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Overview of suitable case studies for benchmarking of time-dependent constitutive models

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Outline

- Background
- Objective
- Field instrumentation
- Selected Test Cases
- Assessment Criteria
- Comparison of Cases
- Recommended Cases
- Conclusions

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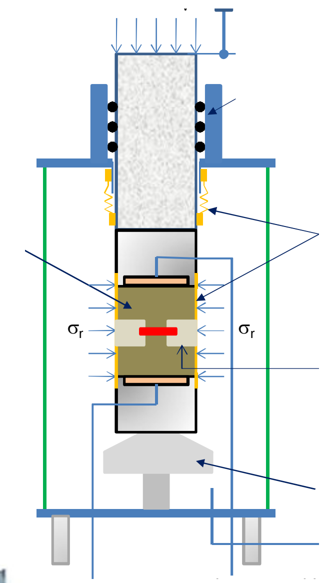
Background

- Recent advances in CREEP modelling include accounting for features such as:
  - anisotropy
  - destructuration
  - temperature effects
- Those creep models require validation at:
  - Element level



  - Boundary value level

Background

- Some complications arise …
  - Constitutive modellers often unaware of complications in field testing and instrumentation
  - Typical field tests have competent site investigation for traditional design methods only
  - Creep tests require time…

  - …actually a lot of time

Background

- As opposed to failure tests not many tests sites are designed to study serviceability limit state, SLS, (long-term deformations)
- Depending on the permeability of the subsoil we are looking at decades rather than months.
  - Implications for test site location
  - Implications for choice of instrumentation
  - Implications for organisation
  - Implications for funding

Background

- Not much data is available. However:
  - Successful sites on clay already in service for 20 years or longer
  - Typically these are national test sites or owned by other governmental bodies

TIEHALLINTO

Pauli Vepsäläinen, Matti Lojander, Mirva Koskinen

Haarajoen koepenger

Maaperän lujittumistutkimus

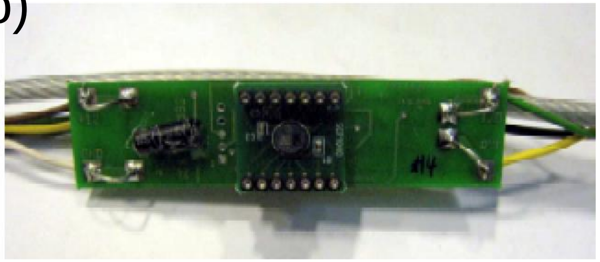
Tiehallinnon selvityksiä 18/2002

Objective

- Within the CREEP project we decided to collect all available data on existing field tests with a special focus on sites with sufficient experimental data available for the use of model calibration (laboratory tests) and validation (instrumented field test)

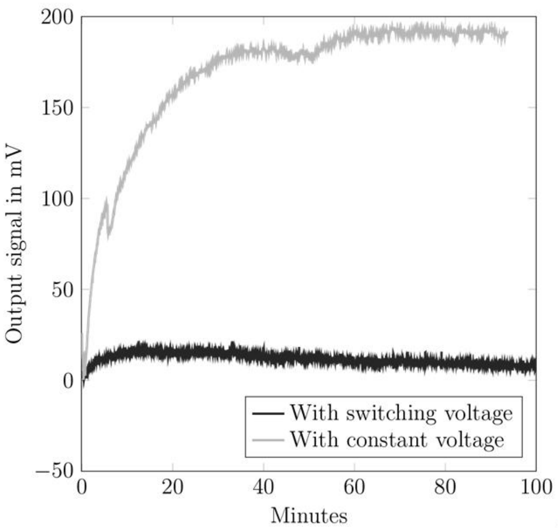
Instrumentation

- Deformations
  - Simple instrumentation most reliable, therefore most often the vertical deformations are available for the longest period
  - Inclinometer data for horizontal deformation measurements most suspect.
  - Extensometers (or tell tale) are most reliable in the centre of the embankment
  - Settlement tubes (fluid pressure related deformation measurement in a tube under the fill) are recently improved with local MEMS transducers(Perniö)



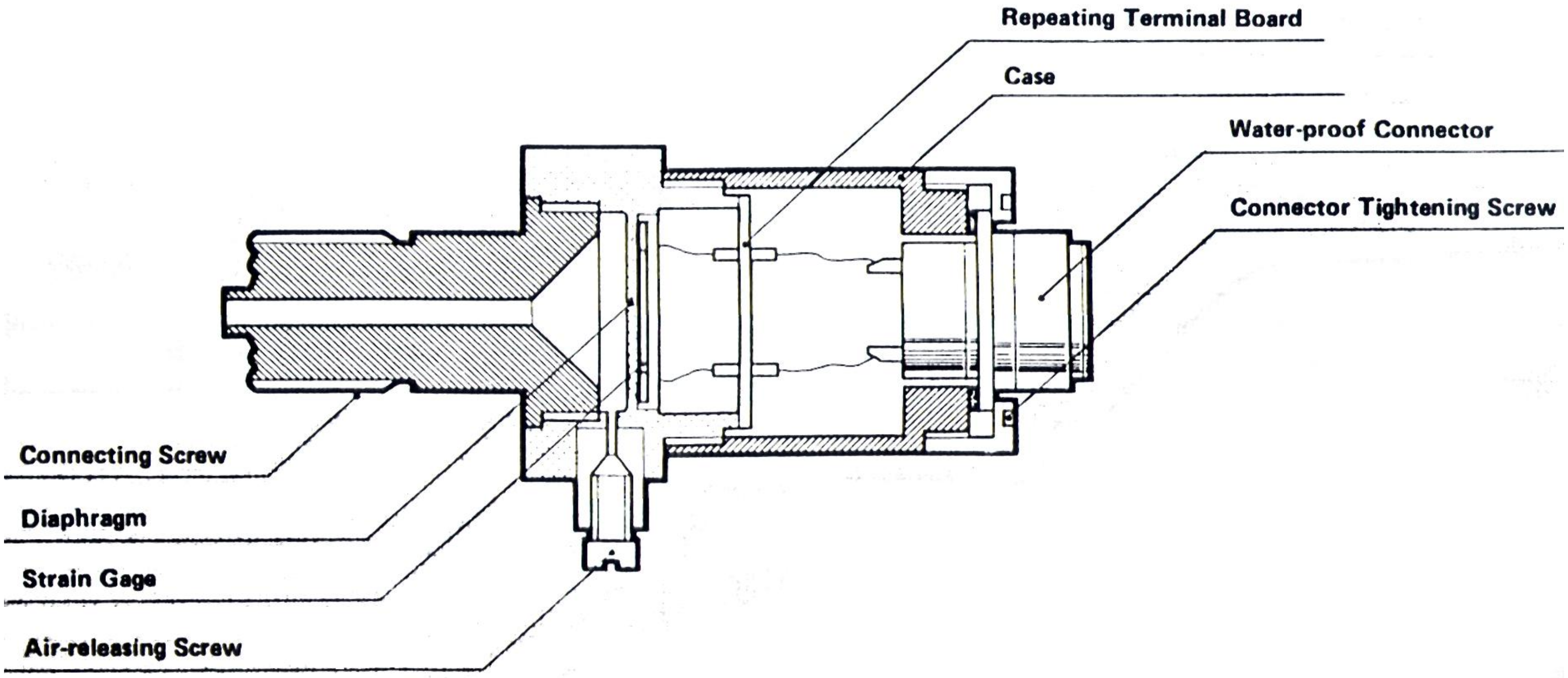
Instrumentation

- Pore pressure reading systems
  - Standpipe (slow and unreliable)
  - BAT system (periodic sampling of data)
  - Dedicated (electrical) piezometers
- Problems with long term saturation of porous discs in case of periodic groundwater table or suction in slope
- Long term stability of electronics (temperature)



Instrumentation

- Two different pore pressure transducer configurations: absolute or relative measurements



Selected Test Cases

- Antoniny, Poland, test embankment on peat: Wolski et al. (1989)
- Booneschans, the Netherlands, test embankment on peat: Zwanenburg et al. (2008a, 2008b, 2012) and Den Haan & Feddema (2013). Only failure test.
- Boston Blue, United States, the original test embankment reported by Ladd et al (1994) and the thesis of Whittle (1974). Presentation Gustav Grimstad
- Gloucester, Canada, the tests performed on clay at the Gloucester site. See McRostie and Crawford (2001) for an overview and a recent paper by Zdravkovic et al. (2002).

Selected Test Cases

- Haarajoki, Finland, the official Haarajoki benchmark case for soft soils. See Vepsäläinen et al. (2002) for an overview, more info and all laboratory data from original benchmark available
- Murro, Finland, the Murro test embankment to assess the performance on sulfite rich soft soil. See Koskinen et al. (2002) and the relevant scientific (Karstunen et al. 2005, Karstunen and Koskinen 2008, Karstunen and Yin 2010, Karstunen et al. 2012 and Yin et al. 2011)
- Three Swedish test embankments in Nödinge, Stora Viken and Surte, to assess the performance of deep mixing in Sweden. See Alén et al. (2006), more info and some related scientific
- papers (Alén et al. 2005b, Alén et al. 2005a, Baker et al. 2005)

Selected Test Cases

- Onsøy, Norway, the benchmark embankment test on the extensively documented Onsøy test site. See the recent paper of Berre (2013) on the essentials and the laboratory data report of NGI (Berre 2010)
- Perniö, Finland, most recent Finnish embankment test on sensitive clay (only brought to failure). English summary reported in Lehtonen (2011), full detail in Finnish report Lehtonen (2010). Lab data will be soon available in the theses of Mansikkamäki (201x) & Mataic (201x).

Selected Test Cases

- Bothkennar, UK, long term load test of shallow foundation on clay (Jardine et al. 1995, Lehane and Jardine 2003), all relevant publications on characterization of the Bothkennar site in the Géotechnique Symposium in print 1992.
- Presentation of Teresea Bodas Freitas this morning

Assessment Criteria

- The assessment of the field cases is performed for two main criteria:
- 1) The quality of the instrumented field test
  - minimum instrumentation
  - spatial density of the embedded instrumentation
  - temporal resolution of the logging
  - general accuracy and precision of the measured physical quantity of the sensor (qualitatively taken into account)

Assessment Criteria

- 2) The quality of the site investigation
  - number and quality of the in-situ tests (e.g. vane or CPT tests),
  - number of boreholes
  - soil sampling method used
  - subsequent laboratory tests for characterisation and assessment of the mechanical and hydraulic parameters
  - for advanced model features additional triaxial tests in extension are required
  - for model development nonstandard stress path triaxial tests will be required

Assessment Criteria

- In direct comparison for the field test:
  - long term test yes/no
  - other instrumentation yes/no
  - the assessed data quality (very poor – very good) for the geometry, pore pressures, vertical displacements, horizontal displacements.
- In direct comparison for the element tests:
  - clay or peat
  - assessed data quality (very poor – very good) for the in-situ tests, sample quality, characterisation, standard laboratory tests and non-standard laboratory tests .

Assessment Criteria

- After comparison the sites are grouped within the following categories:
  - Class 1 (high quality field test and SI)
  - Class 2 (sufficient field test quality and/or SI)
  - Class 3 (insufficient field test quality and/or SI)
- Selected cases in Class 1 are to be considered as benchmark cases

Assessment Criteria

- Rating in tables:

++	very good	state of art level of execution and reporting
+	good	better than standard test level, academic research lab
0	fair	the standard what you can expect in a competently designed and executed experimental programme
–	poor	substandard performance, data missing, poor execution
– –	very poor	erroneous execution, outdated procedures, or missing information on essential aspects of the process and or test

Comparison of Cases

Table 3.1: Instrumented field test data; *vertical drains; **deep mixing

Site	long-term	geometry	pore pres.	vert. displ.	hor. displ.	other instr.
Antoniny	yes	+	0	+	0	no
Booneschans	no	+	0	+	+	yes
Boston Blue	yes	+	0	+	0	no
Bothkennar	yes	+	+	+	+	no
Gloucester	yes	+	0	+	0	no
Haarajoki	yes	0*	0	+	0	no
Murro	yes	+	+	+	+	no
Nö/SV/Su	yes	–**	-	0	-	yes
Onsøy	yes	+	+	+	+	no?
Perniö	no	0	+	++	+*	yes

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Boston Blue	yes	+	0	+	0	no
Bothkennar	yes	+	+	+	+	no
Gloucester	yes	+	0	+	0	no
Haarajoki	yes	0*	0	+	0	no
Murro	yes	+	+	+	+	no
Nö/SV/Su	yes	–**	-	0	-	yes
Onsøy	yes	+	+	+	+	no?
Perniö	no	0	+	++	+*	yes

Comparison of Cases

Table 3.2: SI and lab data score chart; n/a data is not available; *expected results thesis work Mansikkamäki (201x) & Mataic (201x)

Site	clay/peat	in-situ test	sample quality	characterization	std lab tests	non-std lab tests
Antoniny	peat	0	– –	0	0	n/a
Booneschans	peat	+	–	+	0	n/a
Boston Blue	clay	0	– –	0	0	n/a
Bothkennar	clay	+	+	++	+	+
Gloucester	clay	0	+	+	0	n/a
Haarajoki	clay	0	–	0	+	n/a
Murro	clay	0	–	+	+	++
Nö/SV/Su	clay	0	–	0	–	n/a
Onsøy	clay	++	++	++	++	+
Perniö	clay	0	–	0	+*	n/a*

Comparison of Cases

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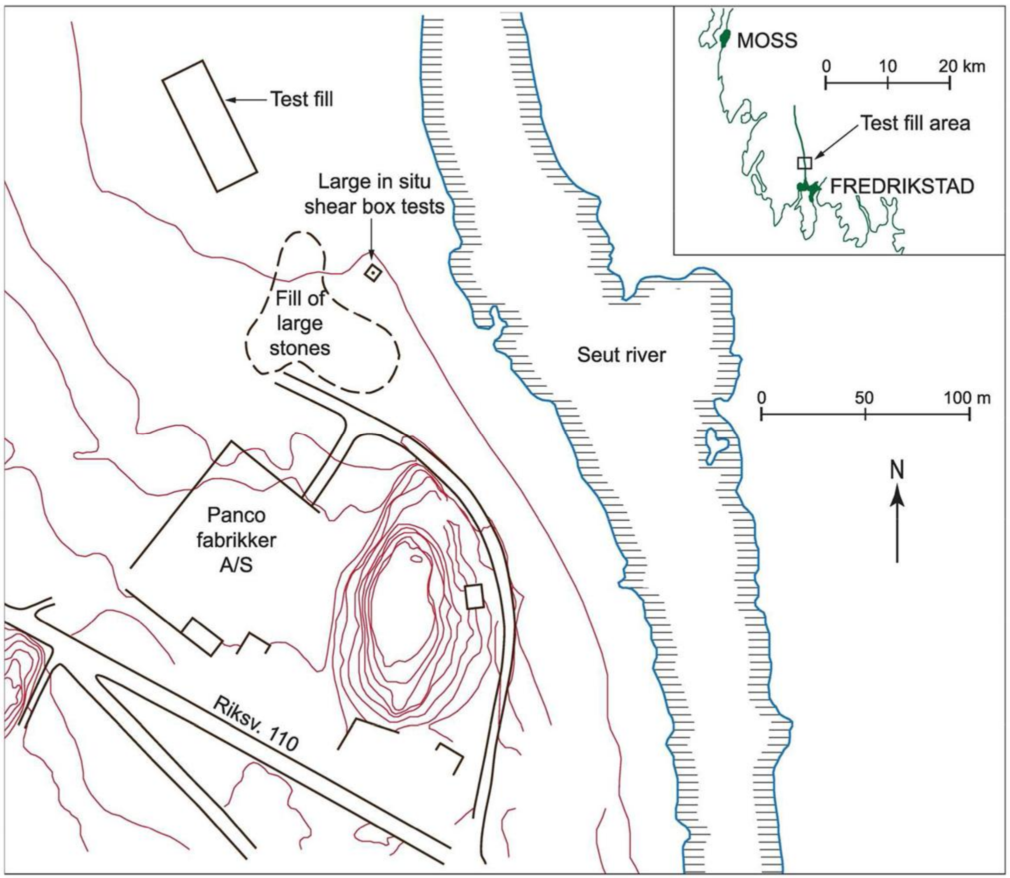
Antoniny	peat	0	– –	0	0	n/a
Booneschans	peat	+	–	+	0	n/a
Boston Blue	clay	0	– –	0	0	n/a
Bothkennar	clay	+	+	++	+	+
Gloucester	clay	0	+	+	0	n/a
Haarajoki	clay	0	–	0	+	n/a
Murro	clay	0	–	+	+	++
Nö/SV/Su	clay	0	–	0	–	n/a
Onsøy	clay	++	++	++	++	+
Perniö	clay	0	–	0	+*	n/a*

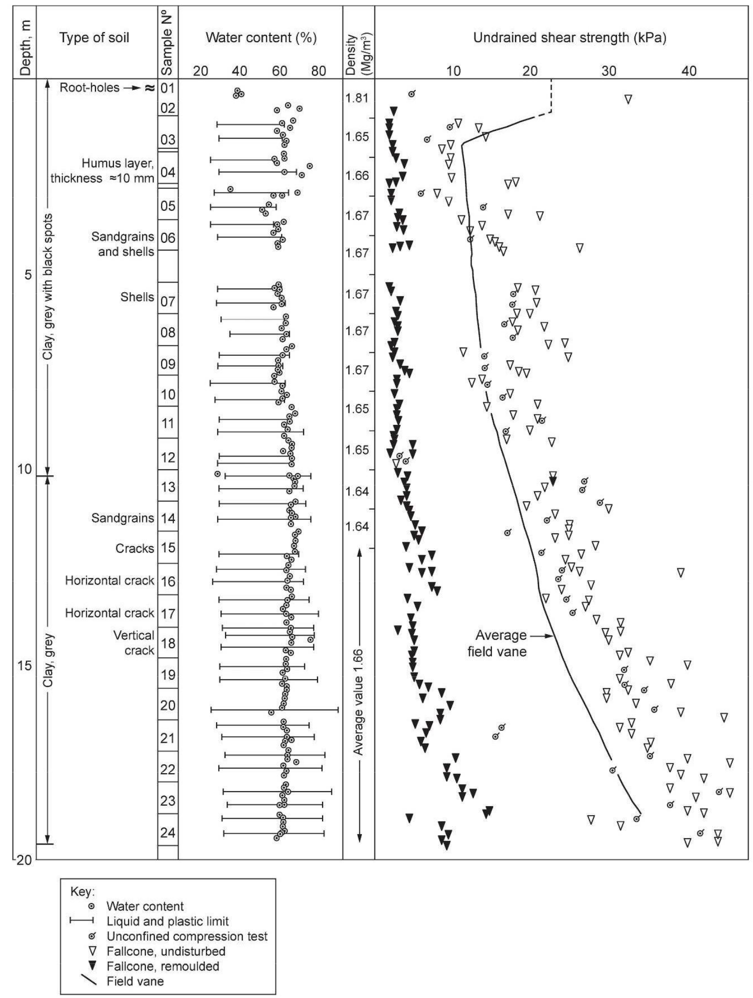
Recommended Cases

- Class 1 (high quality field test and SI)
  - Onsøy (embankment on clay), Murro (embankment on clay), Bothkennar (footing on clay)
- Class 2 (sufficient field test quality and/or SI)
  - Haarajoki, Perniö, (both embankments on clay, but Perniö only failure test)
- Class 3 (insufficient field test quality and/or SI)
  - all others

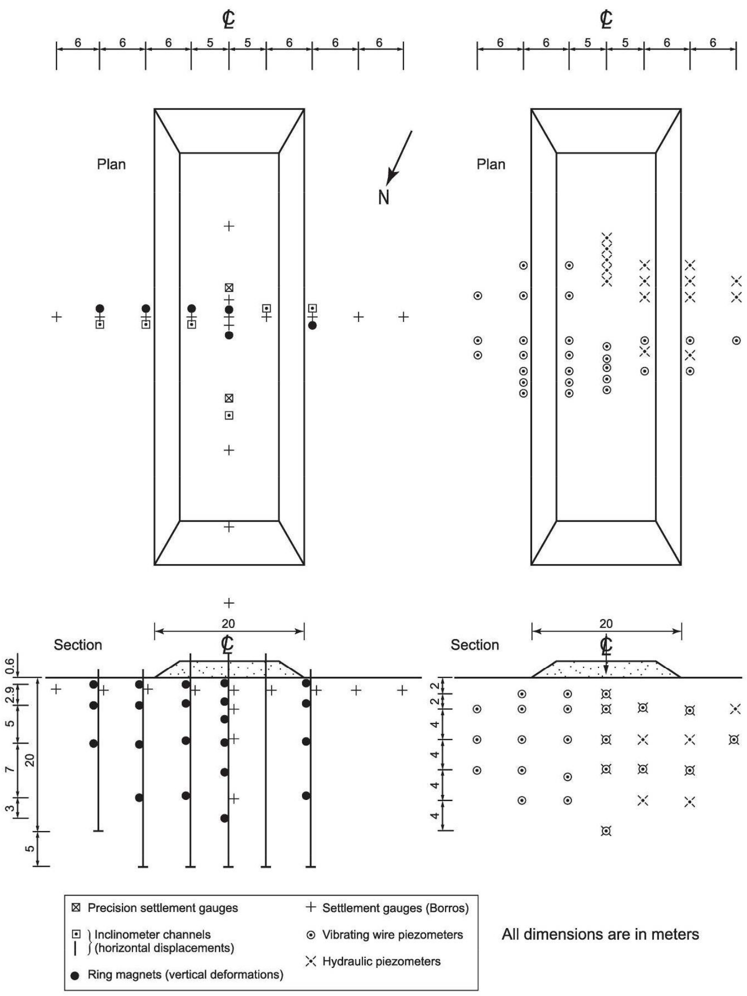
Onsøy

- From Berre (2013)





Onsøy



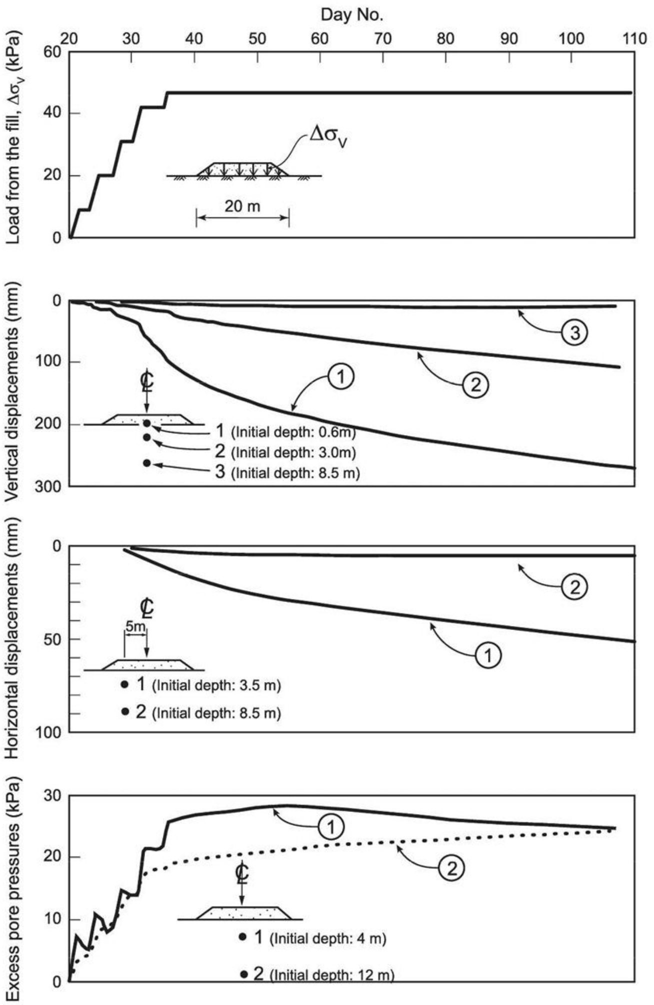


Fig 6. Measured displacements and excess pore pressures versus time

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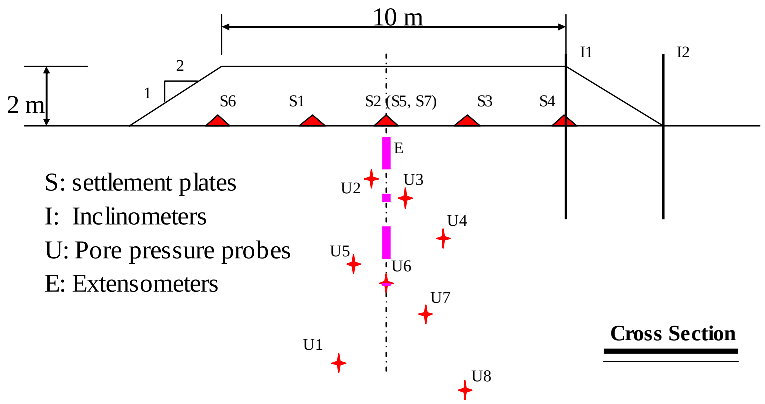
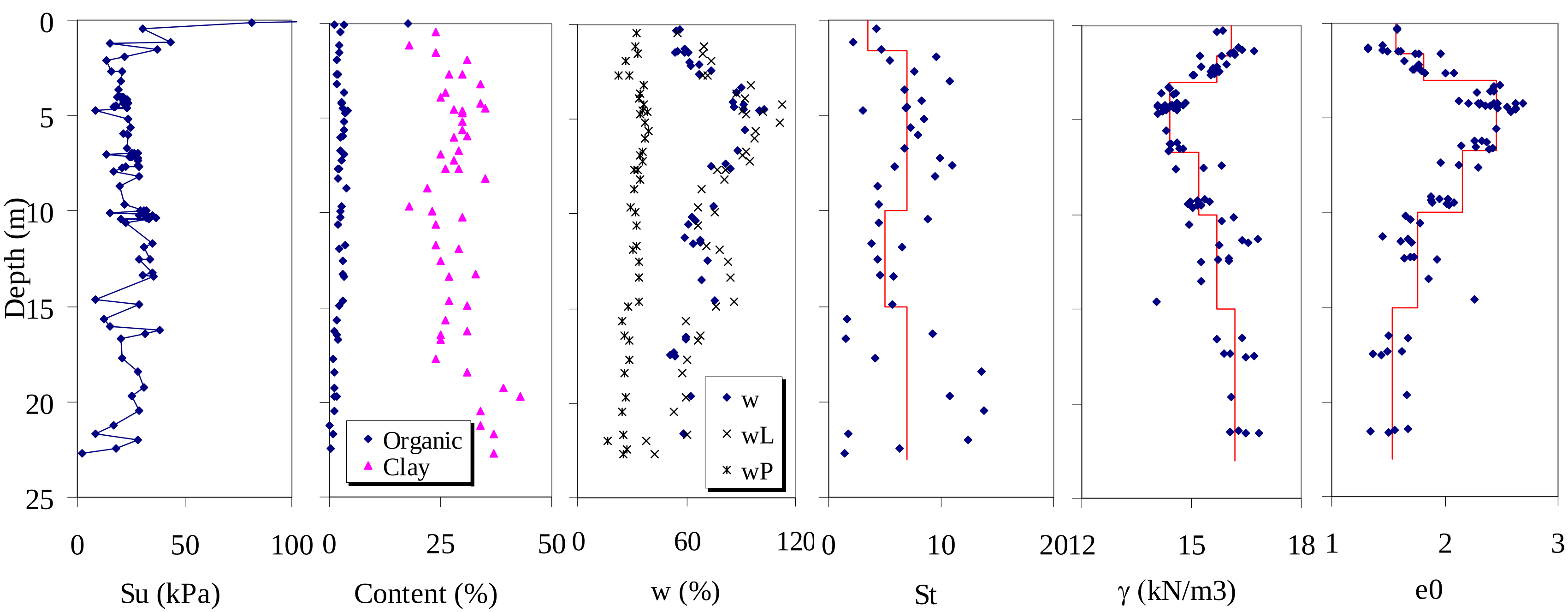
Murro

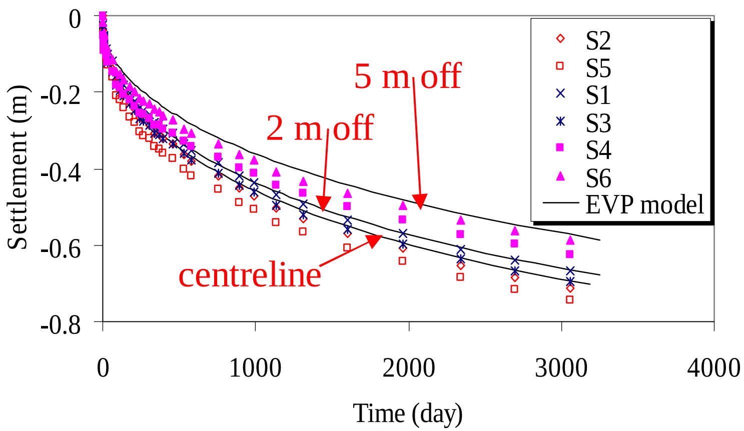
- Karstunen & Yin (2010)

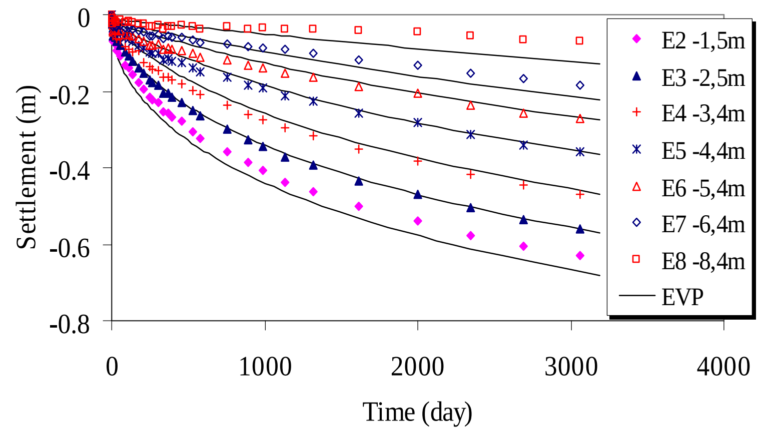


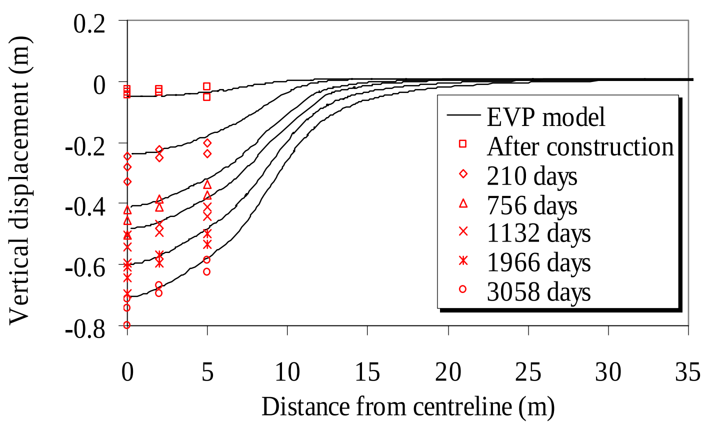


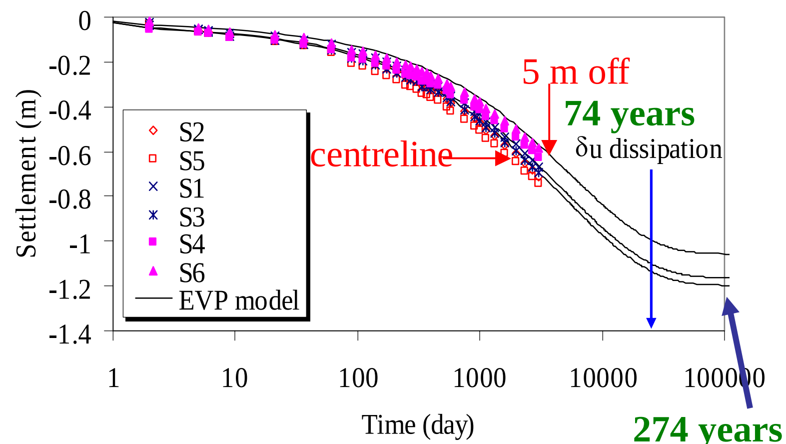
Murro

- Karstunen & Yin (2010)



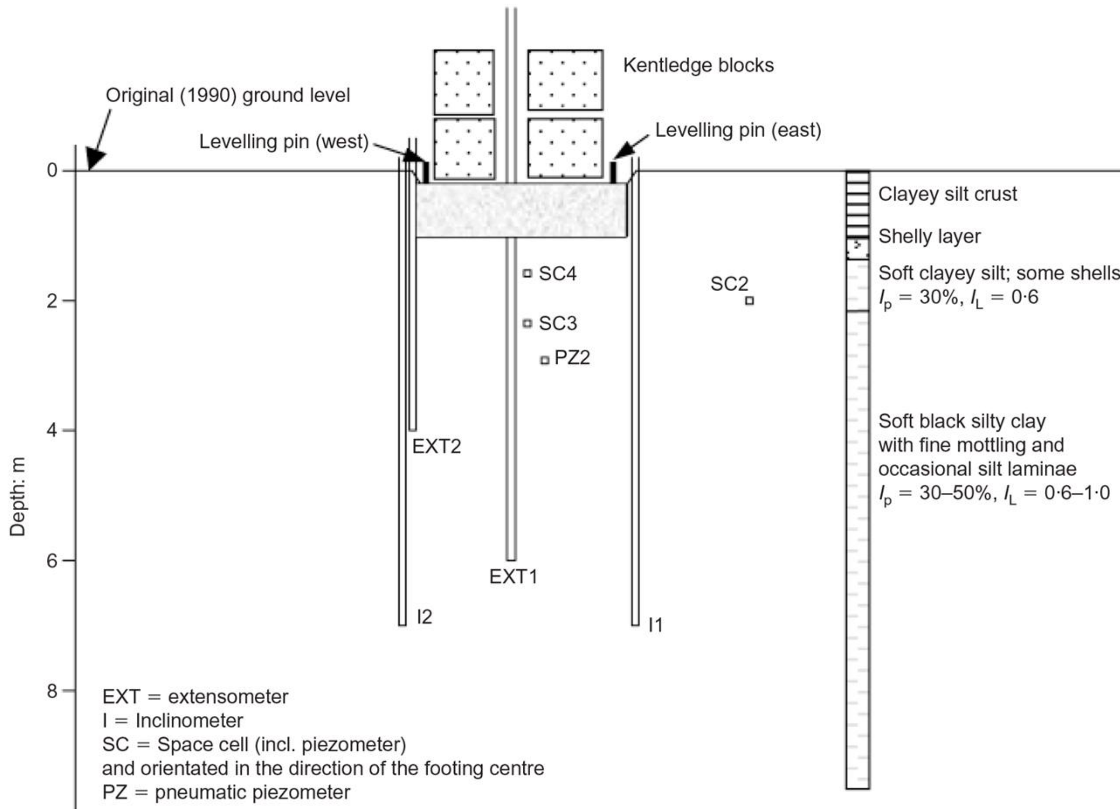






Bothkennar

- Lehane & Jardine (2003)



Bothkennar

- Lehane & Jardine (2003)

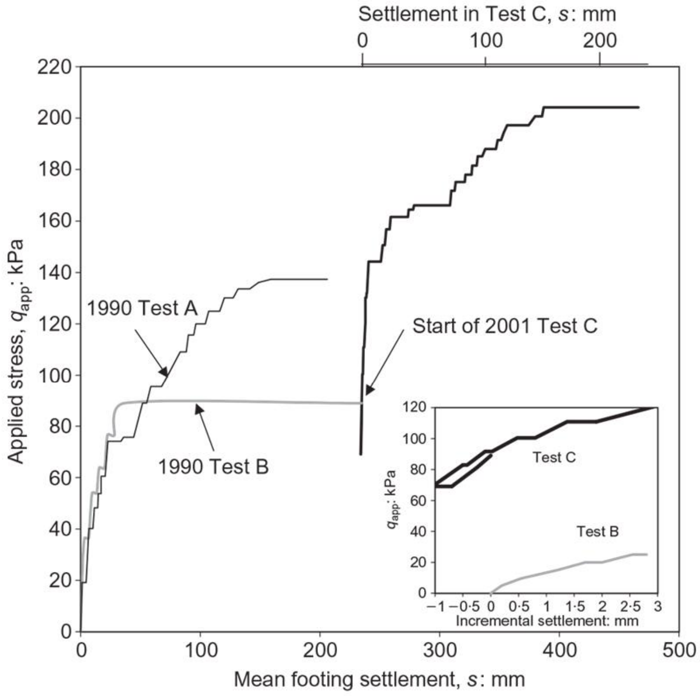


Fig. 6. Relationships between applied stress and mean footing settlement recorded in Tests A, B and C

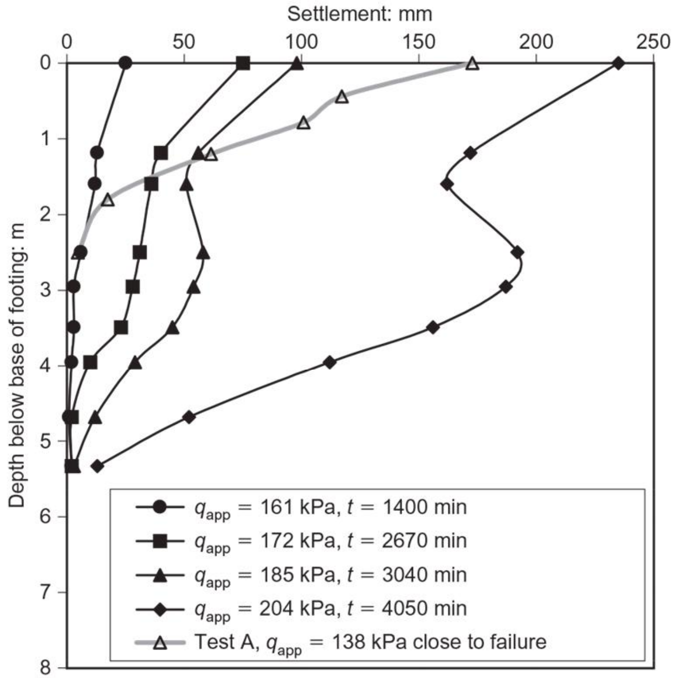


Fig. 7. Distribution of settlement with depth beneath footing centreline in Test C

Conclusions

- As a result the three cases in Class 1 are recommended for further benchmarking. These are the Onsøy and Murro test embankments on clay, and the long-term response for the performance of a shallow foundations on clay, Bothkennar.
- Out of those three cases the Onsøy field test should be considered first, as this site offers the highest quality data additionally to the fact that no benchmark comparisons of advanced models have been published for this site.