Other soils and unusual behaviour

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Examples of :

- CPTU profiles other soil types
- Unusual behaviour

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Examples of CPTU results in other soil types

- **Peat**
- **Silt/ clayey sands**
- **Mine tailings**
- **Underconsolidated clay**
- **Chalk**
- **Other**

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Engineering properties in peat from CPTU ?

- Landva(1986) concluded that due to the very fibrous nature of peat, and the frequent obstructions like stumps and roots, small scale in situ tests like CPT are normally of little engineering use for design of road embankments

  (experience from East Canada mainly)

- CPTU good for identification of peat layers

- In organic soils of non-fibrous nature, CPT and possibly other in situ tests can be useful.

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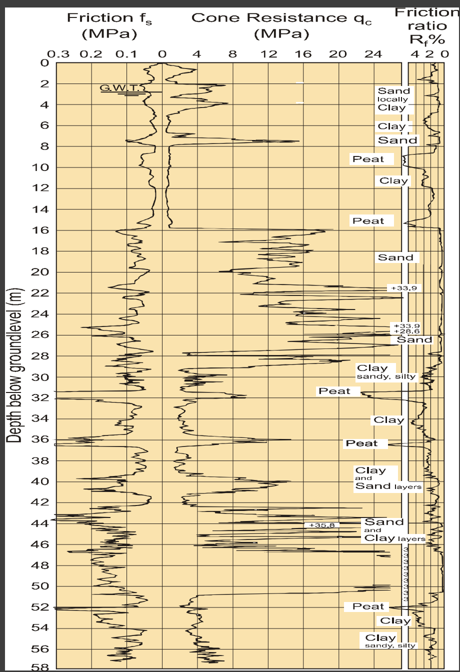
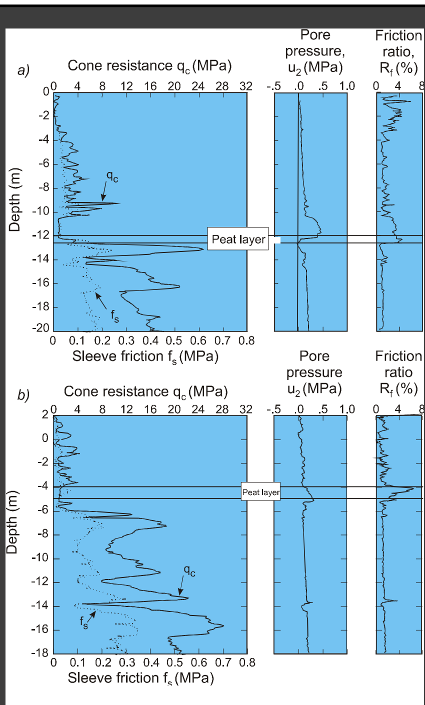


Example of CPT profile from Holland with peat layers

Vos (1982)

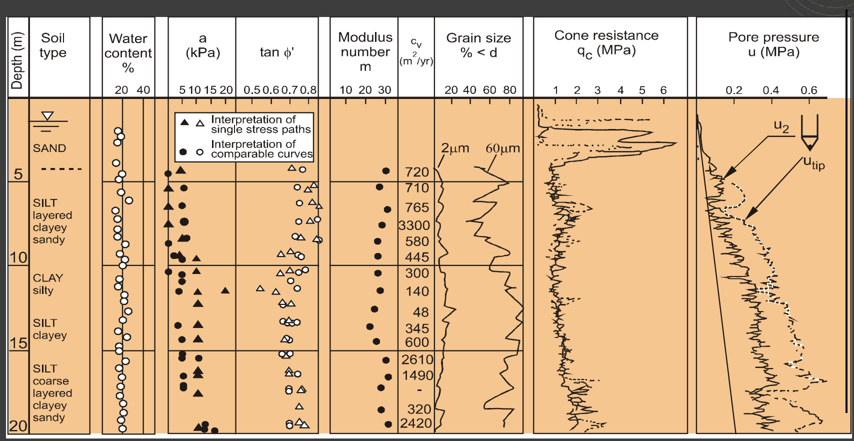


Example of CPTU profiles from coast of Germany with peat layers

Intermediate soils - clayey sands to silt

- Interpretation methods valid for sands or clays may not be applicable for silts since penetration can be partially drained
- According to Bugno and McNeilan (1984) undrained response for standard CPT will occur if permeability of soil is $< 10^{-7}$ to 10^{-6} cm/sec. Soils with permeability between 10^{-6} and 10^{-3} cm/sec will probably behave as partially drained
- **In silts it may be advantageous to do tests at non-standard rates**

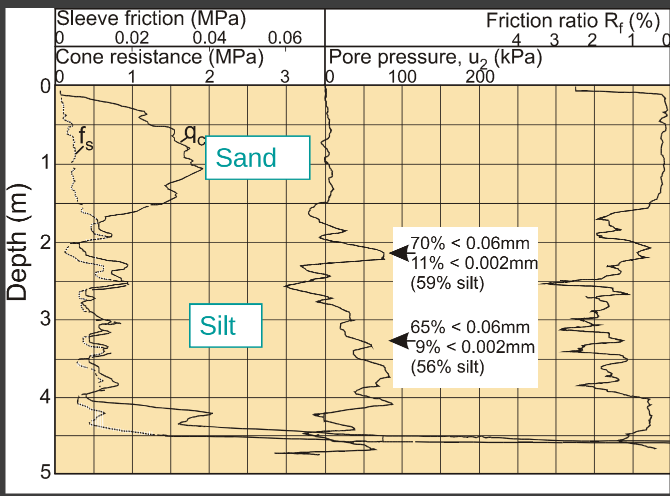
Soil profile and CPTU results in Stjoerdal silt, Norway



a = attraction = c/tanϕ'

After Senneset et al.(1988)

CPTU profile in Keilisnes silt, Iceland



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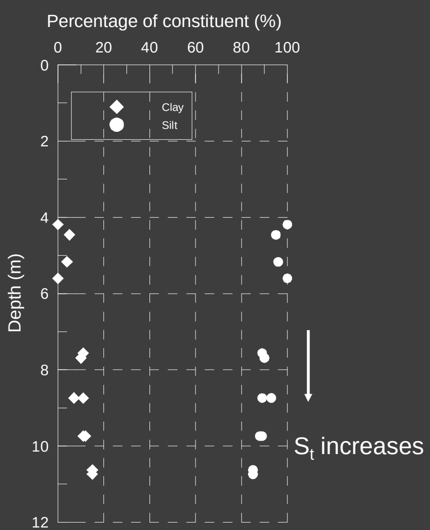
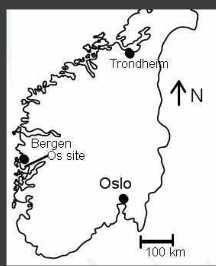
Os (West Norway) silt





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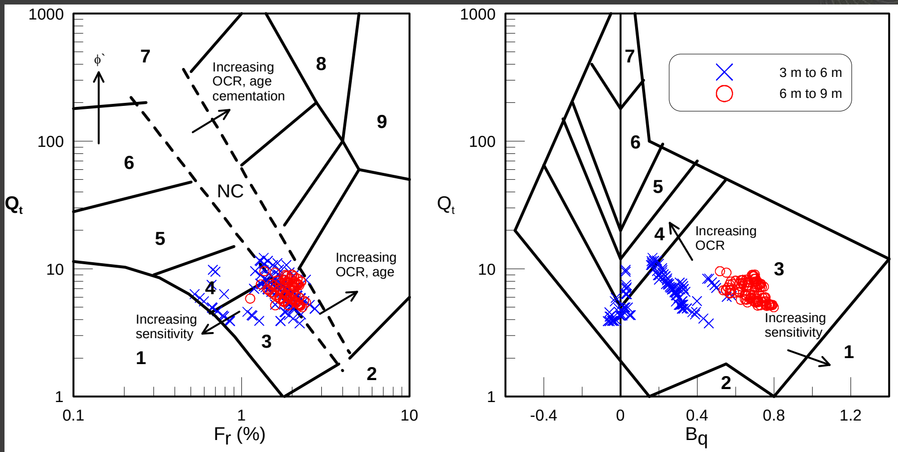
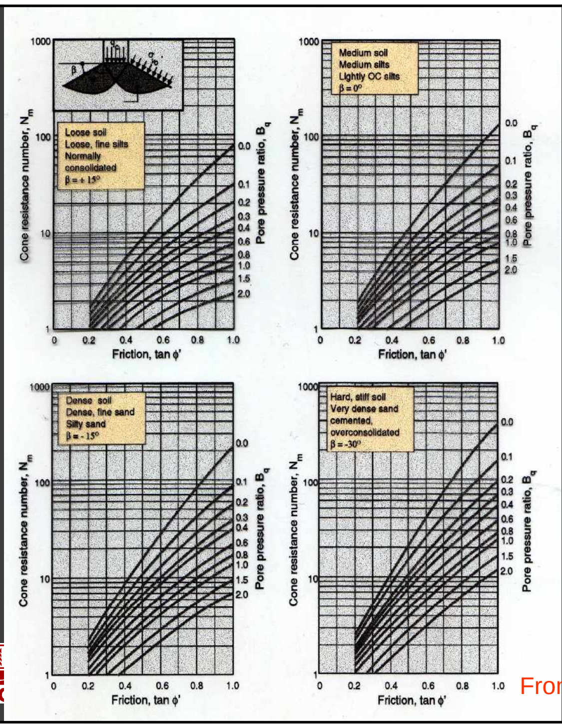
Robertson (1990) chart for Os (West Norway) silt (Long 2008)



Zones / Soil behaviour type (From Robertson, 1990)

1. Sensitive fine grained
2. Organic soils-peats
3. Clays - clay to silty clay
4. Silt mixtures clayey silt to silty clay
5. Sand mixtures silty sand to sandy silt
6. Sands clean sands to silty sandsilt to clayey silt
7. Gravelly sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained



Interpretation in terms of effective stresses

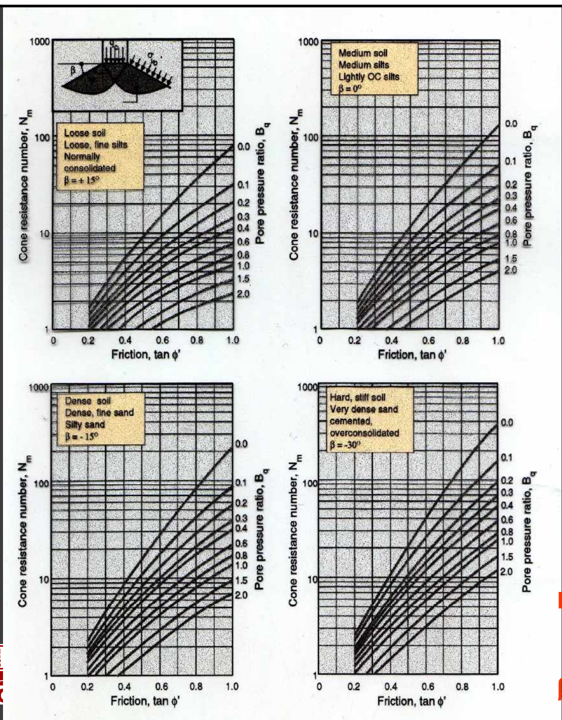
$q_t - \sigma_{vo} = N_m(\sigma_{vo}' + a)$

N_m = cone resistance number

a = attraction = c/tanφ'

β = degree of plastification

From Janbu and Senneset (1989)



Interpretation in terms of effective stresses

$q_t - \sigma_{vo} = N_m(\sigma_{vo}' + a)$

N_m = cone resistance numbe

a = attraction = c/tanφ'

β = degree of plastification

For Norwegian silts:

a = 5 - 10 kPa

β = 15 - 20 degrees

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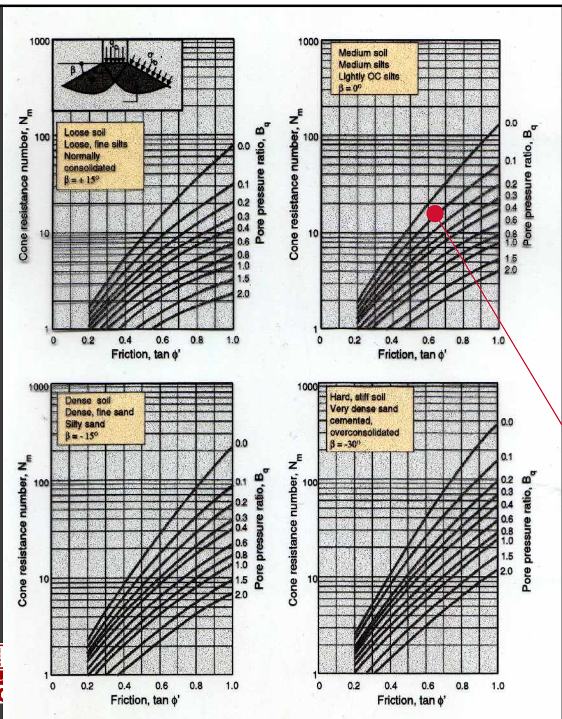

Interpretation in terms of effective stresses

For Stjørdal silt :

10 m depth : q_t = 1.2 MPa

σ_{vo}' = 170 kPa

N_m = 15

tanφ' = 0.65

φ' = 35 degrees

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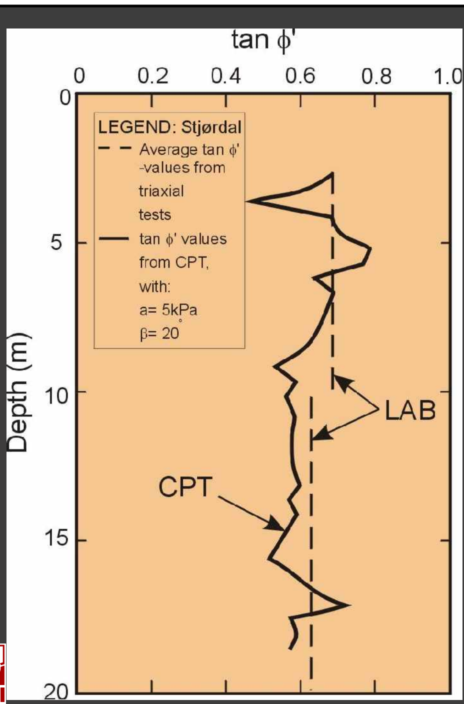
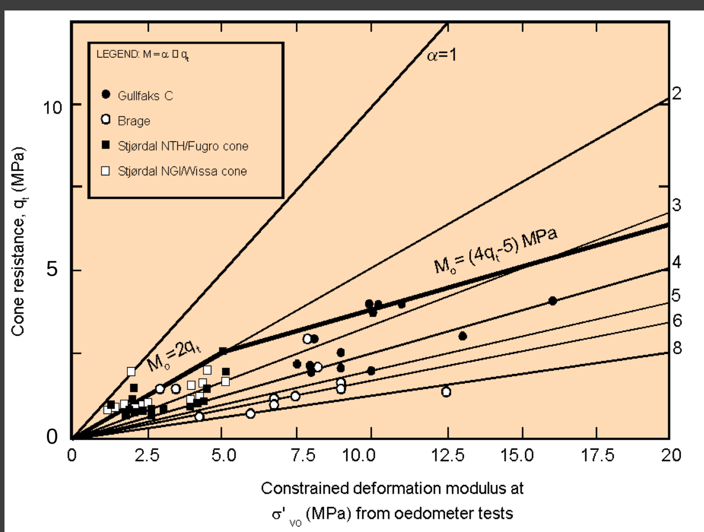


Stjoerdal silt

Effective stress friction angle from CPTU and from laboratory tests

Constrained moduldus,M_o, vs cone resistance for silty soils



From Senneset et al.(1988)

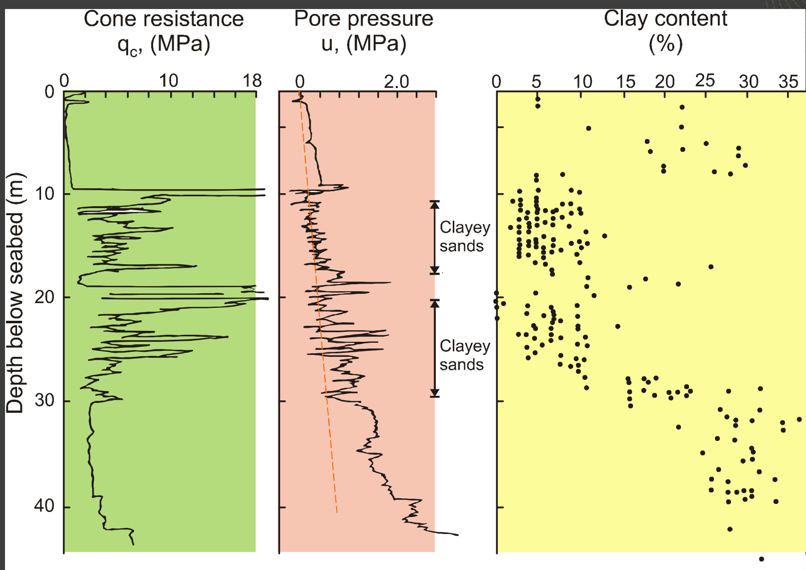
CPTU in silts

Rough conservative estimates of constrained modulus:

for $q_t < 2.5$ MPa $M_o = 2q_t$ MPa

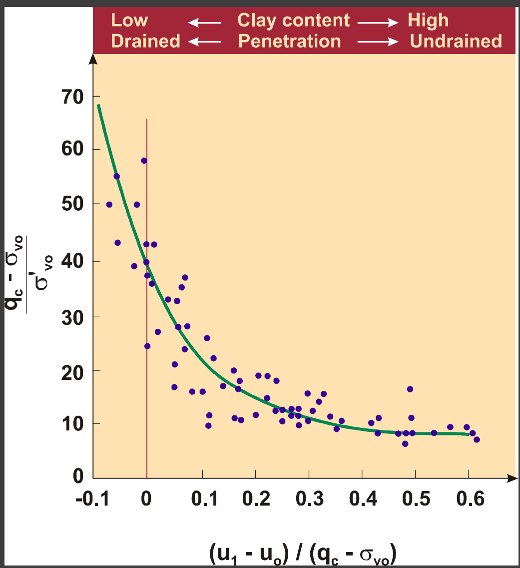
$2.5 \text{ MPa} < q_t < 5$ MPa $M_o = (4q_t - 5)$ MPa

Gullfaks 'C' CPTU profile and correlation with clay content



Hight et al.(1994)

Assessment of in situ variation of clay content, Gullfaks 'C'



Clay content is very important for penetration behaviour

Hight et al.(1994)

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General guidance on interpretation of CPTU in silt/ clayey sand soils

- Important to identify drainage conditions expected in foundation design problem and during cone penetration
- If design problem will be using undrained shear strength and cone penetration is also undrained CPTU data can be used similar to clays
- If design problem involves drained loading and cone penetration is also drained, CPT data can be treated as in sand
- If design problem is expected to involve drained loading but cone penetration is undrained or partially drained, interpretation is more complicated : **use effective stress strength parameters. May consider to do tests at non-standard speeds**

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CPTU in mine tailings

- Stability is frequently a geotechnical problem
- Deposits are often very stratified and CPTU is particularly useful

- **Example from Zelazny Most in Poland**

Żelazny Most Mine Tailings Dam:

- 1) Situated between Lubin and Głogów, Poland
- 2) The biggest hydrotechnical construction in Europe,
- 3) Dimensions:
  - a) diameter – app. 5 km,
  - b) height of dams – over 45 m (east dam),
  - c) length of dams – app. 14 km,
- 4) Accumulation from 1977,
- 5) Hydrotransportation with dumping towards the center.

DEPARTMENT OF GEOTECHNICS ,
AGRICULTURAL UNIVERSITY, POZNAŃ, Poland

Zelazny Most Tailings dam , Poland

- Żelazny Most reservoir (source: KGHM)

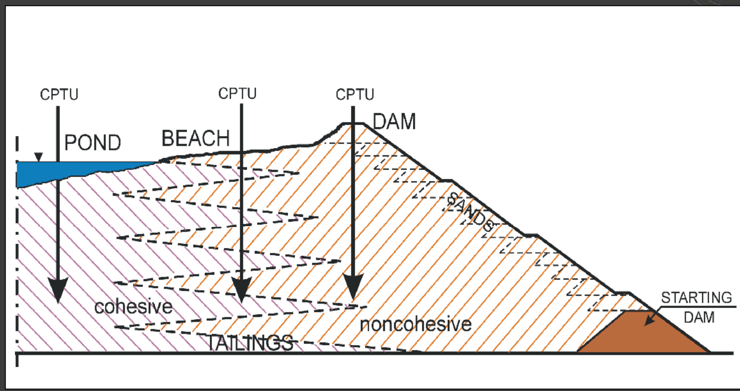
Zelazny Most Tailings Dam

- INVESTIGATIONS

- Due to the method of deposition – three distinct parts in the cross section:
- 1) Dams – mainly noncohesive soils,
- 2) Beaches – both non- and cohesive material,
- 3) Pond – cohesive material, the finest fractions, covers significant part of the reservoir.

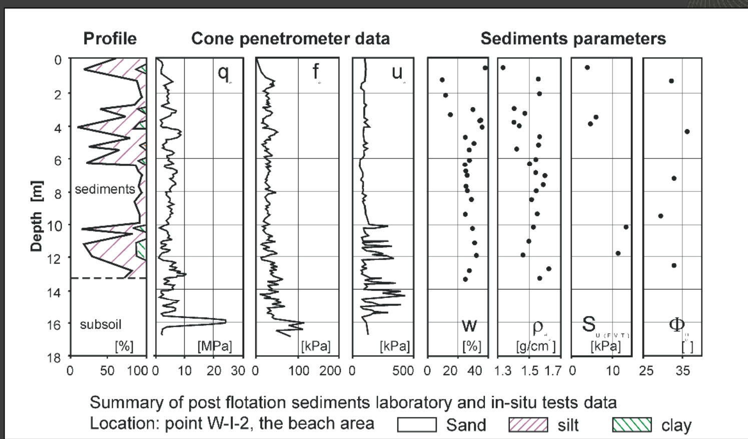
- Investigations:
- 1) dams and beaches – easy access,
- 2) pond – difficult access, out of interest

Zelazny Most tailngs Dam



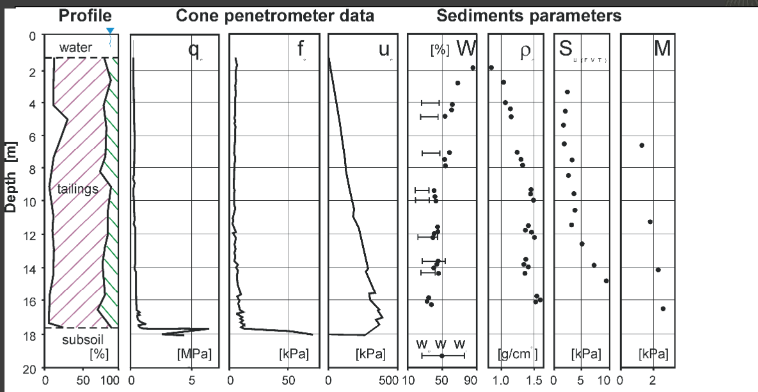
- Part of the cross section

Zelazny Most Mine Talings Dam



- **Beach profile:**
  - **1) mainly sand fraction, laminations of silt and clay fractions,**
  - **2) result – high values of q_c and f_s, u_c close to hydrostatic,**
  - **3) parameters for sediments close to values for natural soils.**

Zelazny Most Mine Tailings Dam



Summary of post flotation sediments laboratory and in-situ tests data
Location: point 5, the pond area

- **Pond profile:**
  - 1) **very weak sediments,**
  - 2) **mainly silt fraction,**
  - 3) **result – low values of q_c and f_s, high excess pore pressure u_c.**

Interpretation like in clay

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Zelazny Most Tailings dam , Poland

CPTU chosen as main test for continously monitoring stability. Thousands of tests have been carried out

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Identification of underconsolidated clay

In many cases it is important to determine if a clay is fully consolidated or not. Alternative approaches :

1. Install piezometers and measure directly in situ pore pressure
2. Carry out piezocone dissipation tests until equilibrium pore pressures have been reached
3. Empirical approach by Tanaka and Sakagami (1989) based on tests in Osaka clay (Japan)

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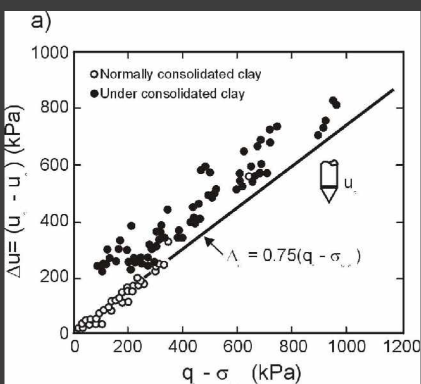
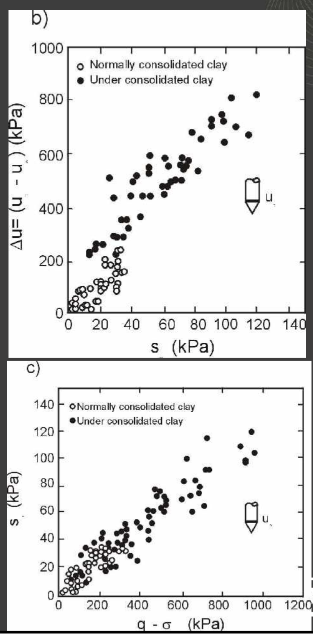
Identification of underconsolidated clay





Tests carried out in NC and underconsolidated Osaka clay

Tanaka and Sakagami(1989)

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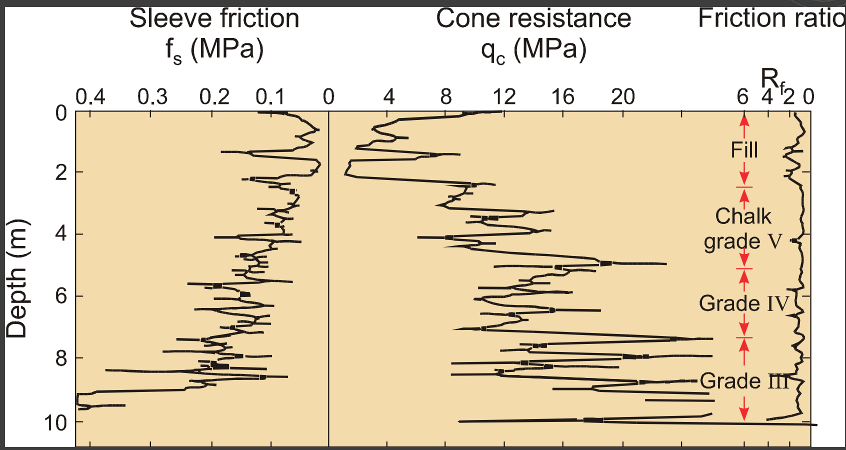
CPT profile in middle chalk at Munford, UK



Power,1982

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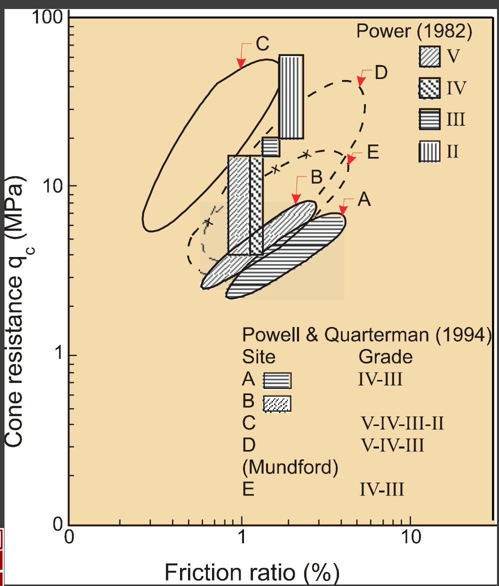
Classification of chalk grade



Unit wt and grade

Powell and Quarterman, 1994

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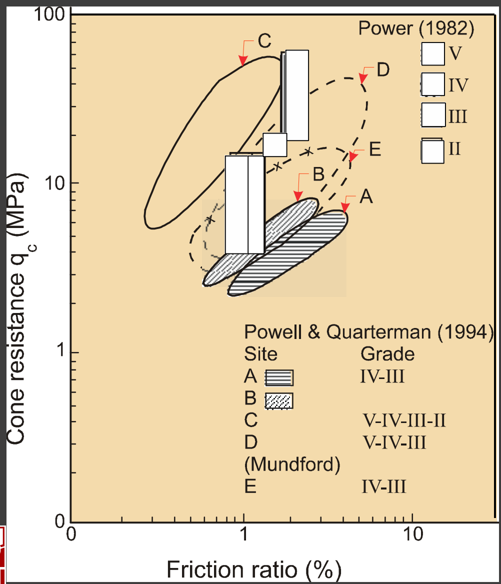
Classification of chalk grade



Powell and Quarterman, 1994

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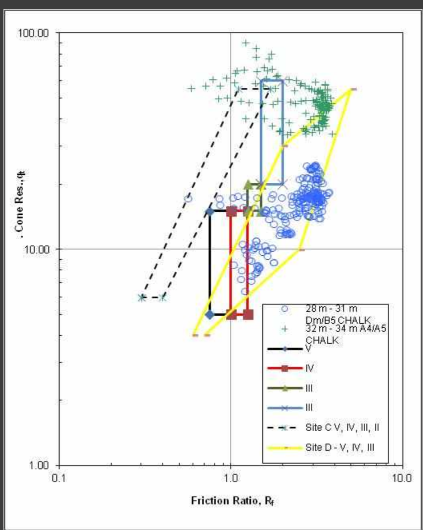
Classification of chalk grade



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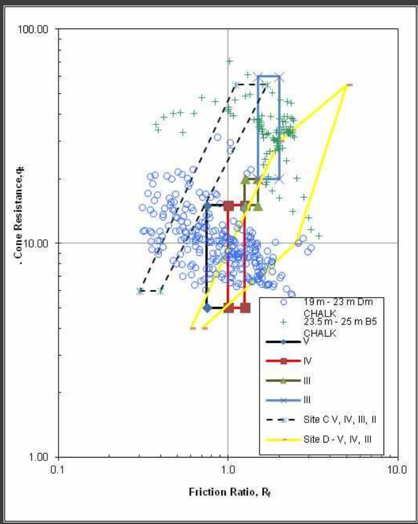
Classification of chalk grade



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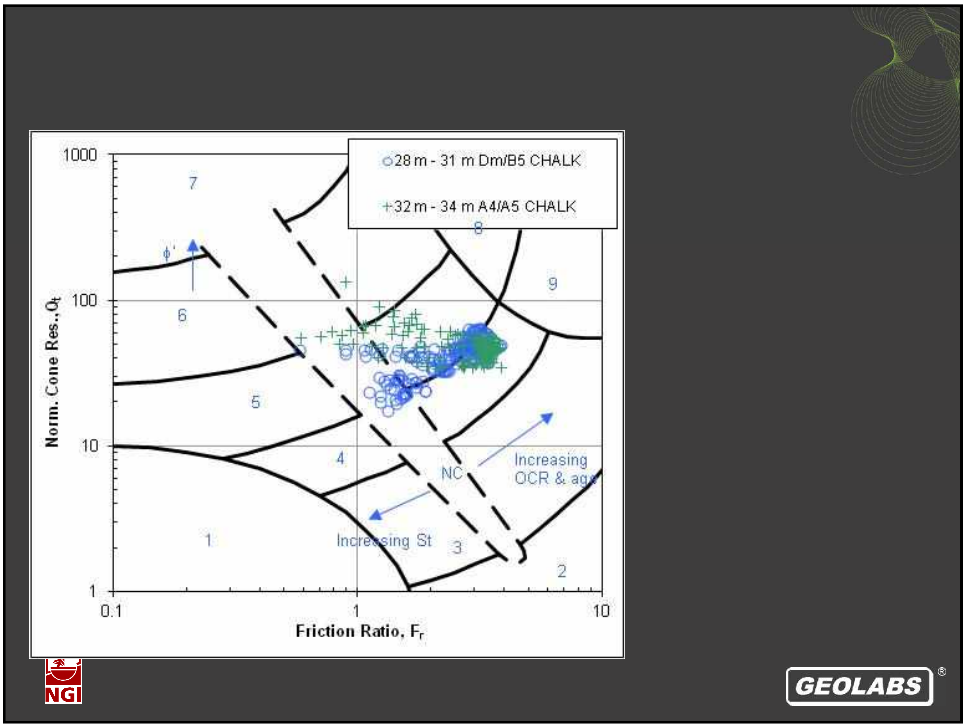
28 m - 31 m Dm/B5 CHALK
32 m - 34 m A4/A5 CHALK
Norm. Cone Res., Q_t
Friction Ratio, F_r
Increasing OCR &
NC
Increasing St
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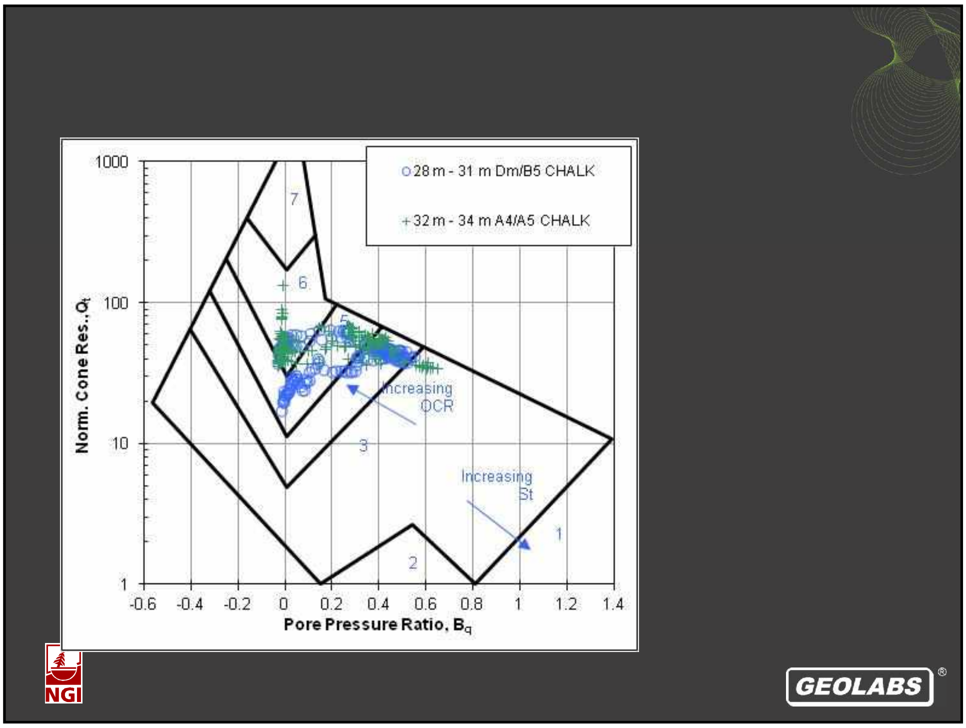
28 m - 31 m Dm/B5 CHALK
32 m - 34 m A4/A5 CHALK
Norm. Cone Res., Q_t
Pore Pressure Ratio, B_q
Increasing OCR
Increasing St
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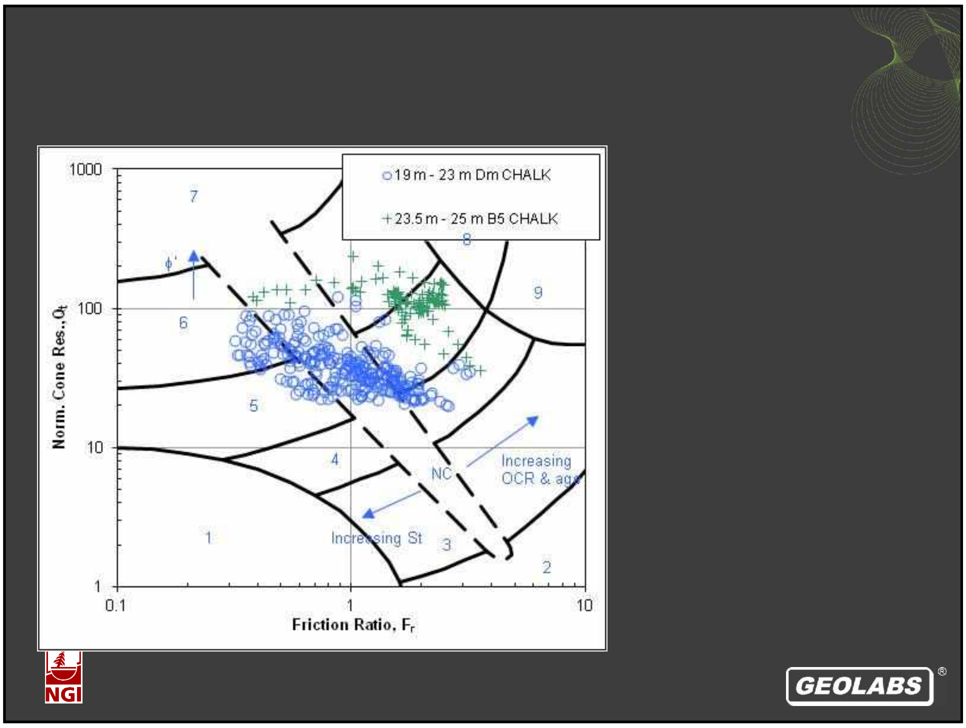
19 m - 23 m Dm CHALK
23.5 m - 25 m B5 CHALK
Norm. Cone Res., Q_t
Friction Ratio, F_r
1000
100
10
1
0.1
1
10
1
2
3
4
5
6
7
8
9
NC
Increasing OCR & age
Increasing St
NGI
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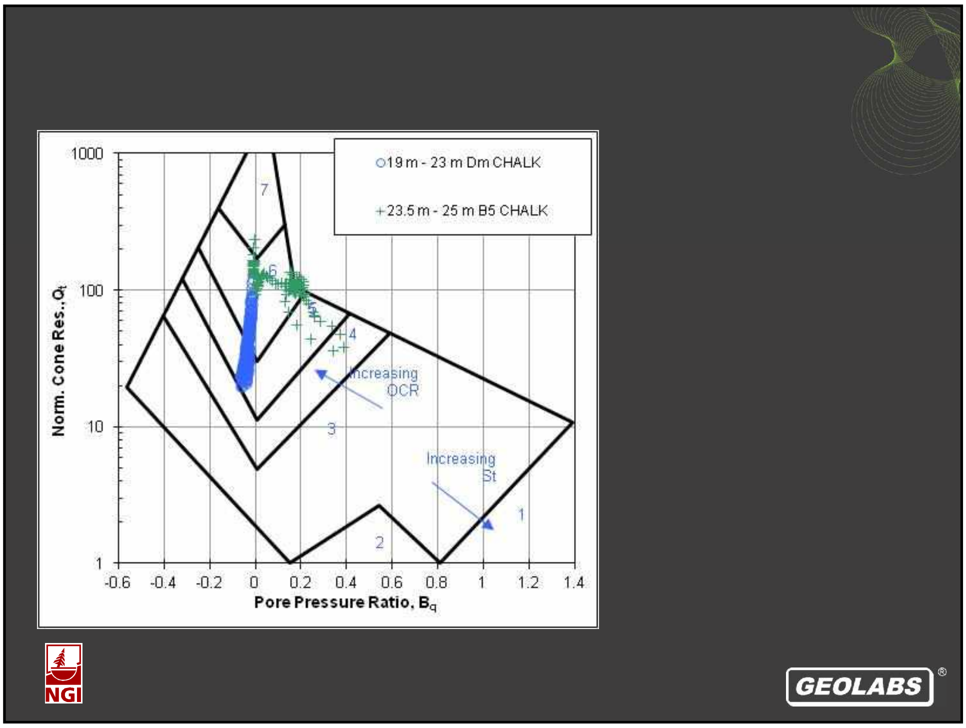
19 m - 23 m Dm CHALK
23.5 m - 25 m B5 CHALK
Norm. Cone Res., Q_t
Pore Pressure Ratio, B_q
1000
100
10
1
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1
2
3
4
6
7
Increasing OCR
Increasing St
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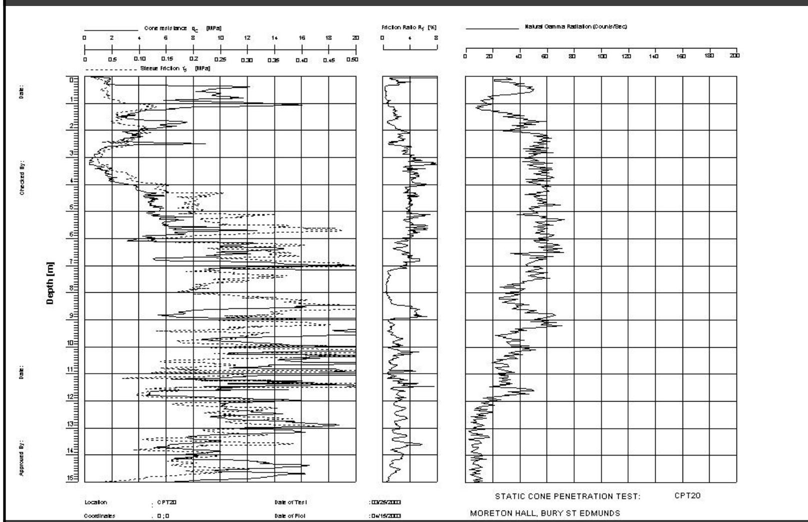
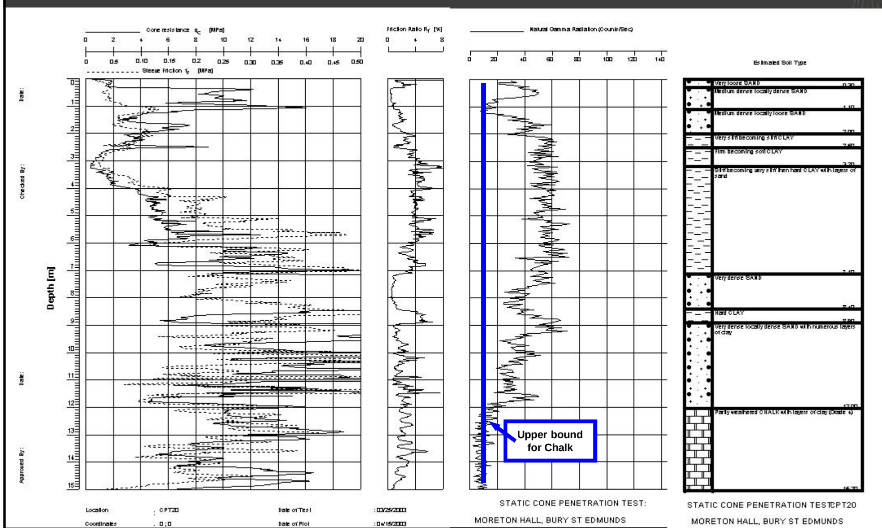
Natural Gamma Cone

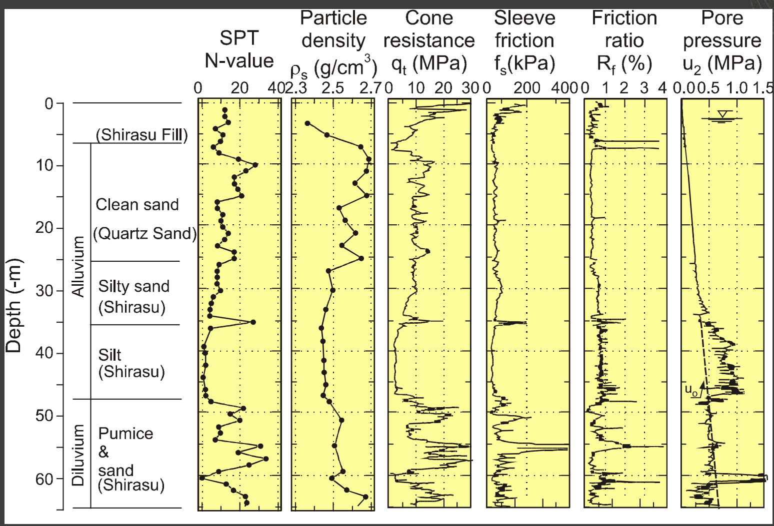


Natural Gamma Cone



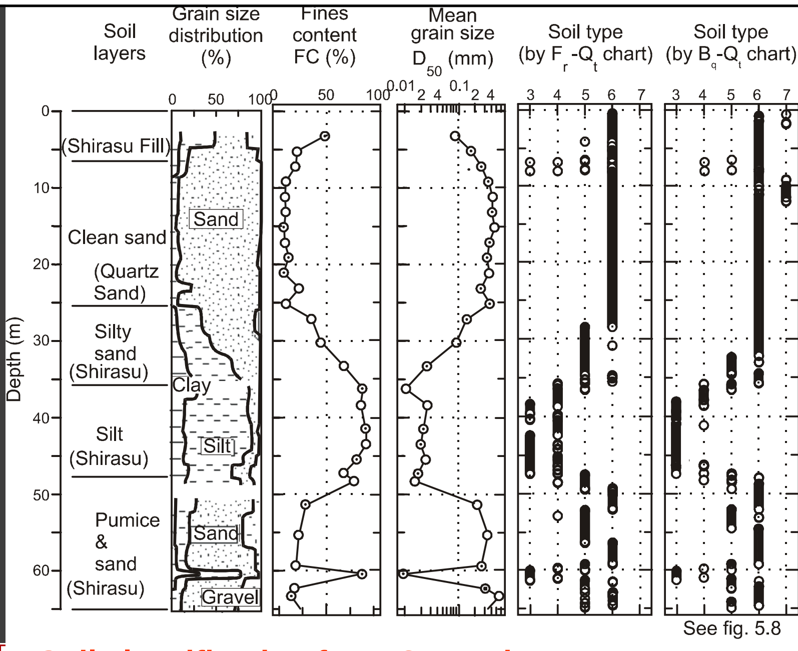
Background gamma

CPTU profile in Japanese volcanic soil



Crushable, low sg, angular

Takesue et al. (1995)



Soil classification from CPTU data compared to laboratory test results

Takesue et al. (1995)

CPTU profiling can be useful in most soils

- Examples of other materials not covered in presentation:
  - Residual soils (e.g. Mayne, 2003)
  - Calcareous soils (see book + some new)
  - Slurry walls (book)
  - Loess soils (book)
  - Permafrost (book)

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Examples of unusual behaviour and effects of non-standard procedures

- **Cavitation of pore water**
- **Effect of stones on u_1 penetration pore pressures**

- Cone size and scale effects
- Cone penetrometer geometry
- Rate of penetration

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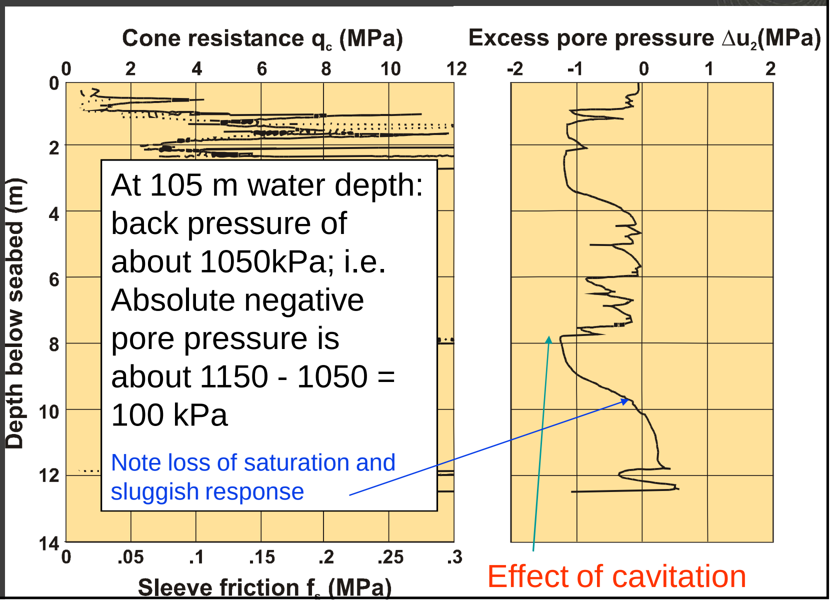
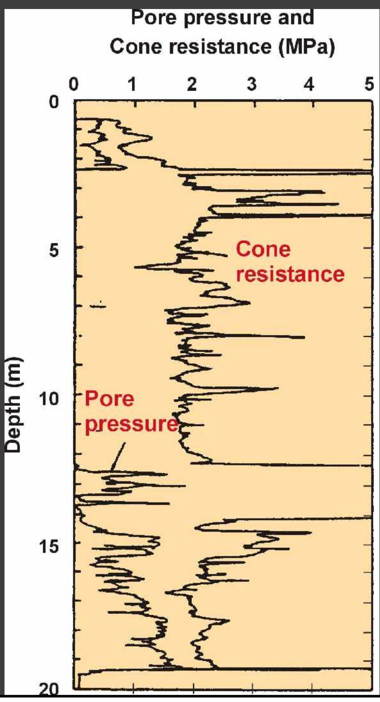
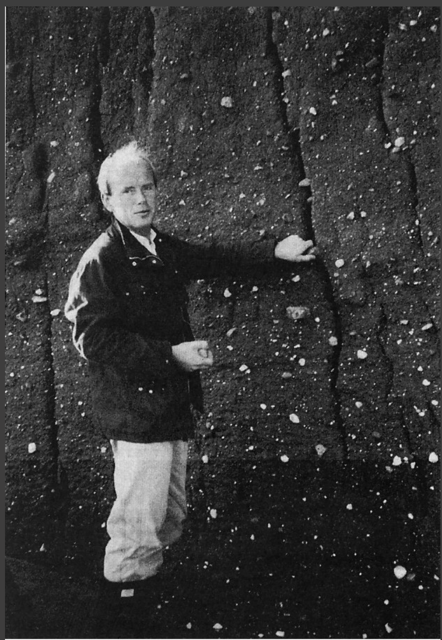
CPTU at Sleipner , North Sea , 105 m wd



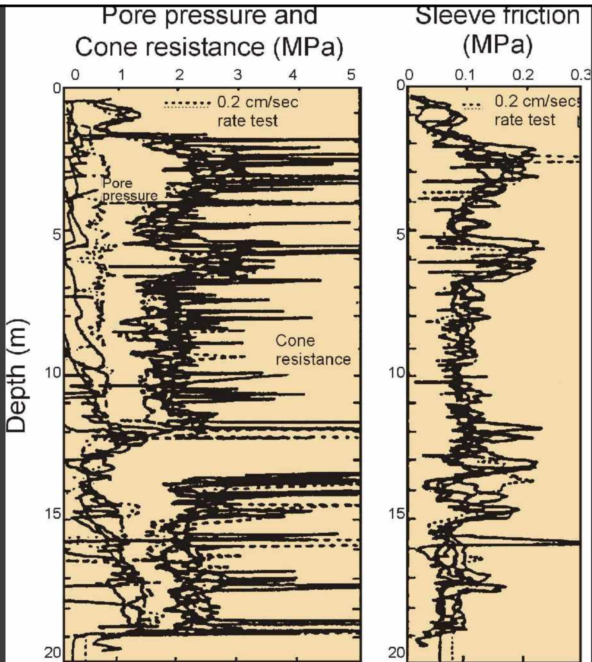


Example of CPTU measurements with u_1 pore pressure in glacial till at cowden in UK

Exposed glacial clay till at Cowden, UK

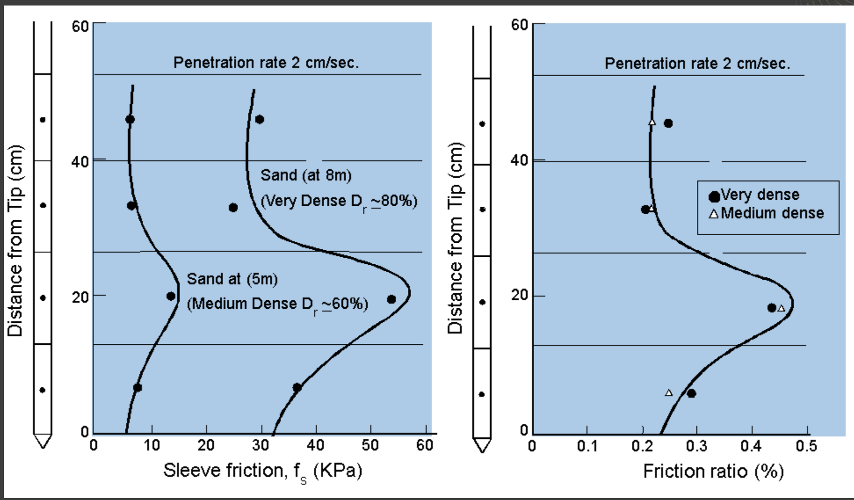


Exposed clay till at Cowden

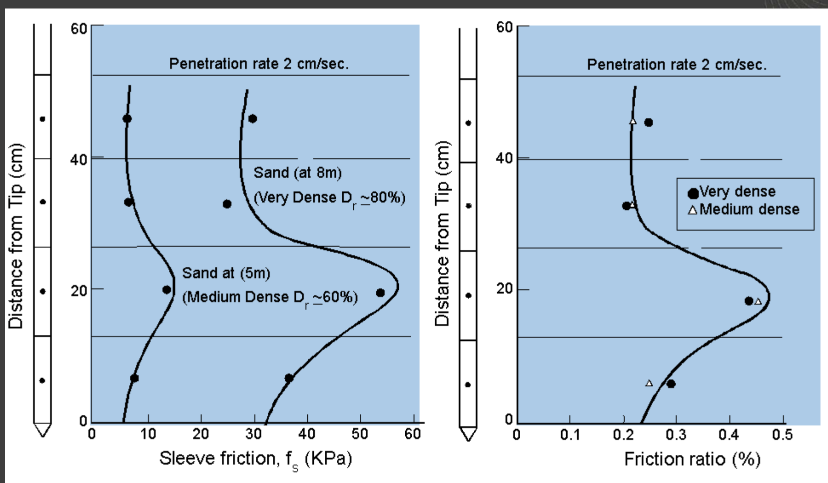


Effect of rate of penetration on u_1 readings in a glacial till at Cowden, UK

Sleeve friction and friction ratio along shaft in sand (McDonald Farm)

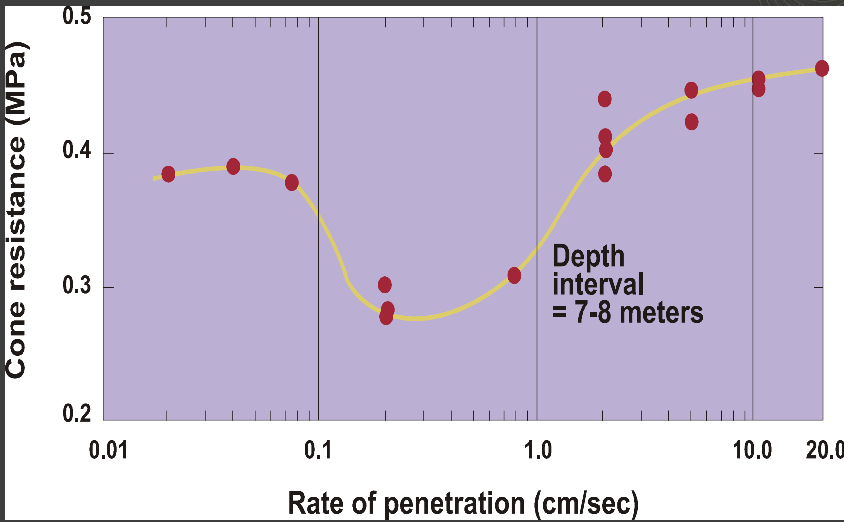


Sleeve friction and friction ratio along shaft in sand (McDonald Farm)



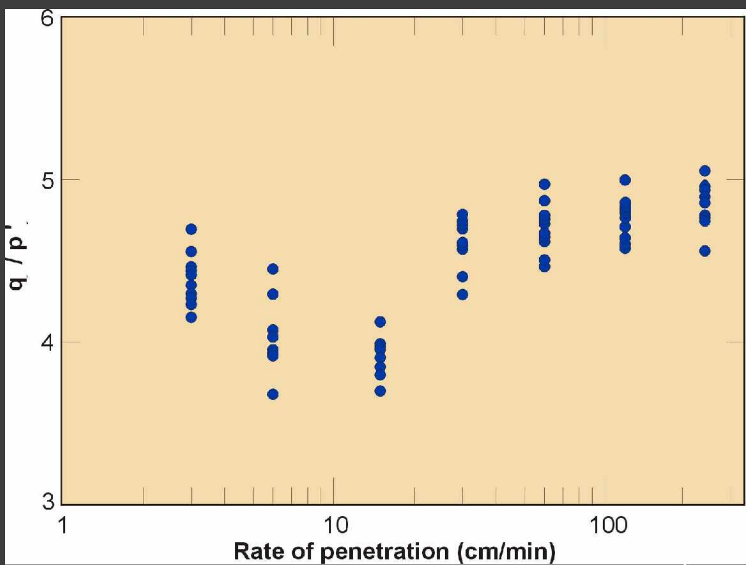
Sleeve friction is now standardised to be just behind cone and 134 mm long, but for special purposes it may be more optimal with different location and length

Influence of rate of penetration on cone resistance



Bemben and Myers(1974)

Influence of rate of penetration on cone resistance



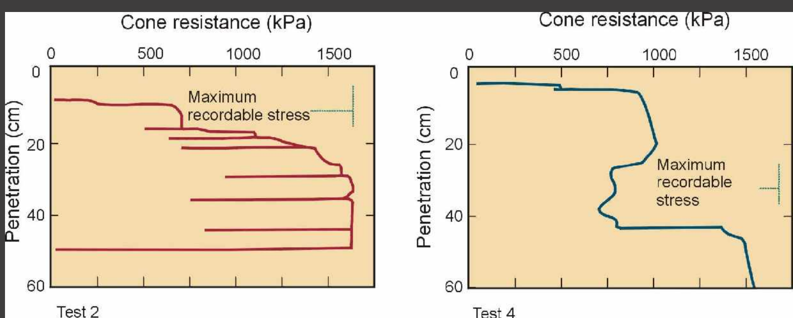
Also Randolph

Roy et al.,1982

CPT/CPTU equipment and procedures

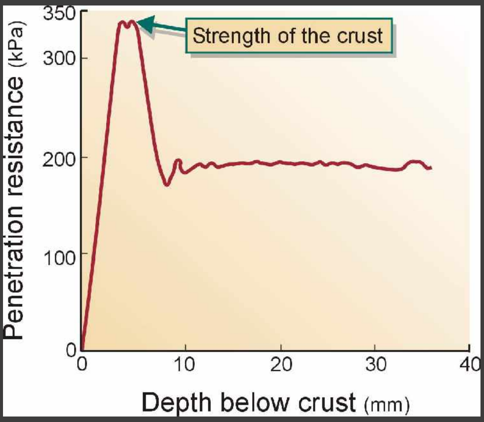
- Results depend very much on details in equipment and procedures
- We should as far as possible stick to IRTP or ASTM
- If we deviate notes should be clearly marked on each plot showing results
- In some cases it may be beneficial to deliberately use non-standard procedures

CPT results on the moon



Mitchell and Houston (1974)

CPT result in Dutch cheese



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- Wealth of information now coming out on other materials but will still need to be assessed!

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And thank you