Engineering Geology and Geotechnics

Jan Valenta

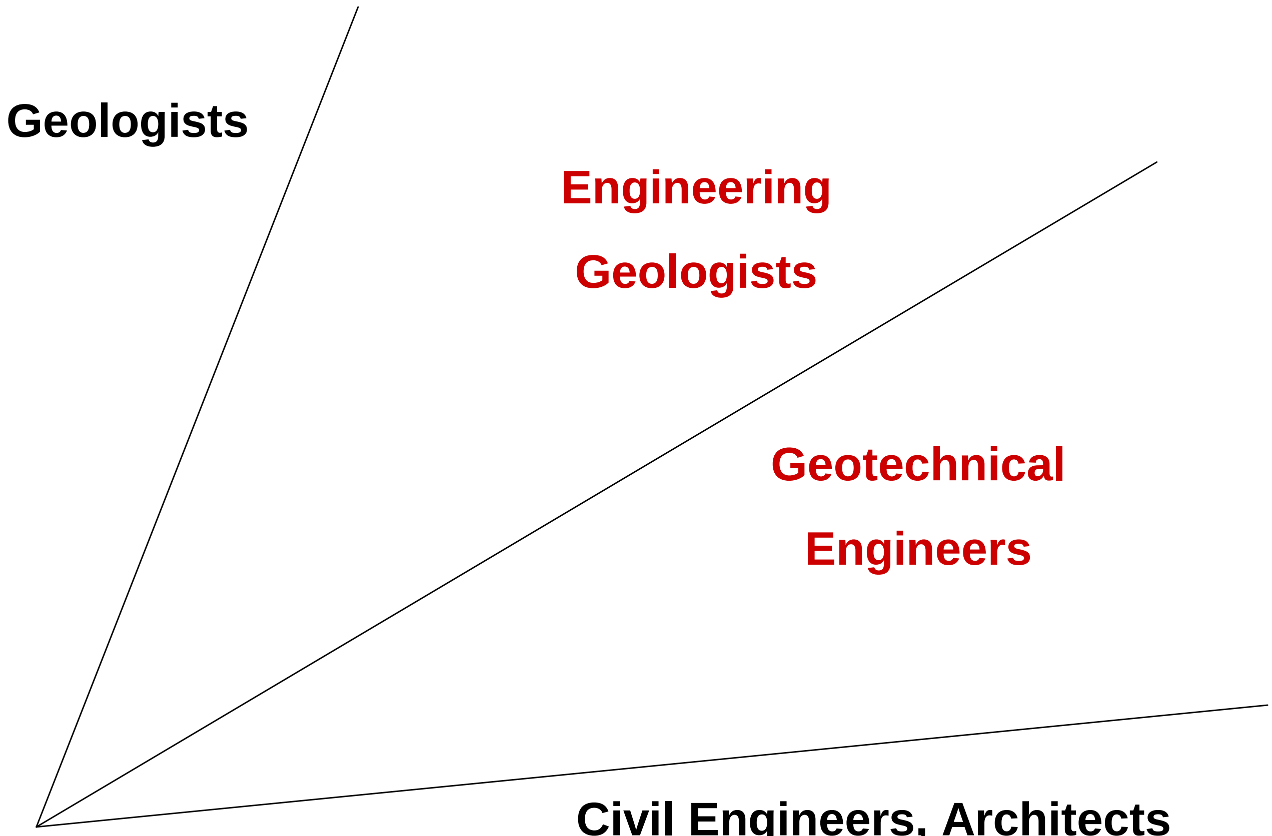
Czech Technical University in Prague

CZECH REPUBLIC
DEVELOPMENT COOPERATION

jan.valenta@fsv.cvut.cz

Introduction to Engineering Geology

jan.valenta@fsv.cvut.cz



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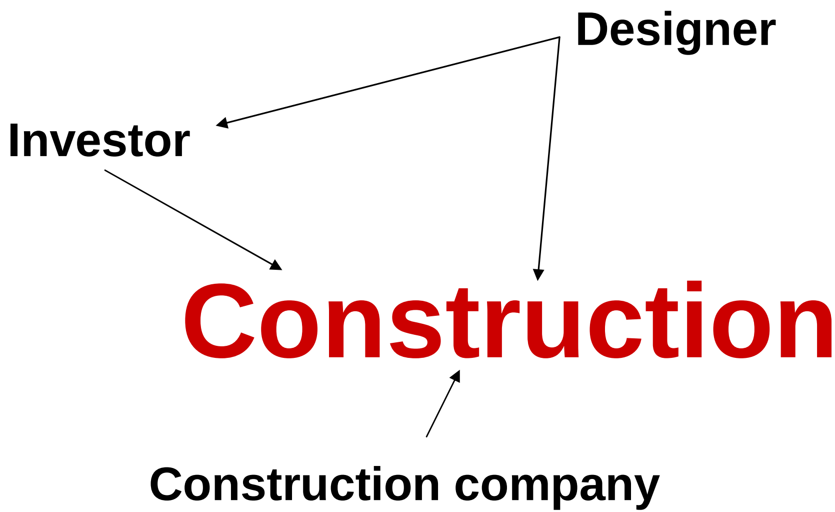
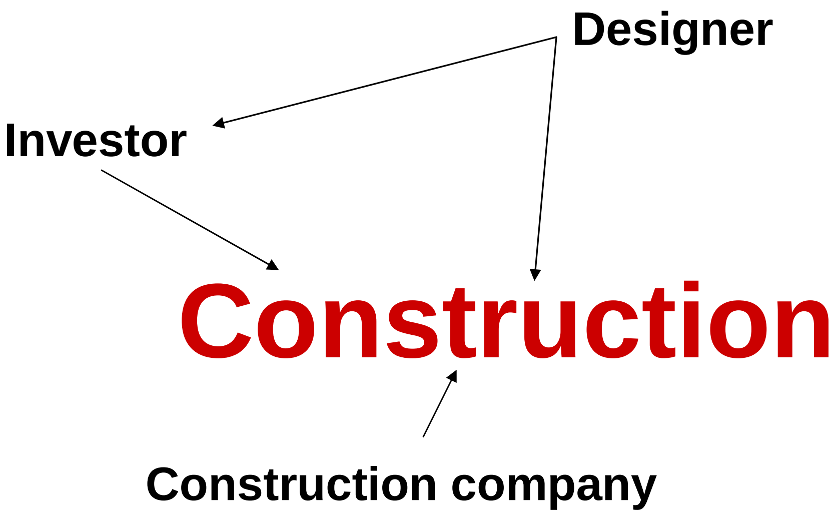

Designer
Investor
Construction
Construction company



The only important questions:

How much?

When?

Soil Mechanics

Rock mechanics

Geotechnics

Engineering geology

Mining Engineering

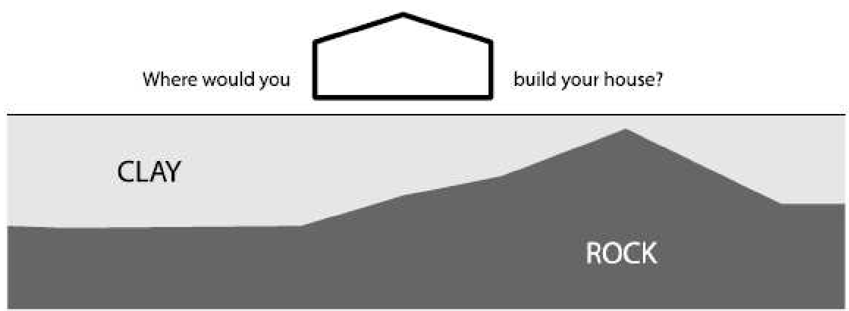
Civil Engineering

Foundation engineering

jan.valenta@fsv.cvut.cz

Engineering Geology – Attaining the Aims

- **All engineering works are built on the ground or in the ground**
- **The ground will always react to the engineering works**
- **The reaction of the ground must be accommodated by the engineering work**



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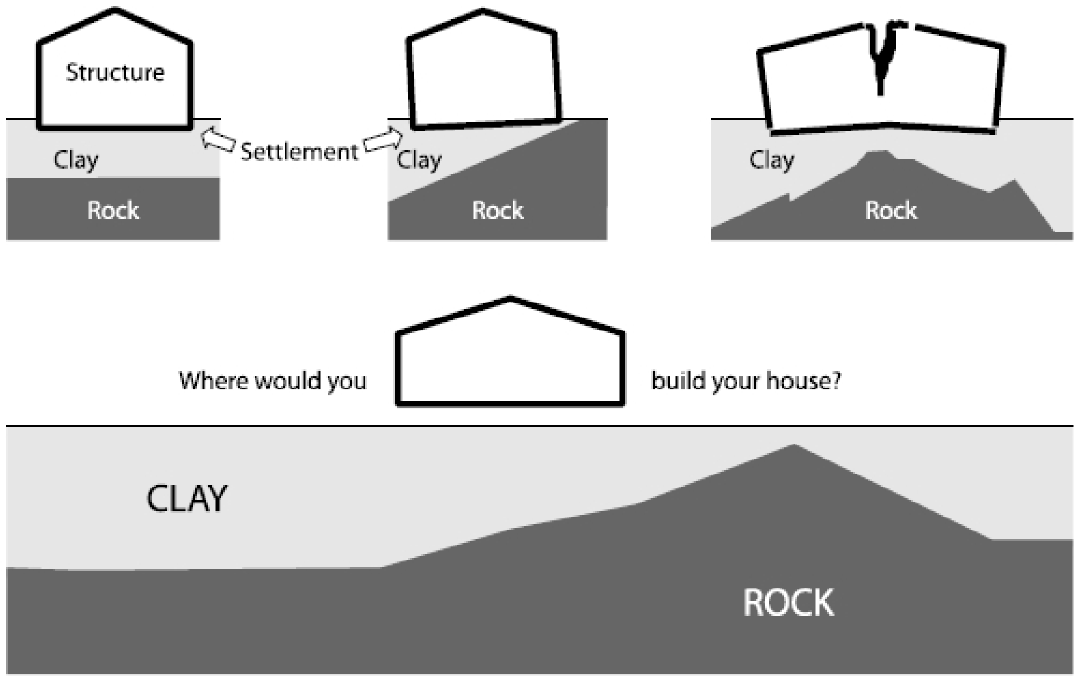
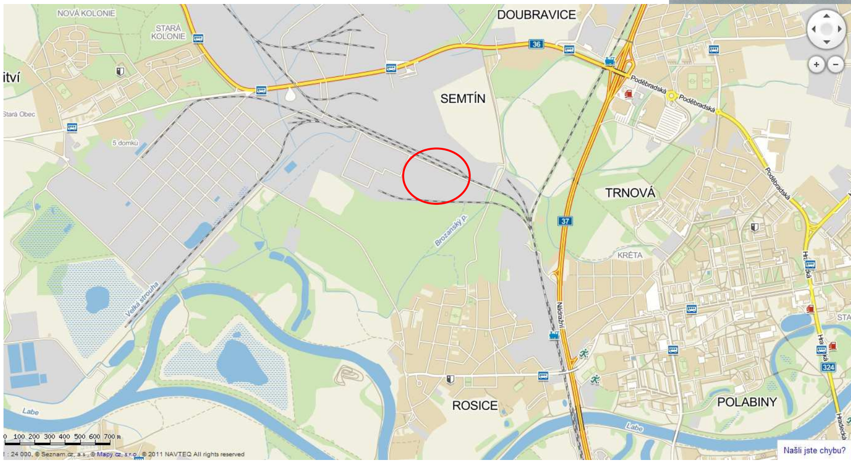
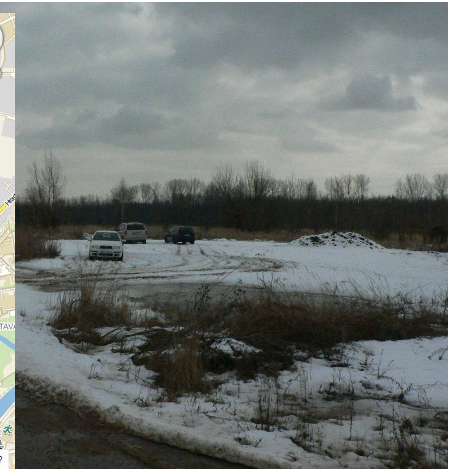
Engineering Geology – Attaining the Aims



Engineering Geology – Attaining the Aims

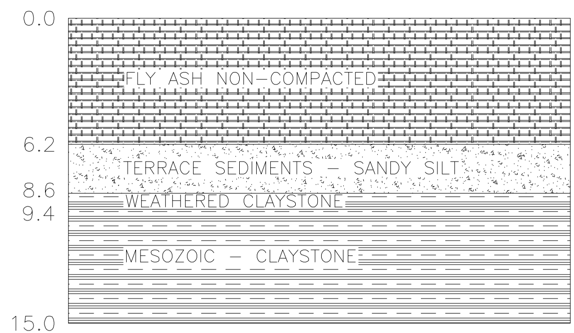




Developer versus Engineering Geologist

finally

Developer with Engineering Geologists



jan.valenta@fsv.cvut.cz

Engineering Geology – Attaining the Aims

Engineering geologists think in „mass“ way:

The ground mass is the volume of ground which will be affected by engineering work

Ground mass effected is different for different stories:

-buildings based on spread foundation

-bulding based on piled foundation

-tunnels

-mining

-earth dams

-roads (cuttings and embankments)

Engineering Geology – Using codes

BS 5930 Code of practice for Site Investigation

EC7 Eurocode 7

BS EN ISO 14688-1 Geotechnical investigation and testing

Engineering Geology and Geotechnics

Jan Valenta

Czech Technical University in Prague

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Desk study

Engineering Geology – Stages of SI

Ususally 3 stages:

1. **Desk Study (Preliminary Investigation Stage)**
2. **Main Investigation Stage**
3. **Costruction and Post-Construction Investigation Stage**

The aim of all stages is:

1. To get relevant geotechnical data to the designer for the design

2. To prepare the designer and investor to problems (it means more money and more time needed)

jan.valenta@fsv.cvut.cz

Desk study (Preliminary Investigation Stage)

The basic information about the locality are known

It is cheap!!!!! (compare with other stages of SI)

Even that most of the investors do not use it !!!!!!!

jan.valenta@fsv.cvut.cz

Desk study (Preliminary Investigation Stage)

Source of information:

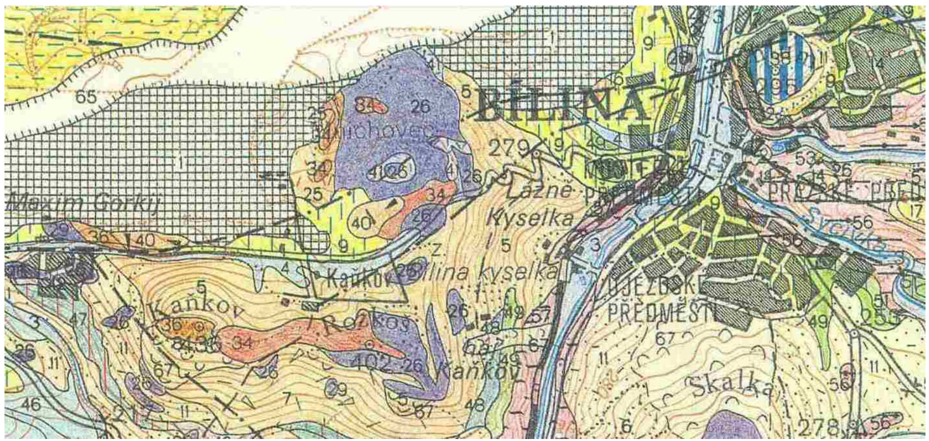
1. **maps in different scale (topographic maps, geological and hydrogeological maps,)**
2. **published articles from the area**
3. **aerial photographs**
4. **Any site investigation reports for adjacent engineering projects**
5. **records of natural hazards (earthquakes, hurricanes, floods)**

jan.valenta@fsv.cvut.cz

Desk study – maps – example Czech Republic

Set of maps in scale 1:50 000

e.g. geological map



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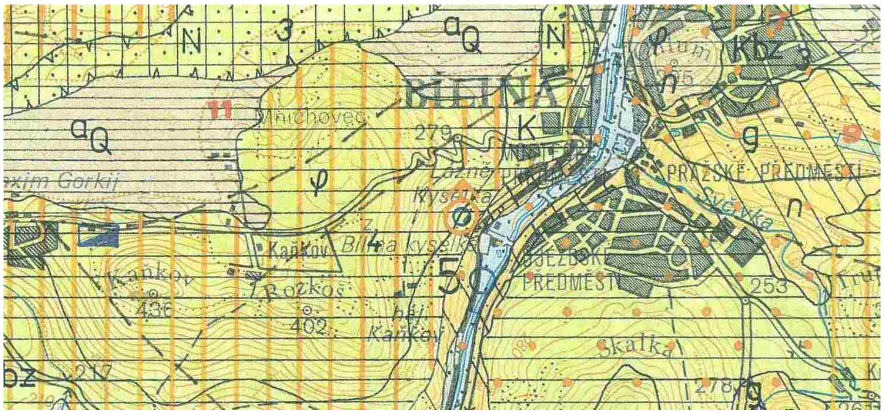
Desk study – maps – example CR

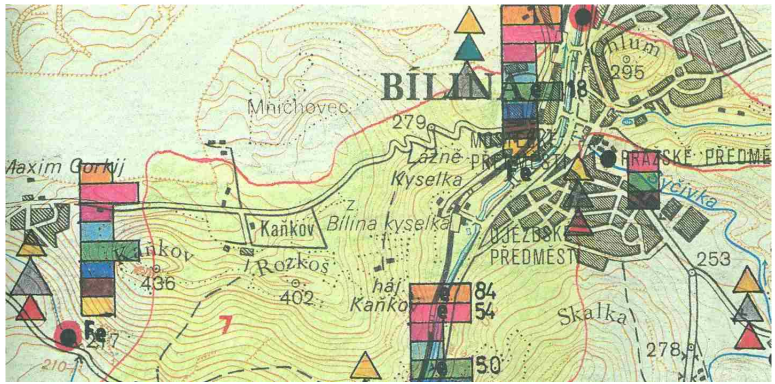
Set of maps in scale 1:50 000
e.g. hydrogeological map



jan.valenta@fsv.cvut.cz

Desk study – maps – example CR

Set of maps in scale 1:50 000
e.g. hydrogeological map



Maps in scale 1:50 000 in CR

one map sheet includes:

- geological map

- hydrogeological map

- map of geophysical fields and their interpretation **(They include gravimetric, aeromagnetic, aero radiometric and gamma spectrometric maps.)**

- Mineral resource maps **(maps show the locations of deposits of raw materials, and the resources they contain together with areas of inferred resources. They provide information about the exploitation of known resources of raw materials, as well as the potential for extraction in the future)**

- Engineering-geological maps **(They are designed for use in regional and local planning, for example in the location of areas suitable for housing and recreational facilities, and the selection of sites for waste disposal)**

jan.valenta@fsv.cvut.cz

Maps in scale 1:50 000 in CR

one map sheet includes:

-Maps of the geochemical reactivity of rocks **(These maps provide fundamental information about the distribution of elements and chemical components in the rock substrate.)**

- Soil map **(These maps provide information about soil cap of the area. There is used the taxonomic soil classification system (type, sub-type,hydromorphic development, soil variety and form) as well as the soil-forming substrate.)**

- Soil-interpretation maps **(These maps show the potential of agricultural and forest soils. They contain information about the ecological and economic factors that govern the effective utilization of the soil resources)**

- Maps of surface water geochemistry **(These maps provide information about the degree of acidification of surface waters, the pollution of streams by heavy metals, contamination by atmospheric dust etc)**

- Engineering-geological maps **(They are designed for use in regional and local planning, for example in the location of areas suitable for housing and recreational facilities, and the selection of sites for waste disposal)**

Maps in scale 1:50 000 in CR

one map sheet includes:

-Maps of environmental geofactors : conflicts of interest **(These maps provide an immediate overview of the areas in which conflicts of interest could exist and the factors responsible.)**

- Maps of environmental geofactors: significant landscape features **(Maps of significant landscape features combine selected ecological information included in other maps of this series with specific data about the influence of human activity, as well as details of the assessment of vegetation condition)**

Maps in scale 1:25 000 in CR

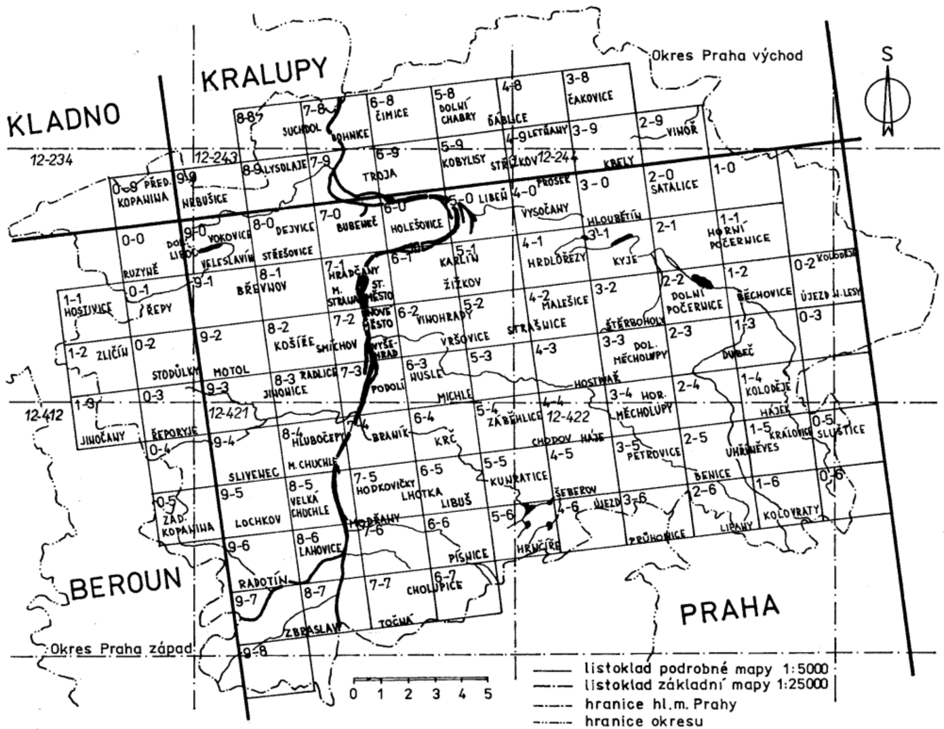
-Geological map

- Mineral resource maps

jan.valenta@fsv.cvut.cz

Engineering geology - maps

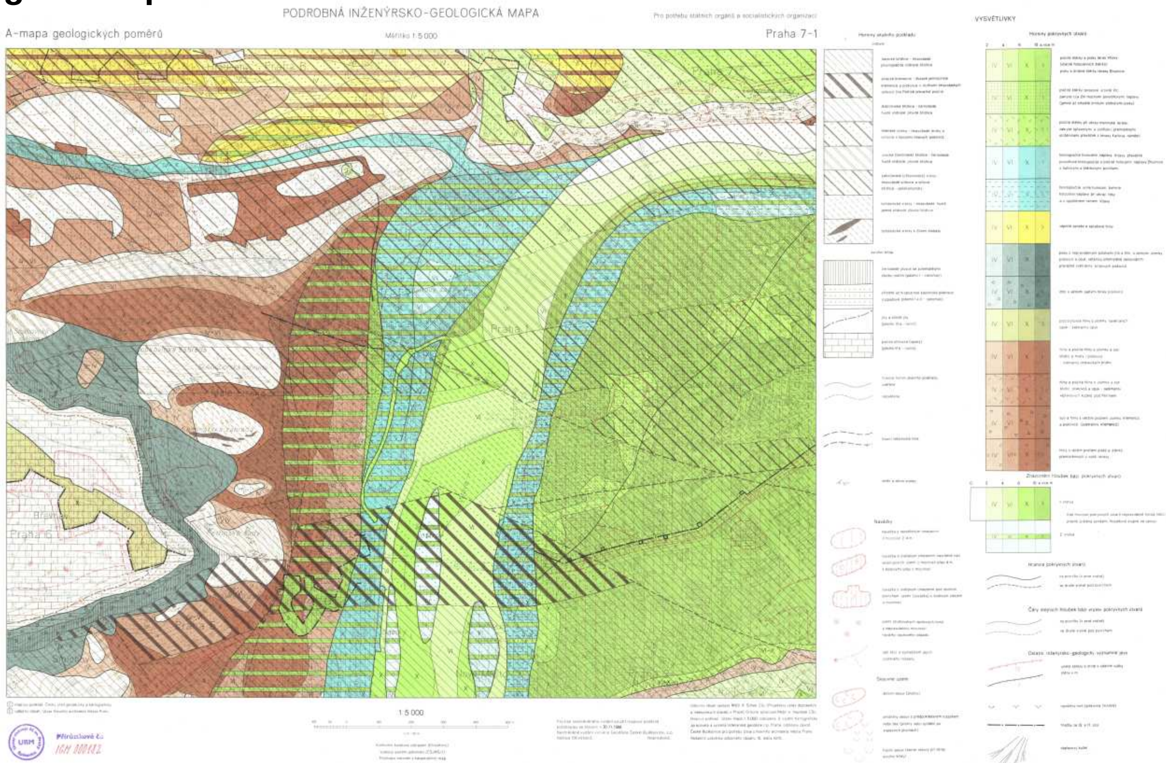
1:5 000



jan.valenta@fsv.cvut.cz

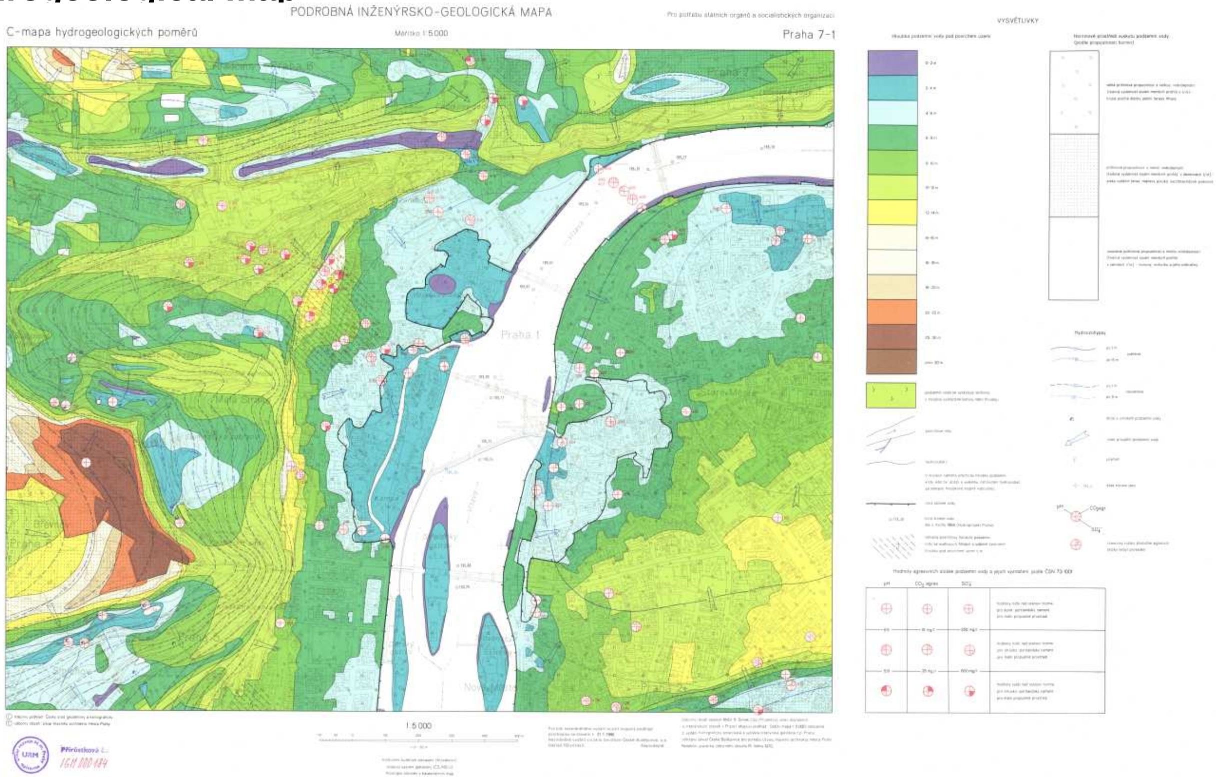
Engineering geology – maps 1:5000

Geological map



Engineering geology – maps 1:5000

Hydrogeological map



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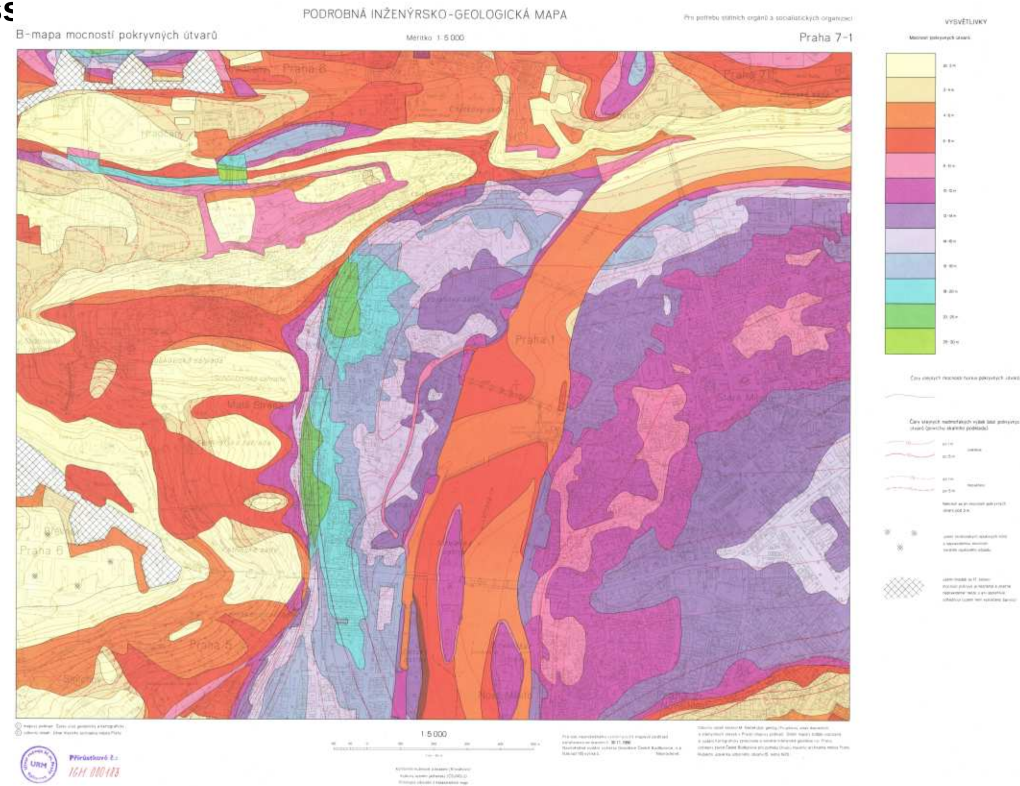
Engineering geology – maps 1:5000

Cover thickness



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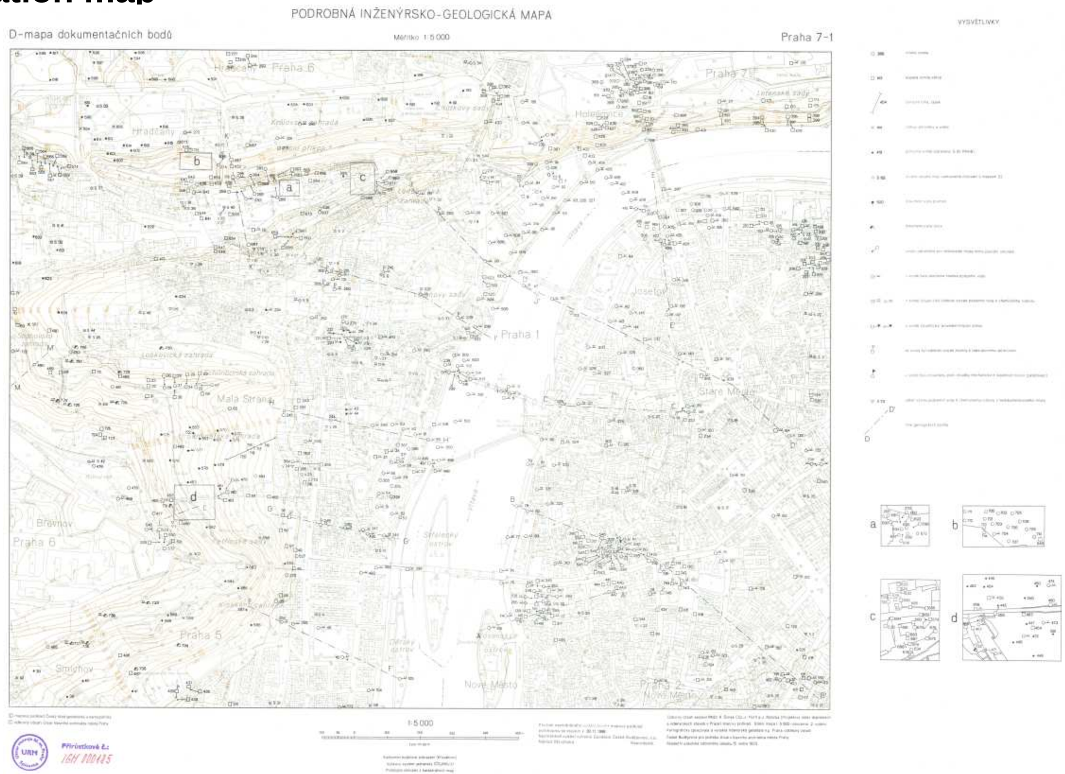
Engineering geology – maps 1:5000

Documentation map



jan.valenta@fsv.cvut.cz

Engineering geolgy - geofond

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www.geology.cz

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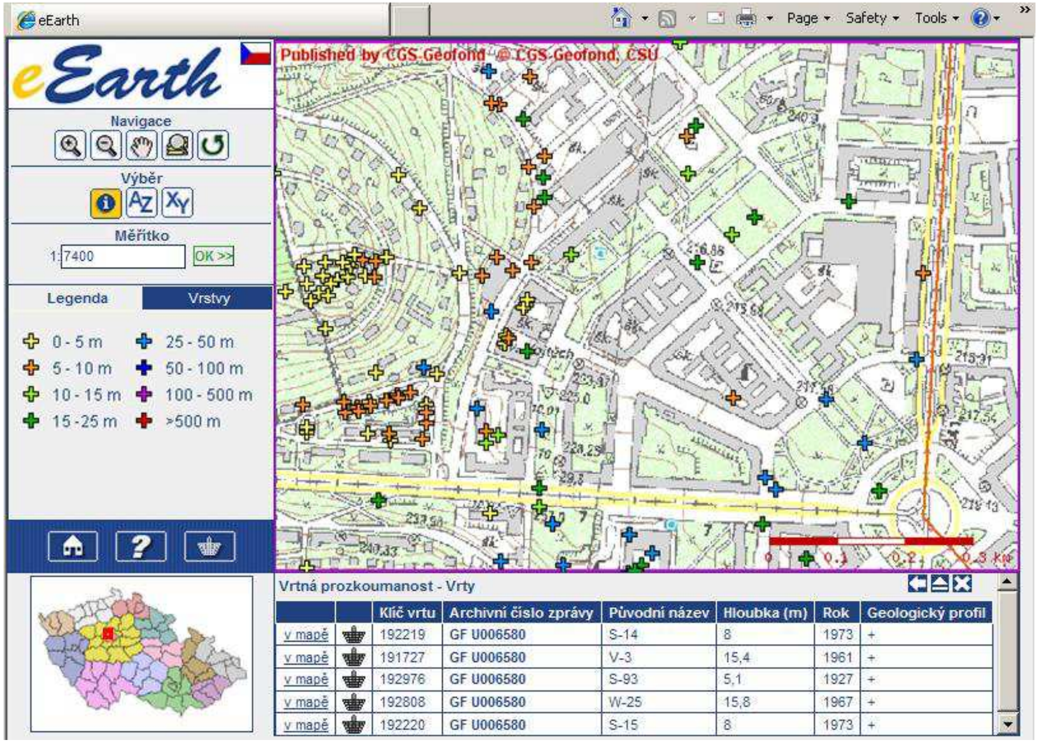
Engineering geolgy - geofond



jan.valenta@fsv.cvut.cz

Further reading and literature

In the presentation is used pictures from:

Czech Geological Survey – Geological Maps in 5:000 scale

www.geology.cz

jan.valenta@fsv.cvut.cz

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Jan Valenta

Czech Technical University in Prague

CZECH REPUBLIC
DEVELOPMENT COOPERATION

jan.valenta@fsv.cvut.cz

Soils and Rocks Description

jan.valenta@fsv.cvut.cz

Soil and Rocks Description

What is that for?

To get the relevant geotechnical data to the designer

Different description

- **Description on site (visual classification)**
- **Description based on test results**

Engineering Geology – Classification

USCS - classification

BS EN ISO 14688-1 Geotechnical investigation and testing

Soil fractions	Sub-fractions	Symbols	Particle sizes mm
Very coarse soil	Large boulder	LBo	> 630
	Boulder	Bo	> 200 to 630
	Cobble	Co	> 63 to 200
Coarse soil	Gravel	Gr	> 2,0 to 63
	Coarse gravel	CGr	> 20 to 63
	Medium gravel	MGr	> 6,3 to 20
	Fine gravel	FGr	> 2,0 to 6,3
	Sand	Sa	> 0,063 to 2,0
	Coarse sand	CSa	> 0,63 to 2,0
	Medium sand	MSa	> 0,2 to 0,63
	Fine sand	FSa	> 0,063 to 0,2
Fine soil	Silt	Si	> 0,002 to 0,063
	Coarse silt	CSi	> 0,02 to 0,063
	Medium silt	MSi	> 0,006 3 to 0,02
	Fine silt	FSi	> 0,002 to 0,006 3
	Clay	Cl	≤ 0,002

jan.valenta@fsv.cvut.cz

Engineering Geology – Classification

Principal fractions:

Gr, Sa,

Secondary fractions:

saGr – sandy gravel

grCl – gravelly clay

for sandy material:

Dense thinly bedded grey fine SAND

Important description: Dense or Loose

Engineering Geology – Classification

Stiff
thinly laminated
brown CLAY

Strength category		Description	Field definition
		Very soft	Extrudes between fingers when squeezed
	20	Soft	Very easily moulded with fingers
	40	Firm	Moderate finger pressure required to mould
Guide to shear strength of clays (kPa)	75	Stiff	Moulded only by strong finger pressure
	150	Very stiff	Can be indented by thumbnail
	300	Hard	Can be scratched by thumbnail

Important description: stiffness

Engineering Geology – Classification

Plasticity

Non-plastic: *40mm long roll and 6mm thick cannot be formed*

Slightly plastic: *40mm long roll and 6mm thick can be formed and will support on its own weight, but 4mm will not support*

Moderately plastic: *40mm long roll and 4mm thick can be formed and will support on its own weight, but 2mm will not support*

very plastic: *40mm long roll and 2mm thick can be formed and will support on its own weight*

BS EN ISO 14688-1 Geotechnical investigation and testing

low plasticity: it is NOT possible 3mm thick roll

high plasticity: it is possible to create 3 mm roll

Dilatancy *– way of recognize silt and clay in soil*

jan.valenta@fsv.cvut.cz

Engineering Geology – Classification

Shear strength determination on site:

pocket penetrometer – unconfined compressive strength (MPa)
for fine grained soils only
test slowly

Unconfined compressive strength (MPa) = 2 x shear strength of soil (MPa)

Engineering Geology – Classification

Shear strength determination on site:

shear vane test – undrained shear strength (MPa)
for fine grained soils only
test slowly

jan.valenta@fsv.cvut.cz

Engineering Geology – Classification

3 adapters
middle – 0 to 1 kg/m²
smallest – 0 to 2.5 kg/m²
biggest – 0 to 0.2 kg/m²

shear strength evaluation

Engineering Geology – Classification

Rocks:
weathered or un-weathered

Decomposed thinly bedded red coarse micaceous SANDSTONE, weak

Guide to unconfined compressive strength of rocks (MPa)		
	Extremely weak	Crumbles in hand
1.0	Very weak	Thin slabs break easily under hand presssure
5	Weak	Thin slabs break under heavy hand presssure
25	Medium strong	Lumps or core broken by light hammer blows
50	Strong	Lumps or core broken by heavy hammer blows
100	Very strong	Lumps only chip with heavy hammer blows. Dull ringing sound
250	Extremely strong	Rocks ring on hammer blows. Sparks fly

Rocks must be named – there is always association with the name
e.g. Limestones – caverns
Quartzites – abrasive, high strength

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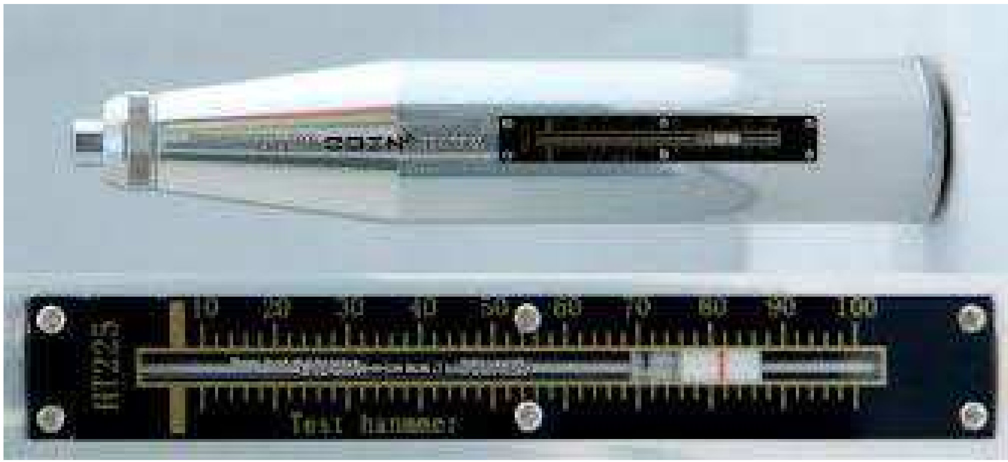
Engineering Geology – Classification

Rocks:
For unconfined compressive strength use Schmidt test hammer



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Soil and Rocks Description

What is that for?

To get the relevant geotechnical data to the designer

Important soil parameters?

Estimation of soil parameters:

Property	Gravel	Sand
Specific gravity	2.5 – 2.8	2.6 – 2.7
Bulk unit weight (kN m^{-3})	14.1 – 22.6	13.7 – 21.6
Dry unit weight (kN m^{-3})	13.7 – 20.6	13.0 – 18.6
Angle of friction (°)	33 – 45	27 – 46
Porosity (%)	25 – 40	25 – 50
Shear strength (kPa)	180 – 550	100 – 400
Permeability (m s^{-1})	10^{-1} – 10^{-4}	10^{-3} – 10^{-6}

Property	Silt	Clay
Specific gravity	2.63 – 2.67	2.55 – 2.76
Bulk unit weight (kN m^{-3})	17.65 – 21.2	14.5 – 21.2
Dry unit weight (kN m^{-3})	14.2 – 19.2	11.6 – 21.2
Void ratio	0.34 – 0.82	0.42 – 0.95
Liquid limit (%)	24 – 36	> 25
Plastic limit (%)	14 – 25	> 20
Permeability (m s^{-1})	10^{-6} – 10^{-9}	10^{-9} – 10^{-12}
Cohesion (kN m^{-2})	< 70	15 – 200
Angle of friction (°)	25 – 35	4 – 17
Coefficient of consolidation (m^2 yr^{-1})	12	5 – 20

jan.valenta@fsv.cvut.cz

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Jan Valenta

Czech Technical University in Prague

CZECH REPUBLIC
DEVELOPMENT COOPERATION

 jan.valenta@fsv.cvut.cz

Main Investigation Stage

jan.valenta@fsv.cvut.cz

Main Investigation Stage

What is that for?

1. **To get relevant geotechnical data to the designer for the design**

2. **To prepare the designer and investor to problems (it means more money and more time needed)**

Main Investigation Stage - planning

Design of site investigation

determine the behaviour of the ground in response to the construction of the engineering work

- know engineering work (size, load, depths of excavation,…)
- determine the geology and hydrogeology,…….(preliminary SI)
  - Establish the size and location of the ground mass that could influence or be influenced by the engineering work
  - list of the data for geotechnical calkulations
  - how to get the data (type of tests (laboratory and field))

possibilities:

boreholes

in situ testing

geophysics

Main Investigation Stage - drilling

rotary core drilling

- *access to the site*
- *pipelines and cables in the ground*

Core diameter (mm)

165
139
112
92
76
54
41
30
20
17

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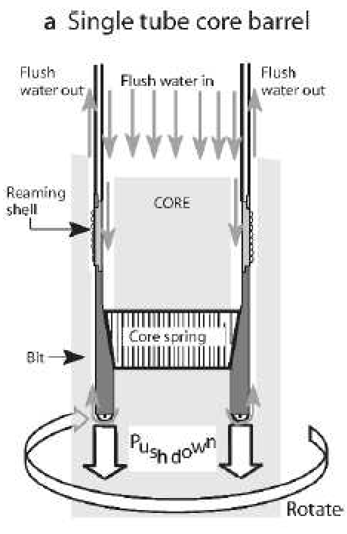
Main Investigation Stage - drilling



- *dry*
- *using flush water*

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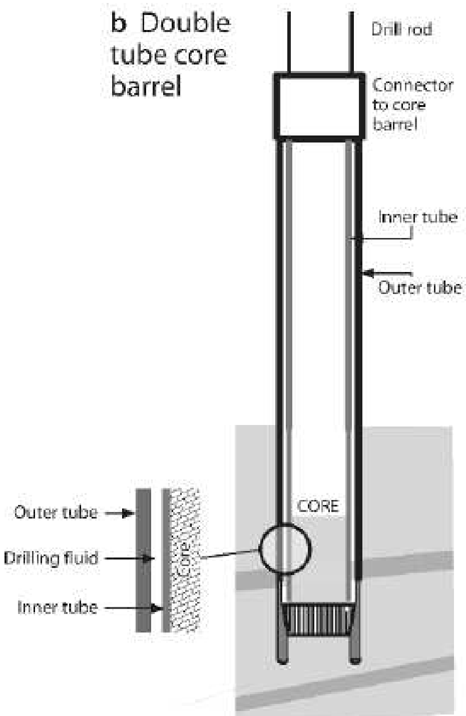
Main Investigation Stage - drilling



double tube core drilling

flushing media – water, drilling mud, polymers

jan.valenta@fsv.cvut.cz

Main Investigation Stage - drilling

rotary core drilling
- *time of description*
- *any water remarks*

jan.valenta@fsv.cvut.cz

Main Investigation Stage - drilling

rotary core drilling

jan.valenta@fsv.cvut.cz

Main Investigation Stage - drilling

percussion boring with cable tools

Main Investigation Stage – trial pits

Trial pits

Main Investigation Stage – trial pits

Trial pits

jan.valenta@fsv.cvut.cz

Main Investigation Stage – trial pits

Trial pits – investigation of foundation

jan.valenta@fsv.cvut.cz

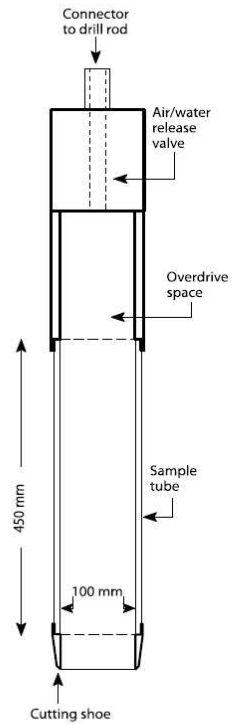
Sampling

Disturbed

Undisturbed

jan.valenta@fsv.cvut.cz

Sampling - undisturbed



100 mm
Open tube sampler

jan.valenta@fsv.cvut.cz

Sampling

Purpose of sample	Material	Weight or volume of bulk sample	Diameter and length of tube or core sample (mm)	
			Diameter	Length
Chemical composition	Clays and silts	0.5–1.0 kg	38	75
	Sands	0.5–1.0 kg	38	75
	Gravels	3.0 kg	90	200
	Rocks	0.5 kg	38	75
	Groundwater	2.5 l		
Structural characteristics incl. grain size, porosity etc.	Clays and silts	0.5–1.0 kg	90	90
	Sands	1.0–2.5 kg	90	200
	Gravels	4.5–45 kg	90	200
	Rocks (coarse grained)	0.3 m^3	90	90
	Rocks (fine grained)	0.15 m^3	75	75
Strength characteristics incl. elastic moduli, shear strength, consolidation etc.	Clays and silts	$(0.3\ m)^3$	38	75
	Sands	$(0.3\ m)^3$	38	75
	Gravels	$(0.5\ m)^3$	0.2	0.3 m
	Rocks (weathered)	2 of $(0.3\ m)^3$	90	200
	Rocks (unweathered)	1 of $(0.3\ m)^3$	75	150
Hydraulic characteristics incl. permeability, etc.	Clays and silts	$(0.15\ m)^3$	38	75
	Sands	$(0.2\ m)^3$	38	75
	Gravels	$(0.5–1.0\ m)^3$	0.2	0.4 m
	Rocks (coarse grained)	$(0.3\ m)^3$	90	200
	Rocks (fine grained)	$(0.15\ m)^3$	75	150
Comprehensive examination	Clays and silts	20–45 kg	90	200
	Sands	20–45 kg	90	200
	Gravels	45–90 kg	0.2	0.4 m
	Rocks	2 of $(0.3\ m)^3$	90	200
	Groundwater	4.5–10.0 l		

Further reading and literature

In the presentation is used picures from:

Price, D.G: Engineering Geology – principles and practice (2009)

Czech Geological Survey – Geological Maps in 5:000 scale

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Jan Valenta

Czech Technical University in Prague

CZECH REPUBLIC
DEVELOPMENT COOPERATION

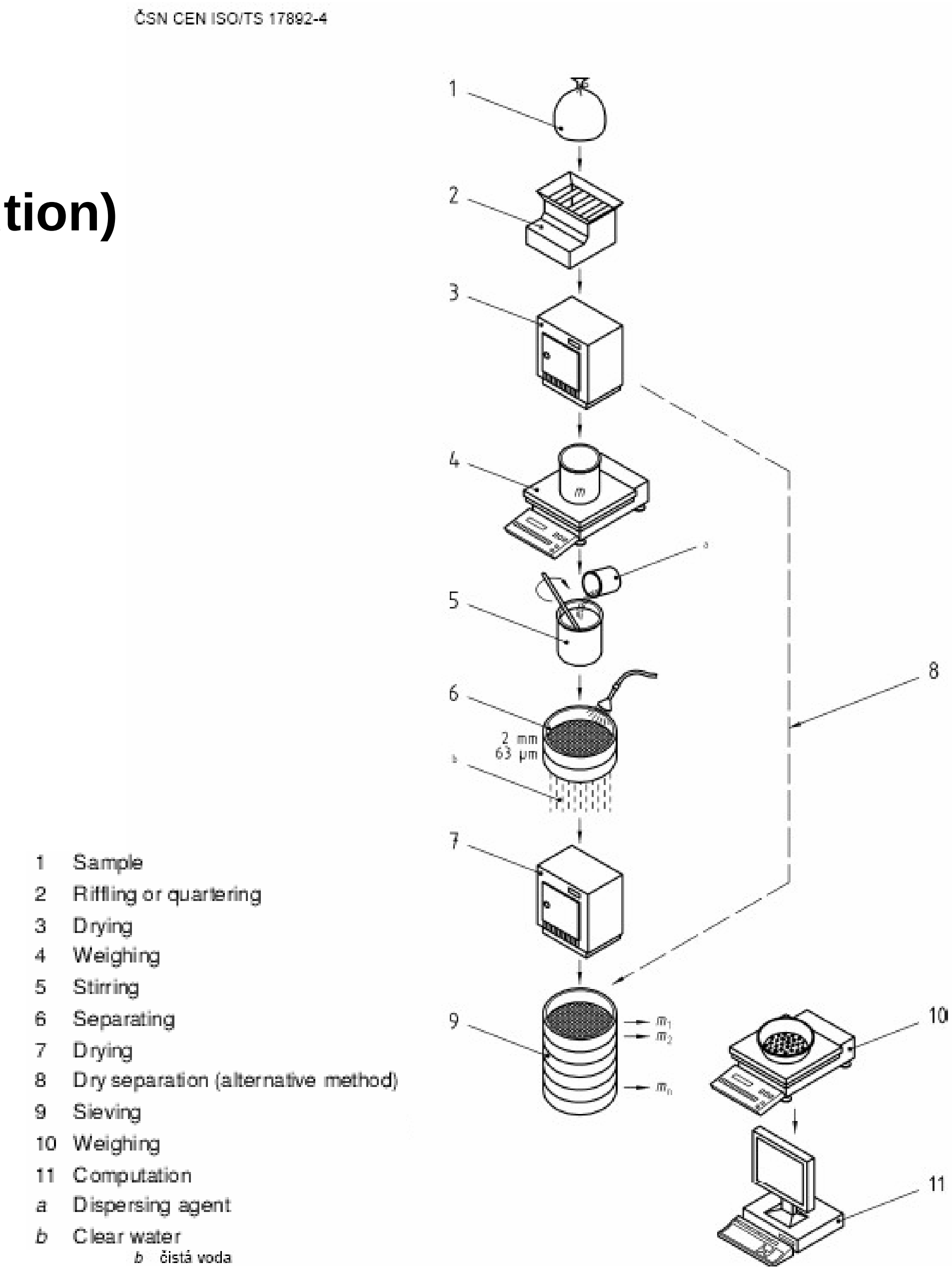
 jan.valenta@fsv.cvut.cz

Laboratory tests (index tests)

jan.valenta@fsv.cvut.cz

Laboratory tests

Sieve analysis (particle size distribution)



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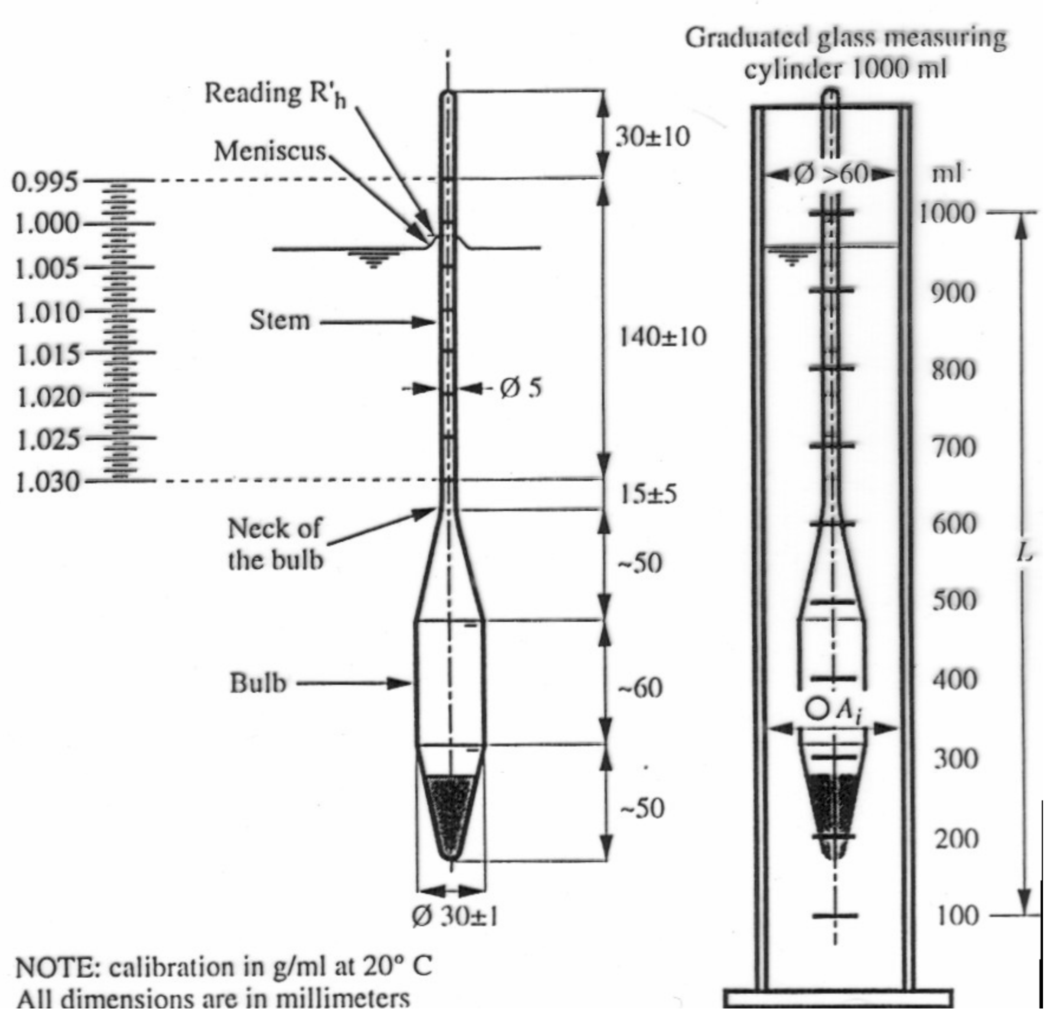
Laboratory tests

Sedimentation – using hydrometer



jan.valenta@fsv.cvut.cz

Laboratory tests

Atterberg limits (Consistency limits)

Atterberg limits describes the effect of changes of moisture content on the plasticity of clay soils.

Liquid Limit w_L(is the water content at which the soil changes from liquid to solid material with plastic behaviour)

Plasticity Limit w_P(is the water content at which the soil stops being plastic)

Plasticity index $I_p = w_L - w_p$
Shrinkage limit w_S

Limits are – constant for a soil sample

jan.valenta@fsv.cvut.cz

Laboratory tests

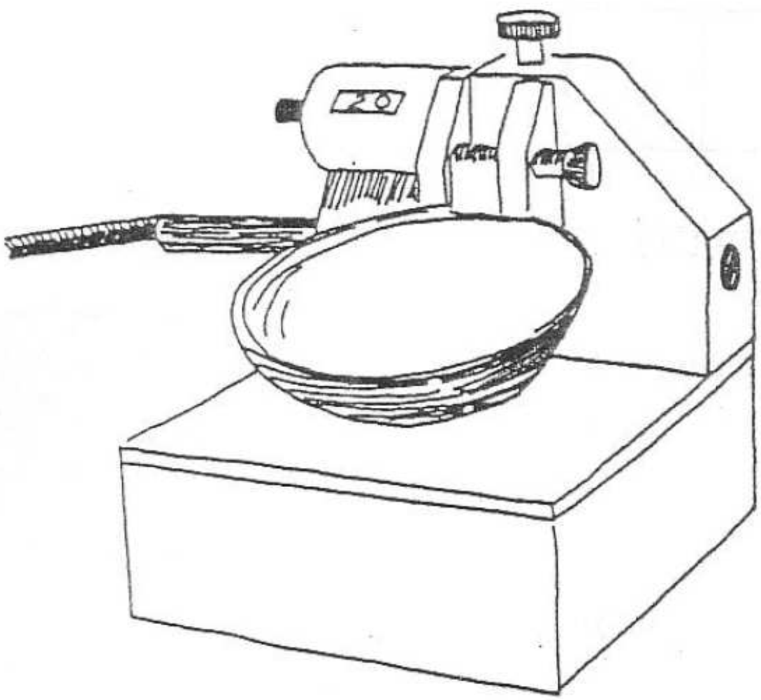
Liquid limit (w_L)

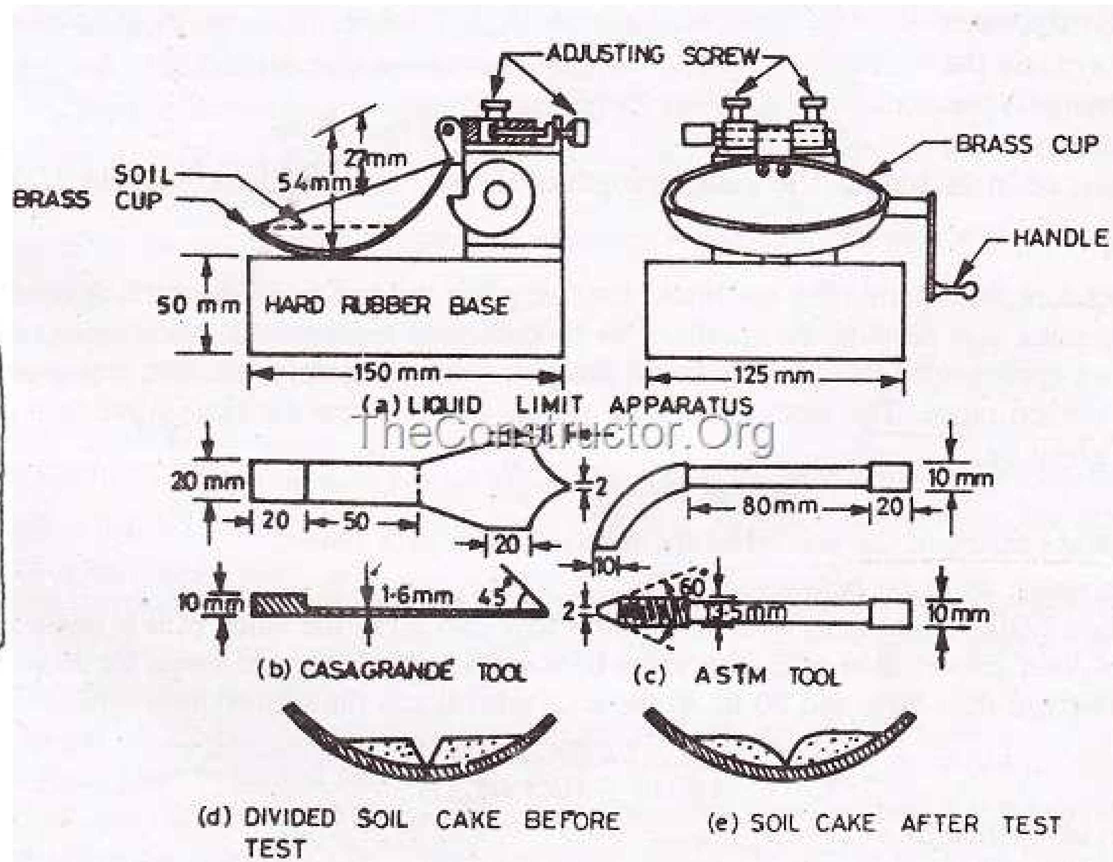
Looking for water content at which the 10mm penetration is reached (for 60° cone and 60g)

jan.valenta@fsv.cvut.cz

Laboratory tests

Liquid limit (w_L) Casagrande method





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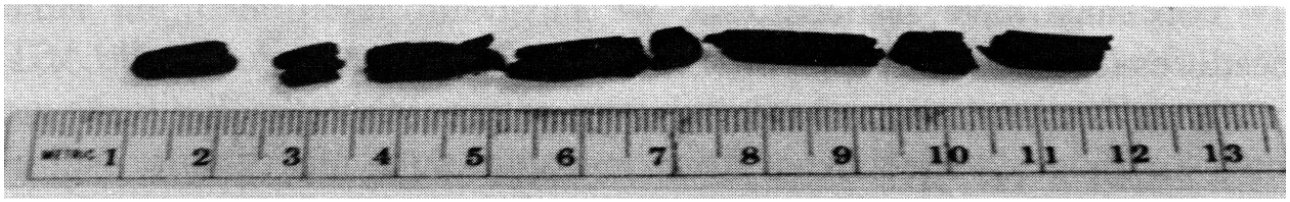
Laboratory tests

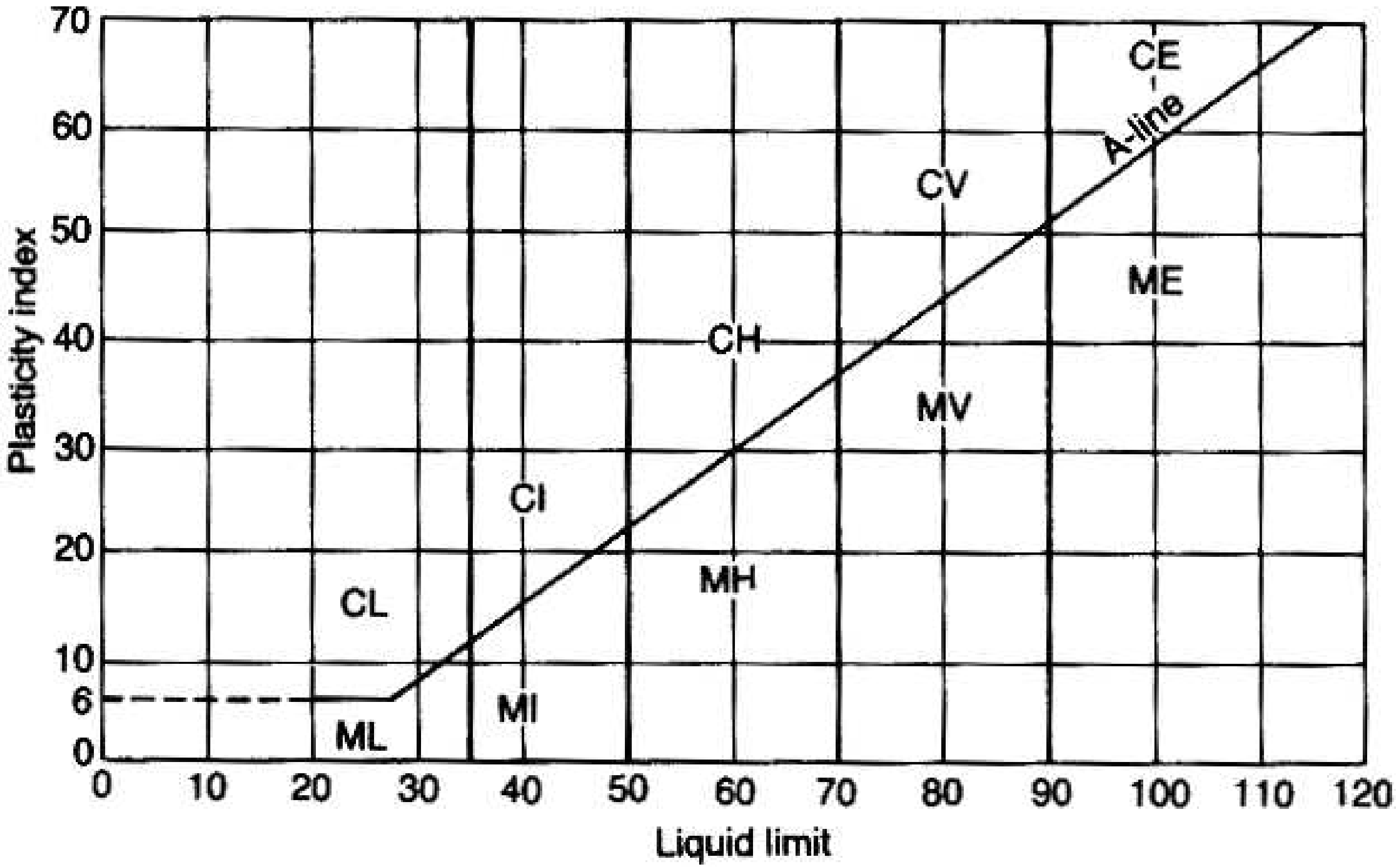
Plasticity limit w_P



Looking for the water content at which the soil crumbles as shown

Laboratory tests

Casagrande plasticity chart



Plasticity – L, I,H,E,

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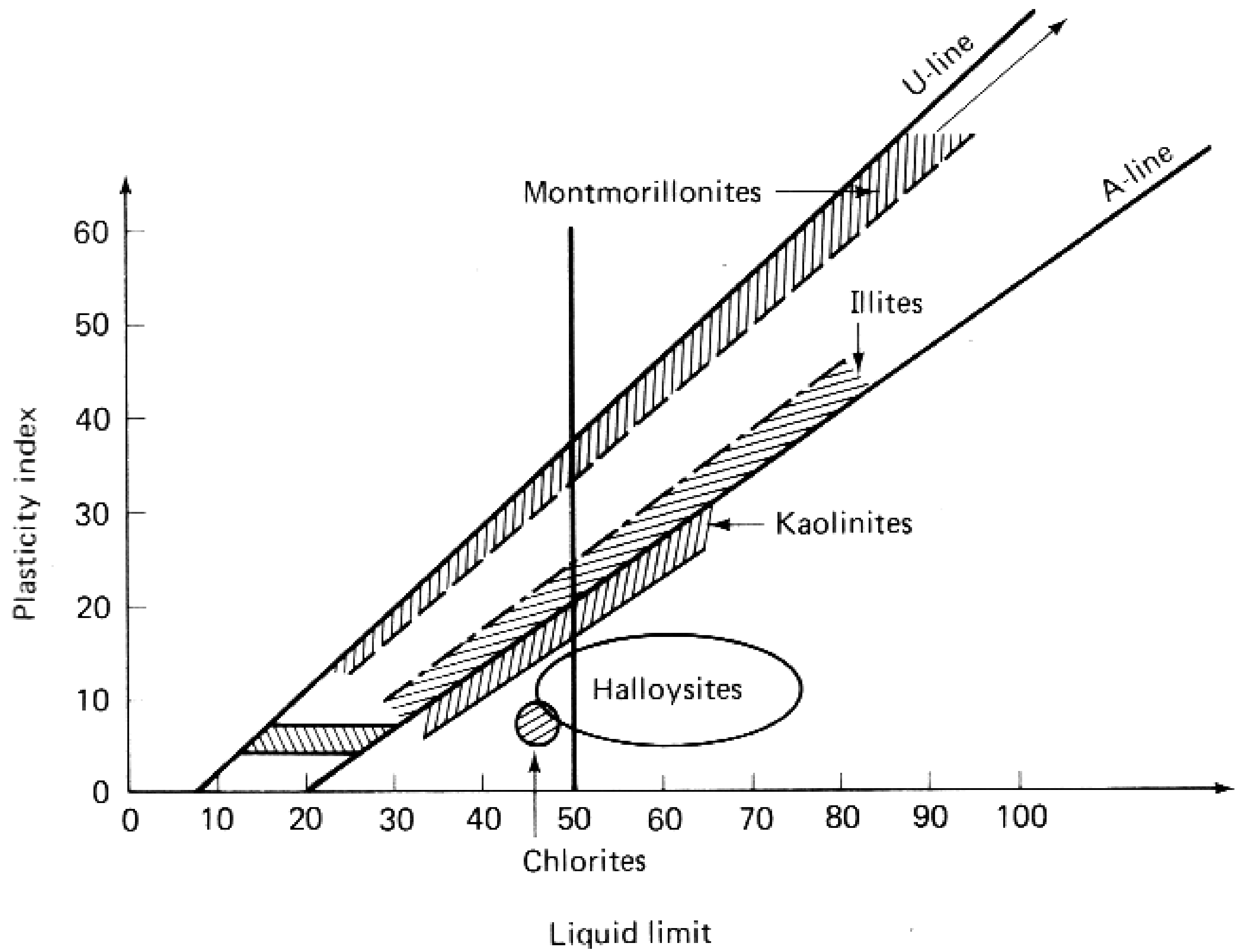
Laboratory tests

Clayey minerals



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Laboratory tests – state properties

Consistency (state) – fine grained-soils

Consistency index Ic = $(w_L - w) / (w_L - w_P)$

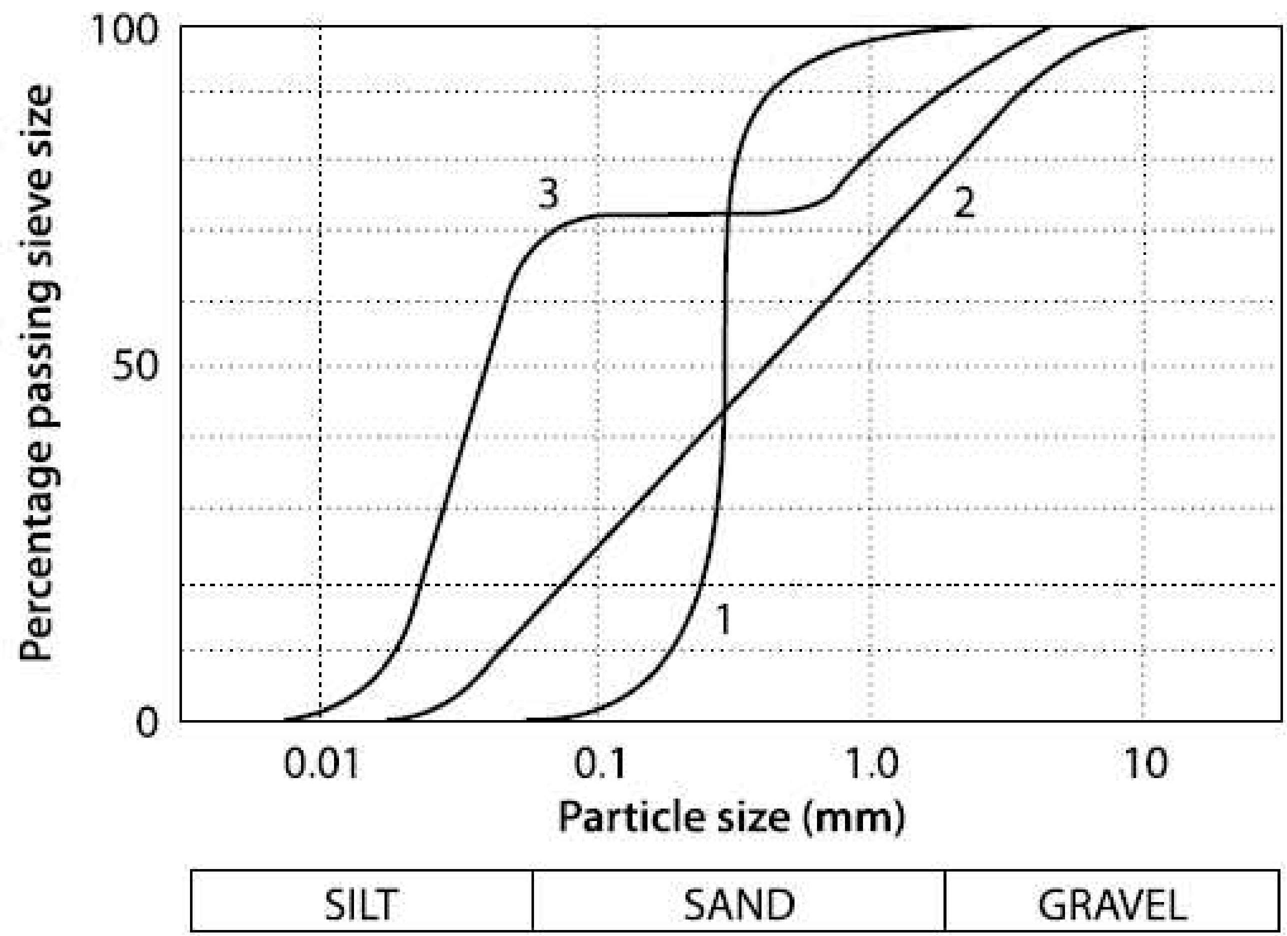
EN 14688-2

very soft $I_C < 0{,}25$
soft I_C = 0,25 to 0,50
firm I_C = 0,50 až 0,75
stiff I_C = 0,75 až 1,0
very stiff I_C > 1,0

jan.valenta@fsv.cvut.cz

Laboratory tests

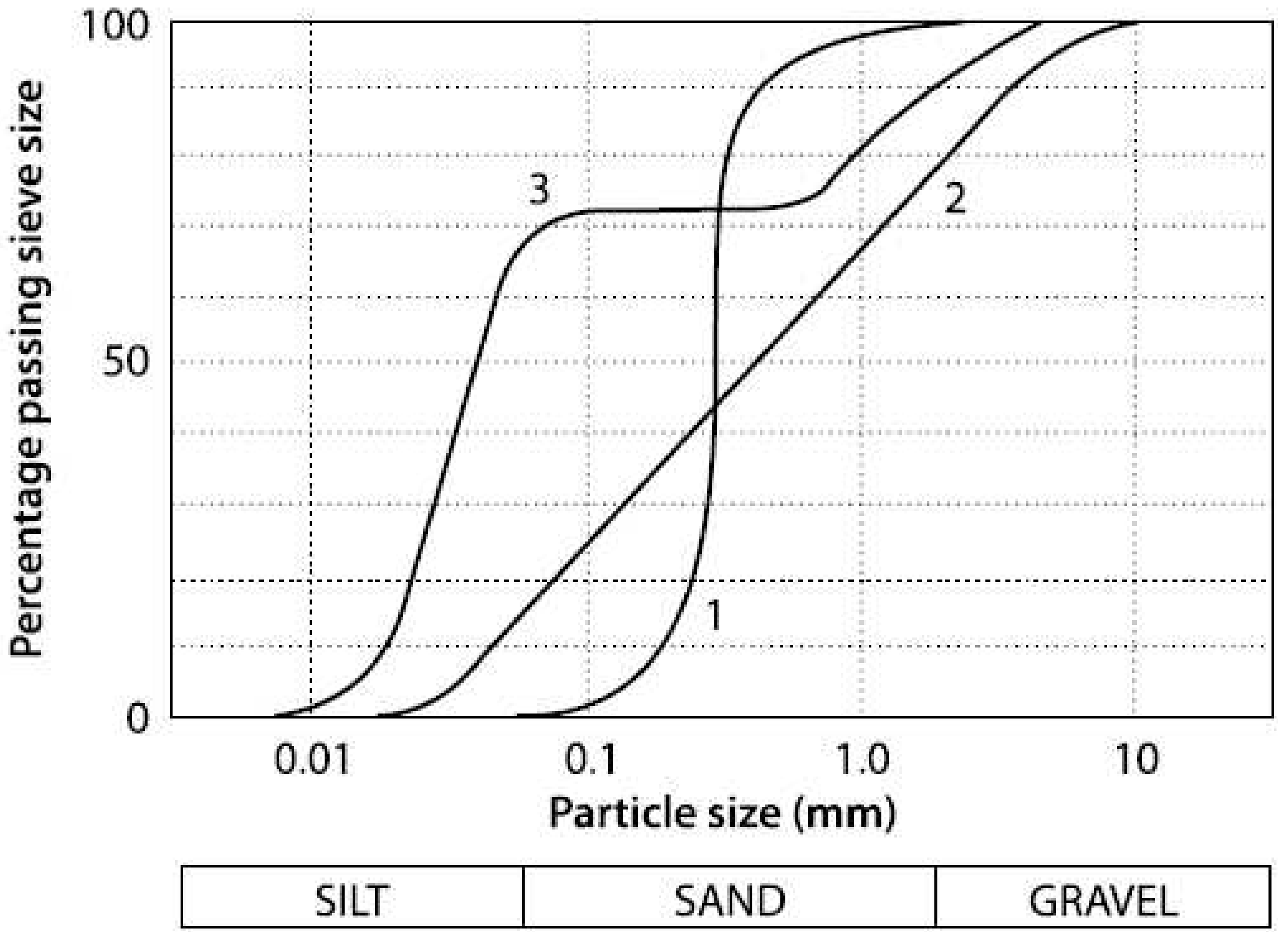
Sieve analysis (particle size distribution)



jan.valenta@fsv.cvut.cz

Laboratory tests

Sieve analysis (particle size distribution)



s =

g =

f =

Uniformity coefficient
$C_u = D_{60}/D_{10}$

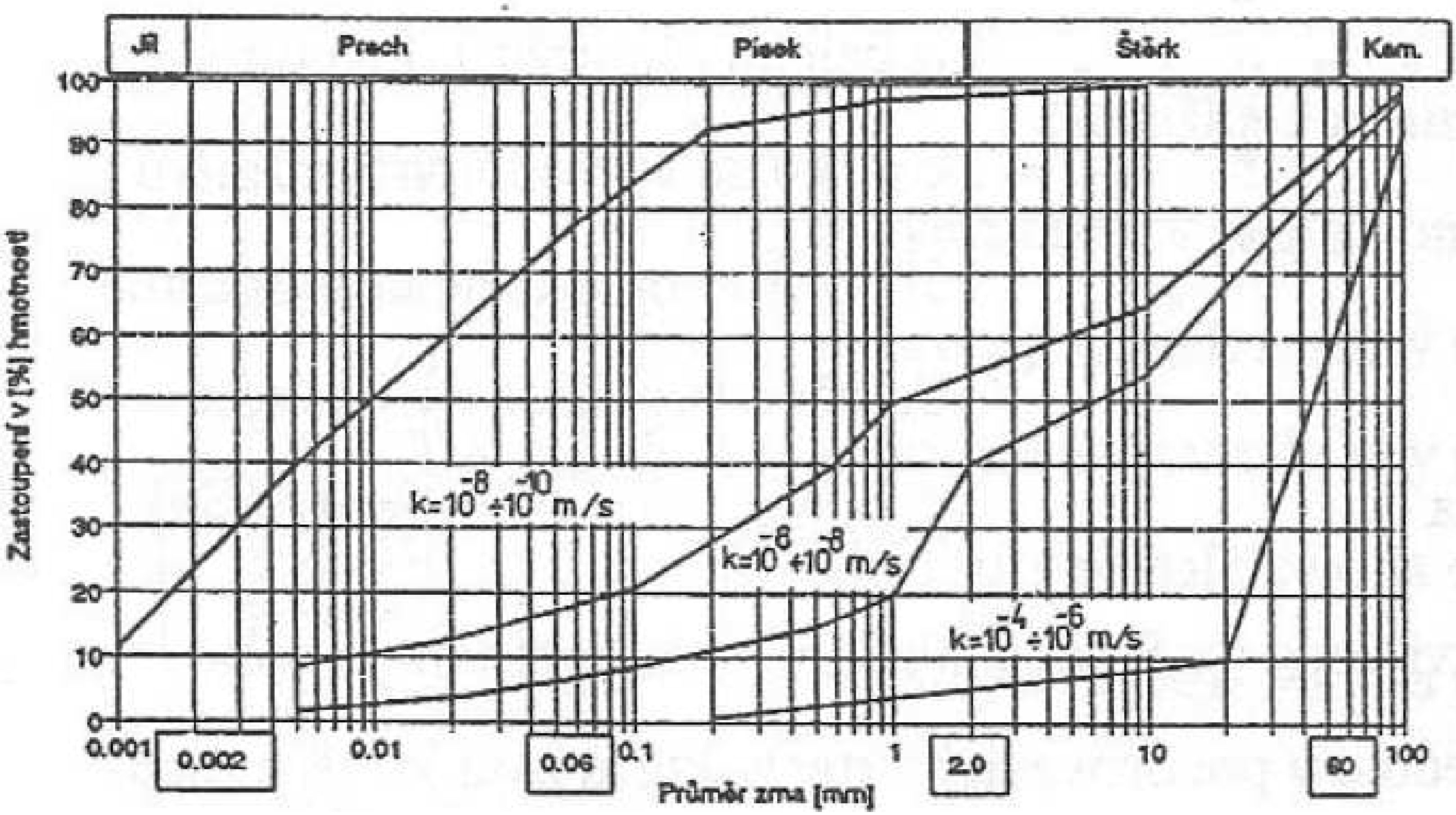
Coefficient of curvature
$C_c = D_{30}^2/D_{60}*D_{10}$

Laboratory tests

Hydraulic conductivity estimation

for sand

k [ms-1] = $0,01D_{10}^2$ [mm]

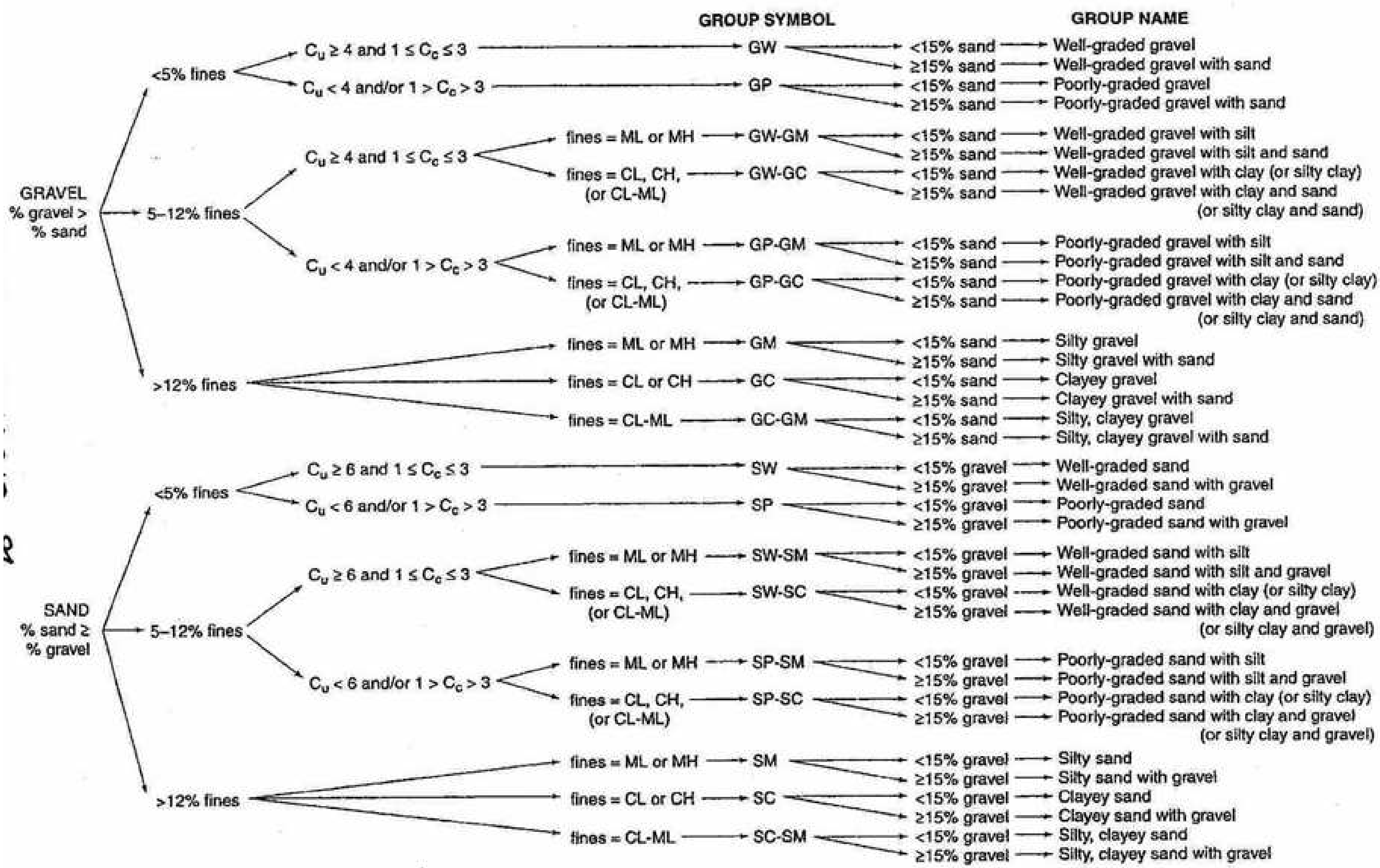


Laboratory tests

Frost – heaving of soil

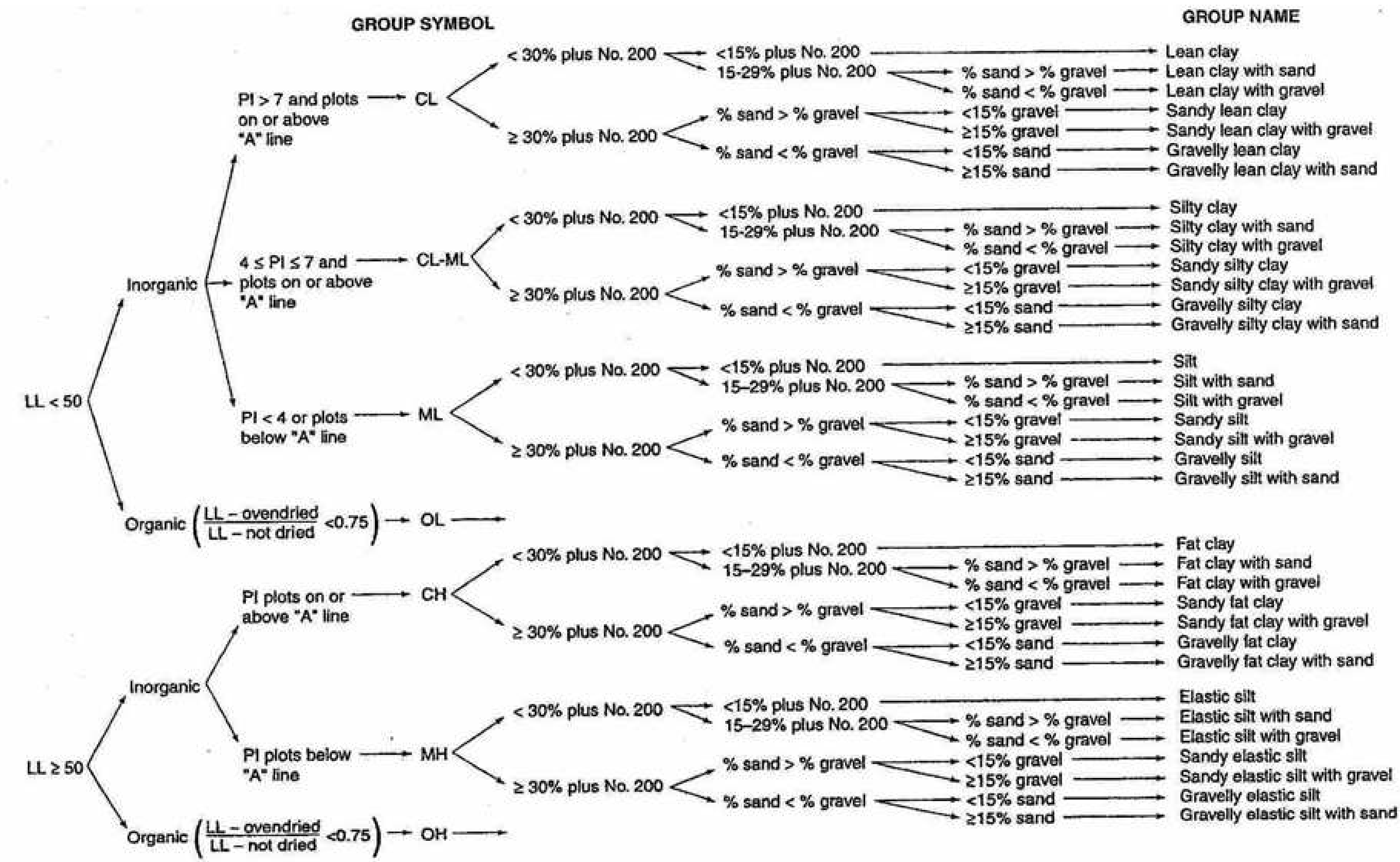
jan.valenta@fsv.cvut.cz

Laboratory tests USCS Classification



jan.valenta@fsv.cvut.cz

Laboratory tests USCS Classification



jan.valenta@fsv.cvut.cz

Laboratory tests

Sieve analysis (particle size distribution) and hydrometer analysis

Soil fractions	Sub-fractions	Symbols	Particle sizes mm
Very coarse soil	Large boulder	LBo	> 630
	Boulder	Bo	> 200 to 630
	Cobble	Co	> 63 to 200
Coarse soil	Gravel	Gr	> 2,0 to 63
	Coarse gravel	CGr	> 20 to 63
	Medium gravel	MGr	> 6,3 to 20
	Fine gravel	FGr	> 2,0 to 6,3
	Sand	Sa	> 0,063 to 2,0
	Coarse sand	CSa	> 0,63 to 2,0
	Medium sand	MSa	> 0,2 to 0,63
	Fine sand	FSa	> 0,063 to 0,2
Fine soil	Silt	Si	> 0,002 to 0,063
	Coarse silt	CSi	> 0,02 to 0,063
	Medium silt	MSi	> 0,006 3 to 0,02
	Fine silt	FSi	> 0,002 to 0,006 3
	Clay	Cl	⩽ 0,002

jan.valenta@fsv.cvut.cz

Laboratory tests

Sieve analysis (particle size distribution) and hydrometer analysis

Principal fractions:
Gr, Sa,
Secondary fractions:
saGr – sandy gravel
grCl – gravelly clay

siclSa – silty clayey Sand

siclfSa – silty clayey fine grained Sand

clfSa<u>si</u> – clayey fine grained Sand interbeded by silt

jan.valenta@fsv.cvut.cz

Laboratory tests – state properties

Other laboratry properties (state)

water content W_w/W_d [%]

Density at natural water content [kg/m^3]

Dry density [kg/m^3]

Degree of saturation [%]

Unit weight $\gamma = \rho g$ [kg/m^3]

Void ratio $e = Vp / Vs$ [-]

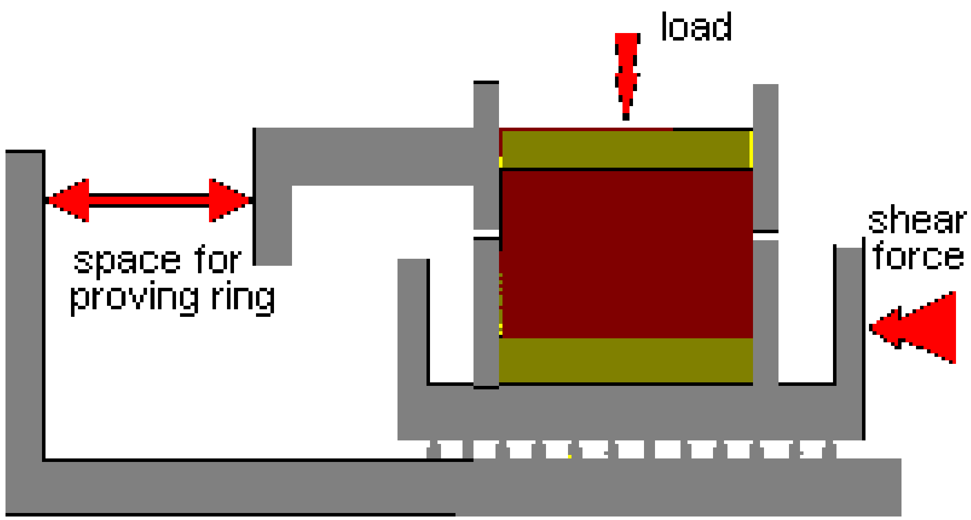
Relative density

$RD=(e_{max}- e) / (e_{max}- e_{min})$

- very loose ID= 0 to 0,15
- loose ID= 0,15 to 0,35
- medium ID= 0,35 to 0,65
- dense ID= 0,65 to 0,85
- very dense ID = 0,85 to 1,0

Laboratory tests

Shear box test



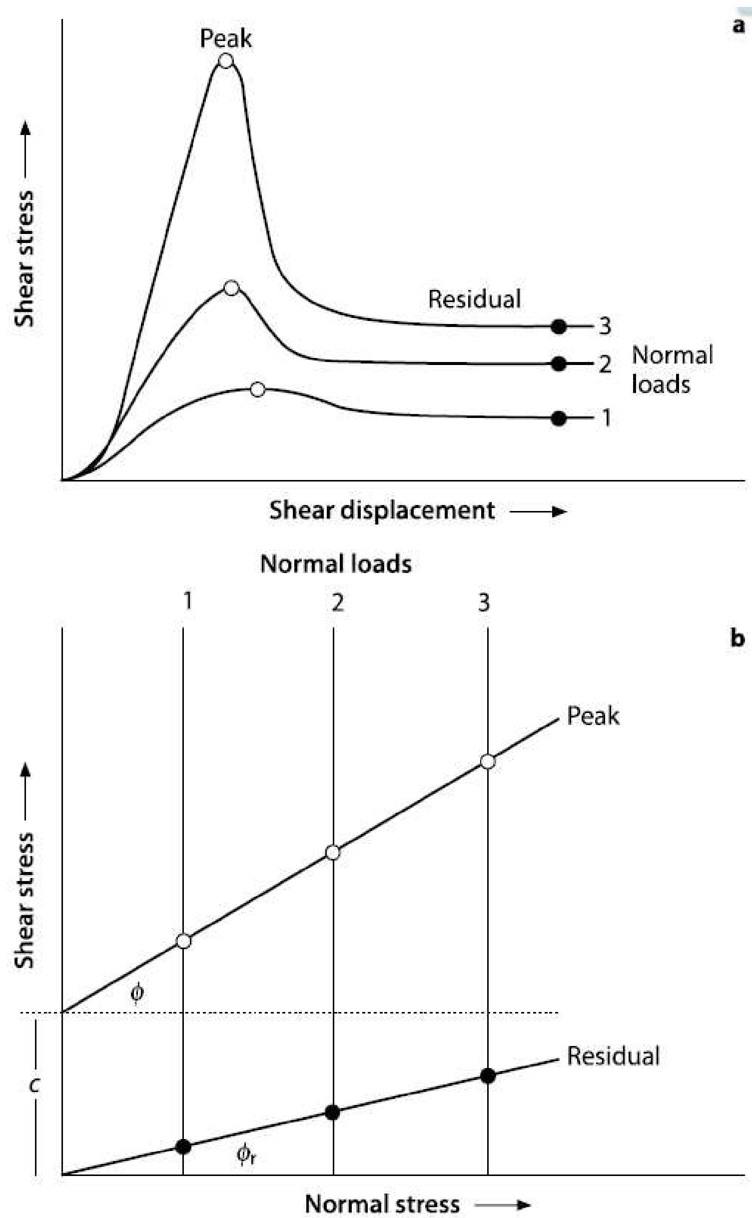
Direct measurement of shear forces – N, T

Recalculation to stresses (σ,τ)

jan.valenta@fsv.cvut.cz

Laboratory tests

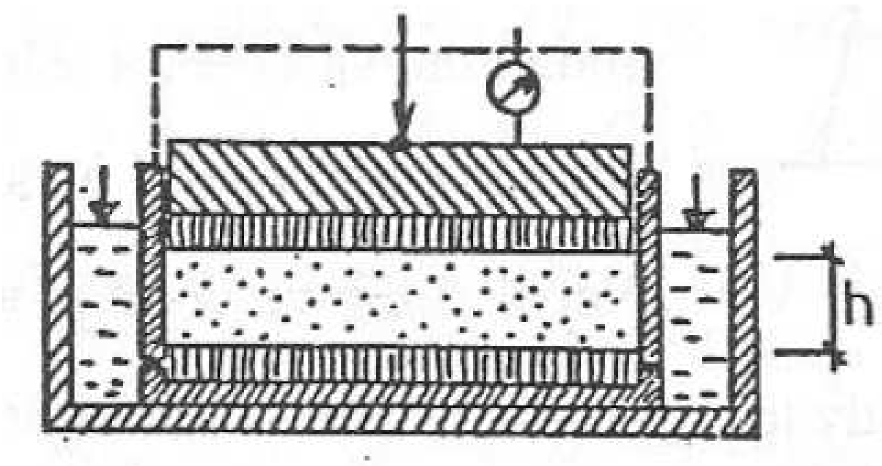
Shear box test



jan.valenta@fsv.cvut.cz

Laboratory tests

Oedometer

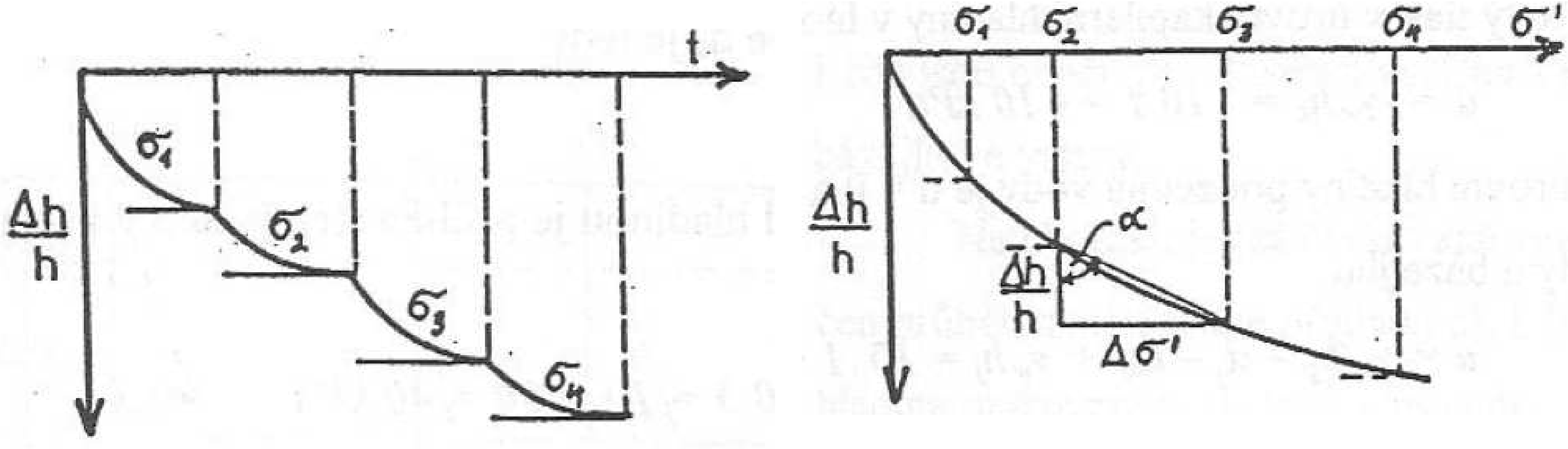


Direct measurement of forces – N, movement s (settlement)

Recalculation to stresses (σ)

Laboratory tests

Oedometer



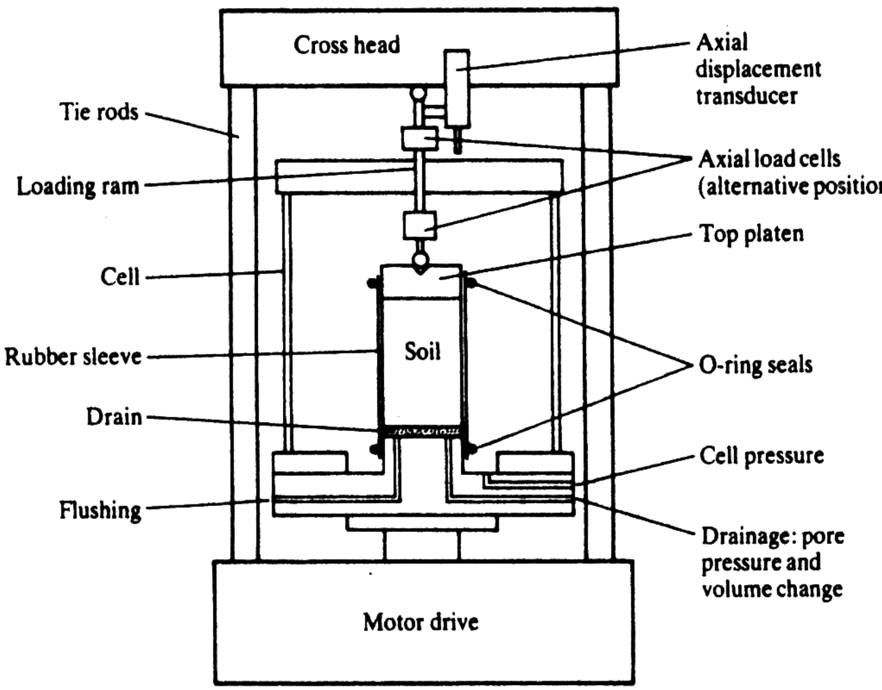
Modulus E_{oed}

jan.valenta@fsv.cvut.cz

Principal of effective stresses

Laboratory tests

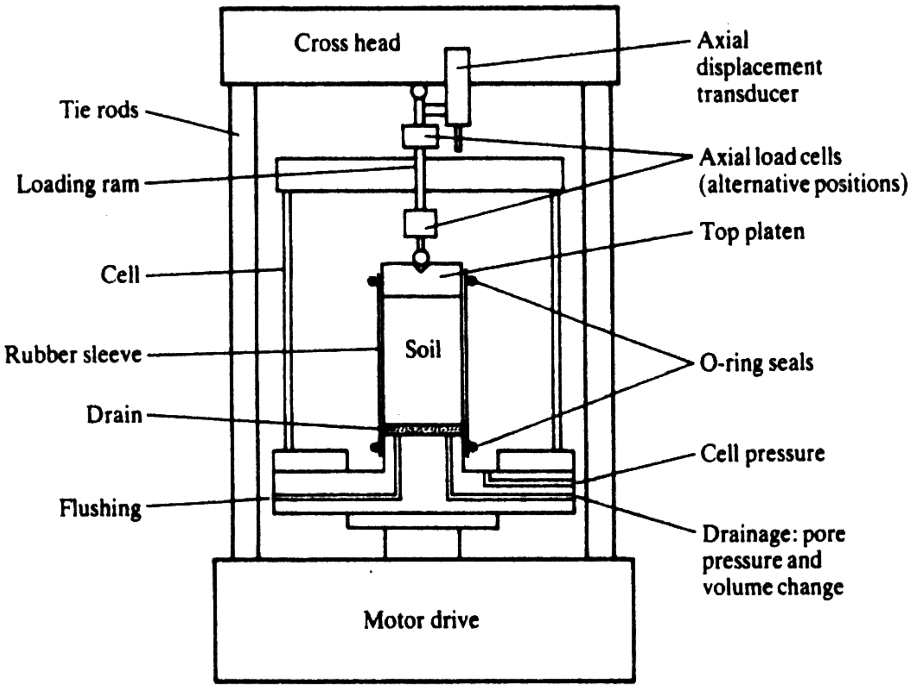
Triaxial aparatus – strength and stiffness



jan.valenta@fsv.cvut.cz

Laboratory tests

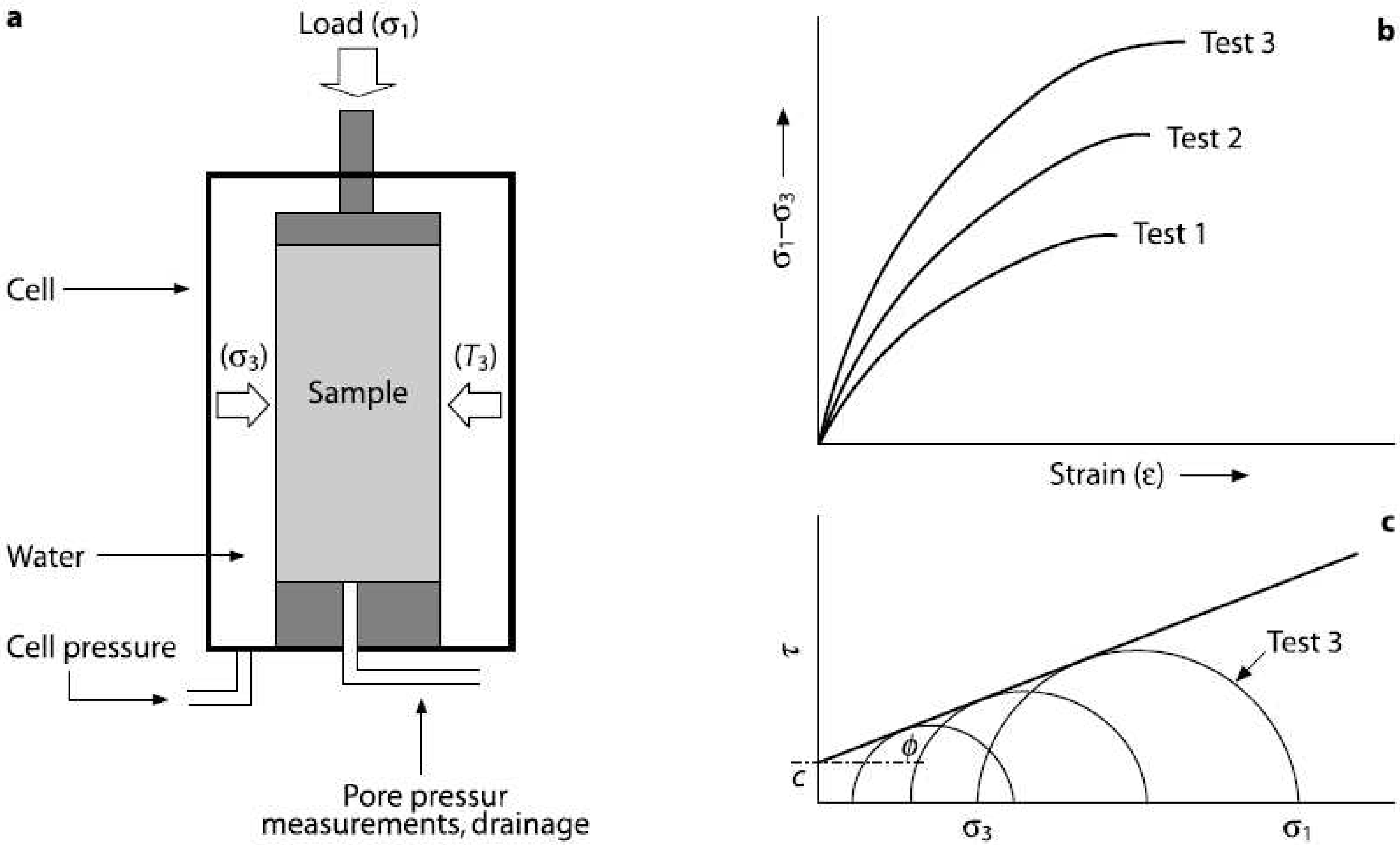
Triaxial aparatus – strength and stiffness



jan.valenta@fsv.cvut.cz

Laboratory tests

Triaxial aparatus – strength (total and effective)



Further reading and literatury

In the presentation is used picures from:

Price, D.G: Engineering Geology – principles and practice (2009)

Czech Geological Survey – Geological Maps in 5:000 scale

www.geofond.cz

jan.valenta@fsv.cvut.cz

Construction problems and engineering geology on construction site

jan.valenta@fsv.cvut.cz

Filling and compacting

Filling and compacting

What sort of material is suitable for compacting?

What influence well compacted material?


EVERGREEN


R-625
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NELSONS TRANSPORT

jan.valenta@fsv.cvut.cz