FRANÇOIS MATHIJSSEN

hydronamic

THE ENIGMA'S IN THE CURRENT PRACTICE OF GEOTECHNICAL ENGINEERING

2018 INGEOKRING AUTUMN SYMPOSIUM

A TRIBUTE TO PETER VERHOEF: ENGINEERING GEOLOGY AS AN EYE-OPENER FOR CIVIL ENGINEERING

Enigma decipher device

"Enigma" according to Cambridge dictionary:
Something that is mysterious and seems impossible to understand completely

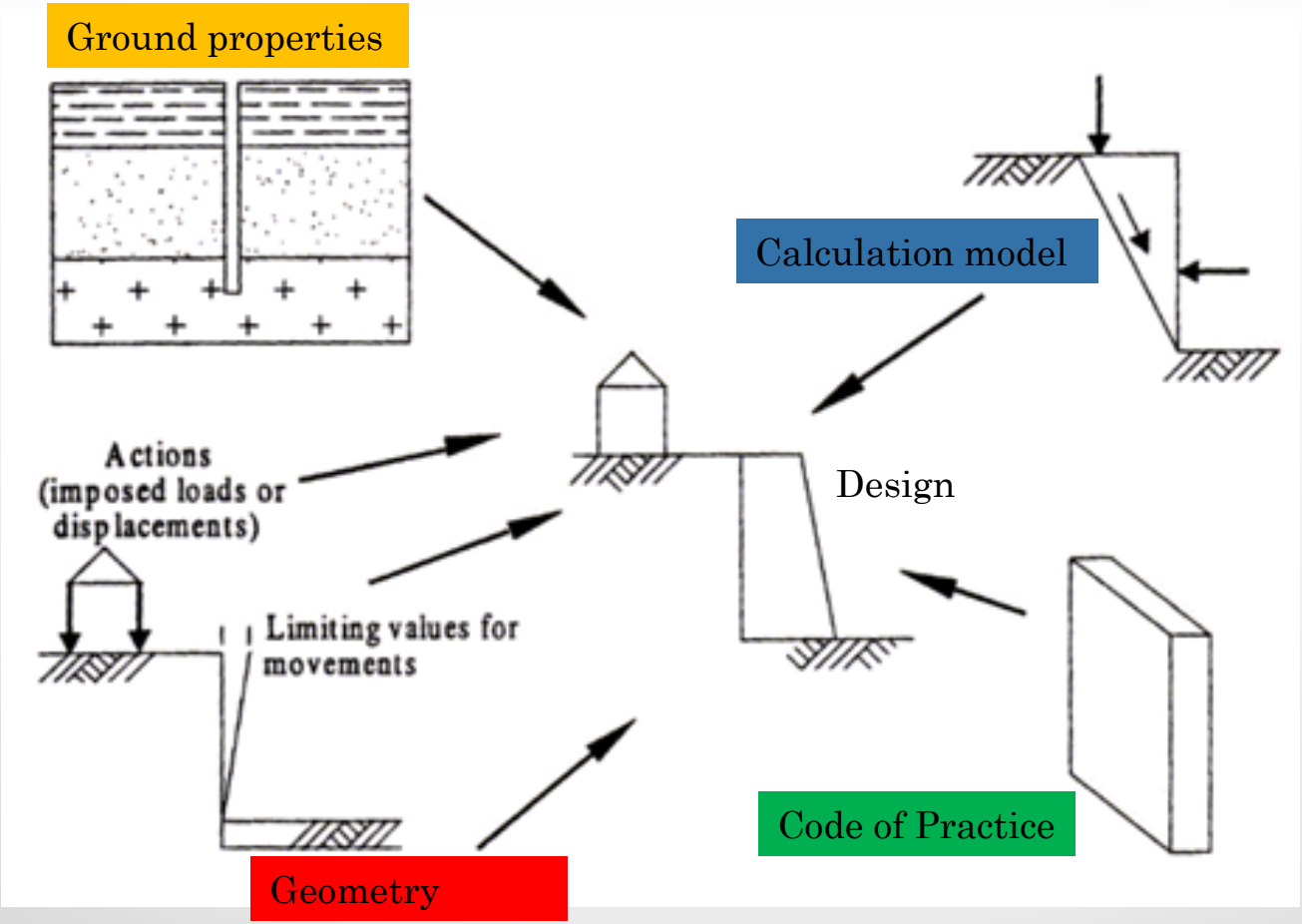
Friday 23rd November 2018

CURRENT PRACTICE
(Caricature of) Projects in GC-2

- Soil investigation performed prior to contract (sometimes Geotechnical Baseline Report).
- CPT based selection of characteristic parameters using Table 2b – NEN_9997-1.
- Selection of CONSTANT parameter-values.
- Limit State calculation models for conventional mechanism.
- Detailed illustration of situation in Finite Element Model for detailed analysis.
- Mechanism verification and partial factors according to codes and regulations

Does the above approach suffice for slope monitoring on these projects?

COMPONENTS OF (GEOTECHNICAL) DESIGN



Components of a geotechnical design (Fig. 2.2 – Orr & Farrell, 1999)

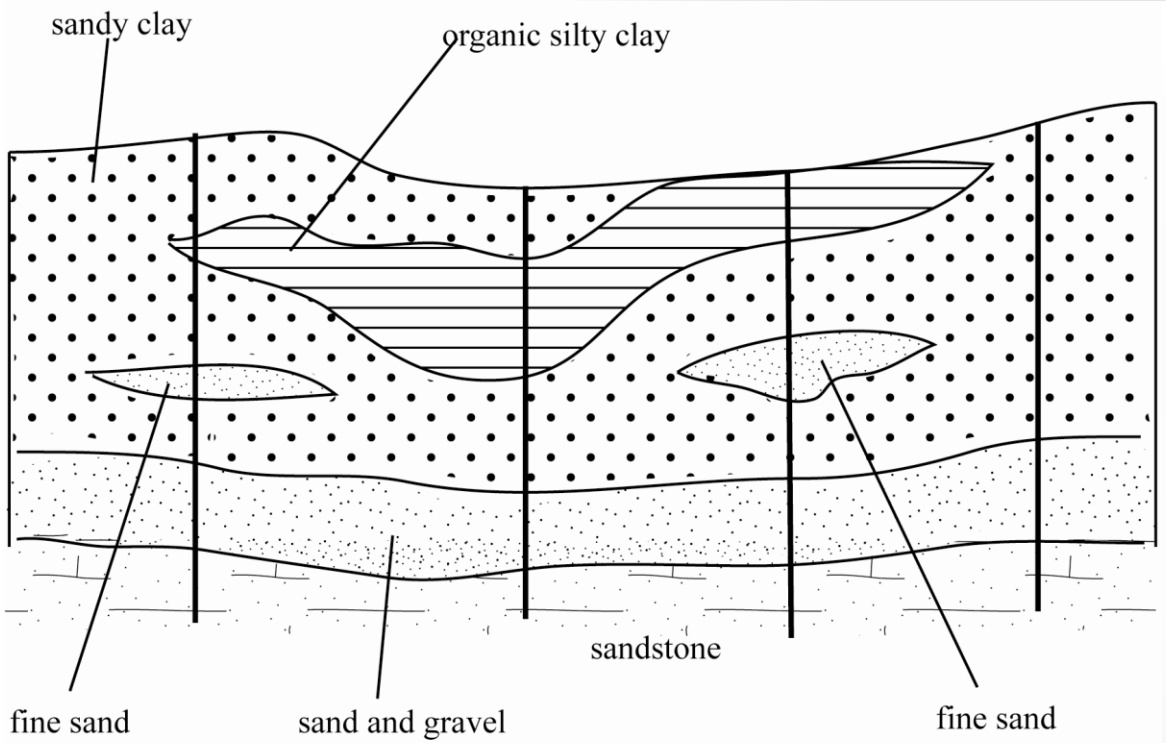
“A GOOD MODEL”

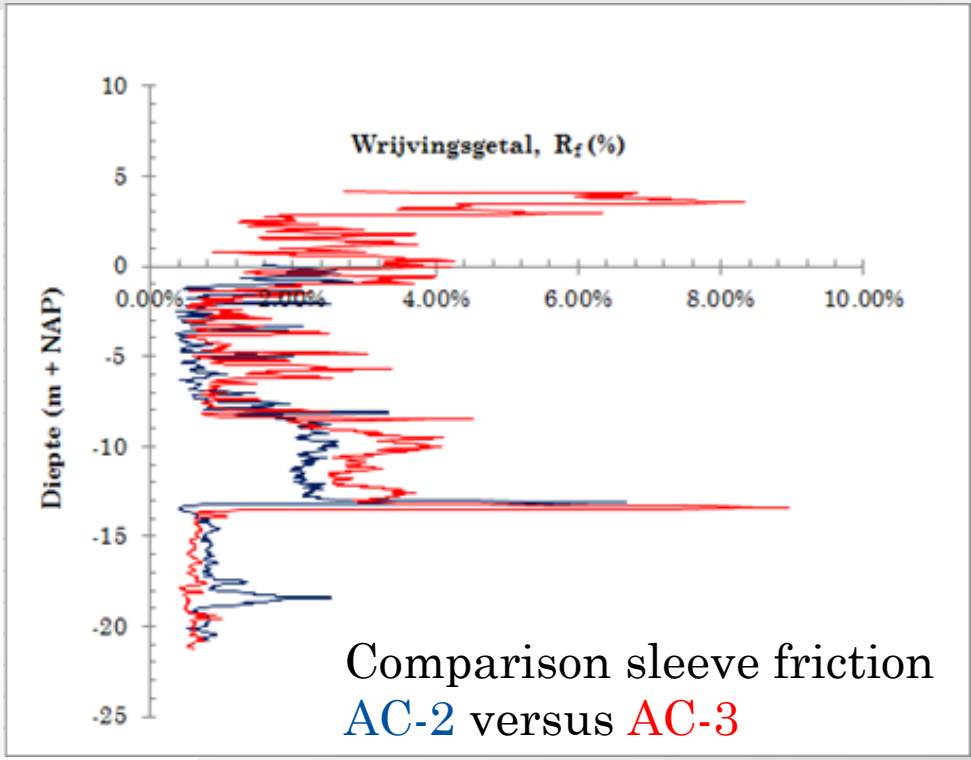
“Scientific understanding proceeds by way of constructing and analyzing “models” of the segments or aspects of reality under study. **The purpose of these models is not to give a mirror image of reality, not to include all its elements in their exact sizes and proportions**, but rather to single out and make available for intensive investigation those elements which are decisive. **We abstract from nonessentials, we blot out the unimportant to get an unobstructed view of the important**, we magnify in order to improve the range and accuracy of our observation. **A model is, and must be, unrealistic in the sense which the word is most commonly used**. Nevertheless, and in a sense paradoxically, **if it is a good model it provides the key to understanding reality**.”

Baran, P.A. & Sweezy, P.M. (1966) Monopoly Capital an Essay on the American Economic and Social Order .

GROUND PROPERTIES

CPT-based geological characterisation





Comparison sleeve friction
AC-2 versus AC-3

table 9.14 Average success rates (for both original and extended rules)

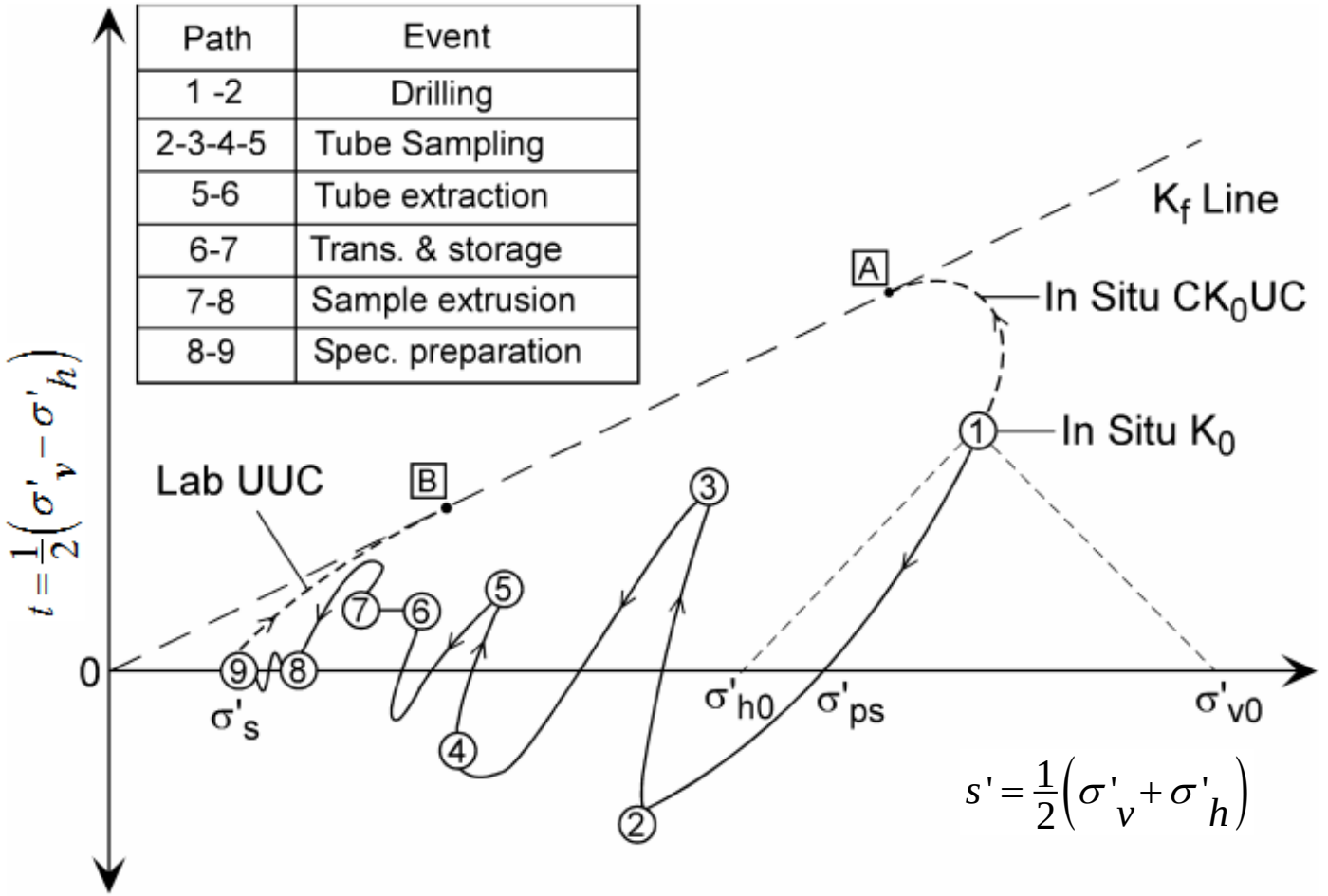
	Average decision rules-based success rate (%)	*Average main constituent-based success rate (%)*
Peat	26-33	24-37
Humose clay	45-59	64-70
Inorganic clay	27-58	46-67

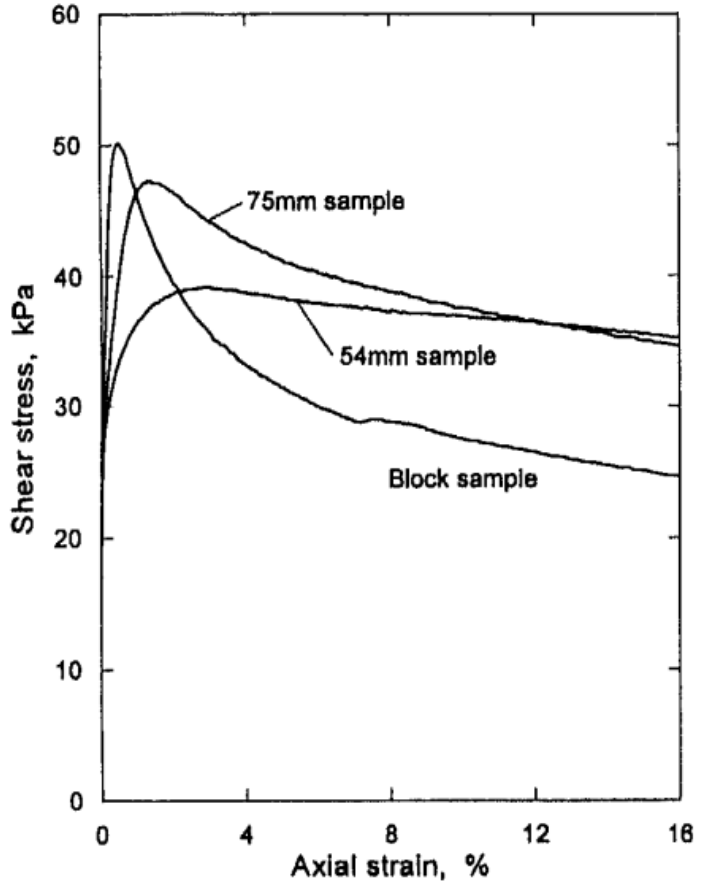
Mollé, J. (2005) The accuracy of the interpretation of CPT-based soil classification methods for soft soils. M.Sc. Thesis, Delft University of Technology, Delft.

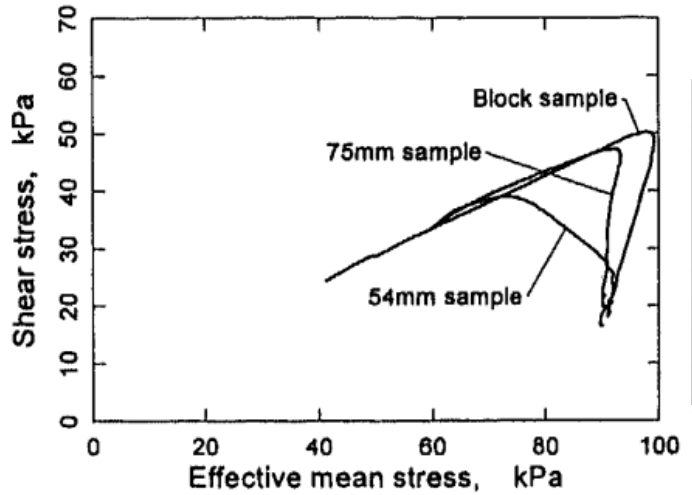
GROUND PROPERTIES

Sampling induced disturbance

Path	Event
1 -2	Drilling
2-3-4-5	Tube Sampling
5-6	Tube extraction
6-7	Trans. & storage
7-8	Sample extrusion
8-9	Spec. preparation





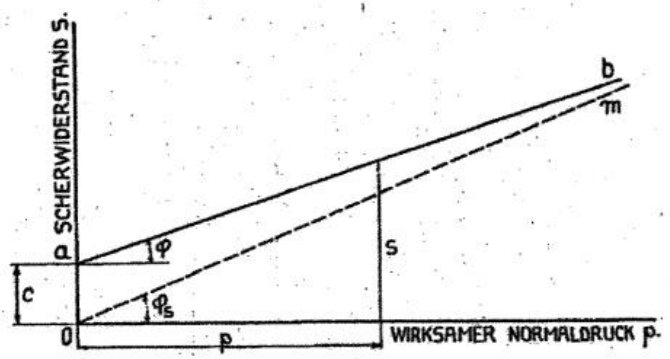


Lunne, T., Berre, T., & Strandvik, S. (1997) Sample disturbance in soft low plasticity Norwegian clay. Proc. Sym. On Recent Developments in Soil and Pavement Mechanics. Rio de Janeiro. Balkema: 81-92.

Ladd, C. C., & DeGroot, D. J. (2003) Arthur Casagrande Lecture: Recommended Practice for Soft Ground Site Characterization. 12th Panamerican Conference on Soil Mechanics and Geotechnical Engineering. Massachusetts. 60.

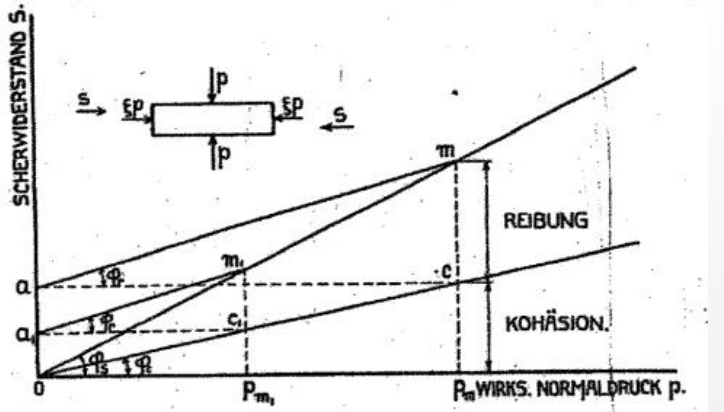
SOIL PARAMETERS

Coulomb's failure criterion (1/2)



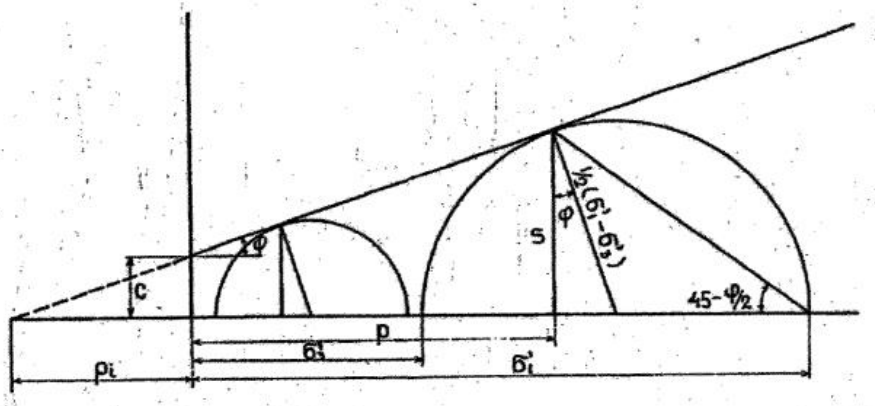
COULOMB'SCHE BRUCHBEDINGUNG.

ABB. 7.



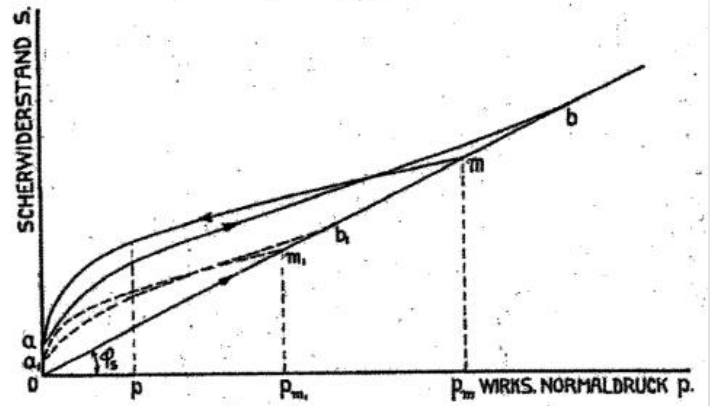
KREY-TIEDEMANN'SCHE BRUCHBEDINGUNG.

ABB. 9.



COULOMB'SCHE BRUCHBEDINGUNG IN MOHR'SCHER DARSTELLUNGSWEISE.

ABB. 10.



HYSTERESIS-SCHLEIFE DES SCHERWIDERSTANDES.

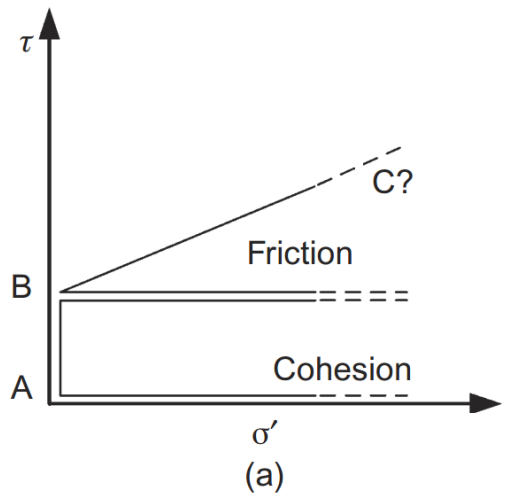
ABB. 11.

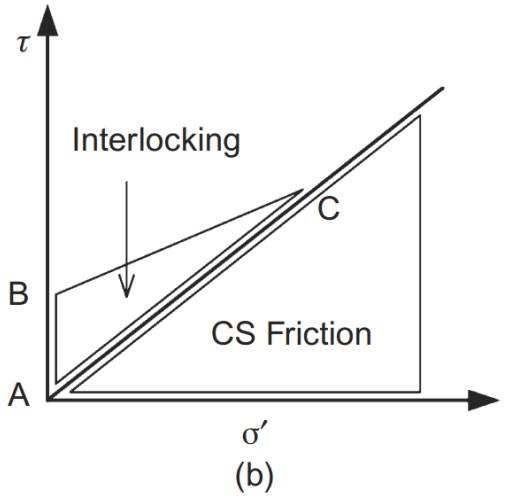
Hvorslev, M. J. (1937) Über die Festigkeitseigenschaften gestörter bindiger Böden. Kopenhavn, Denmark. Danmarks Naturvidenshabelige Samfund, 45.

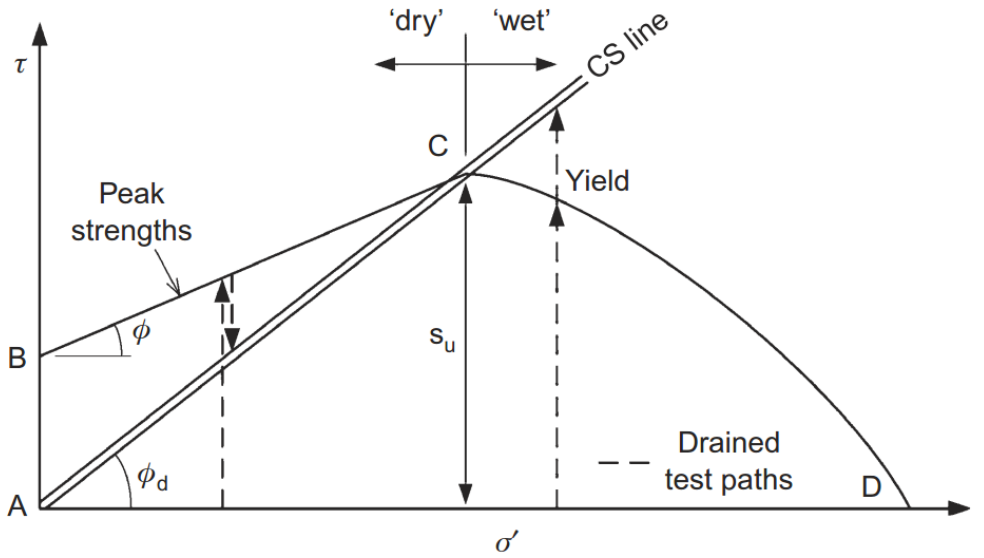
SOIL PARAMETERS

Coulomb's failure criterion (2/2)

- **Soil parameters and a model are uniquely interlinked.**
- **Soil parameters may be assumed constant, but in reality are density, stress, temperature and rate dependent.**





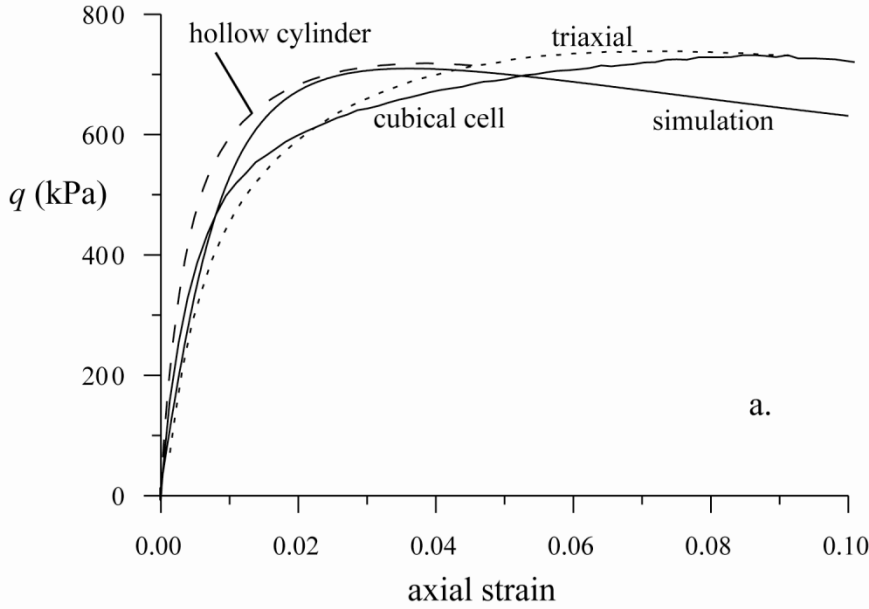


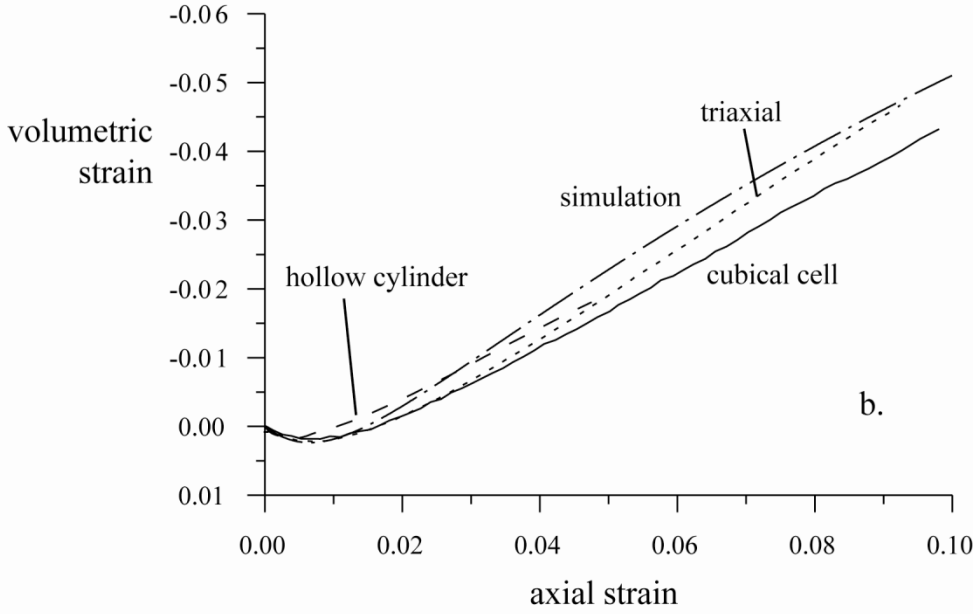
Schofield, A. N. (2006) Interlocking, and peak and design strengths. *Géotechnique*, **56**(5), 357–358.

SOIL PARAMETERS

Device dependent response

- Data from supposedly the same test in different apparatus are NOT the same
- What accuracy should be expected in comparing simulation and observation of the test?
- The various components of the geotechnical design determine the parameter value approximation.

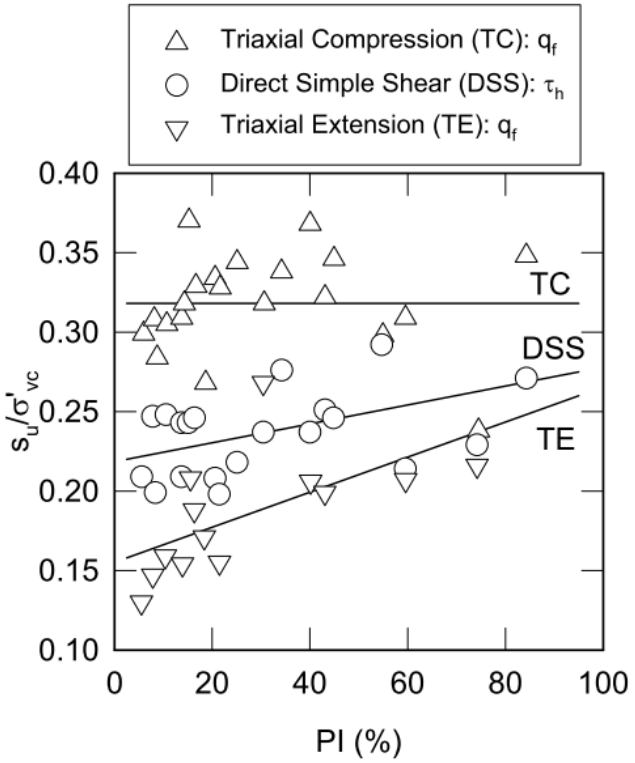


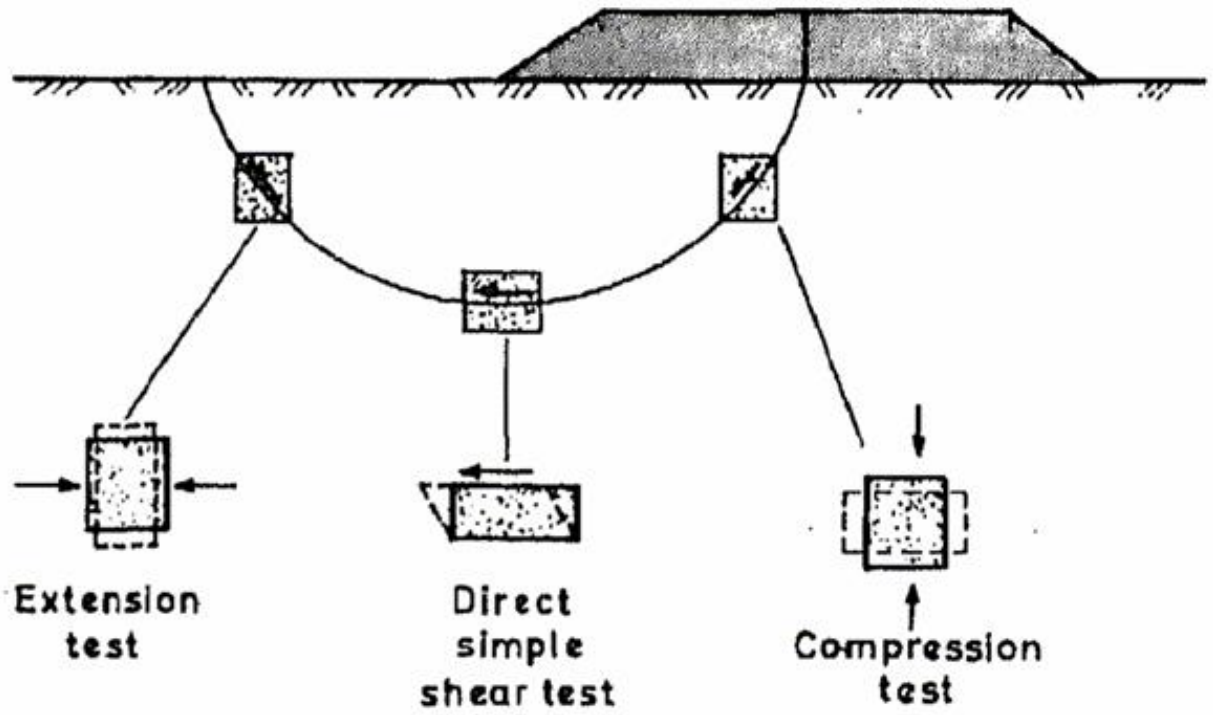


D. Muir Wood (2005)

SOIL PARAMETERS

Anisotropy in mobilised strength ratio



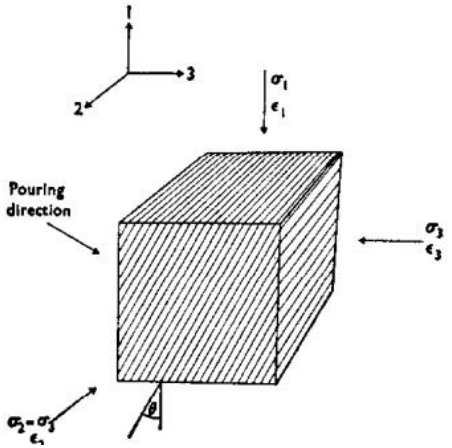


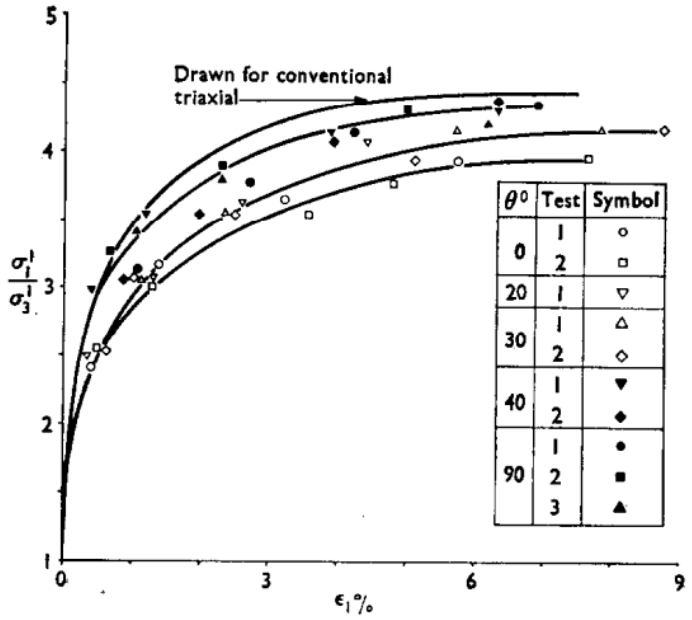
Bjerrum, L. (1973) Geotechnical problems involved in foundations of structures in the North Sea. *Géotechnique* **23**(3), 319–358.

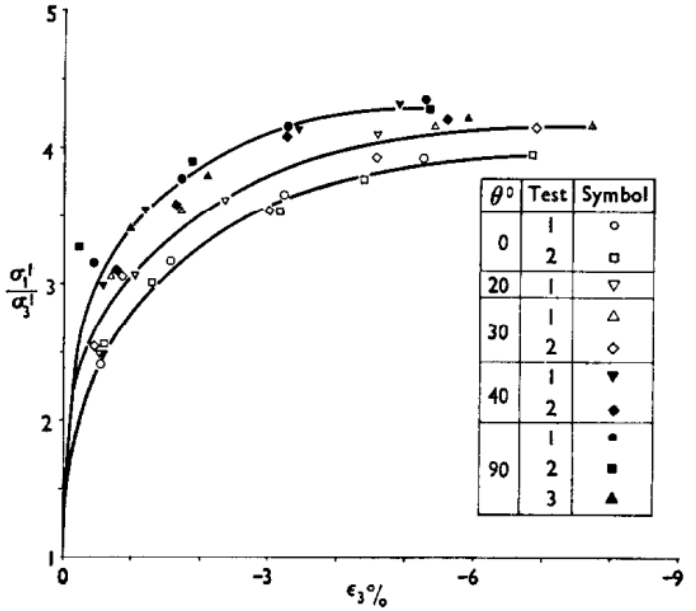
Ladd, C. C., & DeGroot, D. J. (2003) Arthur Casagrande Lecture: Recommended Practice for Soft Ground Site Characterization. 12th Panamerican Conference on Soil Mechanics and Geotechnical Engineering. Massachusetts. 60.

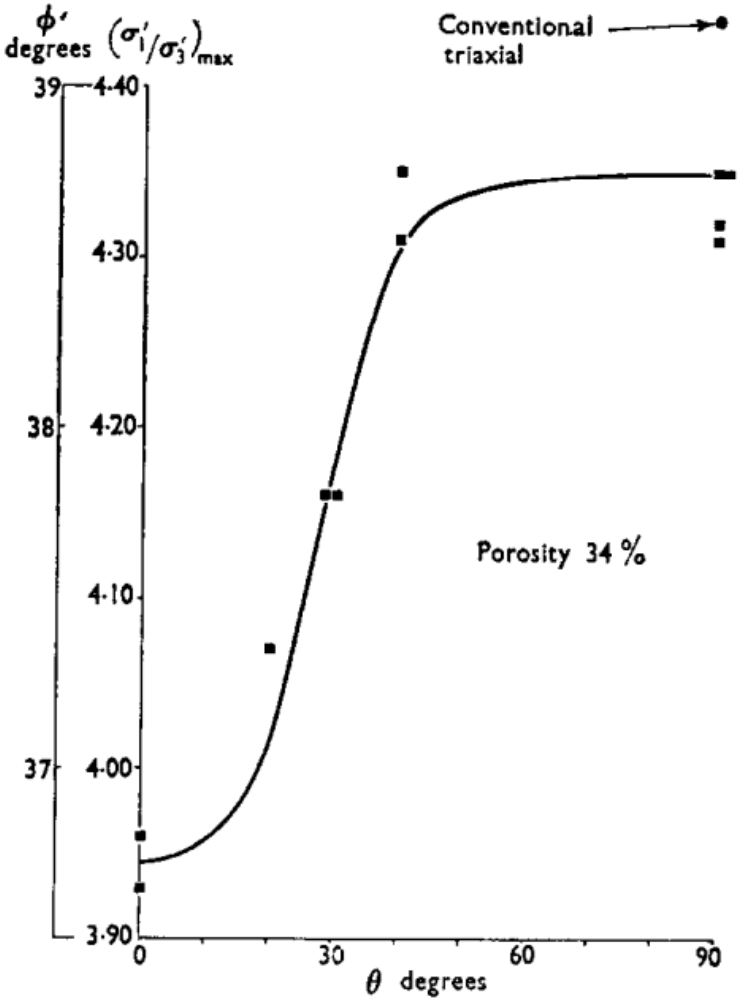
SOIL PARAMETERS

Inherent anisotropy in sand





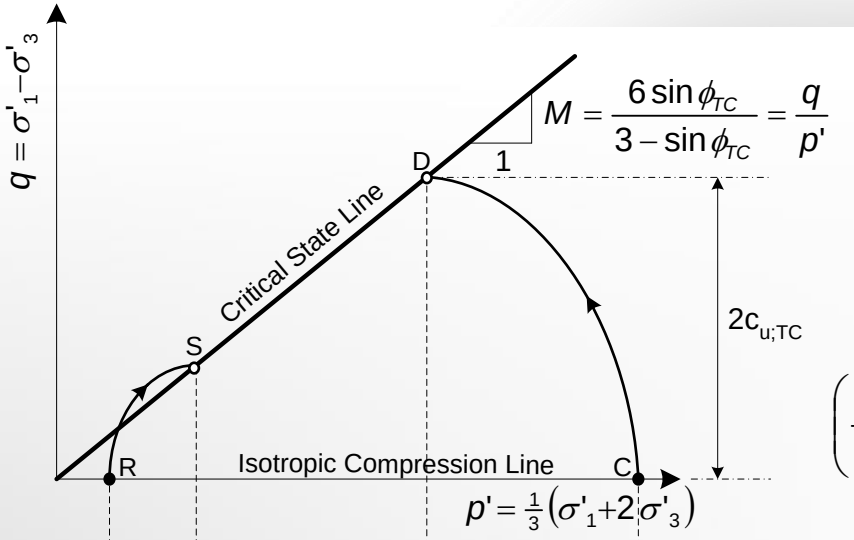




Arthur, J.R.F. & Menzies, B.K. (1972) Inherent anisotropy in a sand. *Géotechnique* **22**(1), 115–128.

SOIL PARAMETERS

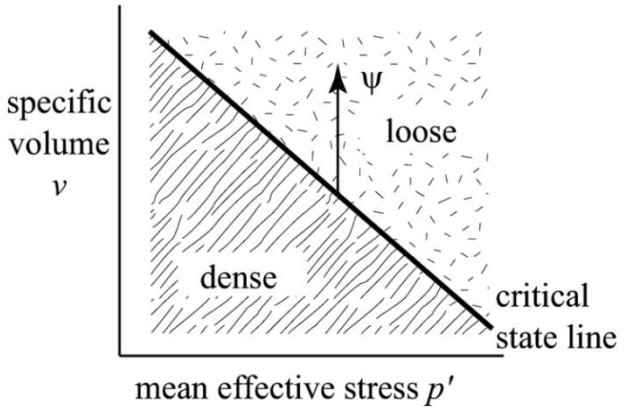
Idealised undrained behaviour from CIUTC-tests

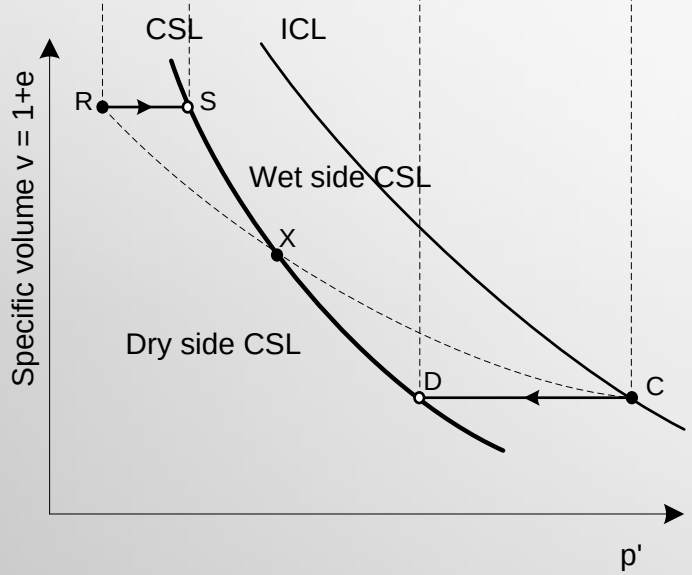


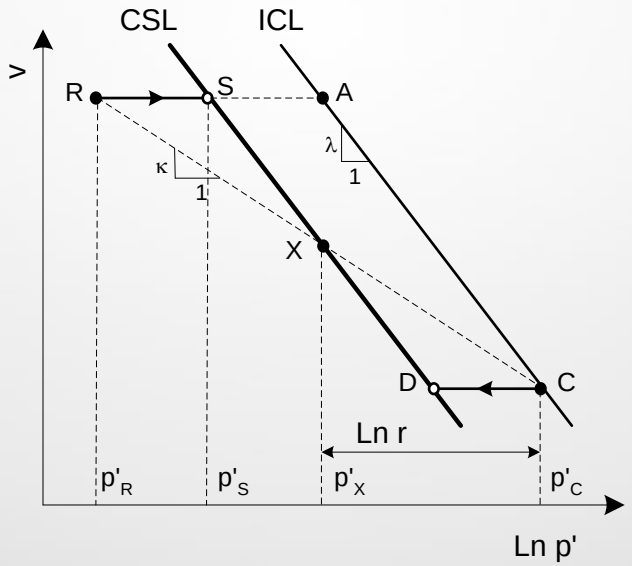
$$R = p'_C / p'_R = OCR \qquad r = p'_C / p'_X$$

$$\frac{c_{u;TC}}{p'_R} = \frac{M}{2}\left(\frac{R}{r}\right)^{\Lambda} \approx \frac{M}{2}\left(\frac{1}{2}\right)^{\frac{\lambda-\kappa}{\lambda}}$$

$$\left(\frac{c_{u;TC}}{\sigma'_{v0}}\right) = \left(\frac{c_{u;TC}}{\sigma'_{v0}}\right)_{NC} R^{\Lambda} = \left(\frac{c_{u;TC}}{\sigma'_{v0}}\right)_{NC} OCR^{\Lambda}$$







$$\psi = v - v_\lambda + \lambda \ln p'$$

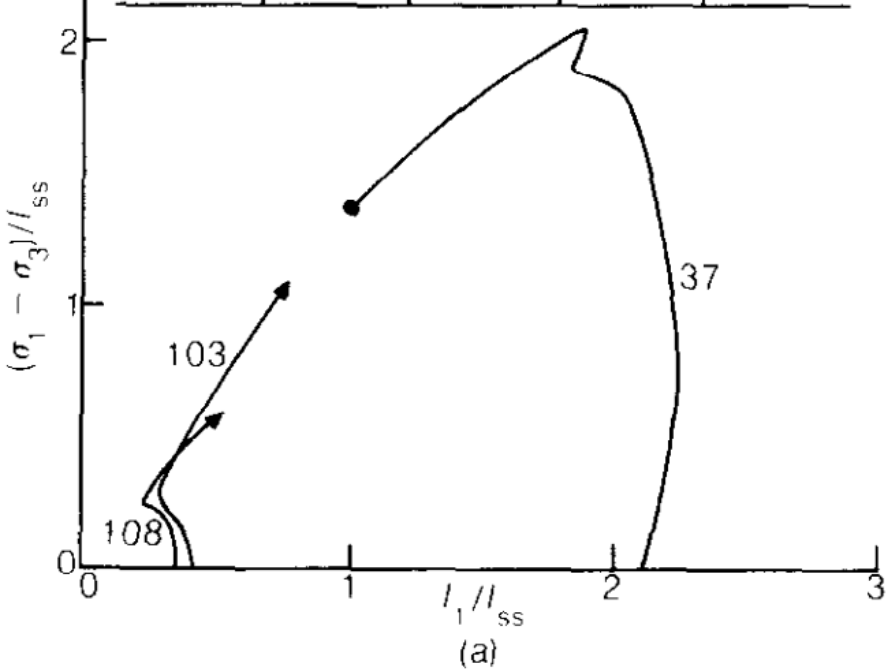
$$\psi = e_c - e_{CSL}$$

After: Wroth, C. P. (1984) The interpretation of in situ soil tests. *Géotechnique* **34**(4), 449–489.
Muir Wood, D. (2007) The magic of sands. The 20th Bjerrum lecture presented in Oslo, 25th November 2005. *Can. Geotech. J.* **44**(11), 1329-1350.

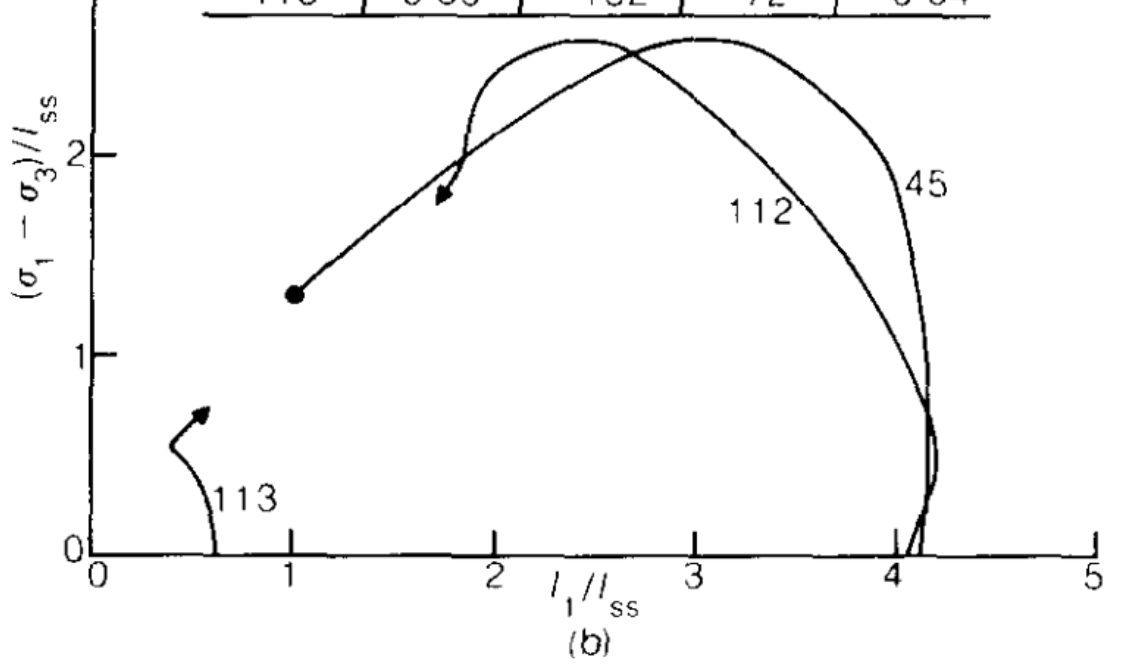
SOIL PARAMETERS

State parameter as indicator of volumetric behaviour on loading

Test	e	I_{1c}: kPa	D_r: %	ψ
37	0·71	350	33	+0·03
103	0·71	50	33	−0·03
108	0·65	300	50	−0·033



Test	e	I_{1c}: kPa	D_r: %	ψ
45	0·67	350	56	0·11
112	0·58	1100	75	0·11
113	0·59	152	72	−0·04

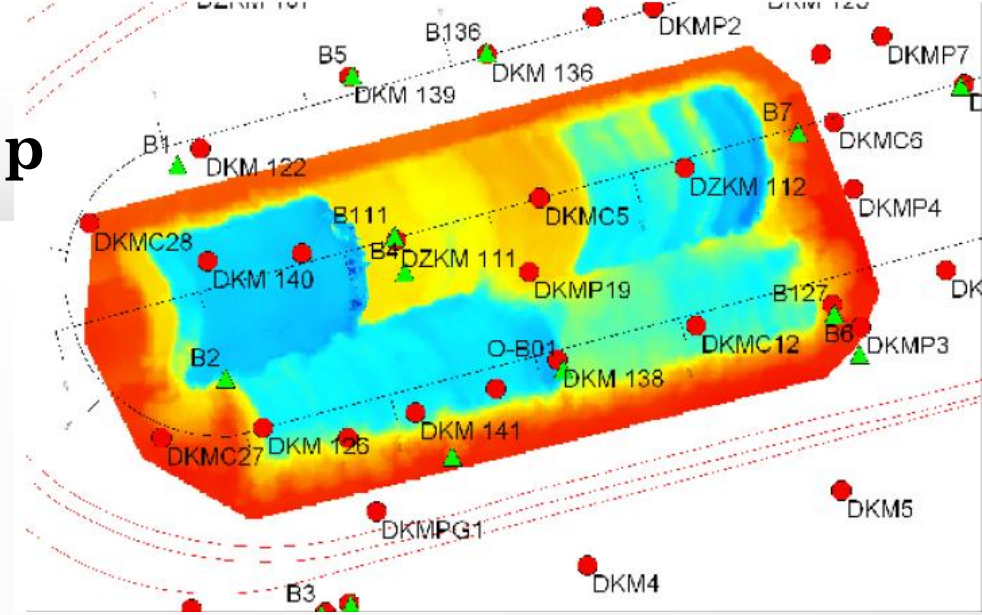


Been, K., & Jefferies, M. G. (1985) A state parameter for sands. *Géotechnique* **35**(2), 99–112.

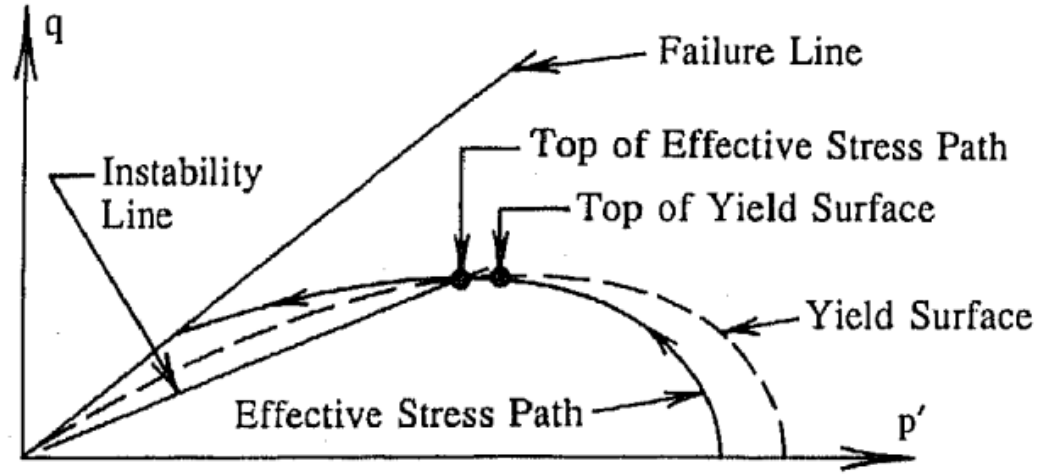
LIQUEFACTION MODEL

Dredge Sludge depot Hollandsch Diep

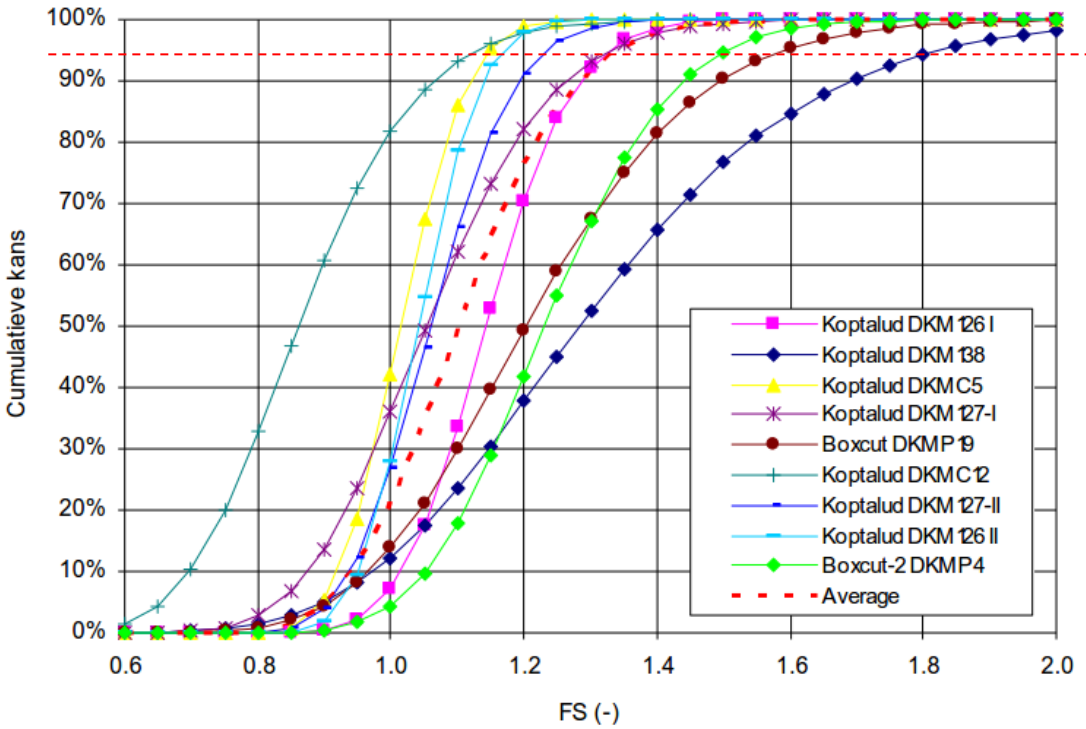
- Modified state parameter model
- 1st order 2nd moment probabilistic approach
- Validation with test failures including effect equipment and work method



P_f = 95%



Location of instability line for loose sand (Fig. 7 – Lade, 1992)

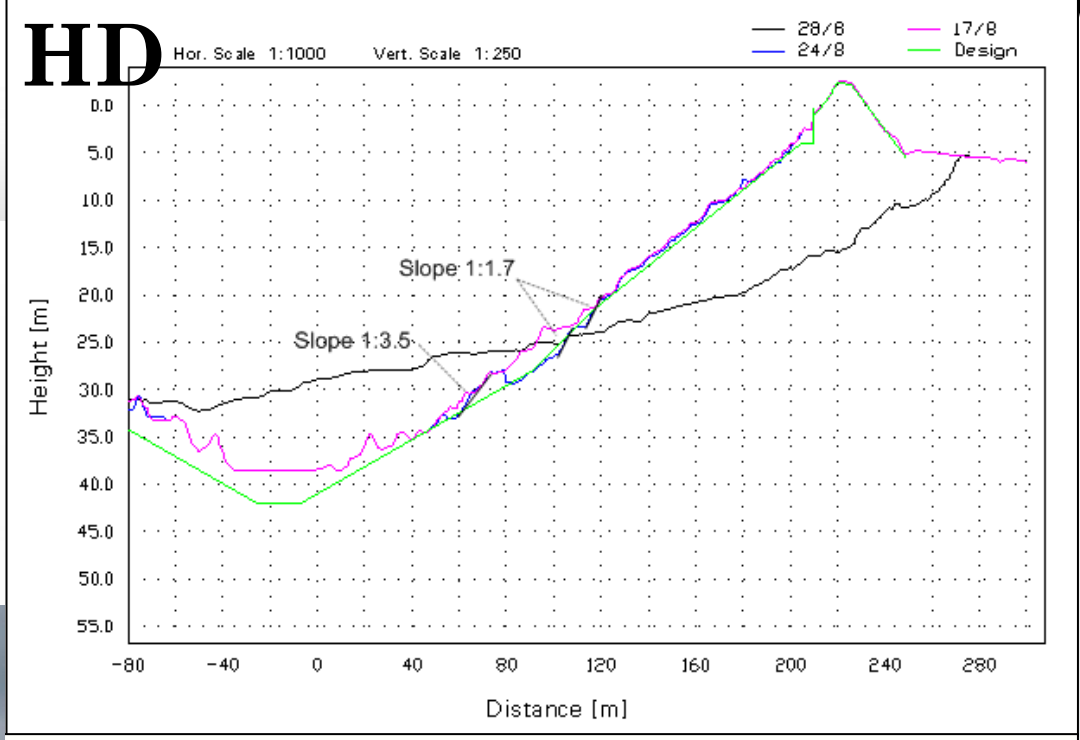


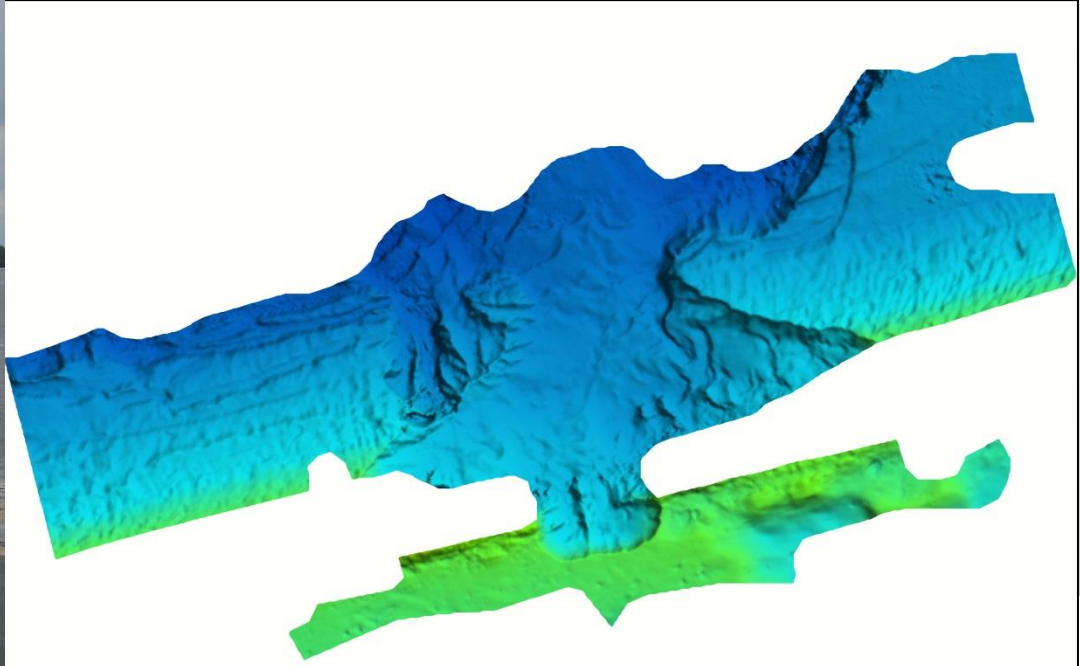
LIQUEFACTION MODEL HD

Large (unplanned) instability

Instability of ~ 350,0000 m³ occurred during profiling depot slopes

Paleochannel with laminated Holocene clay/ sand sediments had liquefied after longer period of time

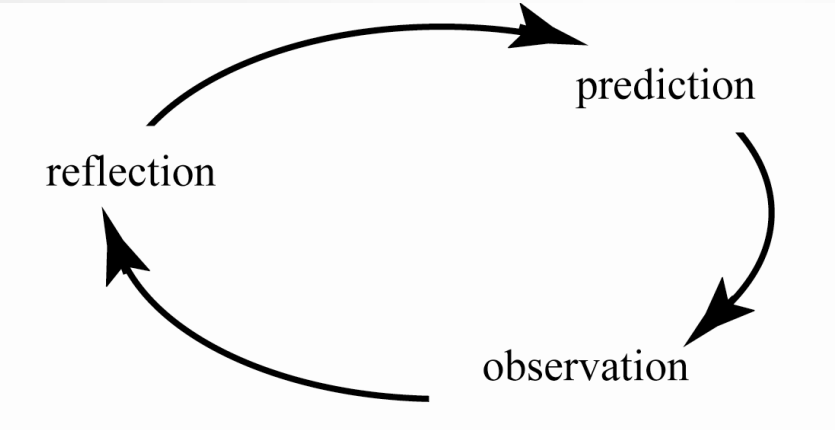




GEOTECHNICAL MODELLING *REALITY*

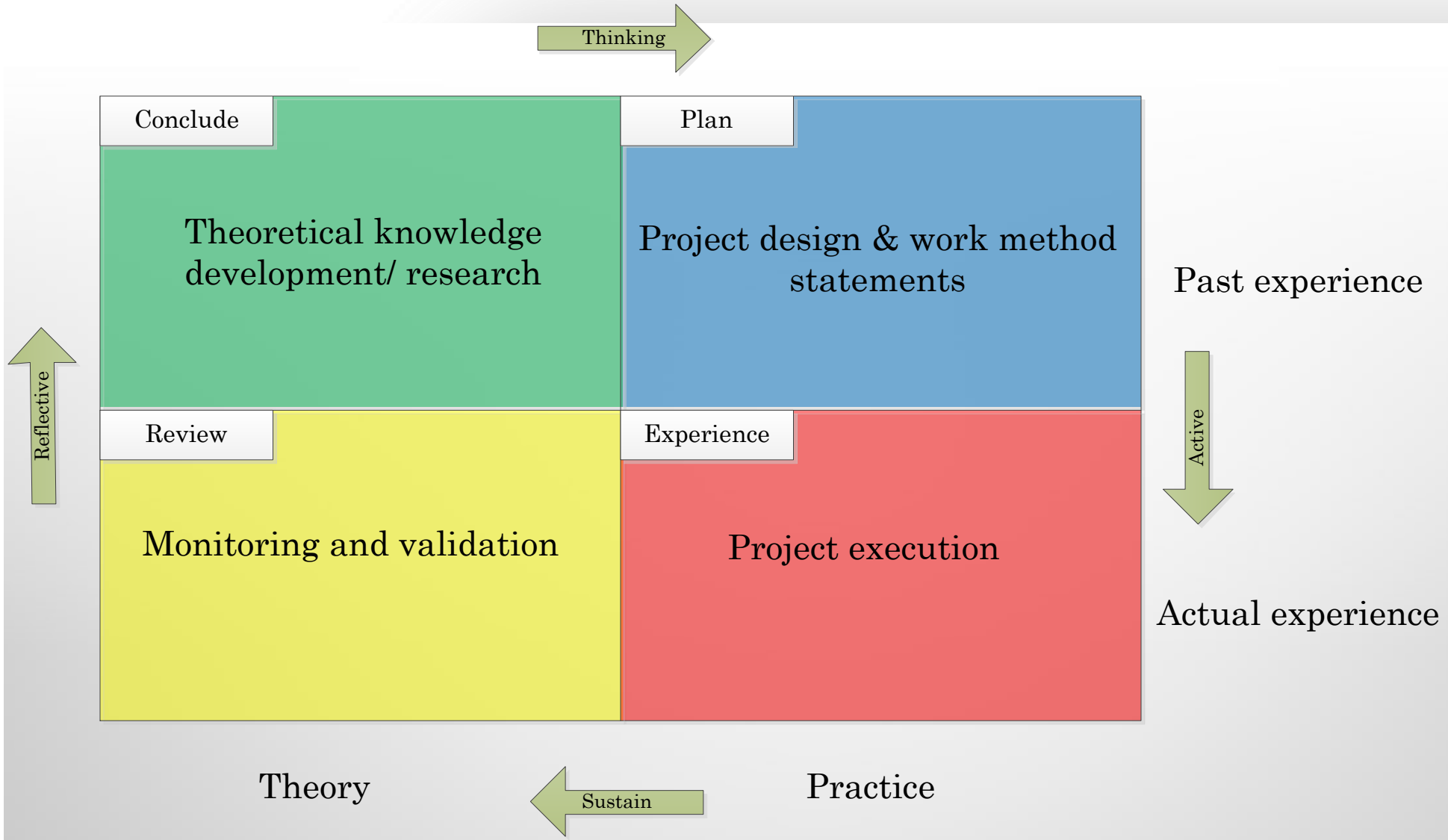
The way forward

- Always start with prediction of what you expect to happen
- If observation is unexpected, then reflection is required to improve predictions
- A good model-test is one which surprises
  - route to advance of scientific understanding
  - design model-tests with this in mind
- Scientific conjectures cannot be proved – only refuted
- Absence of evidence does not mean evidence of absence
- Rival hypotheses can be sifted using carefully chosen testing



Muir Wood, D. (1990) Soil behaviour and Critical State Soil Mechanics, Cambridge, Cambridge University Press.
Muir Wood, D. (2004) Geotechnical modelling, Oxfordshire, Spon Press.

LEARNING CYCLE



After: Kolb, A. Y., & Kolb, D.A. (2007) Experiential Learning Theory: A Dynamic, Holistic Approach to Management Learning, Education and Development. IN Armstrong, S.J., & Fukami, C. (Ed.) Handbook of management Learning, Education and Development.

CHARACTER INGREDIENTS

- Zest – Enthusiasm, eagerness, energy, and interest
- Grit – Courage and determination despite difficulty
- Self-Control – The ability to control your emotions and actions
- Social Intelligence – The capacity to know oneself and to know others
- Gratitude – The feeling or quality of being grateful
- Optimism – Believe that putting in effort pays off
- Curiosity – Eagerness to explore new things

Paul Tough (2011) What if the secret to success is Failure?, The New York Times Magazine, 14th September 2011

CONCLUSIONS

In general:

- Geological characterisation requires a thorough classification and state and variability assessment.
- Soil parameters are uniquely interrelated with a model.
- Experimental testing and modelling should capture the essential(s).
- The reliability of the prediction(s) is directly proportional to the degree of understanding and capturing of the essential(s).
- Reliability of the integral system is depending on the interrelationship between the various components and the variation thereof.

On present engineering practice:

- Pre-tender soil investigation and GBR limits risk assessment and modelling.
- CPT based selection of characteristic parameters in Table 2b – NEN_9997-1 (2017) does not improve understanding.
- Parameters are in general rheological models of the order: $R(e,\sigma`,\dot{e},\dot{\sigma}`)$
- Parameters are therefore NOT constant but state and loading dependent

Enigma code (an imperfect model concept):

- Integral balance in geotechnical modelling
- Continuous development with learning cycle
- Character ingredients (Zest; Grit; Self-Control; Social intelligence; Gratitude; Optimism; Curiosity)

QUESTIONS?

Measured excess pore water pressure in sand after installation piezometers on crest of dam dredge sludge depot Hollandsch Diep after closure