Uwagi o laboratoryjnych badaniach parametrów geotechnicznych

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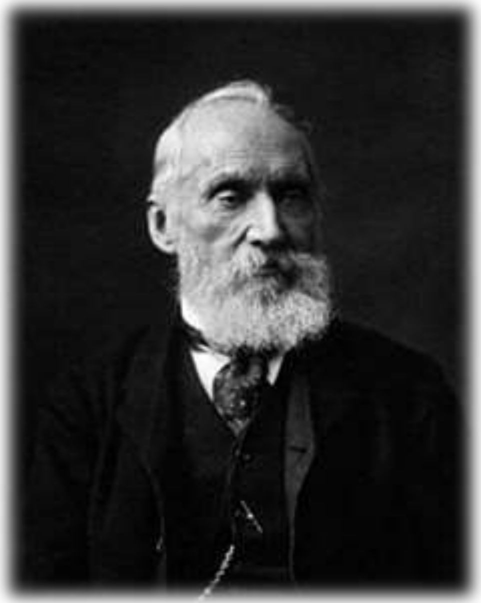
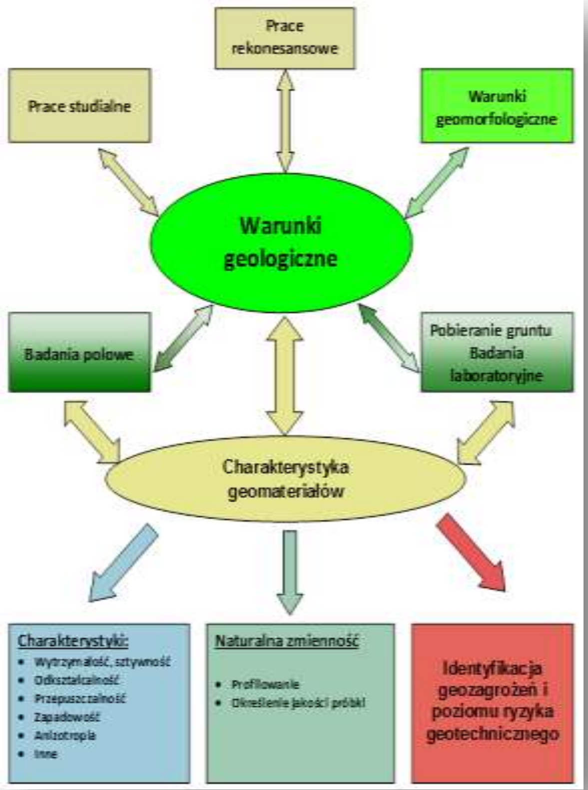
Ocena ilościowa



Lord Kelvin

„Jeśli to o czym mówisz potrafisz zmierzyć i wyrazić w liczbach, to wiesz coś o tym.
Ale kiedy nie możesz wyrazić tego za pomocą liczb, twoja wiedza jest skromna i niedostateczna”.

Ocena charakterystyki geomateriałów



$$F_{SB} = (\sigma', S_r, e, \dot{\varepsilon}, T, \emptyset)$$

Hight, Leroueil (2003)

Badanie geotechniczne

Definicja według PN-B-02481: 1998 *Geotechnika. Terminologia podstawowa, symbole literowe i jednostki miar.*

2.9 badanie geotechniczne – badania geotechniczne polowe, **<u>laboratoryjne</u>** i inne, wykonywane w celu ustalenia warunków geotechnicznych na terenie projektowanej konstrukcji i w jej otoczeniu oraz określenie właściwości gruntów lub skał występujących w podłożu gruntowym lub stanowiących materiał gruntowy.

Parametr geotechniczny

- Parametr geotechniczny to wielkość fizyczna, która charakteryzuje właściwość ciała - ośrodka gruntowego. Właściwość tą można odróżnić jakościowo i wyznaczyć ilościowo.
- Parametry służą do opisu samego ośrodka gruntowego i oceny jego zachowania się w relacji z obiektem budowlanym.
- Definicja według PN-B-02481: 1998 *Geotechnika. Terminologia podstawowa, symbole literowe i jednostki miar.*

2.10 parametr geotechniczny – wielkość wyrażająca ilościowo właściwość gruntu lub skały, stosowana w obliczeniach projektowych i badaniach kontrolnych.

Badania laboratoryjne – warunki konieczne

- Wiedza – podstawy merytoryczne : mechanika gruntów, hydrogeologia….
- Procedury i standardy badań.
- Instrukcje i specyfikacje inwestora.
- Aparatura.
- Personel.
- Doświadczenie.
- Laboratorium.
- Czas.
- Koszty.

Wiedza – podstawy merytoryczne

- Terzaghi K. 1923 A method of calculating of permeability of clay from the variation of hydrodynamic stress with time.
- Terzaghi K. 1924 Theorie der hydrodynamischen Spannungserscheinungen und ihr erdbautech.
- Terzaghi K. 1925 Erdbaumechanik auf bodenphysikalischer Grundlage.
- Terzaghi K. 1936 The shearing resistance of saturated soils and the angle between the planes of shear.
- **Bishop A. W., Henkel D. J. 1957 The measurement of soil properties in the triaxial test.**
- Bishop A. W. 1966 The strength of soils as engineering materials.

Wiedza – podstawy merytoryczne….

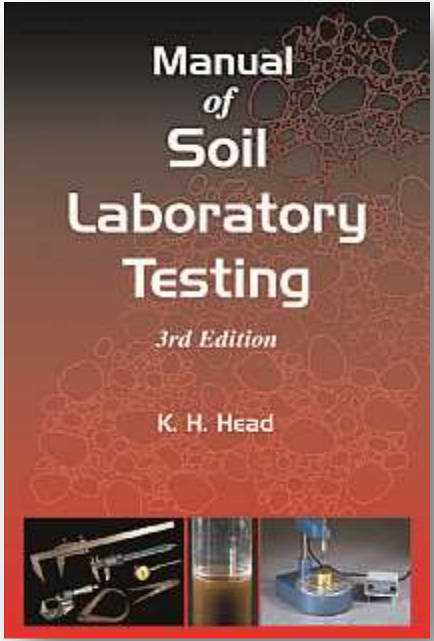
Minimum: kurs geologii inżynierskiej, mechaniki gruntów, hydrogeologii, statystyki….

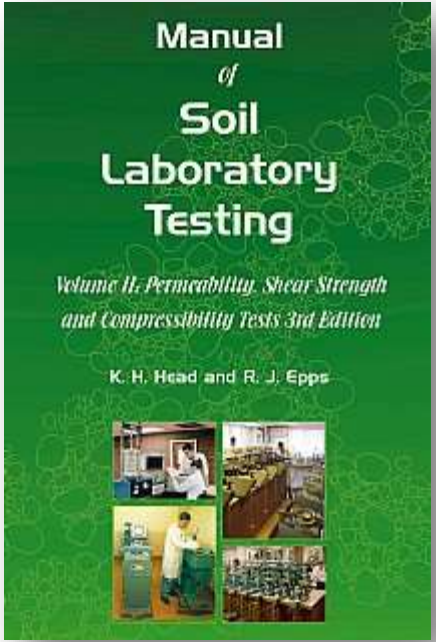
Studia specjalistyczne, szkolenia, ustawiczne samokształcenie.

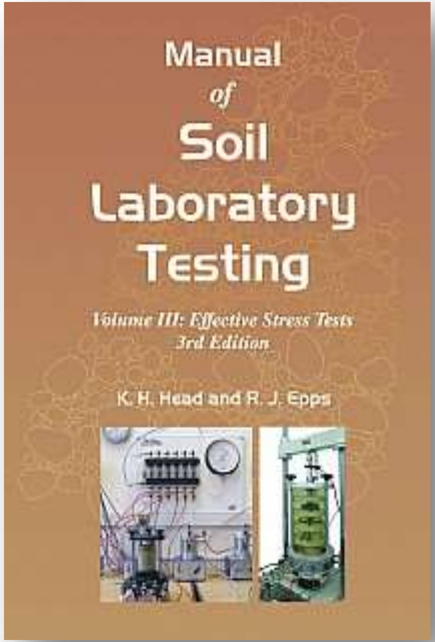
Podręczniki akademickie, czasopisma naukowe i branżowe, materiały konferencyjne, videoblogi i webinaria ze stron **IEAG**, **ISSMGE**, uczelni i instytutów, firm.

INTERNATIONAL ASSOCIATION FOR ENGINEERING GEOLOGY AND THE ENVIRONMENT

SIMSG ISSMGE


Manual
of
Soil
Laboratory
Testing
3rd Edition
K. H. Head


Manual
of
Soil
Laboratory
Testing
Volume II: Permeability, Shear Strength and Compressibility Tests 3rd Edition
K. H. Head and R. J. Epps


Manual
of
Soil
Laboratory
Testing
Volume III: Effective Stress Tests
3rd Edition
K. H. Head and R. J. Epps

Procedury i standardy badań

STAN OBECNY:

- Eurokod 7 PN-EN-1997-1÷2,
- PN-EN-ISO-17892-1÷12
- ASTM-D,
- BS 1377-1÷8,
- PN-B-04481.

NOWA GENERACJA – IDZIE NOWE:

prEN 1997-1: 202x Eurocode 7: Geotechnical design – Part 1: General rules

prEN 1997-2: 202x Eurocode 7: Geotechnical design – Part 2: Ground properties

prEN 1997-1:202x Draft October 2020

3 Terms and definitions

4 Basis of design

5 Materials

11 Testing

Annex A Characteristic value determination procedure

Annex D Qualifation and professional experience

3 Terms, definitions and symbols

3.1.3.1
derived value of a ground property (to be modified according to EN1997-2)
value of a ground property obtained by theory, correlation or empiricism from test results or field measurements

3.1.3.2
nominal value of a ground property
cautious estimate of the value of a ground property that affects the occurrence of a limit state

NOTE to entry: further explanation of 'cautious estimate' is given in 4.3.2.

3.1.3.3
characteristic value of a ground property
statistical determination of the value of a ground property that affects the occurrence of a limit state having a prescribed probability of not being attained. This value corresponds to a specified fractile (mean, superior or inferior) of the assumed statistical distribution of the particular property of the ground.

3.1.3.4
representative value of a ground property
nominal or representative value taking into account the conversion factor

NOTE to entry: further explanation is given in 4.3.2.

3.1.3.5
best estimate value of a ground property
estimate of the most probable value of a ground property

3.1.2.3 measured value of a ground property

value of a ground property recorded during a test

4.3.2 Material and product properties

4.1.2.3 Geotechnical Category

4 Basis of design

4.3.2 Material and product properties

(1) <REQ> Limit states shall be verified using Representative values of ground properties

(2) <REQ> Prognosis of the behaviour of a geotechnical structure shall be determined using best-estimate values of ground properties.

NOTE 35. The representative value and the best-estimate refer to a particular ground property of a single geotechnical unit.

NOTE 36. Guidance on the selection of structural material properties is given in the other Eurocodes.

(3) <REQ> The determination of representative values of ground properties shall take into account:

- pre-existing knowledge including geological information and data from previous projects;
- uncertainty due to the quantity and quality of site-specific data (4.1.2.3);
- uncertainty due to the spatial variability of the measured property; and
- the zone of influence of the structure at the limit state being considered.

5 Materials

5.1 Ground

(1) <REQ> Values of ground properties shall be determined according to EN 1997-2.

NOTE 68. Properties of groundwater are specified in 6.

(2) <REQ> Values of ground properties shall be determined appropriately for the limit states considered.

(3) <RCM> The time period for which a ground is considered to remain undrained should be based on its hydraulic conductivity, stiffness, degree of saturation, and the proximity of drainage boundaries.

(4) <RCM> Values of ground strength parameters should be used only within the stress and strain ranges over which they are evaluated.

(5) <REQ> The effects of ground and groundwater on materials incorporated into the ground shall be determined using the exposure classes defined in EN 206.

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11 Testing

11.1 General

11.1.1 Use of testing

(1) <PER> Testing may be used to determine ground properties, determine parameters for use in design, verify capacity of structural element, check quality of construction material or product, and to control the behaviour of the geotechnical structure or part of it.

(2) <PER> Testing may be used as part of ground investigation, verification by calculation, verification by testing, and verification by the Observational method.

(3) <PER> Tests may be carried out either on a sample of the actual geotechnical structure or structural element or on full scale or reduced scale models.

11.1.2 Test planning

(1) <RCM> The types, numbers, and other testing requirements should be consistent with the Geotechnical Category.

(2) <RCM> Prior to carrying out tests, a Test Plan should be compiled that includes, but is not limited to:

- test objectives and scope;
- specifications of sample preparation, as required;
- loading specifications;
- testing arrangements;
- period of time from execution to test, where relevant;
- test equipment (characteristics, maintenance and calibration requirements);
- measurement plan and frequency;
- prediction of test results;
- method for test evaluation and reporting;
- acceptance criteria;
- requirements from comparable experience, if any.

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Annex A Characteristic value determination procedure

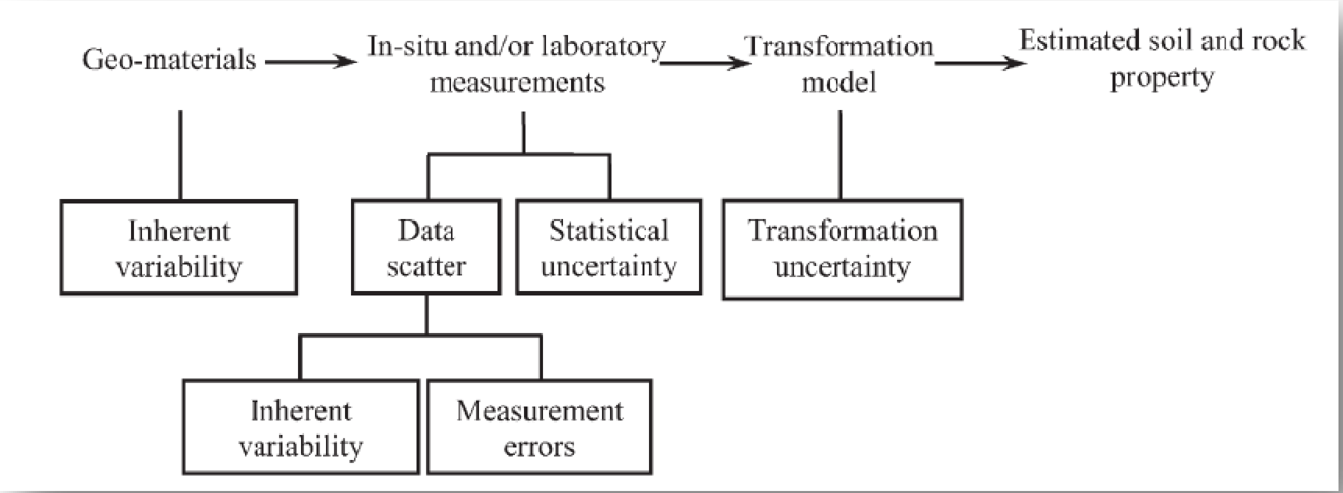

Table A.2 (NDP) — Indicative values of coefficient of variation for different ground properties

Soil / Rock Type	Ground parameter	Symbol	Coefficient of variation V_x (%)
All soils and rocks	Weight density	ρ	5-10
Fine-grained soils	Undrained shear strength	c_u	30-50
All soils and rocks	Cohesion	c	30-50
All soils and rocks	Angle of internal friction	$\tan \varphi$	5-15
All soils and rocks	Shear strength	τ	15-25
All soils and rocks	Unconfined compressive strength	q_u	20-80
All soils	Modulus of deformability(1)	E or G	20-70
Fine-grained soils	Vertical or horizontal consolidation coefficient	c_v or c_h	30-70
All soils	At-rest "in-situ" coefficient	K_0	20-100
All soils	Hydraulic conductivity(2)	k	70-250

Note (1): It refers to the different modulus of deformation whose symbols appear in 3.2.1. & 3.2.7/EN 1997-2.

Note (2): Given the high value of the coefficient of variation for the hydraulic conductivity, this procedure should not be used.

prEN 1997-2:202x Draft October 2020

3 Terms, defintions, and symbols.

5 Ground investigation.

8 Strength.

9 Stiffness and compressibility.

10 Cyclic, dynamic, and siesmic properties.

Annex A Ground Investigation Report.

Annex F Methods for determining stiffness and consolidation properties.

3 Terms, definitions and symbols

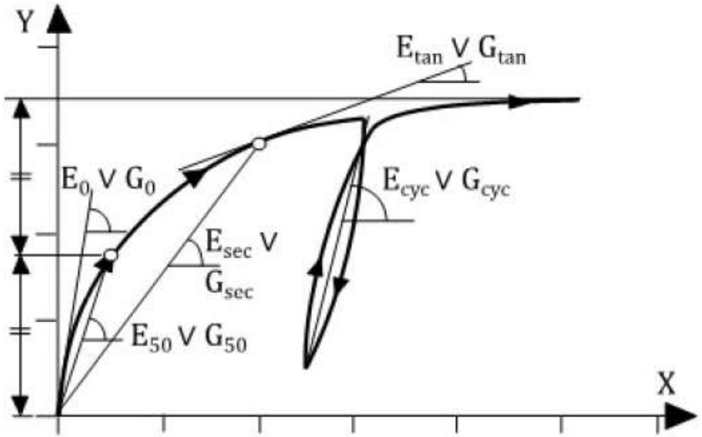

Figure 3.1 — Definition of modulus on stress-strain curve (Key: X = strain, Y = shear stress)

3.1.9 Terms relating to geothermal properties

3.1.9.1 thermal conductivity

ratio of the thermal flux through a cross-sectional area (Fourier's law) to the applied thermal gradient

3.1.9.2 heat capacity or specific heat capacity

capacity of a material to store thermal energy

3.1.9.3 thermal diffusivity

ratio of the thermal conductivity to the specific heat capacity

5 Ground investigation

Table 5.1. Minimum amount of Ground Investigation for different Geotechnical Categories

Geotechnical Category	Minimum amount of Ground Investigation
GC3	All items given below for GC1, GC2 and, in addition: – sufficient investigations to capture the variability of the ground; – sufficient investigations to capture the relevant properties for all geotechnical units using more than one ground investigation method; – sufficient investigations to capture the scatter of the properties of each geotechnical unit
GC2	All items given below for GC1 and, in addition: – sufficient investigations to identify all geotechnical units in the zone of influence; – determination of relevant ground properties by in-situ and laboratory testing and by monitoring
GC1	All items given below: – desk study of the site, review of comparable experience; – site inspection

Table 5.3. Laboratory test standards

Type of test	Test standard
Laboratory testing of soil	EN ISO 17892 (all parts)
Laboratory testing of rock	ISRM Suggested Methods

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5.4.2 Number of in-situ and laboratory tests

(1) <REQ> The number of in-situ and laboratory tests in a geotechnical unit shall be determined from:

- the variability of the ground;
- previous documented experience in ground with the same variability;
- the Geotechnical Category.

(2) <RCM> The number of in-situ tests should be appropriate for the ground investigation techniques used and typical uncertainty levels of the test results.

NOTE 1. The use of more than one ground investigation technique can reduce uncertainty in derived values.

NOTE 2. Guidance on the confidence levels of different ground investigation techniques is given in Annex B.

(3) <RCM> The number of samples for laboratory tests should be appropriate for the material to be sampled and potential sample disturbance.

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5.4.5 Sampling and laboratory testing

(1) <RCM> Samples should be taken from all geotechnical units.

(2) <REQ> Sampling and groundwater measurements shall comply with EN ISO 22475-1.

(3) <REQ> Laboratory testing shall comply with EN ISO 17892 (all parts).

(4) <REQ> Planning of the sampling and selection of the equipment for taking each sample shall be appropriate for the:

- parameters to be measured;
- tests to be carried out;
- minimum sample quality class;
- material to be sampled;
- required diameter and mass of the sample; and therefore
- appropriate sampler.

(5) <RCM> Before taking specimens for testing, the quality of recovered samples should be assessed and recorded in the Ground Investigation Report.

NOTE 1. See Table E.1 for guidance on verifying sample quality.

(6) <REQ> Soil samples obtained using Category A samplers (as defined in EN ISO 22475-1) shall be handled and fixed in order to avoid deformation, desaturation, or swelling of samples during transport and storage.

(7) <PER> For coarse soil and fills, reconstituted, reconsolidated specimens may be used to obtain lower bound measurements of stiffness.

(8) <RCM> Reconstituted specimens of coarse soils should have approximately the same composition, bulk mass density, and water content as the in-situ material.

(9) <REQ> The procedure used to reconstitute soil specimens shall be recorded in the Ground Investigation Report.

(10) <REQ> Planning of laboratory testing shall consider:

- the selection of test samples;
- the conditions of storage before testing;
- maximum allowed time between sampling and laboratory testing.
- whether desiccated samples are to be re-saturated and by which technique;
- the number of tests required per geotechnical unit;
- whether parallel tests are to be run on the same geotechnical unit.

Table 8.1 – Direct determination of soil strength properties

Property	Test	Standard	MQC	Comments on suitability and interpretation
Peak drained shear strength (c'_p, φ'_p)	Consolidated triaxial compression (TX)	EN ISO 17892-9	1	See 8.2.1 (4) to (10)
	Direct shear	EN ISO 17892-10	1	
	Direct simple shear (DSS)	ASTM 6528-17	1	
Critical state shear strength (φ'_{cs})	Consolidated triaxial compression (TX)	EN ISO 17892-9	1-4	See 8.2.1 (5) to (9)
	Direct shear	EN ISO 17892-10	1-4	See 8.2.1 (4) to (9)
	Direct simple shear (DSS)	ASTM 6528-17	1-4	
Residual shear strength (c'_{res}, φ'_{res})	Direct shear	EN ISO 17892-10	1	
	Ring shear	EN ISO 17892-10	1	
Peak undrained shear strength ($c_{u,p}$)	Unconfined compression test (UC)	EN ISO 17892-7	1	See 8.2.1 (4), (8), and (12) In the triaxial tests, compression is undrained
	Unconsolidated undrained triaxial compression (UUTX)	EN ISO 17892-8	1	
	Consolidated triaxial compression (TX)	EN ISO 17892-9	1	
	Laboratory vane	ASTM D4648	1	
	Field vane (FVT)	EN ISO 22476-9	-	See 8.2.1 (12) and (13)
	Direct simple shear (DSS)	ASTM 6528-17	1	
Remoulded undrained shear strength $c_{u,rmd}$	Laboratory vane	ASTM D4648	1	
	Field vane (FVT)	EN ISO 22476-9	-	

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Table 9.2 – Direct determination of ground stiffness properties from laboratory tests

Strain level	Property	Test	Standard	Values obtained
Very small small (< 10^{-5})	G_0	Bender elements (BE)	-	One
	G_0	Resonant column tests	ASTM D4015-15	Several/full curve
	K_p	P-wave pulsar elements	EN 14579 EN 14146	One
Small (10^{-5}-10^{-2})	G, G_{cyc}	Consolidated Undrained Direct Simple Shear Testing (DSS)	ASTM 6528-07	Several/full curve
	G, E	Consolidated triaxial compression tests on water saturated soils (TxT with measurement of local strains)	EN ISO 17892-9	(Partially applicable) Several/full curve
	E	Unconfined compression test (UCT)	EN ISO 17892-7 EN 14580 ISRM Methods*	(Partially applicable) Several
	G_{cyc}, E_{cyc}	Determination of the Modulus and Damping Properties of Soils Using the Cyclic Triaxial Apparatus (CTxT)	ASTM D3999-91	Several/full curve
	$G_{0,RC}$	Modulus and Damping of Soils by Fixed-Base Resonant Column Devices (RC)	ASTM D4015-15	Several/full curve
Medium (10^{-2}-10^{-1})	E_{OED}	Incremental loading oedometer test	EN ISO 17892-5	Several
	E_{OED}	Constant Rate of strain test (CRS)	ASTM D4186-6 SS 27126	Full curve
	G, G_{sec}	Consolidated Undrained Direct Simple Shear Testing (DSS)	ASTM 6528-17	Several/full curve
	G, E	Consolidated triaxial compression tests on water saturated soils(TxT- with measurement of local strains)	EN ISO 17892-9	Several/full curve
	E	Unconfined compression test (UCT)	EN ISO 17892-7 EN 14580 ISRM Methods*	Several
	K_s, K_n	Discontinuity shear test	ISRM Methods*	-
Large (> 10^{-1})	G, G_{sec}	Consolidated Undrained Direct Simple Shear Testing (DSS)	ASTM 6528-17	Several/full curve
	G, E	Consolidated triaxial compression tests on water saturated soils(TxT with measurement of local strains)	EN ISO 17892-9	Several/full curve
	G, E	UCT – Rock?	ISRM Methods*	-

*ISRM Methods = ISRM Suggested Methods

Table 9.4 – Direct determination of compression and consolidation properties

Property	Test	Standard	MQC	Value obtained
Compression index (C_c)	Incremental loading oedometer	EN ISO 17892-5 ASTM D4186-6	1	1-dimensional value
	Constant rate of strain (CRS)	ASTM D4186-6 SS 27126	1	1-dimensional value
	Consolidated triaxial compression on water saturated soils (TxT)	EN ISO 17892-9	1	Isotropic value
Recompression index (C_r)	Incremental loading oedometer	EN ISO 17892-5	1	For any loading cycle
	Constant rate of strain (CRS)	ASTM D4186-6 SS 27126	1	Single value
One-dimensional compressibility (m_v)	See Table 9.2 ($m_v = 1/E_{OED}$)			
Pre-consolidation pressure (σ'_p)	Incremental loading oedometer	EN ISO 17892-5	1	1-dimensional value
	Constant rate of strain (CRS)	ASTM D4186-6 SS 27126	1	1-dimensional value
	Consolidated triaxial compression on water saturated soils (TxT)	EN ISO 17892-9	1	Isotropic value
Coefficient of vertical consolidation (c_v)	Incremental loading oedometer	EN ISO 17892-5	1	At any loading or unloading step
	Constant rate of strain (CRS)	ASTM D4186-6 SS 27126	1	At any set of readings
Coefficient of horizontal consolidation (c_h)	CPTU	EN ISO 22476-1	-	-
	FDT	EN ISO 22476-5	-	-
	SBP	EN ISO 22476-6	-	-
	DMT	EN ISO 22476-11	-	-
Coefficient of secondary compression (C_α)	Incremental loading oedometer	EN ISO 17892-5	1	Several values

Table 9.6 — Direct determination of swelling properties from laboratory tests

Property	Test	Test standard	MQC	Comments on suitability and interpretation
Swelling pressure (σ_g)	One specimen with axial surcharge Huder Amberg method	ISRM suggested methods	n/a	σ'_{v0} deduced from the Ground Model should be provided
	under zero volume change	NF P94-090 UNE 103602:1996 ASTM D4546	1	Specific to stress path
	Several specimens with axial surcharge	NF P94-091	-	-
Swelling amplitude (ε_g)	Free swelling	NF P94-090 UNE 103602:1996	1	Specific to stress path
	Linear swelling	EN 13286-47	-	Unbound and hydraulically bound mixtures
Swelling coefficient (C_g)	Several specimens with axial surcharge; one-Dimensional Swell or Settlement Potential	NF P 94-091 DIN 18135-K BS 1377 ASTM D2435 and D4546	1	Pressures should be specified
	Huder Amberg method	ISRM suggested methods	?	
Swelling index (C_{sw})	Incremental loading oedometer test (unloading)	EN ISO 17892-5	1	Several conventional values

Table 10.1 – Laboratory tests for measuring response to cyclic and dynamic actions

Strain level	Laboratory test (and associated test standards)					
	Cyclic torsional shear (CTS)	Cyclic direct simple shear (CDSS)	Cyclic triaxial (CTxT)	Resonant column (RC)	Bender elements (BE)	Cyclic triaxial (CTxT) for rock
	JGS0543	ASTM D8296-19	ASTM D3999 ASTM D5311	ASTM D4015-07	ASTM D8295-19	JGS 2561 JGS 2562
Very small (< 10^{-5})	(full)	-	-	full	one	(full)
Small (10^{-5} - 10^{-2})	full	full	(full)	(full)	-	full
Medium (10^{-2} - 10^{-1})	-	(full)	full	-	-	-
- = not applicable; 'one' = one conventional value; 'full' = full curve; () = partially applicable						

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Table 12.1 — Direct determination of geothermal properties

Property	Method	Applicable to			Comment
		Soil	Rock	Fluid	
Thermal conductivity	Multi-probe method	Yes	Yes		Transient field and lab. method
	Single-probe method (needle-probe)	Yes	Yes	Yes	Transient field and lab. method
	Divided-bar method		Yes		Stationary laboratory method
	Transient plane source (TPS)	Yes	Yes	Yes	Transient laboratory method
Thermal diffusivity	Multi-probe method	Yes	Yes		Transient field and lab. method
	Single-probe method (needle-probe)	Yes	Yes	Yes	Transient field and lab. method
	Transient plane source (TPS)	Yes	Yes	Yes	Transient laboratory method

Annex A Ground Investigation Report

13. Laboratory testing
    a. List of investigations performed and on which samples
    b. Dates tests performed
    c. Names and qualifications of laboratory personnel
    d. Calibration certificates and documents
    e. Main observations during testing (quality, sample content)

Annex B Suitability of test methods
Annex F Methods for determining stiffness and consolidation properties

Stopień naruszenia próbki – OCR 1-4.

Definicja sztywności gruntu.

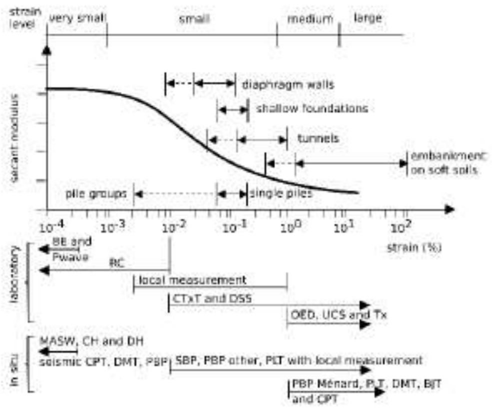
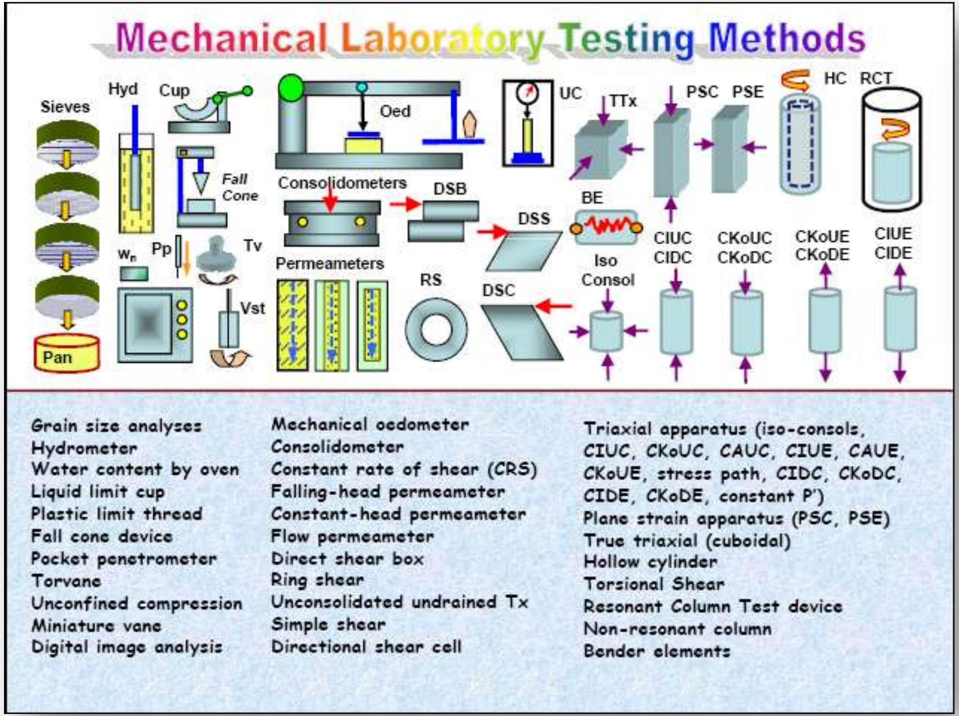


Figure F.1 – Typical strain ranges for common geotechnical constructions and tests (see Atkinson and Sällfors, 1991)

Instrukcje i specyfikacje inwestora

Aparatura



Mayne i inni 2009

+ badania termiczne !!

Personel

Jaki personel?

1. Wykształcony……
2. Świadomy.
3. Zmotywowany.
4. Kreatywny.
5. Zadowolony.

DOŚWIADCZENIE

Złota zasada: „pochylamy się nad próbką”

Laboratorium

- Akredytacja laboratorium - wdrożona polityka jakości.
- Dobrze zorganizowana efektywna struktura.
- Minimum biurokracji.
- Nadzór techniczny.
- Kalibracja.
- Wzorcowanie.

BADANIE: POCZĄTEK - KONIEC

Czas - koszty

Liczba stanowisk badawczych.

Optymalizacja „set-up-u”.

Zarządzanie procesem badawczym.

Potencjalny „przerób”.

Sprawność dostarczania prób gruntu.

KOSZTY - NAKŁADY - STRATY- ZYSK

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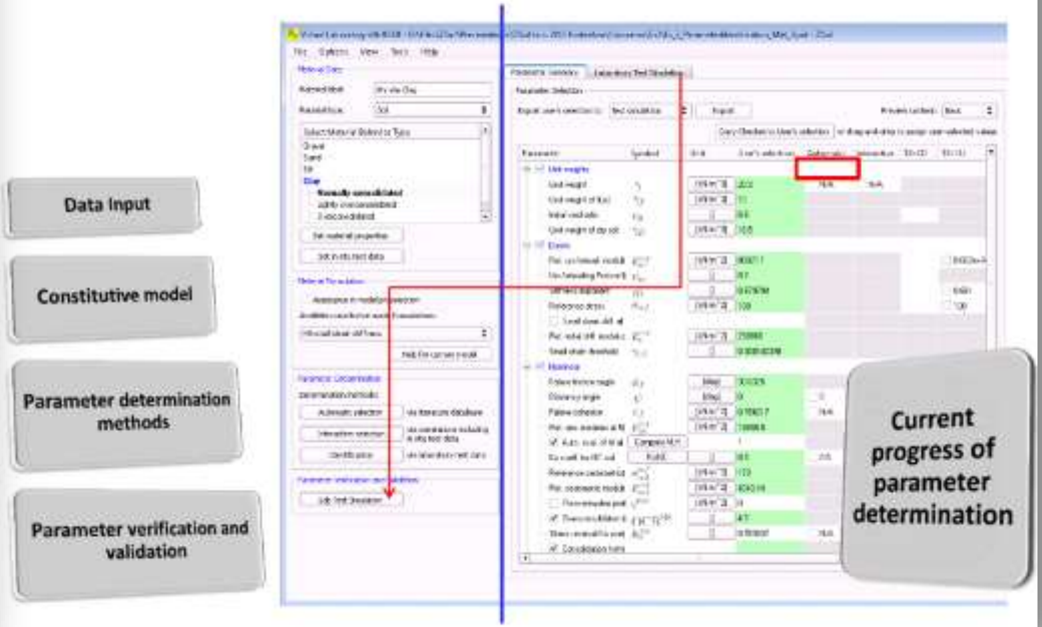
Oprogramowanie do modelowania geotechnicznego…

Automatic and interactive parameter selections

- **4 constitutive models for soils**
  - Hardening – Soil small strain
  - Modified Cam Clay
  - Mohr- Coulomb
  - Cap

Assistance in parameter determination v2016



Sfinansowano ze środków Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej

Kryterium Coulomba-Mohra

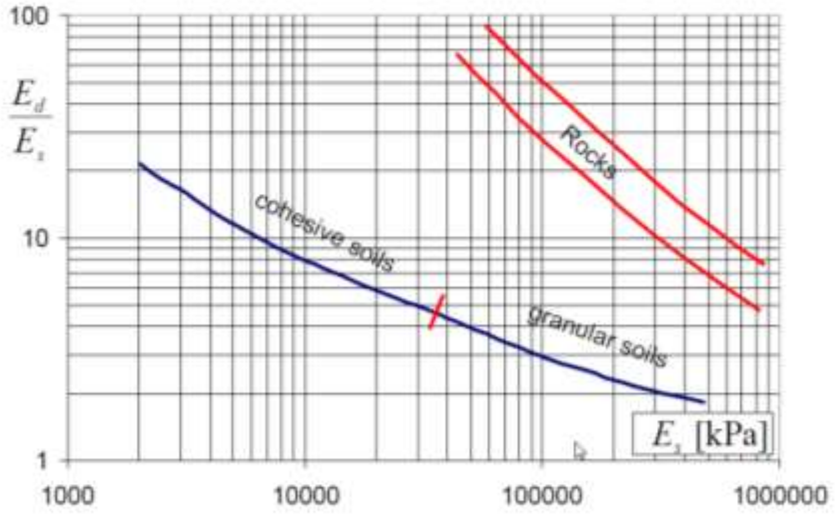
$$|\tau| \leq \sigma \tan \varphi + c$$

$$\sigma'_1 - \sigma'_3 = (\sigma'_1 + \sigma'_3) \sin \varphi' + 2c' \cos \varphi'$$

$$q - p \sin \varphi' - c \cos \varphi' = 0$$

$$\tau_f = c' + (\sigma - u) \tan \varphi' + (u_a - u) \tan \varphi^b$$

Moduł dynamiczny-moduł statyczny



Approximate relation between "static" E_s and "dynamic" modulus E_d corresponding to E_0 proposed by Alpan (1970)

Dziękuję za uwagę