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In Situ Tests in Geotechnical Engineering

Jacques Monnet

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In Situ Tests in Geotechnical Engineering

Foreword

Jacques Monnet is a very incisive researcher, who does not accommodate with the classical approaches of *in situ* testing techniques or interpretation approaches, innovating with utmost originality in equipment, procedures and analysis. However, what could be seen as a pure speculative attitude, which frequently characterizes some of our researchers seeking for new publications, often complicating the objectiveness of ground characterizations, he has always proved to have a practical attitude giving solutions to problems that other more common test procedures do not solve. That was the case of some of the innovative pieces of equipment like the *Géomécamètre* described along with others in this book.

The result of his work expressed now in this book surpassed my expectations since I was not envisaging such an enriching document, plenty of objective solutions, together with the description of advanced techniques that he has been pursuing during his professional activity, allowing the enrolment of new solutions in "non-textbook" ground conditions and special projects.

As Jacques refers to, at beginning of the book, *in situ* tests for ground characterization have been suffering from a lack of credibility to some well known scientists, who prefer well controlled laboratory tests, pointed out as fundamental where the test conditions are well known and the measures are realiable and can allow the direct determination of the parameters that feed the increasing numerical codes available in geotech practice, with complex models behind them. This may be a consequence of the inertia of *in situ*

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testing specialists to diffuse the potentiality of *in situ* data, as well as being well interpreted and obtained from the most adapted techniques.

Jacques Monnet decided not to follow the usual pattern developed in many textbooks where the distinct technologies (equipment and procedures) are displayed sequentially. This practice is somehow an invertion of the natural process of geoengineering, conception/design of geotechnical problems, looking at the properties to be determined in each big group of grounds (soils or rocks – or intermediate material), and then looking for the tools/methods that can help that process.

This book starts with the techniques and processes that allow the measurement of the essential physical indices and the sampling processes to obtain representative samples to deduce the best information in laboratory tests, where we forget that the soil has its own history before arriving at the laboratory. After detailing the processes of drilling, preparation, transportation of soils, through sampling, the chapter concludes with an approach to rock mechanics, finishing the natural step to the following, most important chapters related to the mechanical and hydraulic properties of soils. The approaches of each chapter are ruled by the properties that geotechnical practitioners are seeking, for which distinct solutions in terms of techniques (equipment, procedures and methods) are proposed, including common/classical tests, or advanced techniques. This comes as being quite logical as, for "direct" shear strengths, shear tests in boxes, vane tests, and the "Philonnat *phicomètre*" are suggested; for stress-strain relationships, and therefore for the evaluation of deformability and compressibility, the surface load tests (PLT), dilatometers (DMT), penetrometers (SPT, DP, CPT...), pressuremeters (PMT, SBPT) and dilatometer (DMT) tests as well as some new techniques, like "Géomécamètre", are presented and their essential interpretation methods are developed. Then a very important chapter, currently forgotten in handbooks of site investigation, deals with permeabilty tests in soils, executed in localized points (from boreholes), but also the more generalized solutions for the evalaution of transmissivity, like the pumping tests with multi-checking points. The books ends with an interesting resumé of the essential properies that can be derived and how they can be deduced from sustained correlations.

In summary, this book is a highly recommendable document for students and researchers, accademics and practitioners in engineering and will contribute to constructing one more pillar to allow for a better understanding of the geotechnical "terroirs", enhanced by the advantage and the potentiality of using good *in situ* equipment, adapted for the purpose of our projects and interpreted with competence.

António Viana da Fonseca
Chair of ISSMGE-TC1202
Ground Characterization from In Situ Testing
September 2015

Symbols & Notations

Symbols	Designations	Units
a	Side of the square plate	m
a	Dilatation coefficient of the pipes (PMT)	cm^3/MPa
a	Bore radius (PMT)	m
A	Transverse section of the pile	m^2
A	Reading of the detachment pressure of the membrane (DMT test)	kPa
A	Length of penetration measured (drilling parameter)	m
A_c	Straight section of the cone (penetrometer)	m^2
A_n	Straight section of the pile at the level of n	m^2
A_u	Straight section of the cone (penetrometer) above the cylindrical part of the cone	m^2
α	Angle of attack of the bevel of case of the core drill, in degrees	degree
α	Slope of the unitary drawdown curve (well)	m^{-2}/h
α	Empirical drilling parameter (drilling parameter)	
b	Radius of the first plastic zone (PMT)	m
B	Diameter of the plate or width of the foundation or the pile	m
B	Reading of the pressure for a membrane advancement of 1.1 m (DMT)	kPa

B	Diameter of the injection or pumping cavity (Lefranc)	m
B_c	Semi-thickness of the pressure sensor	m
$B\theta$	Normalized interstitial pressure ratio (CPTU)	
β	Empirical bore parameter (drilling parameter)	
c	Radius of the second plastic zone	m
c'	Effective cohesion of the soil	kPa
c_u	Apparent undrained cohesion of the soil	kPa
c_r	Residual cohesion of the soil	kPa
C	Coefficient of the shape of the cavity (Lefranc)	
C	Empirical coefficient of the distribution of constraints (sensor)	
C_a	Surface index of a core drill, expressed as a percentage	
$C_{\square}$	Creep coefficient	
C_c	Compression index (odometer; Log scale)	
C_i	Internal play index of a core drill expressed as a percentage	
C_0	External play index of a core drill expressed as a percentage	
C_R	Calculated rotational torque of the drill head (drilling parameter)	kN.m
C_{Rmax}	Maximal rotational torque of the drill head (drilling parameter)	kN.m
C_s	Elastic swelling index (odometer; Log scale)	C_c
C_v	Vertical consolidation coefficient	m^2/s
C_{vh}	Horizontal consolidation coefficient	m^2/s
d_c	Diameter of the sensitive surface of the pressure sensor	m
d_i	Interior diameter of the calibration tube (PMT)	m
d_{ij}	Distance between two data sets (cluster)	
d_s	Diameter of the pressuremeter probe (PMT)	m
d_t	Diameter of the borehole (PMT)	m
D	Granularity, all parameters linked to it	m

D	Bore diameter (drilling parameter)	m
D_c	Diameter of the pressure sensor	m
DG	Degradability coefficient of the rocky material expressed as a percentage	
D_1	Internal diameter of the case or the crown of the core drill	m
D_2	External diameter of the case, crown at the end of the core drill	m
D_3	Internal diameter of the sheath or tube of the core drill, in millimeters	m
D_4	External diameter of the coring sheath or tube	m
$\delta\chi$	Deformation of the pressure sensor	m
$\delta\sigma$	Deformation of the ground at the level of the pressure sensor	m
$\delta\chi$	Deflection of the sensitive surface of the pressure sensor	m
ΔA	Reading of the detachment pressure of probe membrane in open air (DMT)	kPa
ΔB	Reading of the pressure for a membrane advancement of 1.1 m in open air (DMT)	kPa
$\Delta\sigma\iota$	Stacking increment of the plate	m
$\Delta\sigma\iota$	Pressure increment on the plate	kPa
e	Void ratio	
e_0	Initial void ratio	
e_1	Total stacking of the first load of the plate	m
E	Elastic modulus of the soil; Young's modulus	kPa
E^e	Elastic modulus of the soil (PMT)	kPa
E_{oed}	Odometric modulus of the soil	kPa
E_u	Undrained elastic modulus of the soil; Young's modulus	kPa
E	Drilling energy (drilling parameter)	kW
E_D	Elastic modulus of the soil (DMT)	kPa
E_M	Pressiometric modulus of the soil (PMT)	kPa

E_n	Elastic modulus at level n of the pile	kPa
E_v	Vertical elastic modulus of the soil	kPa
F	Safety coefficient	
F_{max}	Maximal push force (drilling parameter)	MN
F	Hammer impact frequency (drilling parameter)	Hz
FR	Fragmentation coefficient of a rock, expressed as a percentage	
Φ	Friction angle of the soil	degree
Φэ	Effective friction angle of the soil	degree
$\Phi_{\chi\varpi}$	Angle at the critical or residual state	degree
Φ_{μ}	Intergranular friction angle	degree
Φ_{ρ}	Residual friction angle	degree
Φ_{υ}	Undrained friction angle of the soil	degree
Γ	Elastic shearing modulus	kPa
γ	Specific weight of the soil	kN/m^3
γ	Empirical drilling parameter (drilling parameter)	
γ_{δ}	Dry specific weight of the soil	kN/m^3
γ_{M}	Specific weight of the drilling fluid (drilling parameter)	MN/m^3
$\gamma_{O\Pi N}$	Specific weight of the soil at the Proctor optimum	kN/m^3
γ_{σ}	Specific weight of the grains of the soil	kN/m^3
$\gamma_{\sigma\alpha\tau}$	Saturated specific weight of the soil	kN/m^3
h	Load variation due to sampling or injection (Lefranc)	M
h_p	Height of the water in the well (well)	M
H	Length of penetration of the core drill, from the bottom of the bore	M
H	Distance from the injection cavity to the impermeable surface (Lefranc)	M
H_{ini}	Initial overload or discharge (Lefranc)	M

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H_i	Load at injection ("*Géomécamètre*" test)	M
H_{max}	Maximal retaining force (drilling parameter)	MN
H_p	Load at pumping ("*Géomécamètre*" test)	M
H_w	Distance from the injection cavity to the water table (Lefranc)	M
i	Hydraulic gradient	
I_A	Calculated alteration index (drilling parameter)	
I_c	Consistency index	
i_{crit}	Terzaghi critical hydraulic gradient	
IC	Net coring index	
I_D	Compactness index	
I_D	Material index (DMT)	
I_f	Fracturing index	
I_p	Plasticity index	
k	Permeability coefficient of the soil	m/s
k_h	Horizontal permeability coefficient of the soil	m/s
K_c	Sensor influence coefficient	
K_D	Horizontal constraint index (DMT)	
K_s	N_s/M_s ratio	
k_s	Reaction modulus of the soil	kPa/m
K_w	Westergaard modulus of the soil	
K_0	Coefficient of ground at rest	
k_0	Empirical parameter based on the drilling results of the calibration test (drilling parameter)	
K_1	Empirical parameter based on the drilling results of the calibration test (drilling parameter)	
κ	Slope of the compression curve–elastic decompression (compression.isotrope; Ln scale)	λ
l_g	Length of the guard cell of the pressure meter probe (PMT)	M

l_s	Length of the central cell of the pressure meter probe (PMT)	M
L	Length of the injection cavity, of the sieve (Lefranc ; well)	M
LA	Los Angeles coefficient	
L_b	Length of the modified or lost sample at its inferior part	M
L_e	Length of the shortening of the sample during coring	M
l_e	Length of the probe ("*Géomécamètre*" test)	M
L_g	Gross length of the sample, after retrieval of the core drill, including the sections modified or lost at the extremities	M
L_n	Net length of the sample after conditioning	M
L_t	Useful length of the coring tube	M
λ	Lamé coefficient	kPa
λ	Slope of the blank compression curve (compression, isotrope; Ln scale)	
m	Coefficient of the shape of the cavity (Lefranc)	
m_0	Corrected coefficient of the shape of the cavity (Lefranc)	
m_{td}	Total dry mass	Kg
m_{th}	Total wet mass	Kg
M	Mass of the hammer (dynamic penetrometer)	Kg
M	Drained vertical elastic modulus of the soil (DMT)	kPa
M'	Mass struck: anvil + string of rods (dynamic penetrometer)	Kg
M_c	Elastic modulus of the sensor	kPa
M_E	Soil modulus during VSS plate test	kPa
M_s	Elastic modulus of the soil	kPa
M_{DE}	Micro Deval coefficient	
μ	Lamé coefficient	kPa
n	Porosity	Kg
n	Dilatancy ratio (PMT)	
N	Friction ratio (PMT)	

N_s	Deformation coefficient of the soil, pressure sensor	
N_{dh}	Number of blows to produce a penetration of h (dynamic penetrometer)	m^{-1}
$N϶_{70}$	Number of blows (SPT)	
ν	Poisson's coefficient	
ν_{υ}	Undrained Poisson's coefficient of the soil	
OCR	Overconsolidation ratio	
p	Pressure applied by the pressuremeter probe on the terrain (PMT)	kPa
p	Hydraulic pressure measured in the feed motor or in the jack (drilling parameter)	MPa
p_{CR}	Hydraulic pressure in the rotation motor (drilling parameter)	MPa
p_e	Inherent resistance of the pressuremeter probe, after correction (PMT)	kPa
p_e	Inherent resistance of the packers (Lefranc)	kPa
p_{el}	Inherent resistance limit of the pressuremeter probe (PMT)	kPa
P_E	Calculated net push applied to the drilling tool (drilling parameter)	MPa
p_f	Creep pressure of the pressuremeter test (PMT)	kPa
P_F	Pressure of the drilling fluid measured at the level of the pump exit (drilling parameter)	MPa
p_g	Inflation pressure of the packers (Lefranc)	kPa
p_H	Back pressure measured (drilling parameter)	MPa
P_H	Back pressure measured (drilling parameter)	MPa
p_{Hmax}	Maximal back pressure measured (drilling parameter)	MPa
p_i	Water pressure at injection ("*Géomécamètre*" test)	kPa
P_I	Pressure of the drilling fluid calculated at the level of the exit of the drilling tool (drilling parameter)	MPa
p_j	Water pressure at the injection threshold j (Lugeon)	kPa
P_M	Power of the hammer (drilling parameter)	MW

p_{max}	Maximum water pressure at injection (Lefranc)	kPa
p_{max}	Maximum push pressure in the feed motor or the jack for a force of F_{max} (drilling parameter)	MPa
P_{max}	Maximum push on a tool measured in the terrain (drilling parameter)	MPa
P_O	Gross calculated push applied to the drilling tool (drilling parameter)	MPa
p_P	Water pressure at pumping ("*Géomécamètre*" test)	kPa
p_0	Membrane detachment pressure (DMT)	kPa
p_1	Pressure for a membrane advancement of 1.1 mm (DMT)	kPa
p_1	Pressure at the start of the pseudo elastic range (PMT)	kPa
p_2	Pressure at the end of the pseudo elastic range (PMT)	kPa
p_{LM}	Pressiometric pressure limit of the terrain (PMT)	kPa
p_{LM}^*	Net pressiometric pressure limit of the terrain (PMT)	kPa
p_m	Inherent resistance of the membrane of the central measurement cell (PMT)	kPa
p_r	Pressure read on the pressure volume controller (PMT)	kPa
q_c	Resistance to the static penetration of the cone (CPT)	kPa
q_d	Resistance to the dynamic penetration of the cone (PDA, PDB)	kPa
q_{net}	Ultimate resistance of the soil under a foundation	kPa
q_{sn}	Mean unitary lateral friction of section n of the pile	kPa
Q	Water flow injected or pumped into the bore (Lefranc)	m^3/s
Q_a	Constant water flow pumped or injected into the bore (Lefranc)	m^3/s
Q_C	Pile creep critical load	kN
Q_e	Maximum load applied during the pile control test	kN
Q_i	Water flow at injection ("*Géomécamètre*" test)	m^3/s
Q_p	Water flow at pumping ("*Géomécamètre*" test)	m^3/s
Q_t	Normalized resistance to penetration (CPT)	-

Q_{LE}	Conventional rupture load of the pile	kN
Q_{ELS}	Load at the service limit state of the pile	kN
Q_{ELU}	Load at the ultimate limit state of the pile	kN
Q_G	Elastic limit load of the constitutive materials of the pile	kN
Q_j	Flow injected at threshold j (Lugeon)	m^3
Q_L	Limit load of the pile	kN
Q_{max}	Maximum load for the pile loading test	kN
Q_n	Effort in the straight section n of the pile	kN
Q_N	Nominal load of the pile	kN
Q_T	Total effort on the cone of the penetrometer	kN
Q_u	Effort exerted by the interstitial pressure on the superior part of the cone (penetrometer)	kN
Ψ	Dilatancy angle	degree
r_p	Well radius (well)	m
R	Radius of the plate	m
R	Radius of influence of the well (well)	m
R_c	Resistance to simple compression	kPa
R_e	Recording ratio σ_c/σ_s, pressure sensor	
R_f	Friction ratio (CPT)	
R_p	Resistance to penetration (drilling parameter)	s
R_{SR}	Calculated soil-rock resistance (drilling parameter)	MPa/m/s
RQD	Cracking coefficient of a rocky sample	kPa
R_{TB}	Resistance to Brazilian traction	Pa
ρ	Wet density	kg/m^3
ρ_δ	Dry density	kg/m^3
$\rho_{\iota\varphi}$	Correlation coefficient between variables i and j	
$\rho_{O\Pi N}$	Specific weight of the soil at the Proctor optimum	kg/m^3

ρ_σ	Specific weight of the grains of soil	kg/m^3
$\rho_{\sigma\alpha\tau}$	Saturated specific weight of the soil	kg/m^3
S	Packing or deflection	m
S	Well drawdown (well)	m
s_{air}	Matrix sucking of air intake or output	kPa
S	Straight section of the pile	m^2
S	Straight section of the bore (Lefranc)	m^2
S_d	Calculated Somerton index	
S_e	Surface area of the vents at the head of the core drill	m^2
S_O	Section of soil removed by the tool, considered equal to the section of the drilling tool (drilling parameter)	m^2
S_r	Degree of water saturation	
$S_{lat,n}$	Lateral surface of section n of the pile	m^2
σ_χ	Total constraint on the sensor	kPa
σ_χ	Preconsolidation constraint	kPa
σ_0	Total horizontal constraint at rest	kPa
$\sigma\ni_0$	Effective horizontal constraint at rest	kPa
σ_π	Vertical preconsolidation constraint	kPa
σ'_π	Effective vertical preconsolidation constraint	kPa
σ_ρ	Total radial constraint (PMT)	kPa
$\sigma\ni_\rho$	Effective radial constraint (PMT)	kPa
σ_σ	Total constraint on the soil at the level of the sensor	kPa
$\sigma_{\varpi 0}$	Total vertical constraint at rest	kPa
σ_ϖ	Total vertical constraint	kPa
$\sigma'_{\varpi 0}$	Effective vertical constraint at rest	kPa
σ'_ϖ	Effective vertical constraint ("*Géomécamètre*")	kPa
σ_θ	Total circumferential constraint (PMT)	kPa

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