

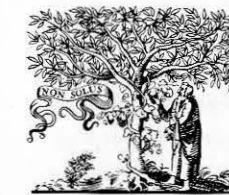
DEVELOPMENTS IN GEOTECHNICAL ENGINEERING 34A

PRACTICAL PROBLEMS IN SOIL MECHANICS AND FOUNDATION ENGINEERING, 1

PHYSICAL CHARACTERISTICS OF SOILS, PLASTICITY,
SETTLEMENT CALCULATIONS, INTERPRETATION OF IN-SITU TESTS

GUY SANGLERAT
GILBERT OLIVARI
BERNARD CAMBOU

Translated by G. GENDARME



ELSEVIER
Amsterdam – Oxford – New York – Tokyo 1984



CONTENTS

Preface	V
Introduction	VII
Notations	XIII
Engineering Units	XVII
<i>Chapter 1. Physical Characteristics of Soil</i>	
1.1 Water content	1
1.2 Water content, degree of saturation	2
1.3 Unit weight and density	4
1.4 Unit weight and density; saturation and water content	4
1.5 Grain-size distribution: effective diameter and Hazen's coefficient	6
1.6 Classification H.R.B.	8
1.7 Atterberg limits	10
1.8 Correction of a grain-size distribution curve: scalping and mixing of soils	13
1.9 Compaction, Proctor diagram and saturation curve	20
1.10 Void ratio of an organic soil	27
1.11 Hydrometer analysis	29
1.12 Relative density (English units)	30
1.13 Design of an optimum grain-size distribution by mixing soils	31
1.14 Study of a soil structure by means of two-dimensional theoretical packing (small-cylinder analogy)	36
<i>Chapter 2. Water in the Soil</i>	
2.1 Permeability of sand	41
2.2 Permeability of clay	41
2.3 Permeability of sand	43
2.4 Average coefficient of permeability of a layered system	44
2.5 Coefficient of permeability determined by pump-out test	45
2.6 Effective stress in sand	48
2.7 Effective stress in a clay	49
2.8 Critical hydraulic gradient of sands at various densities	50
2.9 Blow out and piping	50
2.10 Calculate capillary rise, from laboratory test	53
2.11 Hydraulic gradient and discharge of a subsurface toe drain	55
2.12 Flow net and discharge of seepage through a dam on a homogeneous anisotropic soil foundation	57
2.13 Earth dam: quick-sand condition; drainage blanket; discharge by percolation	64
2.14 Capillary rise in a homogeneous soil, effective stresses	68
2.15 Capillary rise in an analogous soil model	69
2.16 Water table drawdown by vertical drains	71
2.17 Piping conditions in a fractured rock mass	75
2.18 Permeability	76
2.19 Practical application of soil freezing; design of an ice wall	78
Technical note about freezing of soils	81

<i>Chapter 3. Practical Settlement Calculations — Compressibility and Theory of Consolidation</i>	
3.1	Oedometer test on sand 87
3.2	Consolidation test on clay 90
3.3	Approximate evaluation of the compression index C_c and of the settlement of a normally consolidated clay 93
3.4	Approximate evaluation of settlements and of preconsolidation pressure for an overconsolidated clay 95
3.5	Stresses at depth below shallow footings 97
3.6	Settlement under a point load in a clay layer 100
3.7	Determination of the modulus of subgrade reaction, k_s 103
3.8	Time of consolidation of a clay layer with double drainage 104
3.9	Coefficient of permeability 105
3.10	Time of consolidation 107
3.11	Compressibility and consolidation curves; settlement calculation; preloading requirements 108
3.12	Oedometric moduli: behavior of an overconsolidated clay 115
3.13	Consolidation with vertical sand drains 117
3.14	Consolidation of a multi-layered system, Absi's theory; surcharging 119
3.15	Consolidation test on an overconsolidated clay 121
3.16	Determination of C_c and m_v and the settlements of a saturated clay; degree of consolidation 123
3.17	Settlement of shallow footings 126
3.18	Settlement calculation with Newmark's chart, effect of adjacent footings 134
3.19	Solution of Terzaghi's consolidation equation by the finite-difference method: application to a two-layered system 138
<i>Chapter 4. Plasticity and Shear Strength</i>	
4.1	Triaxial test on sand 145
4.2	Triaxial test on sand with cohesion 146
4.3	Evaluation of c and ϕ from a triaxial test result 148
4.4	Triaxial compression tests performed under different draining conditions; Mohr's circles and failure envelopes 149
4.5	Shear strength of a clay; effective stresses 151
4.6	Interpretation of various types of triaxial tests (drained, undrained, consolidated, unconsolidated) 153
4.7	Unconfined compressive strength from a consolidated undrained triaxial test 155
4.8	Relation between Young's modulus, oedometer modulus and Poisson's ratio 157
4.9	Evaluation of Poisson's ratio from triaxial test 158
4.10	Comparison of the principal stress rotations in a direct shear test and in a triaxial test 161
4.11	Triaxial test: determination of the pore-water pressure at failure and of Skempton's A_f coefficient 163
4.12	Stress paths for various test types 165
4.13	Spherical tensor, deviatoric tensor and volume change 168
4.14	Determination of Henkel's coefficients 172
4.15	Coefficients of Henkel. Comparison of two triaxial tests 174
4.16	Influence of loading condition on the behavior of a soil. Bishop and Skempton's coefficients 175
4.17	Measurement of the coefficient of earth pressure at rest K_0 using a triaxial device 177

4.18	Stress paths applied on a soil element during the construction of an earth dam 178
<i>Chapter 5. Plastic Equilibrium</i>	
5.1	The pole of Mohr's circle 183
5.2	Limit equilibrium of a granular, semi-infinite body 185
5.3	Limit equilibrium of semi-infinite granular media with an inclined free surface 186
5.4	Equilibrium of Rankine 190
5.5	Plasticity; limit equilibrium of a weightless mass loaded at the surface; Prandtl corner 194
5.6	Limit equilibrium of a semi-infinite cohesive mass with an inclined free surface 202
5.7	Maximum height of an excavation in cohesive soil 208
5.8	Superposition of two limit equilibrium states 209
<i>Chapter 6. Interpretation of In-Situ Tests</i>	
6.1	Interpretation of static penetration tests (C.P.T.) 213
6.2	Interpretation of a dynamic penetration test 213
6.3	Interpretation of a Delft-type static cone penetrometer test in clay 215
6.4	Interpretation of a static penetrometer test with simple cone point in the clay 217
6.5	Interpretation of a dynamic penetration diagram 218
6.6	Interpretation of a dynamic penetration test of the Sermes type 220
6.7	Interpretation of a dynamic penetration test of the Sermes-type in submerged clay soil 220
6.8	Interpretation of a Bevac-type dynamic penetration test in submerged clay soil 222
6.9	Settlement calculations from cone penetrometer diagrams in the case of a two-layered system 224
6.10	Settlement calculations based on Schmertmann's method and static penetrometer tests in gravels and sands 228
6.11	Settlement calculations of a compressible sloping layer, based on static penetrometer test data 231
6.12	Pile foundation calculation from static cone test in a tri-layer system 236
6.13	Settlement estimates of a surcharge fill, from static-cone penetrometer test data 239
6.14	Settlement calculation of a surcharge fill from the results of an Andina penetrometer test 240
6.15	Settlement computations based on static penetrometer test results 244
6.16	Settlement evaluation in clay soils from static penetrometer tests; influence of fills 247
6.17	Dimensioning shallow footings on sand, based on SPT (Standard Penetration Test) results 249
6.18	Pile capacity determination in sand from SPT 252
6.19	Cost comparison of soil investigations based on different types of in-situ tests 253
6.20	Comparison of settlement calculation based on static penetrometer tests and consolidometer tests data; determination of the value of the coefficient α 255
6.21	Evaluation of the pressuremeter parameters p_p , p_f and E_p for clay 260
6.22	Determination of a bridge foundation based on pressuremeter test results 263
6.23	Estimation of instantaneous settlement from pressuremeter test results 273
6.24	Design a foundation from static and dynamic penetrometer data and from results of pressuremeter tests 273
Bibliography 275	
Index 279	

BIBLIOGRAPHY

- [1] Absi, E., 1965. Généralisation de la théorie de consolidation de Terzaghi au cas d'un multicouche. *Ann. Inst. Tech. Bâtim. Trav. Publics*, 51: 1013.
- [2] Baguelin, F. and Jezequel, J.F., 1973. Le pressiomètre autoforeur. *Ann. Inst. Tech. Bâtim. Trav. Publics*, 307-308: 134-160.
- [3] Baguelin, F., Jezequel, J.F. and Le Mehaute, A., 1979. Le pressiomètre autoforeur et le calcul des fondations. *Congr. Eur. Méc. Sols, Brighton, 1979*.
- [4] Baguelin, F., Jezequel, J.F. and Shields, T.H., 1978. The pressiometer and foundations engineering. *Trans. Tech. Publ. Clausthal*.
- [5] Butterfields, R., 1979. A natural compression law for soils (an advance on $e\text{-log } p'$). *Geotechnique*, 29: 469-480.
- [6] Caquot, A. and Kerisel, J., 1966. *Traité de Mécanique des Sols*. Gauthier-Villars, Paris, 4th ed., 509 pp.
- [7] Chellis, R., 1951. *Pile Foundations*. McGraw-Hill, New York, N.Y., 704 pp.
- [8] Costet, J. and Sanglerat, G., 1981/1983. *Cours Pratique de Mécanique des Sols*, 3rd ed.
 — Vol. 1. *Plasticité et Calculs des Tassements*. Dunod, Paris, (1981), 312 pp.
 — Vol. 2. *Calculs des Ouvrages*. Dunod, Paris, (1983), 464 pp.
- [9] Decourt, L., 1982. Prediction of the bearing capacity of piles based exclusively on N values of the S.P.T. *ESOPT II, Amsterdam, 1982*, 1: 29-34.
- [10] Gielly, J., Lareal, P. and Sanglerat, G., 1969. Correlation between in situ penetrometer tests and the compressibility characteristics of soils. *Proc. Conf. In Situ Invest. Soils Rock, London, 1969*, 167-172.
- [11] Giroud, J.P., 1972/1973. *Tables pour le Calcul des Fondations*.
 — Vol. 1. *Tassement*. Dunod, Paris, 1972, 360 pp.
 — Vol. 2. *Tassement*. Dunod, Paris, 1973, 505 pp.
- [12] Giroud, J.P., Tran Vo Nhiem and Obin, J.P., 1974. *Tables pour le Calcul des Fondations*.
 — Vol. 3. *Force Portante*. Dunod, Paris, 445 pp.
- [13] Lareal, P., Sanglerat, G. and Gielly, J., 1974. Comparison of penetration test data obtained by different static or dynamic penetrometers. *Proc. Eur. Symp. Penetration Test. Stockholm, 2.2: 229-236*.

- [14] Lareal, P., Sanglerat, G. and Gielly, J., 1974. Settlements of two buildings supported on rafts. Comparison with predicted settlements calculated from static cone penetrometer data. *Conf. Settlements Struct., Cambridge (G.B.)*, 37-43.
- [15] Lareal, P., Sanglerat, G. and Gielly, J., 1976. Comparaison des essais de pénétration effectués avec différents pénétromètres statiques ou dynamiques. *Ann. Inst. Tech. Bâtim. Trav. Publics*, 340: 15-24.
- [16] Marche, R., 1974. *Sollicitations en flexion des pieux par les couches qu'ils traversent*. Thesis, École Polytechnique Fédérale de Lausanne.
- [17] Menard, L., 1971. Le tassement des fondations et les techniques pressiométriques. *Ann. Inst. Tech. Bâtim. Trav. Publics*.
- [18] Pilot, G. and Moreau, M., 1973. *La stabilité des Remblais Sols Mous*. Eyrolles, 151 pp.
- [19] De Ruiter, J., 1971. Electric penetrometer for site investigation. *Proc. A.S.C.E., J. Soil Mech. Found. Div.*, 97(2): 457-472.
- [20] Sanglerat, G., 1965. *Le Pénétromètre et la Reconnaissance des Sols*. Dunod, Paris, 230 pp. Transl. in Spanish (1967), in Russian (1971), English (1972, see ref. [19]) and Japanese (1976).
- [21] Sanglerat, G., 1971. Massifs de Terre Armée. *Technica* — Ecole Centrale de Lyon, 20-27.
- [22] Sanglerat, G., 1972. *The Penetrometer and Soil Exploration*. Elsevier, Amsterdam, 464 pp. (2nd ed. in 1979; transl. in Japanese in 1976).
- [23] Sanglerat, G., 1974. Penetration testing in France — State of the art report. *Proc. Eur. Symp. Penetration Test., Stockholm, 1974*, 1: 47-58.
- [24] Sanglerat, G., 1976. Règles de l'art des essais de pénétration en France. *Ann. Inst. Tech. Bâtim. Trav. Publics*, 340: 5-14.
- [25] Sanglerat, G., 1977. *Le pénétromètre statique-dynamique et ses diverses applications pratiques*. Lect. held at Lisbon, Tokyo, Fukuoka, Taipei. Imprimerie du Bâtiment, Lyon, 32 pp.
- [26] Sanglerat, G., 1978. *Pathologie des Fondations et Reprises en Sous-oeuvre*. CAST I.N.S.A., Lyon.
- [27] Sanglerat, G., Gielly, G. and Lareal, P., 1972. Le pénétromètre statique et la compressibilité des sols. *Ann. Inst. Bâtim. Tech. Publics*, 298, Sér. SF/92.
- [28] Sanglerat, G., Girousse, L. and Gielly, J., 1974. Unusual settlements of a building at Nantua. *Conf. Settlements Struct., Cambridge (G.B.)*, pp. 123-132.
- [29] Sanglerat, G., Tran Vo Nhiem, Sejourne, M. and Andina, R., 1974. Direct soil classification by static penetrometer with local side friction measuring device. *Proc. Eur. Symp. Penetration Test., Stockholm, 1974*, 2: 337-344.
- [30] Sanglerat, G., Tran Vo Nhiem, Sejourne, M. and Andina, R., 1976. Classification des sols à l'aide du pénétromètre statique avec manchon

- de mesure du frottement latéral. *Ann. Inst. Bâtim. Tech. Publics*, 340: 25-30.
- [31] Sanglerat, G., Girousse, L. and Bardot, F., 1977. Settlement prediction of building based on static penetrometer data. *Southeast Asian Conf., 5th, Bangkok*, pp. 27-40.
- [32] Sanglerat, G., Girousse, L. and Bardot, F., 1979. Contrôle in situ des prévisions de tassements basées sur les essais de pénétration statique pour 79 ouvrages sur 17 sites différents. *Ann. Inst. Tech. Bâtim. Publics*, 369: 30-40.
- [33] Sanglerat, G., Mlynarek, Z. and Sanglerat, T.R., 1982. The statistical analysis of certain factors influencing cone resistance during static sounding of cohesive soils. *ESOPT II, Amsterdam, 1982*, I: 827-834.
- [34] Sanglerat, G. and Sanglerat, T.R., 1982. Pitfalls of the S.P.T. *ESOPT II, Amsterdam, 1982*, I: 145 pp.
- [35] Sanglerat, G. and Sanglerat, T.R., 1983. Quand et pourquoi faire intervenir un géotechnicien lors d'une expertise bâtiment ou travaux publics? *Cah. Expert. Judiciaire*, Lyons, No. 4.
- [36] Schmertmann, J.H., 1970. Static cone to compute static settlement over sand. *Proc. A.S.C.E., J. Soil Mech. Found. Div.*, SM3, Pap. 7302.
- [37] Soulier, F., Doussot, M., Sanglerat, G. and Bardot, F., 1976. Prévisions et mesures in situ des tassements des remblais de préchargement à l'emplacement de deux réfrigérants pour la centrale nucléaire de Bugey. *Technica*, 390: 30-34.
- [38] Tran Vo Nhiem, 1976. Stabilité des murs de soutènement. *Technica*, 1976: 28-29.
- [39] Winterkorn, H.F. and Fang, H.Y., 1975. *Foundation Engineering Handbook*. 750 pp.
- [40] Wroth, C.P., Roscoe, K.H. and Schofield, A.N., 1958. On the yielding of soils. *Géotechnique*, 8(1): 22-53.