SIL Extensometer	522
32.9	SIL Pneumatic Settlement Gauge	523
32.10	RRL Mercury Settlement Gauge	525
32.11	BRS Magnetic Settlement Gauge	528

32.12	RDSO Magnetic Settlement Gauge	530
32.13	Hydraulic Settlement Gauges	531
32.14	CRR I Composite Device for Settlement, Tilt and Crack in Buildings	535
32.15	CRR I Settlement Gauge for Flexible Pavement	537
33	INCLINOMETERS	539
33.1	General	539
33.2	SIL Inclinometer	539
33.3	Wilson Slope Indicator	542
33.4	Maihak Stationary Clinometer	544
33.5	RDSO Inclinometer	544
34	REFRACTION SEISMOLOGY	547
35	RESISTIVITY EXPLORATION	569
35.1	Electrical Resistivity	569
35.2	Electrode Arrangement	571
35.3	Types of Resistivity Surveys	573
35.4	Resistivity Profiling	573
35.5	Resistivity Sounding	574
35.6	Electrode Spacing	575
35.7	Sources of Interference	576
35.8	Qualitative Interpretation	577
35.9	Quantitative Interpretation	585
35.10	Comparison of Resistivity and Seismic Surveys	591
36	CHEMICAL TESTS	593
36.1	Organic Content (Walkley and Black Method)	593
36.2	Organic Content (Calorimeter Method)	596
36.3	Calcium Carbonate Content	597
36.4	Sulphate Content	599
36.5	Water Soluble Salts (Gravimetric Method)	601
36.6	Water Soluble Salts (Conductivity Method)	603
36.7	Hydrogen Ion Concentration (Electrometric Method)	606
36.8	Hydrogen Ion Concentration (Calorimetric Method)	608
36.9	Exchangeable Cations (Bray and Willhite Method)	610
36.10	Exchangeable Cations (Schofield Method)	612
37	EARTH PRESSURE CELLS	614
37.1	General	614
37.2	Electrical Strain Gauge Cell	616

37.3	Vibrating Wire Cell	619
37.4	Hydraulic Cell	622
38	ELECTRICAL ANALOGY TESTING	623
38.1	General	623
38.2	Conductivity Tray Method	625
38.3	Anisotropic and Dissimilar Soils	630
38.4	Beltronix Analog Plotter	634
38.5	Conductivity Paper Method	635
38.6	Three Dimensional Modelling	637
39	MENARD PRESSUREMETER	645
39.1	General	645
39.2	Pressuremeter	645
39.3	Limit Pressure	650
39.4	Creep Pressure	652
39.5	Pressuremeter Modulus	653
39.6	Modulus and Penetration Resistance	659
40	OYO MONOCELL PRESSUREMETER	660
40.1	General	660
40.2	Lateral Load Tester	660
40.3	Elastmeter	664
40.4	Subgrade Modulus for Pile Analysis	664
41	SOIL EROSION AND RAINFALL SIMULATION	668
41.1	General	668
41.2	Rainfall Simulator (Yadav and Gupta)	669
41.3	Laboratory Rainfall Simulator (Gabriels)	671
41.4	Splash Erosion	678
42	SOIL TRAFFICABILITY	682
42.1	General	682
42.2	Cone Index Test	682
42.3	Remoulding Test	684
42.4	Trafficability Evaluation	686
43	SOIL DISPERSIBILITY	690
43.1	General	690
43.2	Pinhole Test	690
43.3	Crumb Test	696

CONTENTS

xxi

43.4	SCS Dispersion Test	697
43.5	Dissolved Salts Criteria	698
44	BLOCK VIBRATION TEST	700
45	ROCK TENSILE STRENGTH	708
45.1	General	708
45.2	Brazilian Test	708
45.3	Ring Test	710
45.4	Line Load Test	711
45.5	Point Load Test	712
46	ROCK UNIAXIAL COMPRESSIVE STRENGTH	715
47	ROCK TRIAXIAL COMPRESSIVE STRENGTH	717
48	ROCK DIRECT SHEAR STRENGTH	720
49	ROCK SLAKE DURABILITY INDEX	726
50	ROCK POINT LOAD STRENGTH INDEX	729
51	POINT LOAD TEST ON ROCK LUMPS	733
	REFERENCES	735
	INTERNATIONAL SYSTEM (SI) UNITS AND CONVERSIONS	755
	SYMBOLS AND ABBREVIATIONS	761
	INDEX	769