NAM

Assessment of dynamic properties for peat

Factual Report

Deltares

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Date October 2017

Editors Jan van Elk & Dirk Doornhof

General Introduction

The accelerations experienced at surface as a result of the earthquakes induced by the production of gas from the Groningen field is locally dependent on the shallow geological and soil conditions (Ref. 1). This is called the site response effect.

NAM has asked Deltares to build a detailed model of the shallow subsurface below Groningen (Ref. 2 to 5). In preparing this model of the shallow subsurface below Groningen, Deltares has made us of the beta-version of the GEOTOP database of TNO Geologische Dienst Nederland (TNO-NITG) supplemented by more recent data. Additional data collected over the years in support of foundation design and other activities was sourced from Fugro and Wiertsema. These are mainly CPT measurements (cone penetrations tests). Additionally, data measured in the shallow geophone wells was used.

For these calculations of the site response, soil parameters related to stiffness and damping (amongst others) are also necessary. For sand and clay these parameters are derived from well accepted correlations in the literature. However, the properties of locally present peat layers need to be measured in the laboratory. This report and the accompanying report (Ref. 6) present the measurements performed by Deltares on peat samples from Groningen, the analysis of the experimental data and the assessment of peat properties.

References

1. De ondergrond van Groningen: een Geologische Geschiedenis, Erik Meijles, April 2015.
2. Geological schematisation of the shallow subsurface of Groningen (For site response to earthquakes for the Groningen gas field) – Part I, Deltares, Pauline Kruiver, Ger de Lange, Ane Wiersma, Piet Meijers, Mandy Korff, Jan Peeters, Jan Stafleu, Ronald Harting, Roula Dambrink, Freek Busschers, Jan Gunnink
3. Geological schematisation of the shallow subsurface of Groningen (For site response to earthquakes for the Groningen gas field) – Part II, Deltares, Pauline Kruiver, Ger de Lange, Ane Wiersma, Piet Meijers, Mandy Korff, Jan Peeters, Jan Stafleu, Ronald Harting, Roula Dambrink, Freek Busschers, Jan Gunnink
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6. Dynamic behaviour of Groningen peat, Analysis and parameters assessment, Deltares, M. Konstantinou, C. Zwanenburg and P. Meijers, October 2017.

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<tr><td>Initiator</td><td>NAM</td></tr>
<tr><td>Autor(s)</td><td>M. Konstantinou, dr.ir. C. Zwanenburg and dr.ir. P. Meijers</td><td>Editors</td><td colspan="2">Jan van Elk and Dirk Doornhof</td></tr>
<tr><td>Organisation</td><td>Deltares</td><td>Organisation</td><td colspan="2">NAM</td></tr>
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<u>Comment:</u>
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NAM has asked Deltares to build a detailed model of the shallow subsurface below Groningen. In preparing this model of the shallow subsurface below Groningen, Deltares has made us of the beta-version of the GEOTOP database of TNO Geologische Dienst Nederland (TNO-NITG) supplemented by more recent data. Additional data collected over the years in support of foundation design and other activities was sourced from Fugro and Wiertsema. These are mainly CPT measurements (cone penetrations tests). Additionally, data measured in the shallow geophone wells was used.
For these calculations of the site response, soil parameters related to stiffness and damping (amongst others) are also necessary. For sand and clay these parameters are derived from well accepted correlations in the literature. However, the properties of locally present peat layers need to be measured in the laboratory. This report and the accompanying report present the measurements performed by Deltares on peat samples from Groningen, the analysis of the experimental data and the assessment of peat properties.</td></tr>
<tr><td>Directliy linked research</td><td colspan="4">(1) Ground Motion Prediction
(2) Quaternary geology of the Groningen area</td></tr>
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Assessment of dynamic properties for peat

Factual Report

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Assessment of dynamic properties for peat

Factual Report

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Title
Assessment of dynamic properties for peat

Client	Project	Reference	Pages
NAM	1209862-011	1209862-011-GEO-0003	28

Keywords
Dynamic properties, peat, Groningen, earthquake, laboratory testing, factual report

Summary
In order to conduct a risk and hazard assessment for earth quakes in Groningen dynamic sub soil properties are needed. For clays and sands well established properties are available. For peats however limit information on dynamic information is available. Therefore a series laboratory tests on peat samples from Groningen have been conducted.

In total 20 k_0-CRS tests, 20 static Direct Simple Shear tests, 26 Resonant column tests and 10 cyclic Direct Simple Shear tests have been conducted at Ruhr Universität Bochum, Norwegian Geotechnical Institute and Deltares. Bender element measurements have been conducted on the specimen used for resonant column tests. For each tested sample the density, dry density, particle density, water content and loss on ignition is determined.

The results are reported in two reports. This report is the factual report which provides all the measurement data and information on testing procedures, sample selection etc. A companion report provides an analysis and the actual parameter assessment.

References
Contract UI46802

Version	Date	Author	Initials	Review	Initials	Approval	Initials
1	Nov 2016	Dr.ir. C. Zwanenburg		Dr.ir. P. Meijers		Ir. L. Voogt	
		M. Konstantinou					

State
final

Contents

1 Introduction

1.1 Back ground

In accordance to contract UI46802, 10 July 2014, Deltares is working on a risk and hazard assessment for earthquakes in the Groningen area. The risk assessment includes calculations with computer program STRATA for establishing the subsoil response to earthquakes. The required soil parameters for sand and clay are taken using well accepted correlations described in the literature. , In the area of interest, however, also peat layers are present. The dynamic properties of peat, needed for the STRATA calculations, are not well known. To determine the required parameters a field and laboratory study is conducted.

The results of the field and laboratory study are reported by two reports. This report, the factual report, provides an overview of all the test results and testing details. The companion report 1209862-011-GEO-0005 provides data analysis, the parameter assessment and comparison of the obtained results with literature data.

1.2 Objective of this study

The objective of this study is to derive dynamic parameters for the peat layer(s) present in the Groningen area. The parameters are needed for the soil response calculations.
The required parameters consist of shear wave velocity, maximum shear modulus, shear modulus reduction curve and damping curve.

1.3 Research plan

The research was conducted in accordance to the following general steps:

- At the start a literature survey was conducted to gather the available (limited) information on the dynamic parameters of peat.
- Based on the results of the literature survey and the geology of the area locations are selected for soil sampling and peat samples were retrieved.
- The required parameters consist of shear wave velocity, maximum shear modulus, shear modulus reduction curve and damping curve. Parameter assessment requires dynamic testing, such as bender element measurements and resonant column testing. The dynamic testing is conducted by GEO-RUHR Bochum, Germany.
- A number of dynamic tests are conducted in duplo at the Norwegian Geotechnical Institute, NGI.
- Dynamic testing involves small strain testing. However information on larger strains is also needed. Therefore, static and cyclic DSS tests were conducted at Deltares. The results of the static and cyclic DSS tests are also used for classification and comparison to literature data.

2 Field investigation

2.1 Selection sample site

2.1.1 General considerations

The literature review, presented in the companion analysis report suggests that the dynamic properties for peat depend on the pre-consolidation stress and degree of humification. In the Groningen area, both superficial peat layers and peat at a moderate depth are present. The superficial peat layers are likely to have a low pre-consolidation stress while the deeper layers might have a larger pre-consolidation stress. Beforehand, it was expected that both, strongly decayed peat and non- or little decayed peat is present in the Groningen area. Sample selection is based on both criteria; level of pre-consolidation stress and level of humification. It should be noted that beforehand the pre-consolidation stress and degree of humification was not exactly known. Geological description of the samples provided the actual degree of humification and oedometer tests provided information on the pre-consolidation tests.

The selection of sample locations was a stepwise procedure. In the first step a pre-selection was made, based upon general geological understanding of the area and archive material. In a second step the results of the archive study were checked and further elaborated by a series hand augers. The next sections show the results of the successive steps.

2.1.2 Step 1, Results archive study

Appendix A shows the results of the archive study. Relevant borings from the DINO database[1] were selected and interpreted by a geologist, who is familiar with the region. This resulted in 10 profiles, also presented in Appendix A. The location of the profiles is based on the availability of the data, the expert knowledge on expected presence of sub soil peat layers and the location of the profiles in relation to the gas field contour.

From the profiles the 4 most favourable locations were selected. The selected was based upon:

- The thickness of the peat given in the profiles.
- The presence of superficial and deeper peat layers.
- Expected differences in level of decay.
- The availability and accessibility of the location for drilling equipment.

Figure 2.1 shows the 4 locations following from the pre-selection, in which:

1. Nieuwolda, NW
2. Schildmeer, SM
3. Scheemda
4. Siddeburen, SB

In the identification of the borings and samples the above mention abbreviations, NW, SM and SB are used.

[1] *Available through https://www.dinoloket.nl/*

Figure 2.1 Pre-selection of 4 sampling sites

2.1.3 Step 2, Results hand augers

To test the outcome of step 1, in total 10 hand augurs were conducted. The samples were carefully sealed in pvc tubes and brought to the laboratory. In the laboratory the samples were cut lengthwise in two halves. One half was used for inspection and description by a geologist. The second half was photographed. The photos of the hand augers are given in Appendix B.

Number	Location	x [m]	y [m]	z [m NAP]	H [m]
1A-1	Nieuwolda	260100.36	584607.78	-1.16	5.90
1A-2		260167.86	584506.73	-1.47	5.95
1A-3		260135.43	584467.53	-1.26	6.00
2A	Schildmeer	248352.90	587562.34	-1.81	3.00
2B		247610.40	588754.16	-1.59	4.00
2C		248925.97	587242.91	-1.51	3.00
3A	Scheemda	259016.70	577386.50	-0.55	2.55
3B		258962.06	577148.66	-0.14	3.55
4A	Siddeburen	254673.31	583348.20	-1.69	2.45
4B		254860.71	583418.56	-2.61	2.45

Table 2.1 Summary of Hand auger results, exact location in x and y (RD coordinates, the Dutch coordinate system), ground level z is related to NAP and sample length, H

Table 2.1 gives the exact location of the hand augers in x and y-coordinates. The ground level, z, is given in relation to the NAP reference datum. The last column gives the total sample length.

The samples were described by a geologist prior to their distribution to different laboratories for testing purposes. The results are also given by Appendix B. Regarding the peat layer, the soil description is focussed on the distinction between peat, strongly organic clay, Gyttja, and wood. Attention was also given to the degree of humification, in which two levels were distinguished, decomposed (sterk amorf) and non- or little decomposed.

2.1.4 Step 3, Final selection

Based on the geologist description of the hand augers, it was decided to focus on location 1, Nieuwolda, 2, Schildmeer and 4, Siddeburen.

2.2 Piston samples

A stationary Piston Sampler was used for sampling. The sampling was conducted by Fugro GeoServices b.v. in accordance to Eurocode 7 and EN /ISO 22475-1. The sampling activities were supervised by Deltares. The samples were stored in a climate controlled room, at temperature 10° ± 1° C.

Number	Location	x [m]	y [m]	z [m NAP]	H [m]
NW1a2-a	Nieuwolda	260167.797	584506.106	-1.528	5.95
NW1a2-b		260167.112	584506.524	-1.566	1.85
NW1a2-c		260167.639	584507.438	-1.546	1.85
NW1a2-d		260168.404	584507.154	-1.541	1.85
SM2c-a	Schildmeer	248925.612	587243.255	-1.596	3.40
SM2c-b		248926.379	587242.934	-1.548	0.85
SM2c-c		248925.655	587242.203	-1.530	0.85
SB4a-a	Siddeburen	254673.413	583348.284	-1.875	2.65
SB4a-b		254673.701	583349.280	-1.816	0.85
SB4a-c		254672.545	583348.509	-1.796	0.85

Table 2.2 Overview Piston samples, exact position is given by x, y co-ordinates, the ground level, z, is related to NAP datum, H represents total sample length

Table 2.2 shows an overview of the piston samples. At each location, for one boring, the top layer is sampled too. In the other borings only the peat layer was sampled. Sampling the top layer allowed for the assessment of the density which is used for the assessment of the initial effective, field, stress.

Appendix C shows the photos of the piston samples. It should be noted that the photos were taken after selection of specimen for testing, which explains the gaps in the samples. To support specimen selection a thin layer was cut from piston samples to allow description of the original, undisturbed material.

2.3 Hydraulic conditions

The specimens are mainly tested at field effective stress level. To estimate the field effective stress level information on hydraulic conditions is required. Information on the ground water table is derived from the database DINO loket.

Number	Location	x [m]	y [m]	range	max [m gl]	min [m gl]
B08C0064	Nieuwolda	260984	585067	1992-present	0.76	1.20
B07G0093	Schildmeer	248977	587140	1978-present	0.48	0.85
B07H0118	Siddeburen	253427	583220	1992-present	0.65	1.63

Table 2.3 Overview hydraulic data, number and location stand pipe, measurement period and maximum and minimum water table related to ground level

2.4 Testing specimen

From the samples, given by Table 2.2, the specimen are selected and further trimmed. Preferably samples are split in sub-samples with a length of 25 cm. Next the subsamples are further divided into 3 subsamples:

- A 15 cm piece from which a specimen for resonant column testing/bender element is trimmed.
- A 5 cm piece from which a specimen for K0-CRS test is trimmed.
- A 5 cm piece from which a specimen for static DSS test is trimmed.

The basic idea was to have homogeneous 15 cm samples for which RC, DSS and K0-CRS data would be available.

When selecting the samples and specimen it was found that not always 15 cm of more or less homogeneous material was available. Therefore, not for all sub samples complete sets could be made. The specimens for cyclic DSS tests are selected in a later stage from samples that were kept in storage as spare samples.

Specimen ID	Depth top [gl m]	Depth top [NAP m]	$\sigma'_{v,0}$ [kN/m^2]	Laboratory	Test type
NW1A2-a4-1a	-3.10	-4.63	25.14	spare	
NW1A2-a4-1b	-3.25	-4.78	26.30	Deltares	DSS
NW1A2-a5-1A	-3.70	-5.23	25.84	NGI	RC-test
NW1A2-a5-1B	-3.85	-5.38	27.20	Deltares	K0-CRS
NW1A2-a5-1C	-3.90	-5.43	27.25	Deltares	K0-CRS
NW1A2-a5-1D	-3.95	-5.48	25.64	RUB	RC-test
NW1A2-a5-1E	-4.15	-5.68	27.35	Deltares	DSS
NW1A2-a6-1A	-4.30	-5.83	26.54	RUB	RC-test
NW1A2-a6-1B	-4.45	-5.98	27.90	Deltares	K0-CRS
NW1A2-a6-1C	-4.50	-6.03	27.76	Deltares	DSS
NW1A2-a6-2A	-4.80	-6.33	27.13	NGI	RC-test
NW1A2-a6-2B	-4.95	-6.48	28.29	Deltares	K0-CRS
NW1A2-a7-1A	-5.25	-6.78	27.65	RUB	RC-test
NW1A2-a7-1B	-5.40	-6.93	28.81	Deltares	K0-CRS
NW1A2-a7-1C	-5.45	-6.98	28.87	Deltares	DSS
NW1A2-a7-2a	-5.55	-7.08	28.99	Deltares	DSS
NW1A2-a7-2b	-5.60	-7.13	29.34	Deltares	K0-CRS
NW1A2-a7-2C	-5.62	-7.15	29.27	Deltares	cyclic DSS

Specimen ID	Depth top [gl m]	Depth top [NAP m]	$\sigma'_{v,0}$ [kN/m^2]	Laboratory	Test type
NW1A2-b1-1A	-3.58	-5.15	27.04	Deltares	K0-CRS
NW1A2-b1-1B	-3.60	-5.17	27.06	Deltares	K0-CRS
NW1A2-b1-1C	-3.62	-5.19	27.08	Deltares	cyclic DSS
NW1A2-b1-2A	-3.70	-5.27	25.90	NGI	RC-test
NW1A2-b1-2B	-3.85	-5.42	26.08	RUB	RC-test
NW1A2-b1-2C	-4.00	-5.57	27.70	Deltares	DSS
NW1A2-b1-2D	-4.02	-5.59	27.43	Deltares	cyclic DSS
NW1A2-b1-3A	-4.10	-5.67	26.38	RUB	RC-test
NW1A2-b1-3B	-4.25	-5.82	25.90	Deltares	DSS
NW1A2-b2-1	-4.90	-6.47	27.04	NGI	RC-test
NW1A2-b2-2A	-5.10	-6.67	27.57	RUB	RC-test
NW1A2-b2-2B	-5.25	-6.82	29.83	Deltares	DSS
NW1A2-c1-1A	-3.60	-5.15	25.29	RUB	RC-test
NW1A2-c1-1B	-3.80	-5.35	27.00	Deltares	DSS
NW1A2-c1-1C	-3.85	-5.40	27.36	Deltares	K0-CRS
NW1A2-c1-1D	-3.90	-5.45	27.42	Deltares	K0-CRS
NW1A2-c1-1E	-3.95	-5.50	26.20	NGI	RC-test
NW1A2-c1-2a	-4.15	-5.70	27.42	Deltares	DSS
NW1A2-c1-2b	-4.20	-5.75	26.50	RUB	RC-test
NW1A2-c2-1a	-4.85	-6.40	28.25	Deltares	DSS
NW1A2-c2-1b	-4.90	-6.45	27.33	RUB	RC-test
NW1A2-c2-2a	-5.15	-6.70	28.61	Deltares	DSS
NW1A2-c2-2b	-5.20	-6.75	27.69	RUB	RC-test
NW1A2-d1-1A	-3.67	-5.21	25.87	RUB	RC-test
NW1A2-d1-1B	-3.82	-5.36	27.22	Deltares	K0-CRS
NW1A2-d1-1C	-3.87	-5.41	27.28	Deltares	K0-CRS
NW1A2-d1-1D	-3.92	-5.46	26.85	Deltares	DSS
NW1A2-d1-1E	-3.85	-5.39	27.36	Deltares	cyclic DSS
NW1A2-d1-1F	-3.90	-5.44	27.42	Deltares	cyclic DSS
NW1A2-d1-2	-4.15	-5.69	26.34	RUB	RC-test
NW1A2-d2-1A	-4.75	-6.29	28.33	Deltares	K0-CRS
NW1A2-d2-1B	-4.80	-6.34	28.20	Deltares	DSS
NW1A2-d2-1C	-4.85	-6.39	27.27	RUB	RC-test
NW1A2-d2-1D	-4.78	-6.32	28.47	Deltares	cyclic DSS
NW1A2-d2-2A	-5.00	-6.54	27.45	RUB	RC-test
NW1A2-d2-2B	-5.15	-6.69	28.81	Deltares	K0-CRS
NW1A2-d2-2C	-5.20	-6.74	28.67	Deltares	DSS
NW1A2-d2-2D	-5.18	-6.72	28.94	Deltares	cyclic DSS
SB4A-A2-1A	-1.16	-3.04	7.05	Deltares	K0-CRS
SB4A-A2-1B	-1.18	-3.06	4.97	RUB	RC-test
SB4A-A2-1C	-1.35	-3.23	6.16	Deltares	cyclic DSS
SB4A-A2-2A	-1.40	-3.28	4.68	RUB	RC-test
SB4A-A2-2B	-1.55	-3.43	6.06	Deltares	K0-CRS
SB4A-A2-2C	-1.60	-3.48	5.53	Deltares	DSS
SM2C-A2-1A	-1.42	-3.02	8.11	Deltares	DSS

Specimen ID	Depth top [gl m]	Depth top [NAP m]	$\sigma'_{v,0}$ [kN/m^2]	Laboratory	Test type
SM2C-A2-1B	-1.47	-3.07	6.67	RUB	RC-test
SM2C-A2-1C	-1.44	-3.04	8.00	spare	
SM2C-A3-1A	-1.90	-3.50	6.64	RUB	RC-test
SM2C-A3-1B	-2.05	-3.65	8.07	Deltares	DSS
SM2C-A3-1C	-2.07	-3.67	8.07	Deltares	cyclic DSS
SM2C-A3-2A	-2.22	-3.82	8.06	Deltares	K0-CRS
SM2C-A3-2B	-2.24	-3.84	6.51	spare	
SM2C-B1-1A	-1.77	-3.32	8.12	RUB	RC-test
SM2C-B1-1B	-1.92	-3.47	9.55	Deltares	K0-CRS
SM2C-B1-1C	-1.97	-3.52	9.31	Deltares	DSS
SM2C-B1-2A	-2.14	-3.69	9.49	Deltares	K0-CRS
SM2C-B1-2B	-2.20	-3.75	9.70	Deltares	K0-CRS
SM2C-B1-2C	-2.22	-3.77	9.47	Deltares	cyclic DSS
SM2C-B1-2D	-2.25	-3.80	8.68	spare	
SM2C-C1-1A	-1.80	-3.33	8.01	RUB	RC-test
SM2C-C1-1B	-1.95	-3.48	9.10	Deltares	DSS
SM2C-C1-2	-2.13	-3.66	7.57	NGI	RC-test

Table 2.4 Overview tested specimen, gl = ground level; NAP = reference datum, σ'_{vi} = vertical effective field stress level

2.5 Testing procedure

To ensure consistency of the test results among the different laboratories a guideline testing procedure document has been provided to all parties prior to the start of testing. This document is given in Appendix D. Table 1 in this document lists the standards according to which the index classification and advanced tests are performed.

3 Laboratory testing RUB

Resonant column tests and bender element measurements were conducted on 20 specimens at Ruhr Universität Bochum, RUB. Appendix E reports the tests and results. Table 3.1 gives a summary of the characteristics of the specimens tested at RUB.

The resonant column tests form the core of the assessment of the dynamic parameters for peat. Analysis of the data and the actual parameter assessment are given in the analysis report 1209862-011-GEO-0005.

Specimen nr	Depth [m NAP]	Depth [m gl]	ρ [gr/cm^3]	ρ_s [gr/cm^3]	w [%]	LOI [%]	hum
NW1A2-a5-1D	-5.48	-3.95	1.09	1.52	471.2	83.2	a
NW1A2-a6-1A	-5.83	-4.30	1.06	1.49	523.3	89.0	a
NW1A2-a7-1A	-6.78	-5.25	1.06	1.70	486.9	70.7	a
NW1A2-b1-2B	-5.42	-3.85	1.05	1.55	468.9	80.9	a
NW1A2-b1-3A	-5.67	-4.10	1.03	1.46	549.1	91.6	a
NW1A2-b2-2A	-6.67	-5.10	1.04	1.44	539.5	92.9	a
NW1A2-c1-1A	-5.15	-3.60	1.03	1.54	464.0	81.2	a
NW1A2-c1-2b	-5.75	-4.20	1.03	1.45	579.2	91.4	a
NW1A2-c2-1b	-6.45	-4.90	1.04	1.49	608.1	92.3	a
NW1A2-c2-2b	-6.75	-5.20	1.03	1.46	633.0	90.1	a
NW1A2-d1-1A	-5.21	-3.67	1.08	1.48	484.3	89.0	a
NW1A2-d1-2	-5.69	-4.15	1.01	1.46	508.4	87.5	b
NW1A2-d2-1C	-6.39	-4.85	1.03	1.47	606.6	92.2	a
NW1A2-d2-2A	-6.54	-5.00	1.05	1.44	579.6	90.3	a
SB4A-A2-1B	-3.06	-1.18	1.01	1.46	542.5	94.0	b
SB4A-A2-2A	-3.28	-1.40	1.02	1.47	513.9	90.8	b
SM2C-A2-1B	-3.07	-1.47	1.05	1.49	659.8	88.4	a
SM2C-A3-1A	-3.50	-1.90	1.05	1.54	556.6	82.9	b
SM2C-B1-1A	-3.32	-1.77	0.99	1.48	746.9	87.9	a
SM2C-C1-1A	-3.33	-3.95	1.18	1.48	689.4	87.8	a

Table 3.1 Characteristics of specimen tested at RUB, NAP = reference datum, gl = ground level, ρ = density of the specimen before testing, ρ_s = density of the solid particles, w = water content, LOI = loss on ignition, hum = degree of humification, a = not –moderate humified, b = strongly humified

4 Laboratory testing NGI

In total six specimens were subjected to resonant column test and bender element measurements at the Norwegian Geotechnical Institute, NGI. The main purpose of these tests is to cross check results found by RUB. It should be noted that tests at NGI were finished before the tests at RUB started. However, RUB did not have access to the NGI data until their tests were finished.

Appendix F provides the full report of the tests and measurements conducted at NGI. Table 4.1 gives the characteristics of the specimens tested at NGI. An analysis of the results and a comparison between the RUB and NGI data is presented in the analysis report 1209862-011-GEO-0005.

Specimen nr	Depth [m NAP]	Depth [m gl]	ρ [gr/cm^3]	ρ_s [gr/cm^3]	w [%]	LOI [%]	hum
NW1A2-a5-1A	-5.23	-3.70	1.02	1.57	467	85.4	a
NW1A2-a6-2A	-6.33	-4.80	1.02	1.50	620	89.8	a
NW1A2-b1-2A	-5.27	-3.70	1.02	1.48	487	86.6	a
NW1A2-b2-1	-6.47	-4.90	1.02	1.64	567	89.5	a
NW1A2-c1-1E	-5.50	-3.95	1.02	1.68	490	85.2	a
SM2C-C1-2	-3.66	-2.13	1.04	1.48	565	72.7	a

Table 4.1 Characteristics of specimen tested at NGI, NAP = reference datum, gl = ground level, ρ = density of the specimen before testing, ρ_s = density of the solid particles, w = water content, LOI = loss on ignition, hum = degree of humification, a = not –moderate humified, b = strongly humified

5 Static Direct Simple Shear tests

The DSS tests is conducted in accordance to Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Cohesive Soils, ASTM D 6528-07 American Society for the Testing of Materials and NORSOK standard G-0001, Annex D: Laboratory testing, Rev.2, October 2004. In total 20 specimens have been tested, divided in samples with different degree of humification and pre-consolidation stress. Table 5.1 gives an overview of the characteristics of the tested specimens. The particle density, ρ_s, and Loss On Ignition, LOI, are determined after testing. The water content, *w*, reflects initial conditions, before testing. The Over Consolidation Ratio, OCR, represents the ratio of pre-consolidation stress, σ'_{vy} and the vertical effective stress, σ'_{v0} at the start of the shearing phase. The value for σ'_{vy} is derived from the K_0-CRS test results, see chapter 7. The samples are consolidated at field stress level, the vertical effective stress, σ'_{vi} at the start of the shearing phase is equal to the estimated vertical field stress level, σ'_v. The value for σ'_v is estimated from the density of the top layers and ground water table respectively the hydraulic head in underlying sand layer.

Specimen nr	Depth [m NAP]	Depth [m gl]	ρ [gr/cm^3]	ρ_s [gr/cm^3]	w [%]	LOI [%]	OCR [-]	hum
NW1A2-A4-1B	-4.79	-3.26	0.99	1.51	507.9	82.9	1.70	a
NW1A2-A5-1E	-5.69	-4.16	0.92	1.50	479.4	89.5	1.63	a
NW1A2-a6-1C	-6.04	-4.51	0.98	1.50	569.2	87.4	1.39	a
NW1A2-A7-1C	-6.99	-5.46	0.91	1.48	653.9	86.9	1.08	a
NW1A2-A7-2A	-7.09	-5.56	0.96	1.48	524.5	86.9	1.64	b
NW1A2-B1-2C	-5.58	-4.01	0.99	1.54	469.9	82.8	1.46	a
NW1A2-B1-3B	-5.83	-5.83	0.95	1.47	524.7	91.3	1.39	a
NW1A2-B2-2B	-6.83	-5.26	0.87	1.48	633.4	92.8	1.09	a
NW1A2-C1-1B	-5.36	-3.81	1.00	1.54	487.5	83.3	1.56	a
NW1A2-C1-2A	-5.71	-4.16	0.94	1.47	554.1	90.5	1.43	a
NW1A2-C2-1A	-6.41	-4.86	0.89	1.47	606.1	92.4	1.22	a
NW1A2-C2-2A	-6.71	-5.16	0.94	1.45	581.6	92.4	1.13	a
NW1A2-d1-1D	-5.47	-3.93	0.99	1.43	518.5	92.4	1.56	a
NW1A2-d2-1B	-6.35	-4.81	0.96	1.45	659.3	92.8	1.04	a
NW1A2-d2-2C	-6.75	-5.21	0.94	1.44	612.4	92.2	1.23	a
SB4A-A2-2C	-3.49	-1.61	0.93	1.44	533.4	92.9	4.04	b
SM2C-A2-1A	-3.03	-1.43	1.00	1.62	476.5	70.1	1.60	a
SM2C-A3-1B	-3.66	-2.06	1.01	1.90	454.7	70.1	3.14	b
SM2C-B1-1C	-3.53	-1.98	0.91	1.59	538.6	73.5	1.61	a
SM2C-C1-1B	-3.49	-1.96	0.89	1.47	680.5	88.0	1.61	a

Table 5.1 Summary of static DSS tests; characteristics of tested samples. gl = ground level, ρ = initial density, ρs = density solid material, w = water content, LOI = loss on ignition, OCR = over consolidation ratio, mu = degree of humification, a = not –moderate humified, b = strongly humified

Appendix G shows the individual results for each DSS test. Table 5.2 gives a summary of the results. After consolidation the specimen are sheared at constant height. Shearing at constant height represents undrained testing, Dyvik et al (1987). Changes in vertical stress, needed to fulfil the condition of constant height, reflect the changes in pore pressure that would occur for truly undrained conditions. The samples are sheared at a rate of approximately 8%/h, which is typically used for tests on peat.

Table 5.2 provides the peak strength, $s_{u,peak}$, which is the maximum τ measured during the test. The table also provides the mobilised shear strength at 40% strain, $s_{u,40\%}$, which in Dutch guidelines for dikes stability assessment is used as a proxy for large strain strength, van Duinen (2014).

Specimen nr	σ'_{vi} [kN/m^2]	$d\gamma/dt$ [%/h]	$s_{u,peak}$ [kN/m^2]	$s_{u,40\%}$ [kN/m^2]	$s_{u,peak}$ / σ'_{vi}	$s_{u,40\%}$ / σ'_{vi}
NW1A2-A4-1B	26.27	7.98	21.41	19.52	0.81	0.74
NW1A2-A5-1E	27.39	7.97	20.44	19.39	0.75	0.71
NW1A2-a6-1C	27.85	8.00	21.30	21.17	0.76	0.76
NW1A2-A7-1C	28.89	7.97	19.14	18.66	0.66	0.65
NW1A2-A7-2A	29.01	8.03	21.15	20.15	0.73	0.69
NW1A2-B1-2C	27.20	7.86	20.43	18.70	0.75	0.69
NW1A2-B1-3B	25.89	7.99	22.08	21.08	0.85	0.81
NW1A2-B2-2B	29.83	8.00	21.10	20.91	0.71	0.70
NW1A2-C1-1B	26.94	7.99	22.07	19.69	0.82	0.73
NW1A2-C1-2A	27.41	7.98	22.47	20.86	0.82	0.76
NW1A2-C2-1A	28.31	7.97	21.49	20.91	0.76	0.74
NW1A2-C2-2A	28.55	8.00	23.50	22.94	0.82	0.80
NW1A2-d1-1D	26.59	7.97	19.12	18.04	0.72	0.68
NW1A2-d2-1B	28.20	7.94	17.24	15.81	0.61	0.56
NW1A2-d2-2C	28.71	7.98	19.87	18.54	0.69	0.65
SB4A-A2-2C	5.49	8.02	9.69	9.35	1.77	1.70
SM2C-A2-1A	7.79	7.96	11.84	11.25	1.52	1.44
SM2C-A3-1B	7.17	8.00	9.90	-	1.38	-
SM2C-B1-1C	9.31	8.16	10.17	8.77	1.09	0.94
SM2C-C1-1B	9.10	7.96	10.10	9.84	1.11	1.08

Table 5.2 Summary of static DSS test results

Figure 5.1 and Figure 5.2 provide a graphical overview of the test results. Figure 5.1 gives the shear stress, τ, vertical effective stress, σ'_v graphs. It should be noted that pore pressures are not measured in a DSS test. Fluctuations in vertical stress, caused by the requirement of constant height, represents expected pore pressure fluctuation in truly undrained behaviour. All stress paths tend to align along the 1:1 line in Figure 5.1. This is a typical feature of DSS tests on peat, see Den Haan (2014).

Figure 5.2 shows the stress (τ) – strain (γ) curves. Large displacements are applied in the individual tests. It should be noted that results for shear strains beyond γ = 40% are generally considered to be unreliable.

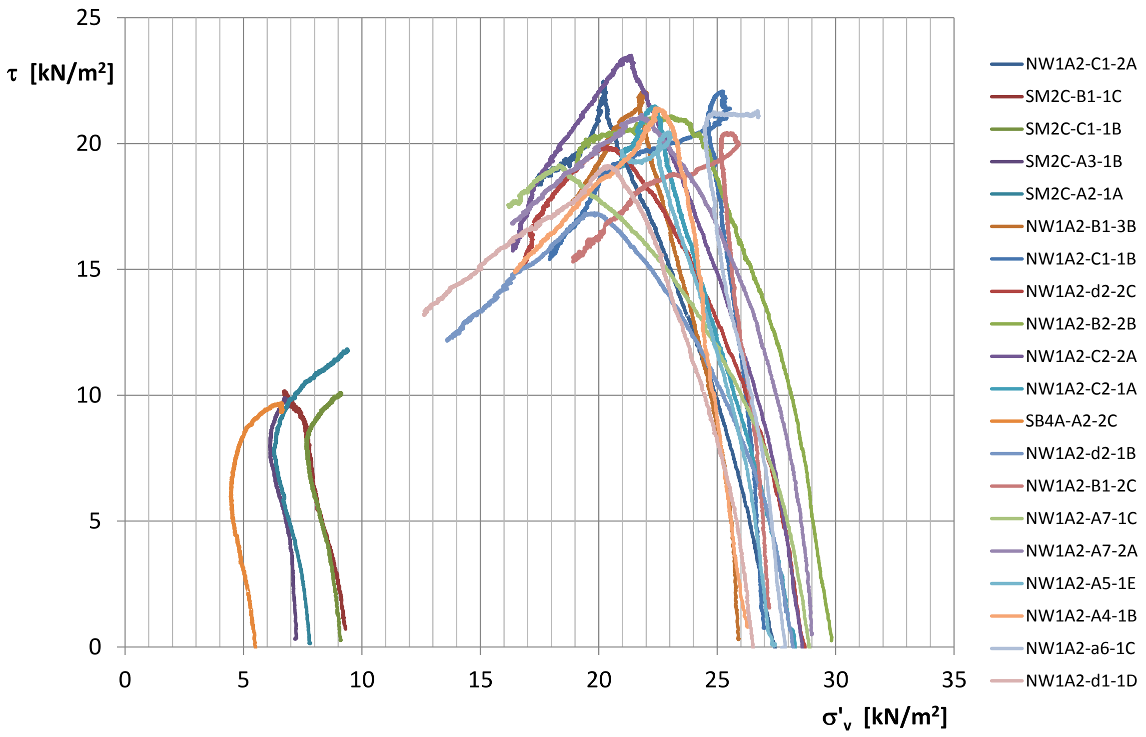

Figure 5.1 Results of static DSS tests, shear stress, τ versus vertical effective stress, σ'_v.

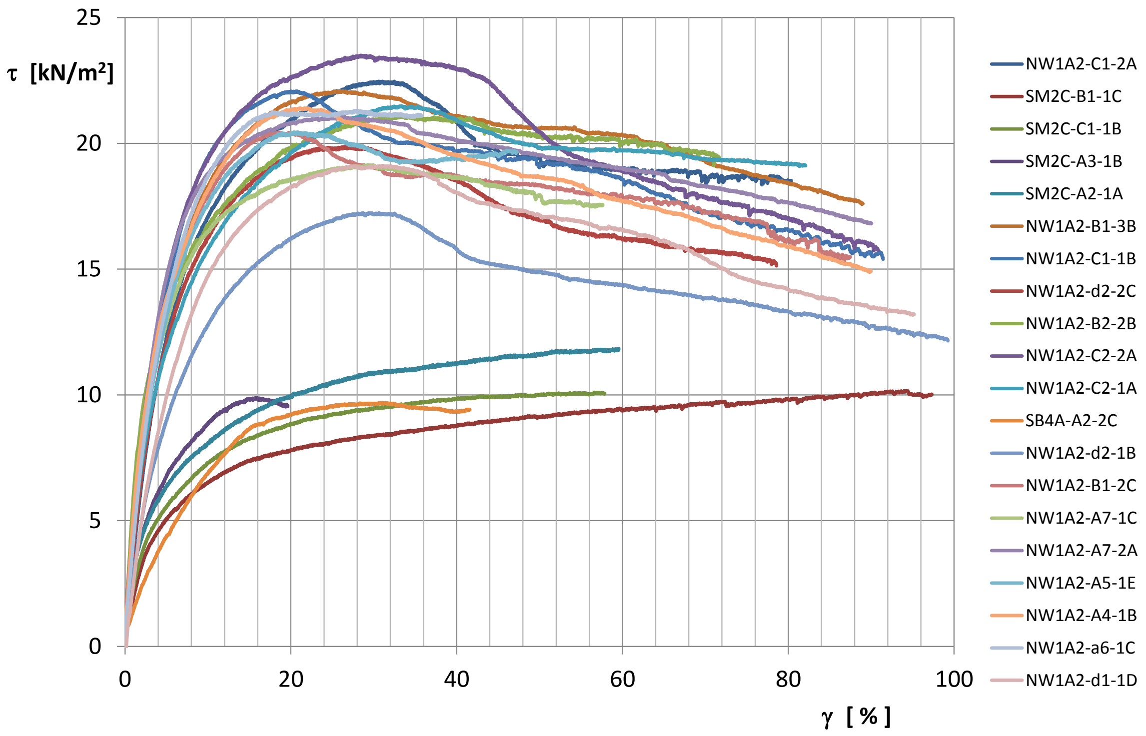

Figure 5.2 Results of static DSS tests, shear stress, τ versus shear strain, γ

Table 5.2 gives the ratio of undrained shear strength, s_u and effective stress at the start of the shearing phase, σ'_{vi}. The ratio s_u / σ'_{vi} strongly depends on the stress history, OCR, according to Ladd (1991):

$$\frac{s_u}{\sigma'_{vi}} = S\left(OCR\right)^m \tag{5.1}$$

In which:

s_u	= undrained shear strength
σ'_{vi}	= vertical effective stress at start shearing phase
S	= s_u- ratio for normally consolidated conditions
OCR	= over consolidation ratio
m	= power

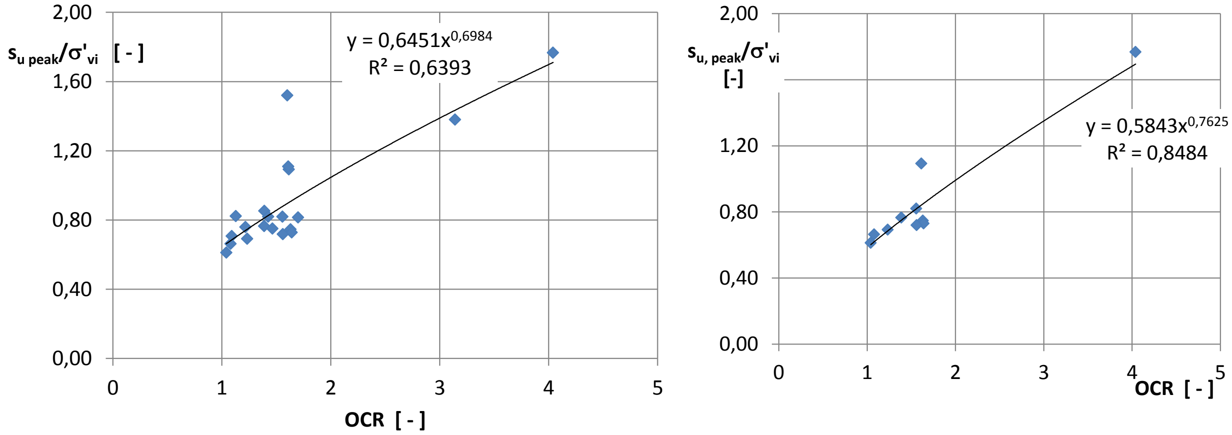

Figure 5.3 Relation $s_{u,peak}$ / σ'_{vi}, left: all data, right: data for which OCR is directly determined

As explained in section 2.4 25 cm samples have been split in specimens to be tested by K0-CRS, DSS, RC/BE etc. This allows for direct comparison for the results of the different tests. Unfortunately, due to limitations in sample length, not all samples could be split this way. The DSS tests for which an adjacent specimen is tested by a K0-CRS test is indicated in Figure 5.2 by σ'_{vy} is directly determined. For other samples the σ'_{vy} is estimated from the depth.

Figure 5.3 shows the results of fitting equation (5.1) to the data by the least squares method. The value for R^2 represents the weighted least squares sum, which is a measure for the accuracy of the fit. The left hand graph shows the fit of all the data. The right hand graph shows the fit of the data points for which the pre-consolidation stress was determined directly. The data points for which the pre-consolidation stress was determined directly show a better fit, indicated by a higher value for R^2 than found when fitting all data.

Parameter	All data	Selection
S	0.65	0.58
m	0.70	0.76
R^2	0.64	0.85

Table 5.3 Fitted parameters for equation (5.1), *selection represents the data points for which σ'_{vy} is determined directly*

The results are summarized by Table 5.3. It should be noted that the undrained shear strength ratio, *S*, for peats is usually considerably larger than found for clays. The value *S* = 0.58 corresponds well to the trend found for Dutch peats, see Zwanenburg & Jardine (2015).

6 K0-CRS tests

Literature seems to indicate that the pre-consolidation stress influences the shear modulus reduction curve and damping curve for peats. To validate this hypothesis for Groningen peat a series of Constant Rate of Strain, CRS oedometer tests are conducted. A CRS test provides a continuous stress strain curve. This allows for a more accurate determination of the pre-consolidation stress than usually found for conventional incremental loading oedometer tests.

The CRS tests is conducted in accordance to Standard Test Method for One-Dimensional Consolidation Properties of Soils Using Controlled-Strain Loading. ASTM D 4186 – 06. American Society for the Testing of Materials. Deltares has developed a CRS device that also measures the horizontal stresses, Den Haan & Kamao (2003). This equipment is especially developed for testing soft soils. The test results allow for analysing the data in p’ – q space and obtaining stiffness parameters for 3D and 2D material models. In total 20 K0-CRS tests are conducted.

A typical K_0-CRS test on peat consists of 6 phases. Table 6.1 gives the maximum respectively the minimum loads for each phase. Two different schemes have been applied. At the Nieuwolda location a clay layer is deposited on top of the peat layer. This leads to higher stresses. Before hand is was expected that at the Nieuwolda location the pre-consolidation stresses in peat layer would be larger than the pre-consolidation stress in the superficial peat layers at Siddeburen and Schildmeer. To assure a good assessment of the pre-consolidation stress a larger load step in phase 1 was applied for the specimen sampled at the Nieuwolda location than applied to the other samples. A larger load step in the first phase implies larger load steps in the following phases.

Phase	**Nieuwolda** **loading till [kN/m^2]**	**Siddeburen / Schildmeer** **loading till [kN/m^2]**
loading	70	25
unloading	14	5
reloading	140	50
relaxation, 16 hours	140	50
reloading	400	150
unloading (end of test)	-	-

Table 6.1 Testing schemes for the Nieuwolda and Siddeburen / Schildmeer samples

In this study K_0-CRS tests are conducted mainly to obtain the pre-consolidation stress. Therefore, conducting phase 1 should be sufficient. However, the extra effort to conduct a complete test, which gives a lot more information on stiffness characteristics of the peat, is small.

Table 6.2 provides the characteristics of the tested specimens.

Specimen nr	Depth [m NAP]	Depth [m gl]	γ [kN/m^3]	γ_s [kN/m^3]	w [%]	LOI [%]	hum
NW1A2-A5-1B	-5.39	-3.87	9.58	14.87	501.0	85.5	a
NW1A2-A5-1C	-5.44	-3.92	7.63	15.22	493.9	83.1	a
NW1A2-A6-1B	-5.99	-4.47	9.98	14.13	620.2	92.5	a
NW1A2-A6-2B	-6.49	-4.97	9.61	14.23	620.2	92.6	a
NW1A2-A7-1B	-6.94	-5.42	9.64	14.9	627.0	82	a
NW1A2-A7-2B	-7.14	-5.61	10.30	16.74	442.2	73.6	b
NW1A2-B1-1A	-5.16	-3.59	9.58	14.76	494.9	86.6	a
NW1A2-B1-1B	-5.18	-3.61	10.26	14.94	521.9	83.2	a
NW1A2-C1-1C	-5.41	-3.86	10.14	15.14	490.4	82.2	a
NW1A2-C1-1D	-5.46	-3.91	9.78	14.81	490.4	85.3	a
MW1A2-D1-1B	-5.37	-3.83	10.00	15.33	469.2	81.2	a
NW1A2-D1-1C	-5.42	-3.88	10.03	15.08	479.7	82.6	a
NW1A2-D2-1A	-6.30	-4.76	9.18	14.71	591.4	89.7	a
NW1A2-D2-2B	-6.70	-5.16	9.60	14.35	637.1	92.7	a
SB4A-A2-1A	-3.05	-1.17	9.94	17.72	397.1	50.9	b
SB4A-A2-2B	-3.44	-1.56	9.68	14.1	558.9	92.5	b
SM2C-A3-2A	-3.83	-2.23	9.90	14.46	360.6	84.8	a
SM2C-B1-1B	-3.48	-1.93	9.10	14.86	748.7	88.2	a
SM2C-B1-2A	-3.70	-2.15	10.36	14.54	718.2	83.7	a
SM2C-B1-2B	-3.76	-2.21	9.61	15.01	691.7	83.7	a

Table 6.2 Characteristics K0-CRS specimen, NAP = reference datum, gl = ground level, ρ = density of the specimen before testing, ρ_s = density of the solid particles, w = water content, LOI = loss on ignition, hum = degree of humification, a = not –moderate humified, b = strongly humified.

Table 6.3 gives a summary of the test results. Detailed results of each individual test are presented by appendix H. The applied displacement rates should be such that the excess pore water pressure does not significantly exceed 10 % of the applied load. Some excess pore water pressure should be measured for the assessment of the permeability characteristics. Specimen NW1A2-A6-2B was the first to be tested. A low displacement rate of 0.07 mm/hour was applied, leading to a long duration of the test. To meet the required planning, larger displacement rates were applied, 0.41 mm/hour. Since for some of these tests the excess pore water pressure exceeded the 10 % of the applied loading at the end of the test, the displacement rate was reduced to 0.29 mm/hour. Table 6.3 gives the applied displacement rate for each test.

Figure 6.1 to Figure 6.6 show some of the test results in graphical form. It should be noted that the Deltares K0-CRS equipment has the option to measure the horizontal stresses during the test. This allows the results to be interpreted in *p’* - *q* space as shown below. For test NW1A2-A6-2B, Figure 6.2 and SM2C-A3-2A, Figure 6.6 a relatively high horizontal effective stress was measured, leading to an horizontal shift of the *p’* – *q* curve of these tests. So far no good explanation for these measurements are found.

Specimen nr	dh/dt [mm/hour]	RR [-]	CR [-]	C_α [-]	σ_{vy} [kN/m^2]
NW1A2-A5-1B	0.41	0.0958	0.5191	0.0434	44.47
NW1A2-A5-1C	0.41	0.0630	0.3936	0.0241	44.42
NW1A2-A6-1B	0.41	0.1047	0.5507	0.0386	38.72
NW1A2-A6-2B	0.07	0.0804	0.4928	0.0385	30.99
NW1A2-A7-1B	0.41	0.0730	0.5697	0.0441	31.10
NW1A2-A7-2B	0.29	0.0813	0.5448	0.0339	48.13
NW1A2-B1-1A	0.29	0.0845	0.5162	0.0533	37.80
NW1A2-B1-1B	0.29	0.1020	0.5396	0.0402	37.85
NW1A2-C1-1C	0.29	0.0953	0.5045	0.0410	42.57
NW1A2-C1-1D	0.29	0.0915	0.5117	0.0507	43.09
MW1A2-D1-1B	0.41	0.0863	0.4655	0.0429	42.47
NW1A2-D1-1C	0.29	0.1000	0.5489	0.0429	44.54
NW1A2-D2-1A	0.30	0.1053	0.4831	0.0382	29.49
NW1A2-D2-2B	0.29	0.1107	0.5468	0.0437	35.50
SB4A-A2-1A	0.29	0.0328	0.4145	0.0449	25.82
SB4A-A2-2B	0.23	0.0396	0.4654	0.0580	24.49
SM2C-A3-2A	0.29	0.0359	0.4329	0.0327	25.29
SM2C-B1-1B	0.23	0.0413	0.5024	0.0723	15.41
SM2C-B1-2A	0.29	0.0504	0.5166	0.0407	16.41
SM2C-B1-2B	0.29	0.0448	0.5353	0.0469	17.15

Table 6.3 Summary of the K0-CRS test results

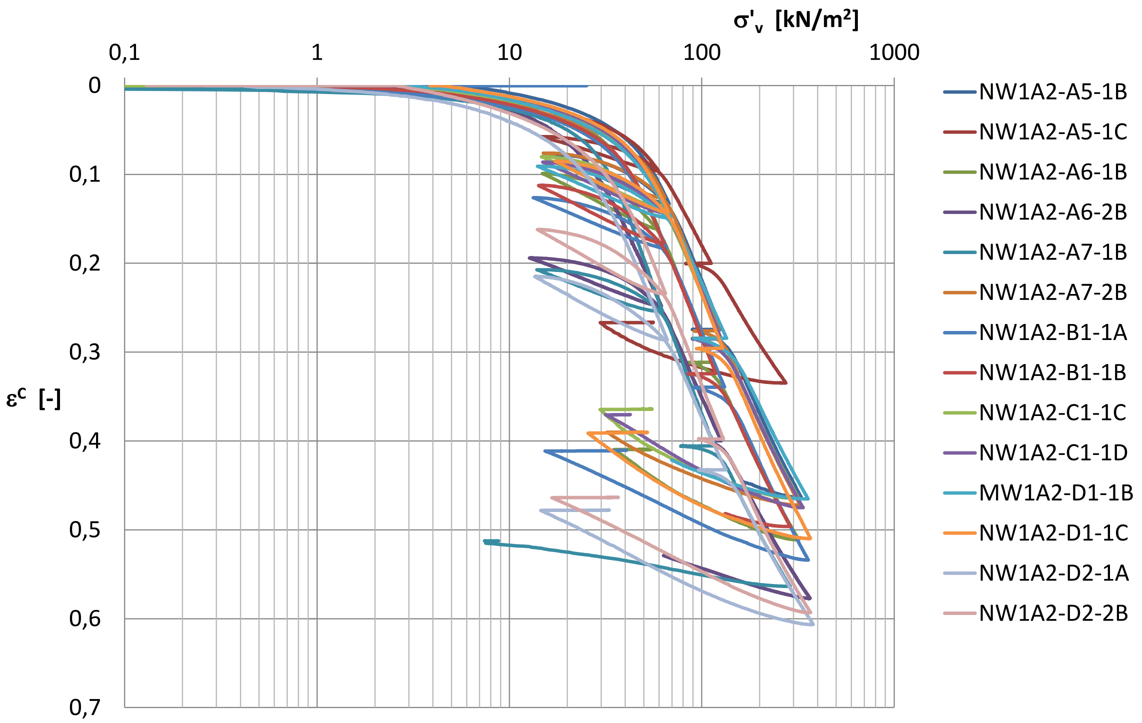

Figure 6.1 Results of the K0-CRS tests for specimen sampled at the Nieuwolda location; stress strain relation, vertical effective stress, σ'_v versus strain ε^C

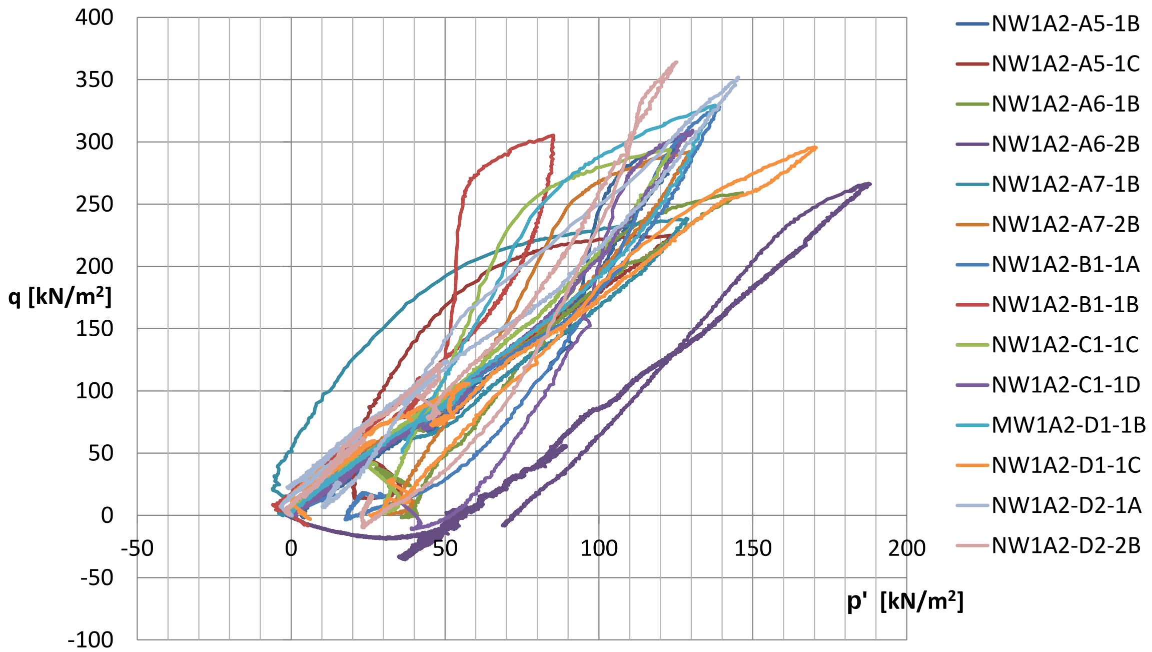

Figure 6.2 Results of the K0-CRS tests for specimen sampled at the Nieuwolda location; stress paths, isotropic effective stress p' versus deviatoric stress q

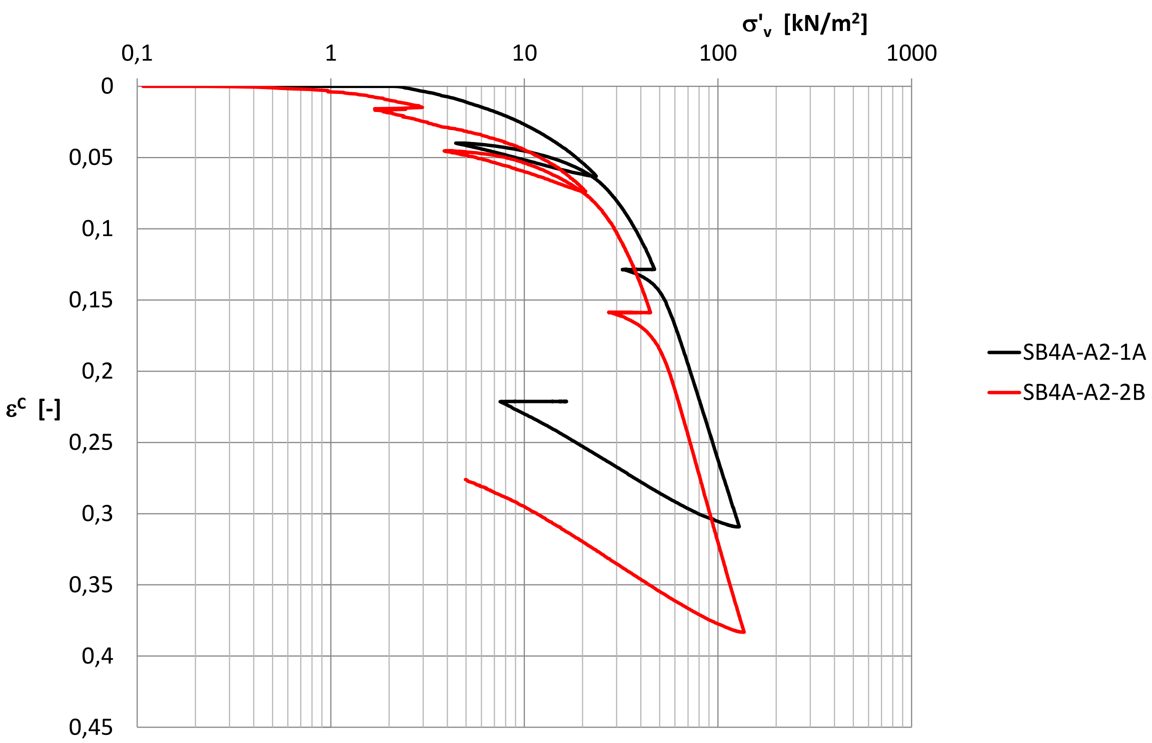

Figure 6.3 Results of the K0-CRS tests for specimen sampled at the Siddeburen location; stress strain relation, vertical effective stress, σ'_v versus strain ε^C

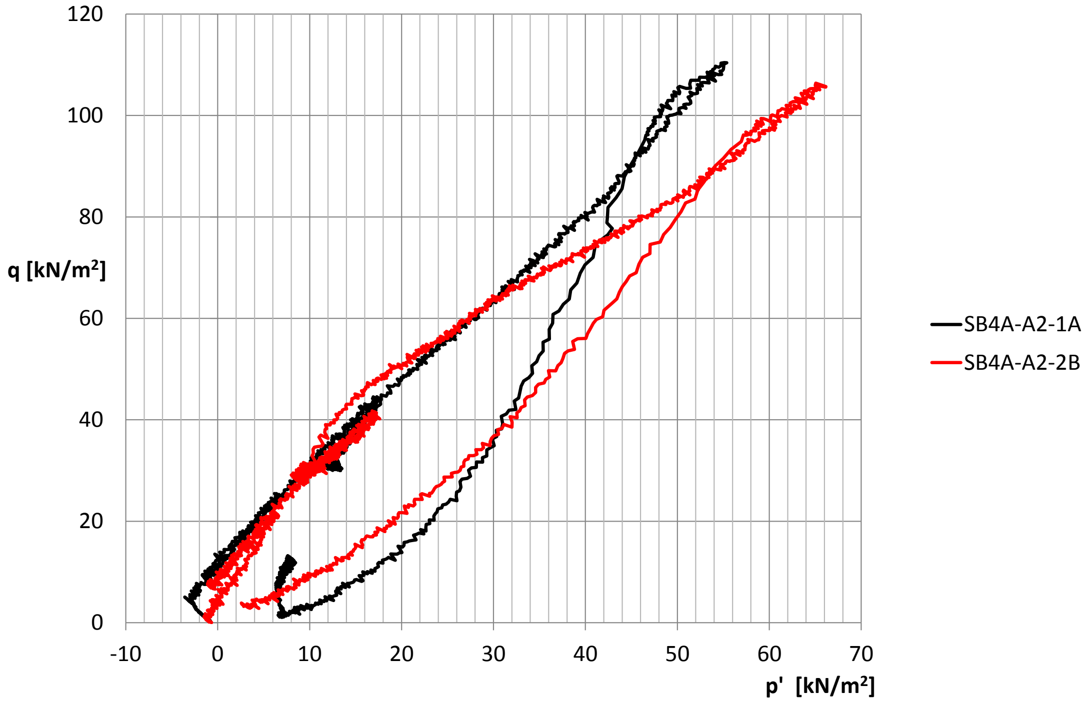

Figure 6.4 Results of the K0-CRS tests for specimen sampled at the Siddeburen location; stress paths, isotropic effective stress p' versus deviatoric stress q

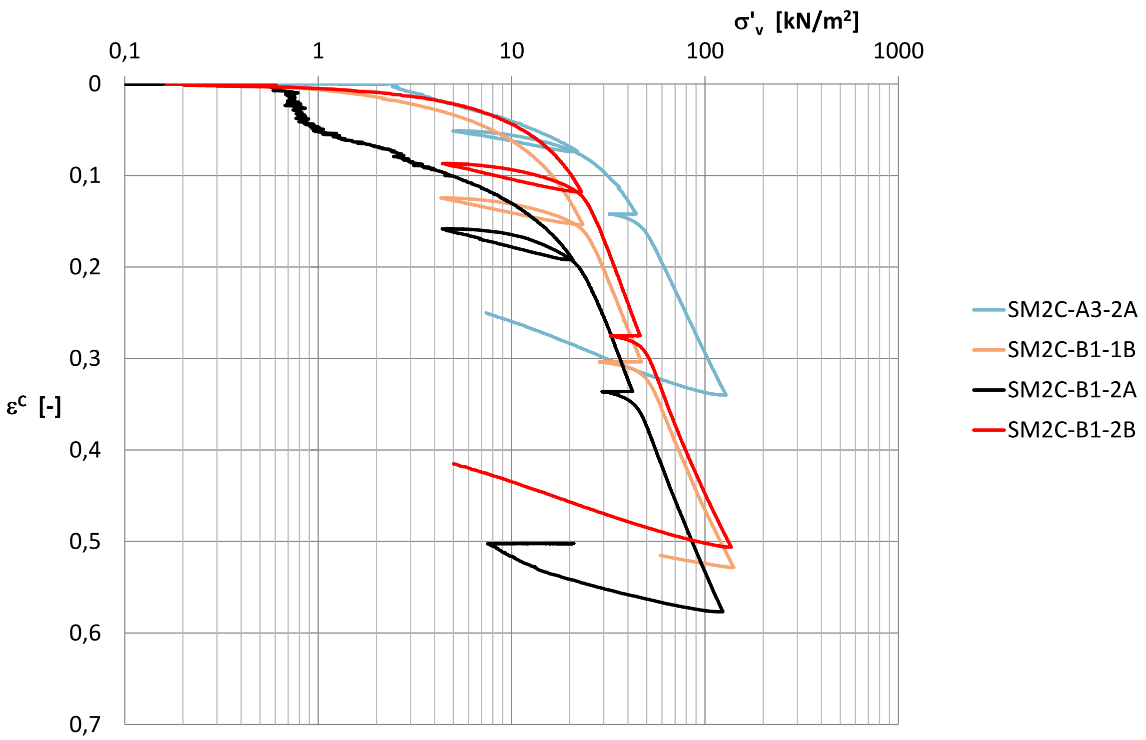

Figure 6.5 Results of the K0-CRS tests for specimen sampled at the Schildmeer location; stress strain relation, vertical effective stress, σ'_v versus strain ε^C

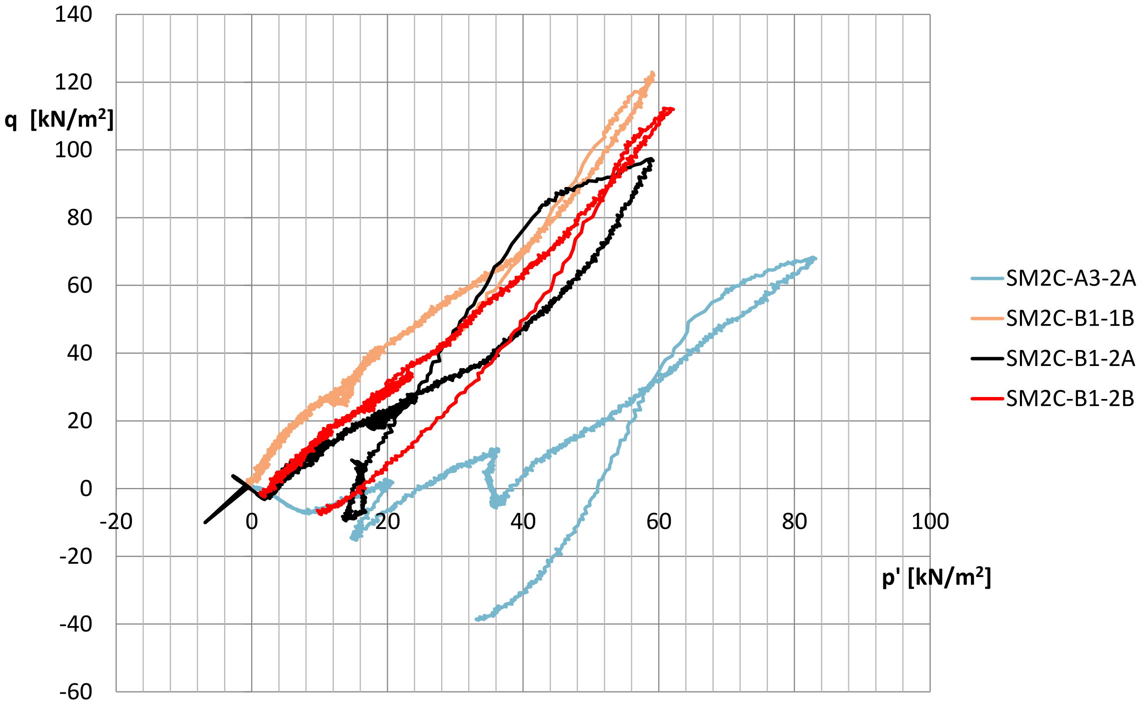

Figure 6.6 Results of the K0-CRS tests for specimen sampled at the Schildmeer location; stress paths, isotropic effective stress p' versus deviatoric stress q

7 Dynamic Direct Simple Shear tests

7.1 Introduction

For accessing the dynamic properties of peat soil in the area of Groningen a number of cyclic simple shear tests (cyDSS) were performed. The stress-strain behaviour was measured under cyclic shear strains ranging from approximately 0.06% up to 40%. Tests were performed on samples retrieved from three different locations; Nieuwolda, Schildmeer and Siddeburen. In this section the results from these tests are summarized and presented.

7.2 Testing equipment

The cyclic direct simple shear apparatus in Deltares lab, manufactured by Wille Geotechnic, has been used for the performance of the series of tests presented in this Chapter. The cyclic simple shear device has been modified to allow cyclic testing of soft soils such as peat.
Modification included the replacement of the horizontal shearing force plates with a three dimensional (3D) load cell. During application of a horizontal shear force a measurable friction of approximately 5 – 7 kPa is developed when the horizontal shear plates are used. When the 3D load cell is employed the occurrence of frictional resistance is minimized.
The measurement system consisted of the following components:

- A 5 kN measuring range load cell (Serial number 1000861) for the measurement of vertical force.
- A 500 N measuring range load cell (Serial number 13304292) for the measurement of horizontal force.
- A 25 mm measuring range potentiometer (Serial number 090319/A) for the measurement of vertical displacement and
- A ±12.5 mm measuring range LVDT for the measurement of horizontal displacement.

The accuracy/accuracy class of all of the above measurement transducers can be seen in the relevant calibration sheets given in Appendix I-1.

It should be noted that the noted accuracy of the measurement transducers is not uniquely related to the accuracy of the measured parameters (i.e. vertical/shear stress).

7.3 Testing programme

A total of 10 cyclic direct simple shear tests were performed on samples from Nieuwolda (7 samples), Schildmeer (2 samples) and Siddeburen (1 sample) locations. Table 7.1 summarizes the tested samples together with their index properties.

a/a	Boring location	Sample ID	Depth_top of the sample (m)	σ_{vc}' (kpa)	WC_initial (%)	WC_final (%)	OC (%)	γ_s (kN/m^3)
1	Nieuwolda	NW1A2-A7-2C	5.62	29.3	217.9	201.5	75.7	15.4
2	Nieuwolda	NW1A2-B1-1C	3.62	27.1	500.9	494.8	84.2	14.94
3	Nieuwolda	NW1A2-B1-2D	4.02	27.4	462.6	468.7	82.2	15.22
4	Nieuwolda	NW1A2-D1-1E	3.85	27.4	471.8	442.2	83.1	15.19
5	Nieuwolda	NW1A2-D1-1F	3.9	27.4	501.4	540	83.4	15.08
6	Nieuwolda	NW1A2-D2-1D	4.78	28.5	635.1	620.5	91.9	14.57
7	Nieuwolda	NW1A2-D2-2D	5.18	28.9	550	563.6	92.4	14.21
8	Siddenburen	SB4A-A2-1C	1.35	6.2	564.5	547.1	92.4	14.03
9	Schildmeer	SM2C-A3-1C	2.07	8.1	472	528.6	73.9	16.49
10	Schildmeer	Sm2C-B1-2C	2.22	9.5	490.7	505.5	60.8	17.93

Table 7.1 Characterisation of the cyclic DSS tests

Where:
- σ_{vc}' is the effective vertical stress at the end of consolidation.
- W is the water content as calculated in accordance with ASTM D2216-10 (Method A) before (initial) and after (final) testing.
- OC is the organic content calculated in accordance with ASTM D2974-07 (Method C).
- γ_s is the solid density calculated in accordance with ASTM D5550-14.

7.4 Testing procedure

Tests were performed on samples trimmed with the help of a cutting ring to dimensions of approximately 20 mm height and 63 mm internal diameter. Lateral confinement of the samples was achieved via the use of a membrane surrounded by a stack of rigid low friction rings. The end caps of the apparatus used had pins embodied to prevent sliding on the interfaces. Each sample was consolidated to the in situ effective vertical stress for a period of 24 hours. After the end of consolidation the samples were subsequently subjected to cyclic loading.
Each sample was subjected to a sequence of fourteen (14) cyclic loading stages. A different shear strain was applied per loading stage. For each shear strain the samples were subjected to 10 sinusoidal cycles of undrained strain-controlled loading at a frequency of 0.1 Hz. The first stage was performed at a shear strain of approximately γ_{SA}=0.06%. Each of the subsequent stages of cycles occurred at higher shear strains. The final stage of cyclic loading usually was at γ_{SA}=40%. Cyclic loading was terminated upon reaching the apparatus maximum shear strain capacity of 8 mm which corresponds to a shear strain of 40% - for a sample with a height of 20 mm.

7.5 Terminology for cyclic simple shear tests

A schematic of a typical hysteresis loop generated from the application of one complete cycle of loading is shown in Fig. 1 for the case of cyclic triaxial testing (ASTM D 3999). Similar hysteresis loops are generated during cyclic simple shear loading when plotting the applied horizontal load against horizontal deformation. The material damping ratio D (%) is defined on each individual hysteresis loop as:

$$D(\%) = \frac{A_L}{4\pi A_T} \times 100$$

Where:
- A_L is the damping or dissipation energy calculated as the area of the hysteresis loop in one cycle of loading (see Fig. 1) and
- A_T is the equivalent elastic energy stored in a single loading cycle calculated as the area of the shaded right triangle shown in Fig. 1.

The secant shear modulus, G_{sec}, for a given hysteresis loop is defined as:

$$G = \frac{\tau_{SA}}{\gamma_{SA}}$$

Where:
- τ_{sa} is the single amplitude shear stress for the given hysteresis loop and
- γ_{sa} is the single amplitude shear strain for the given hysteresis loop.

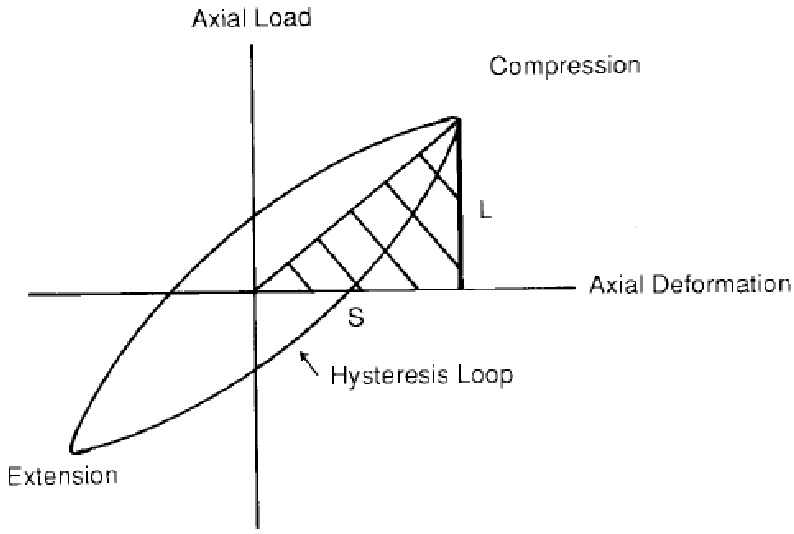

Figure 7.1 Schematic of typical hysteresis loop generated by one cycle of loading in the cyclic triaxial apparatus (after ASTM D 3999).

7.6 Test Results

The test results report plates are given in Appendix I-2. Test results are presented via the use of the following plots for:

(A) Consolidation Phase:
- Root time versus vertical strain (%) plot
- Effective vertical stress (kPa) versus axial strain (%) plot

(B) Cyclic Loading Phase:
- Number of cycles versus shear strain (%) plot
- Shear strain (%) versus horizontal shear stress (kPa) plot
- Number of cycles versus pore-water pressure (kPa) plot
- Number of cycles versus axial strain (%) plot

- Shear strain (%) versus stiffness (MPa) plot
- Shear strain (%) versus damping ratio (%) plot

General comments on the above plots:

- The stress-strain curves are shown for the applied 10 different shear strain stages (10 cycles each stage). For clarity, the inner graph in the relevant plot presents the stress-strain data for the first 6 consecutive shear strain levels at γ_{SA} approximately up to 0.7%. It can be observed that in general the stress-strain behaviour for these initial low strain levels is almost linear with only minor cyclic degradation. With increasing levels of strain, the sample shows progressively greater nonlinearity and evident cyclic degradation.
- The secant shear modulus (G) and the equivalent damping ratio (D) plots show data points for each of the 10 loading cycles at each strain level.
- Changes in pore-water pressure are not directly measured but are inferred from the changes of the normal stress required to maintain the specimen at constant volume.
- The shear modulus and damping ratio data are presented for shear strains, γ_{SA}, higher than 0.2% due to restrictions in the accuracy of the measurement system at lower shear strains. As shown in the number of cycles versus shear strain plot the cyclic loading of the samples terminated immediately upon reaching a shear strain level of 40%. Thus the shear modulus and damping ratio relationships given in the relevant plots are limited to shear strains of approximately 30% which correspond to the maximum applied shear strain level for which data are available. However it should be highlighted that the reliability of the testing data for shear strain of approximately 30% is rather questionable. Based on visual observations at this high strain the sample loses its contact with the top platen of the direct simple shear device possibly due to cracking of the soil.
- In some of the tests the damping ratio values differentiate among the loading cycles for a given constant shear strain level. In these cases the loading cycle number that corresponds to the data points is identified and illustrated in the damping ratio plots.
- In the secant shear modulus (G) and the equivalent damping ratio (D) plots an average curved line that is considered that is considered to best-fit the experimental is shown with blue dashed line style.

References

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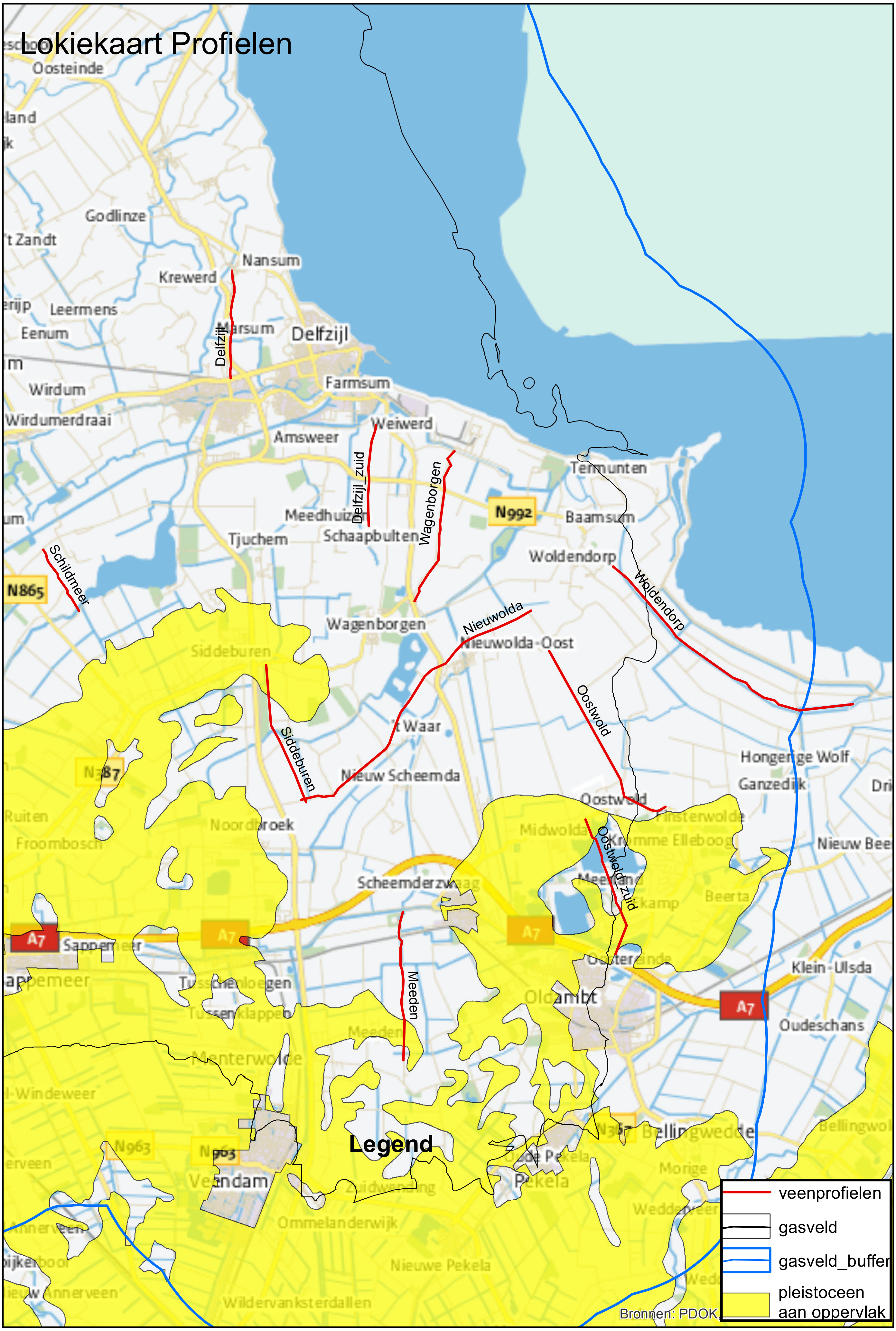
A Results archive study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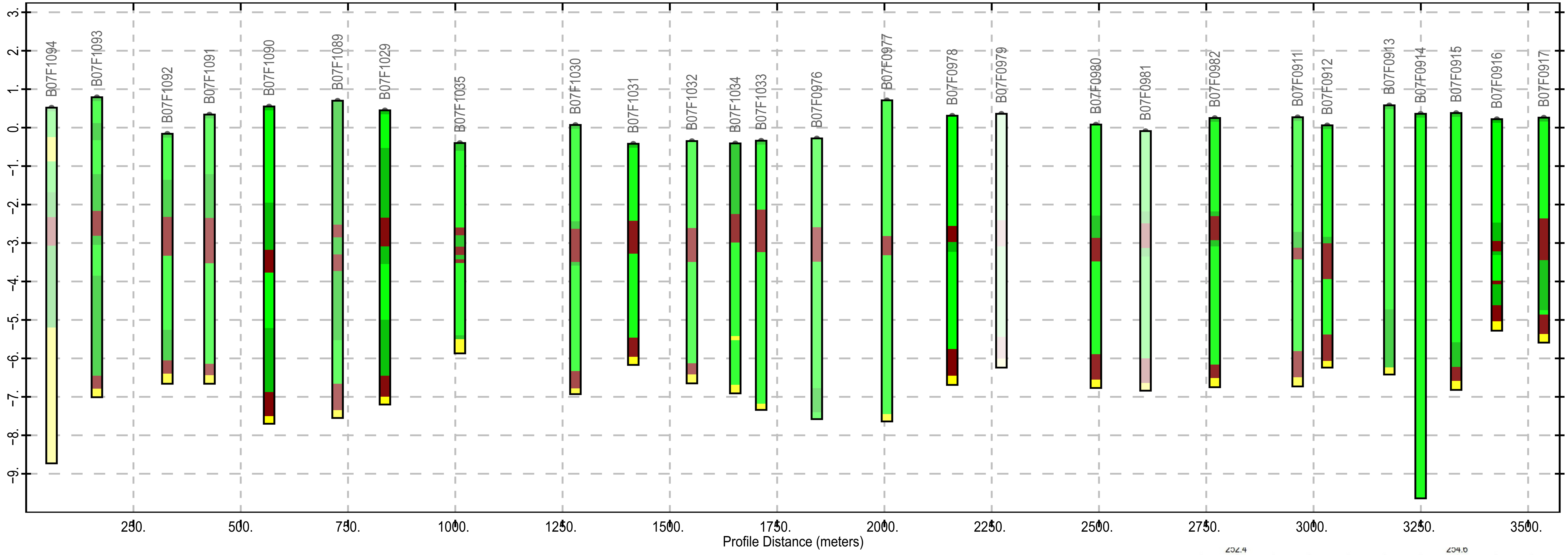

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- Grind
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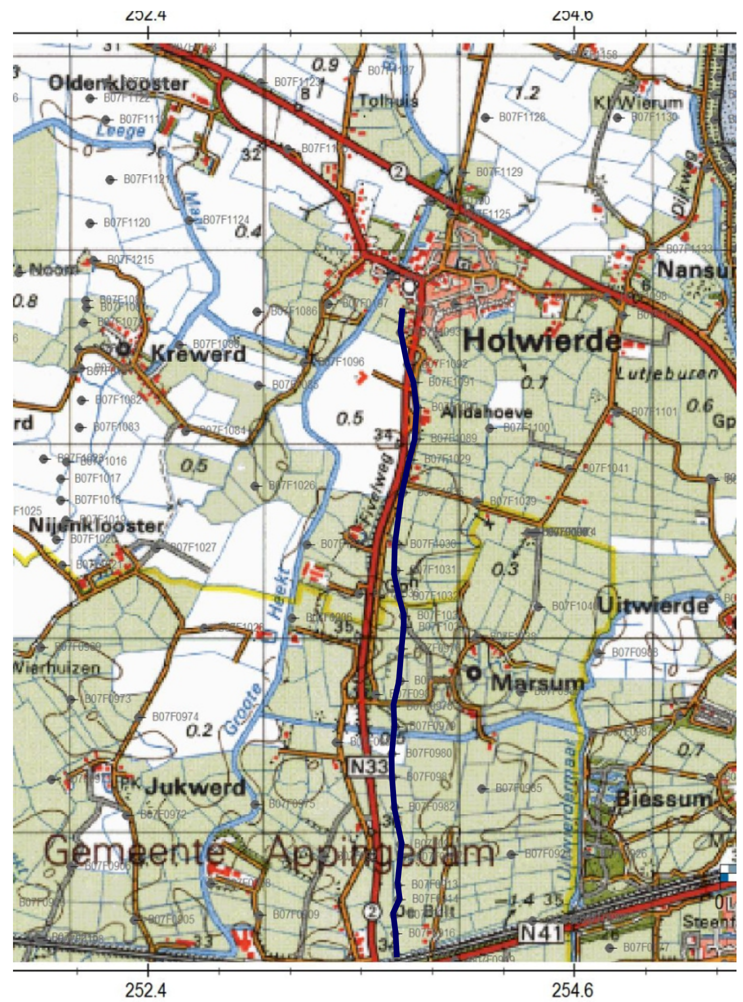
- Zand onbekend



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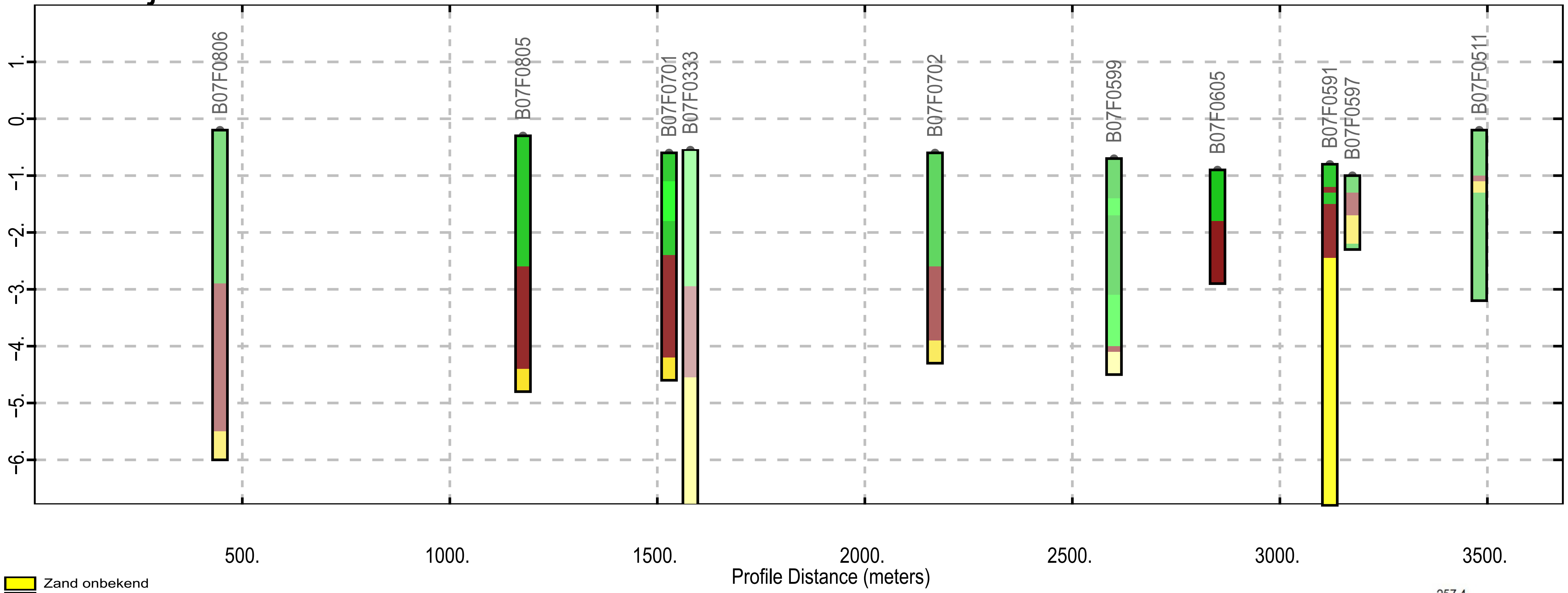

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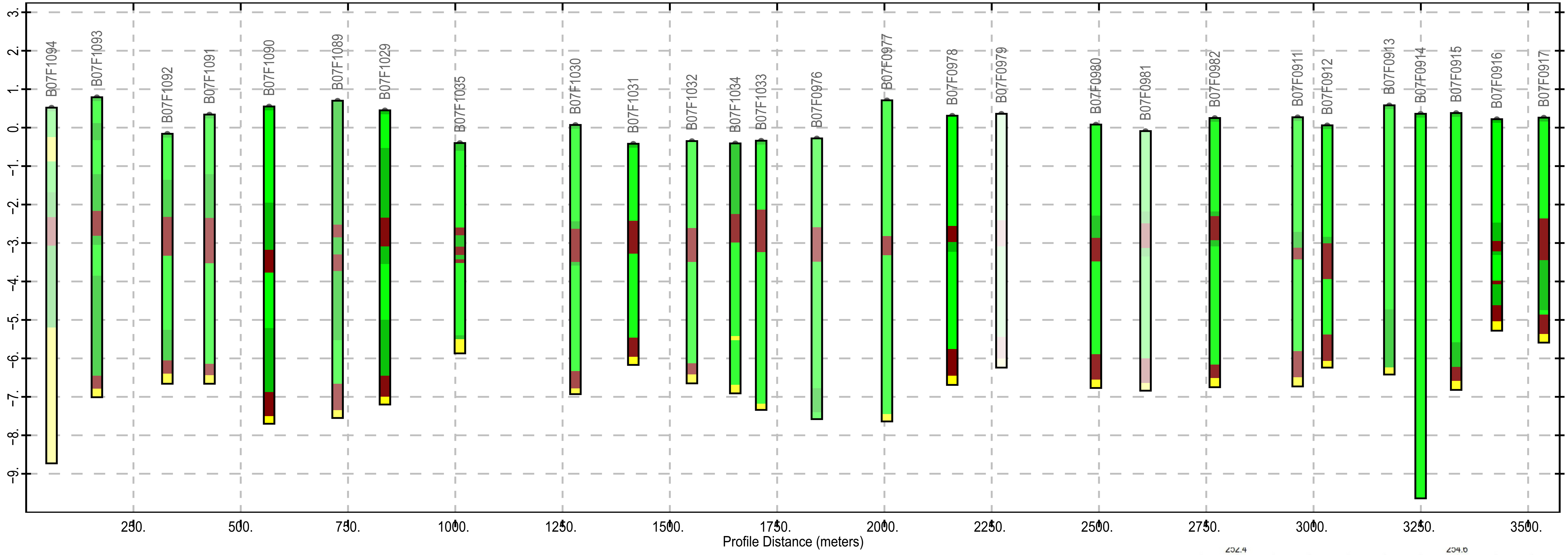

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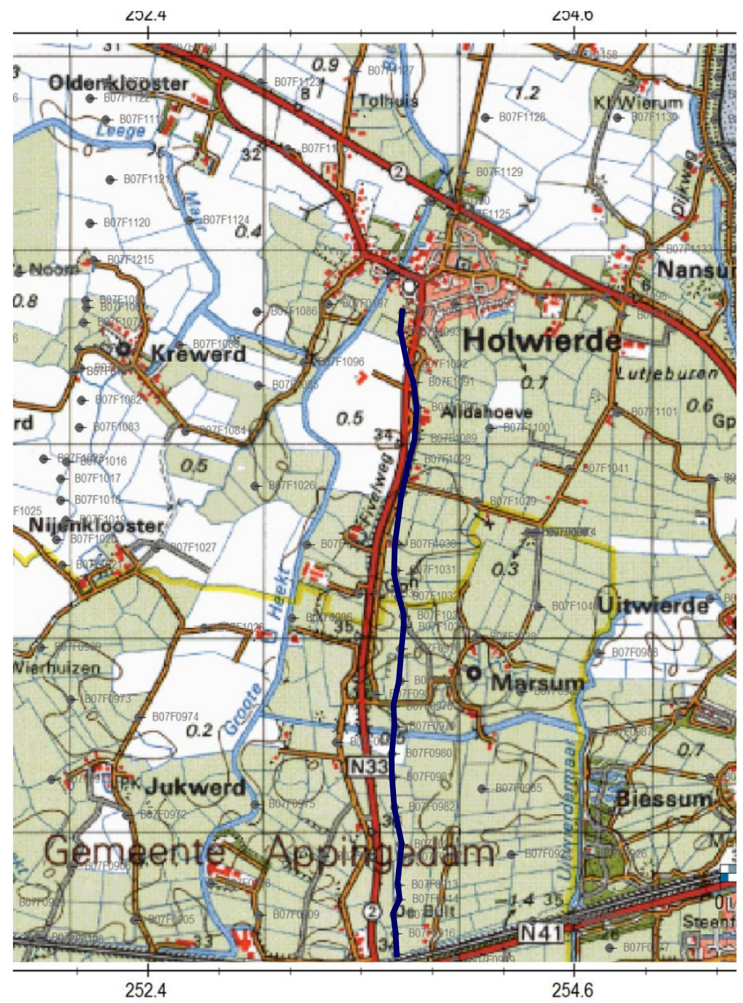

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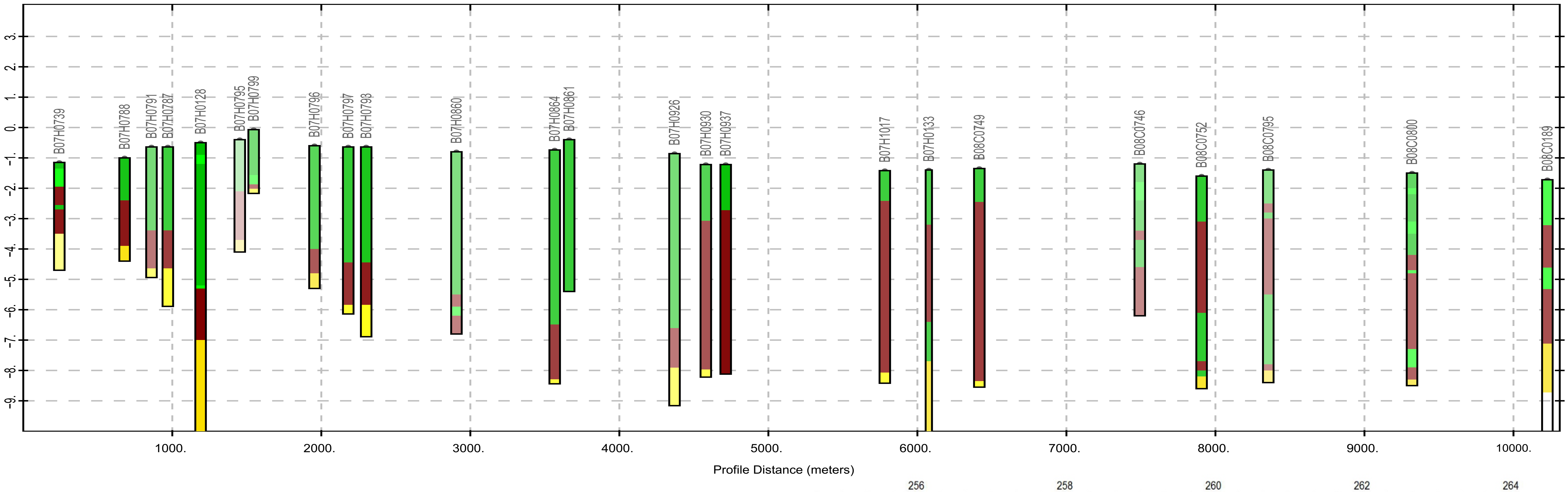

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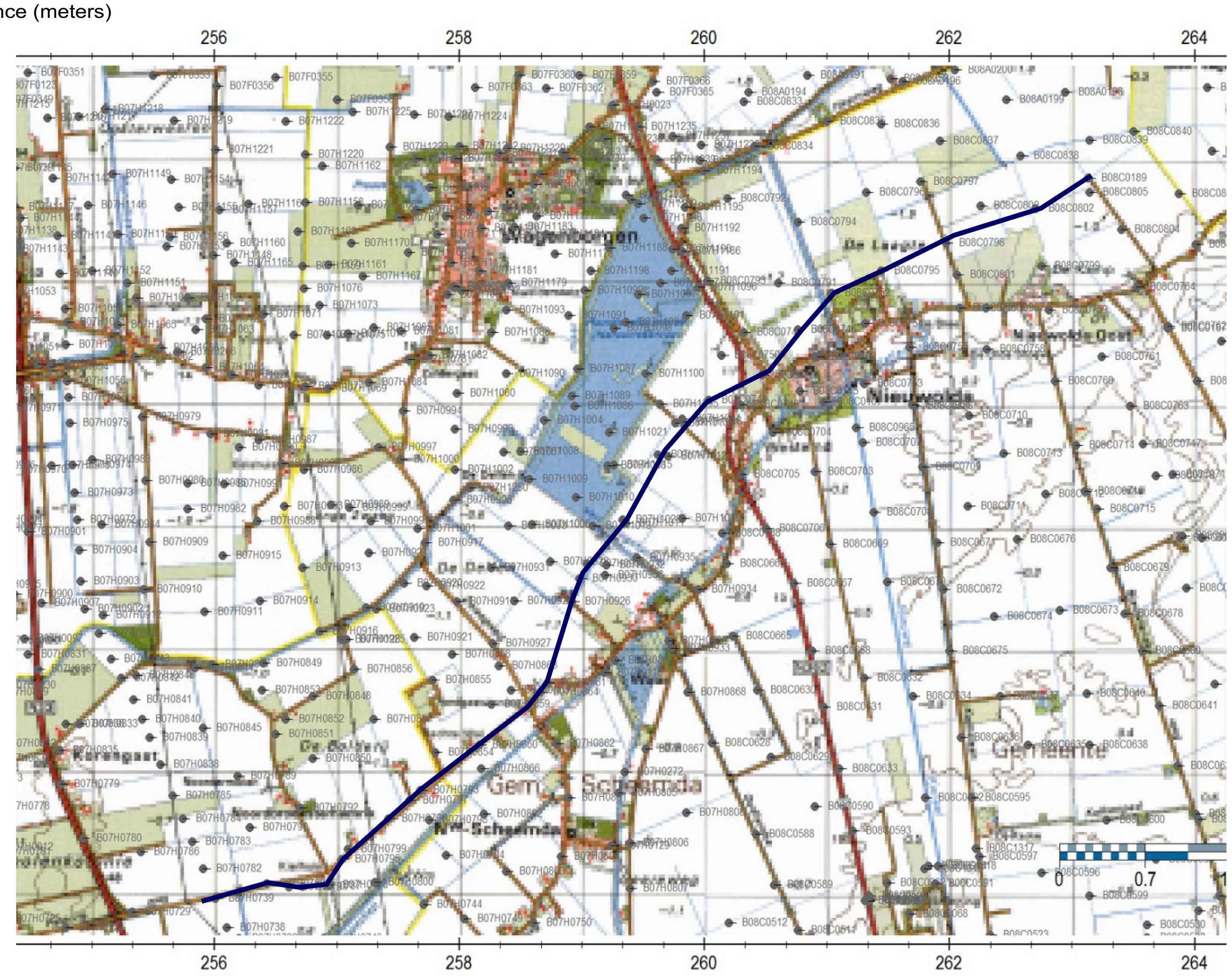

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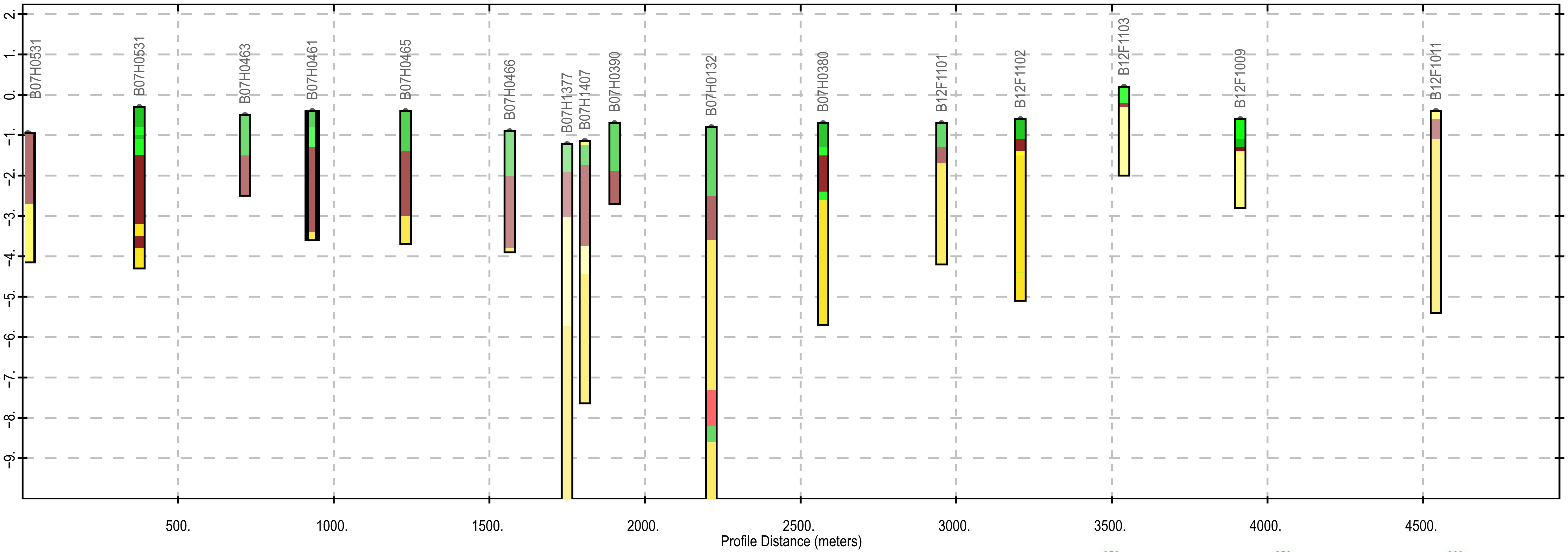

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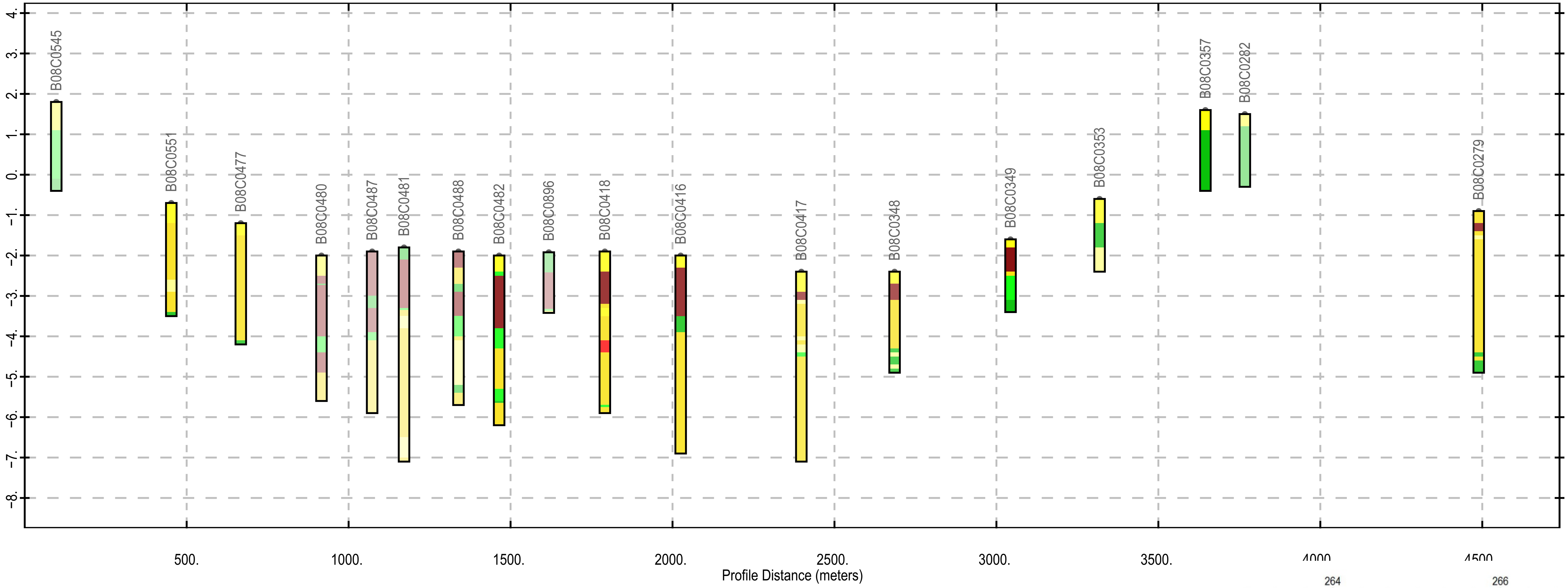

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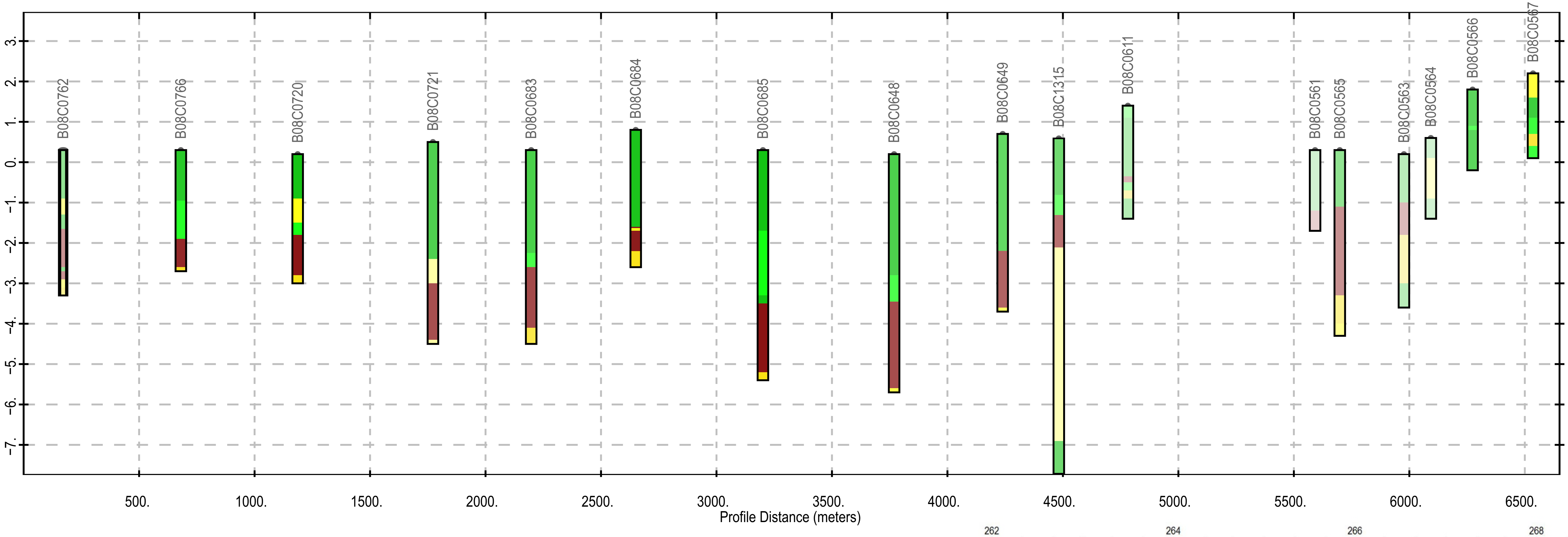

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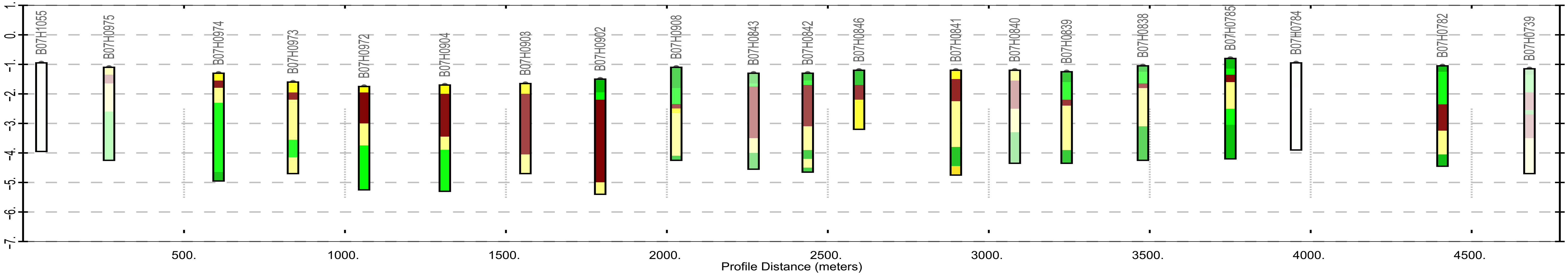

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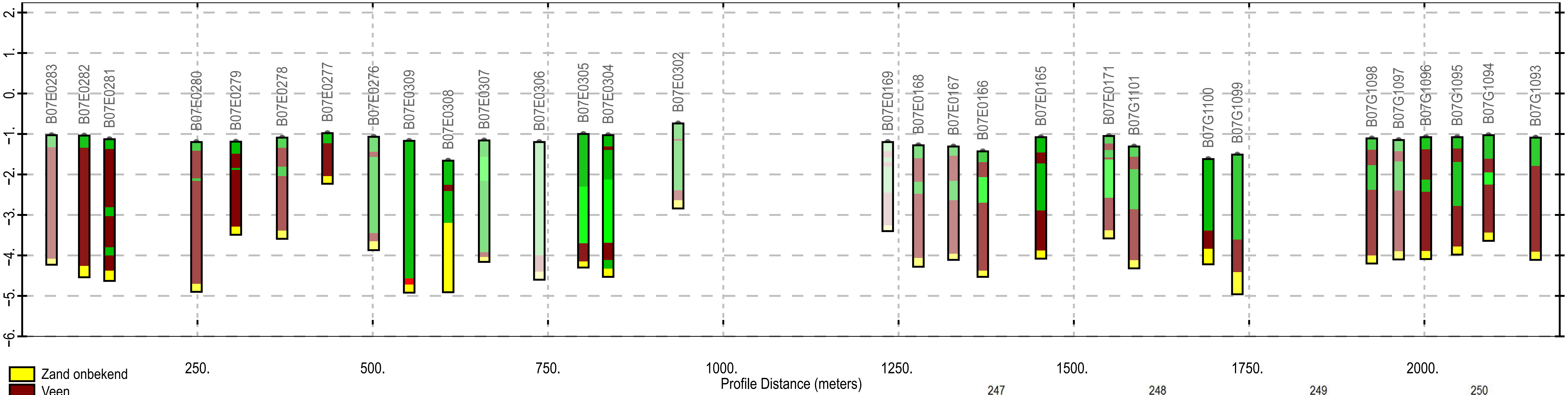

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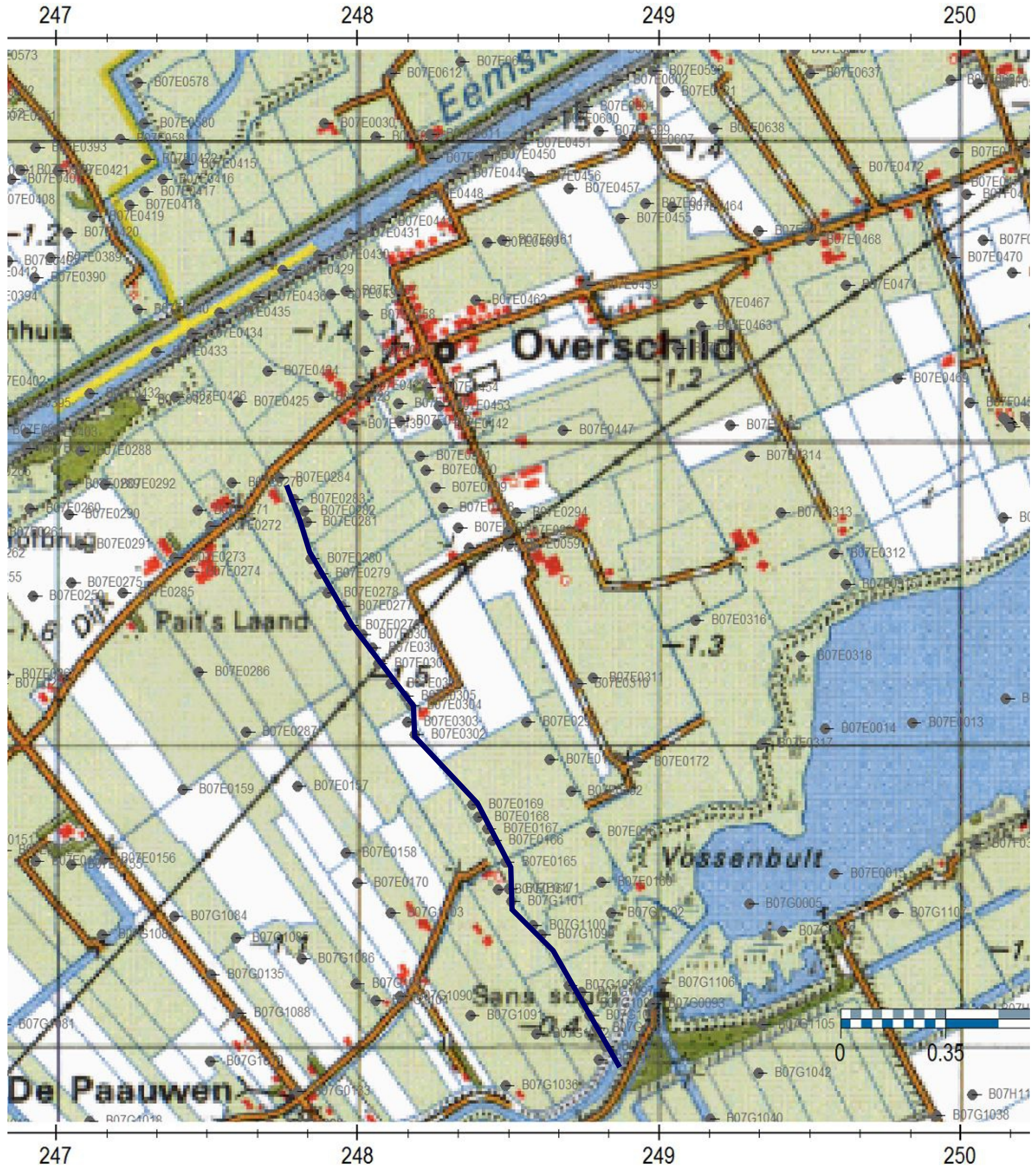

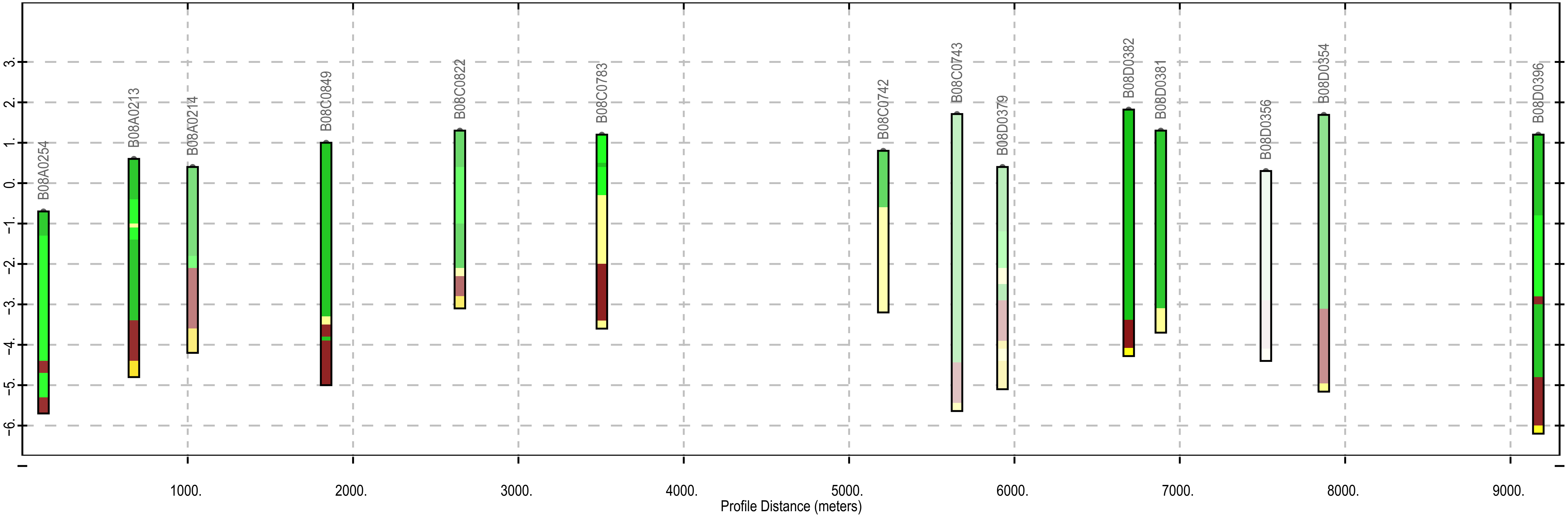

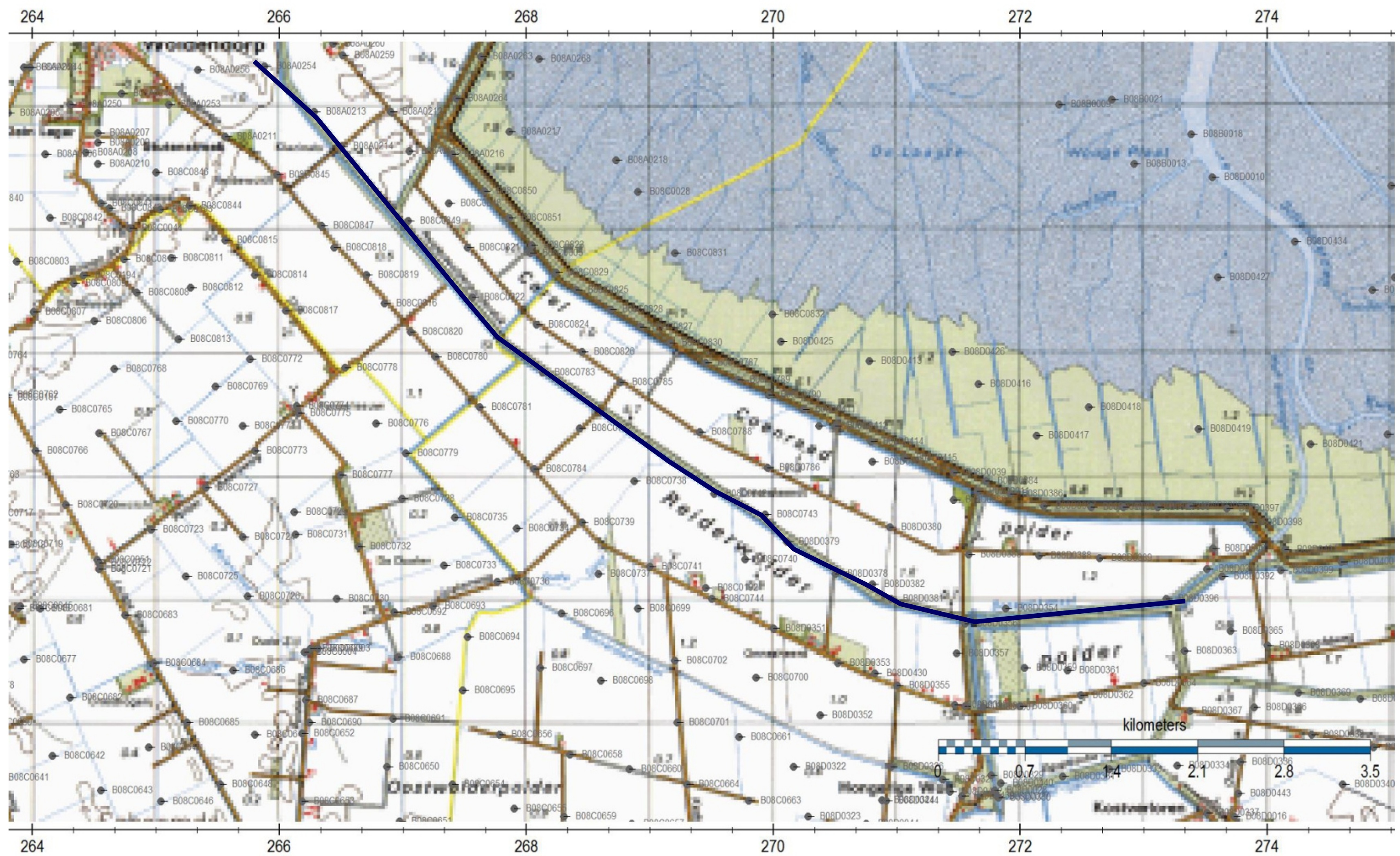

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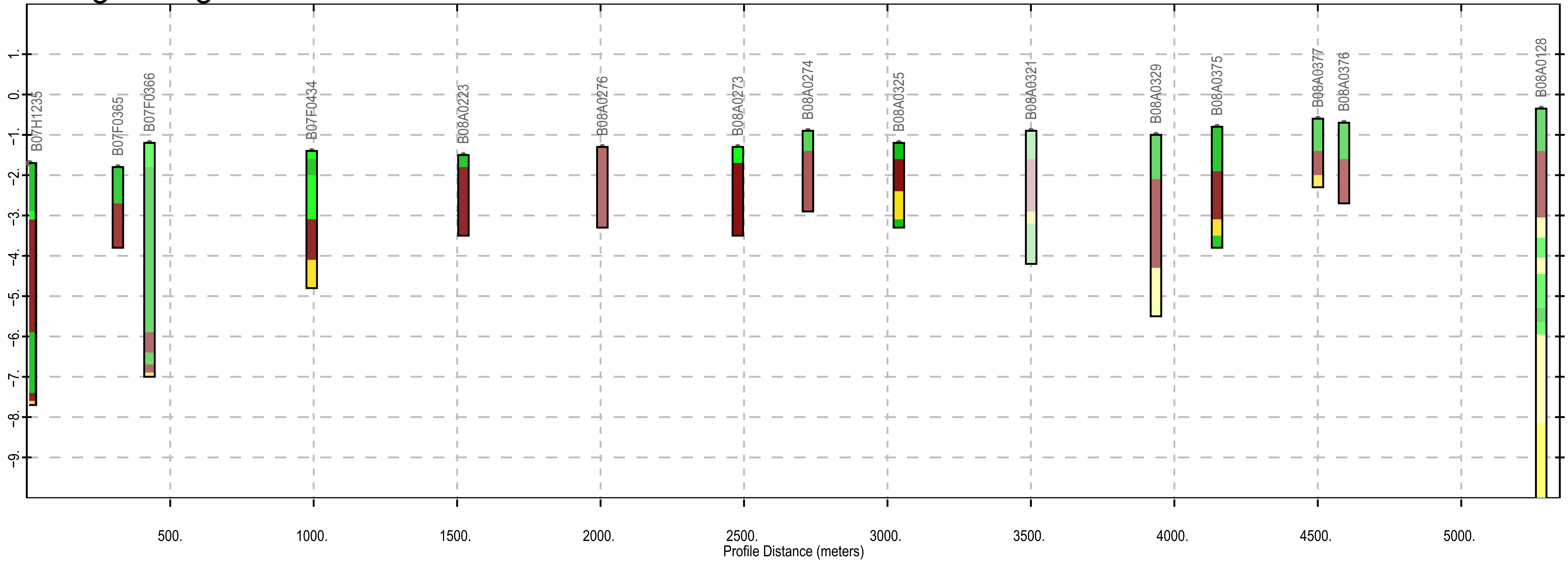

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B Hand Auger drillings

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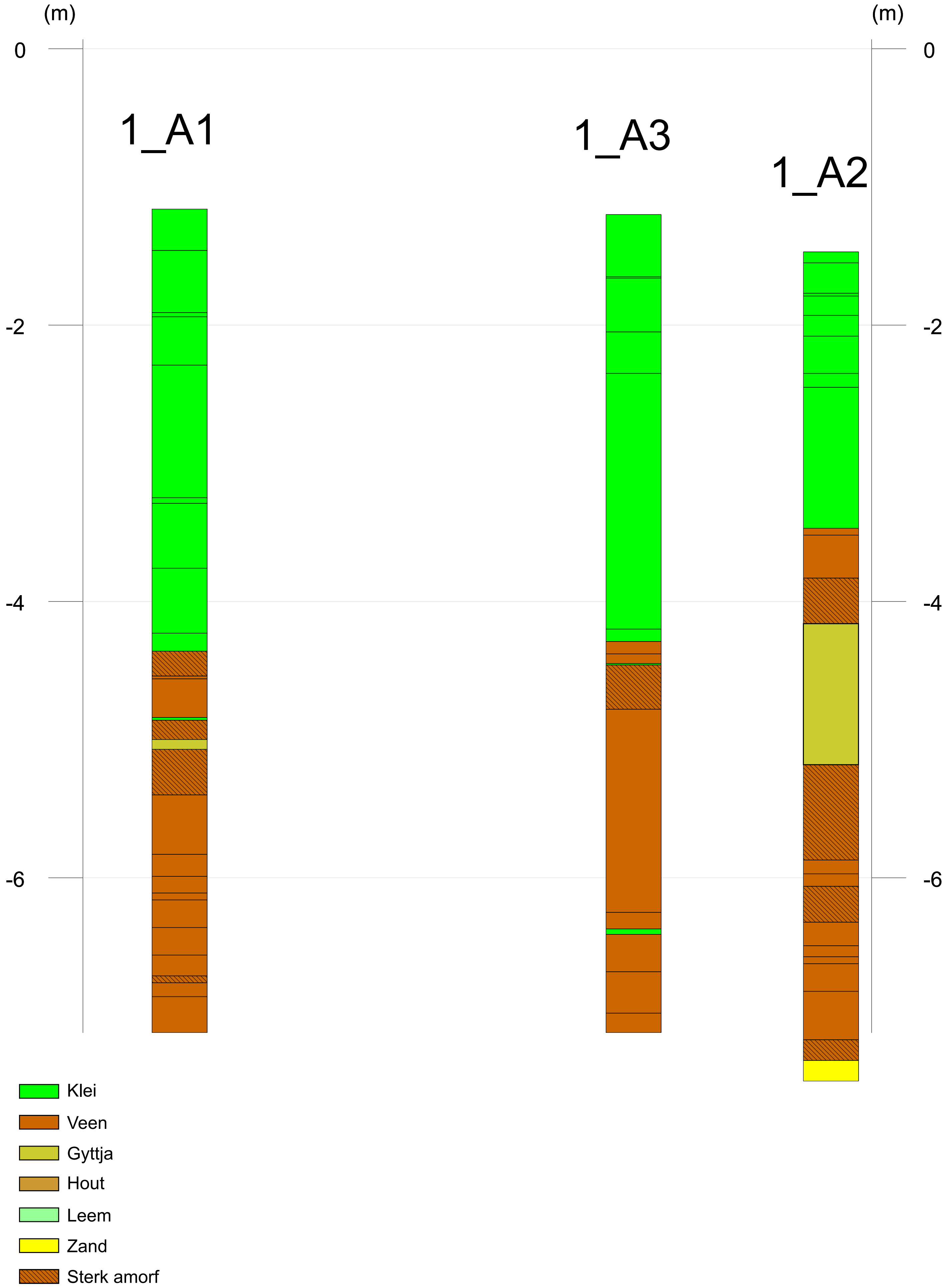

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Zand
Sterk amorf

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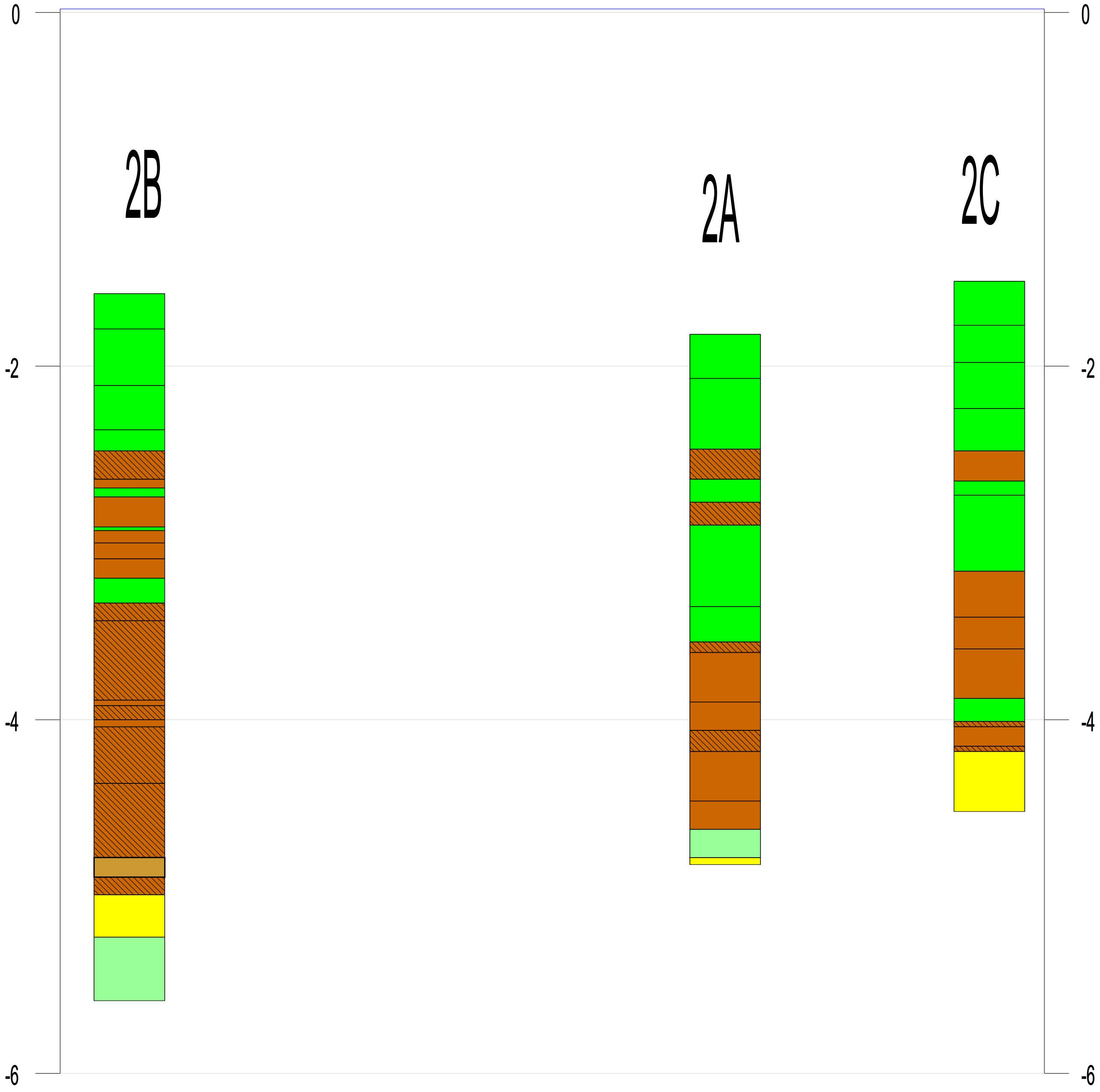

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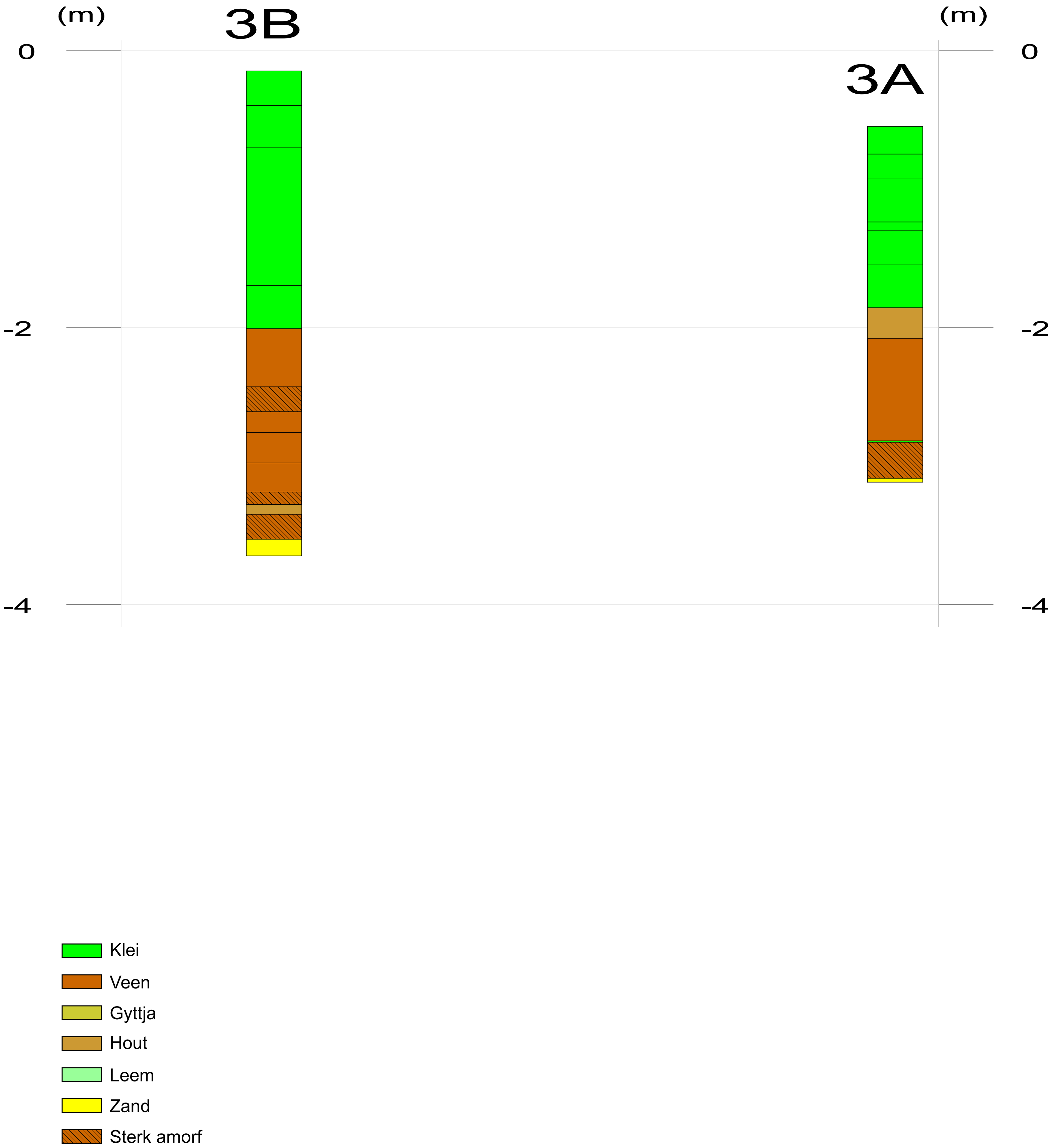

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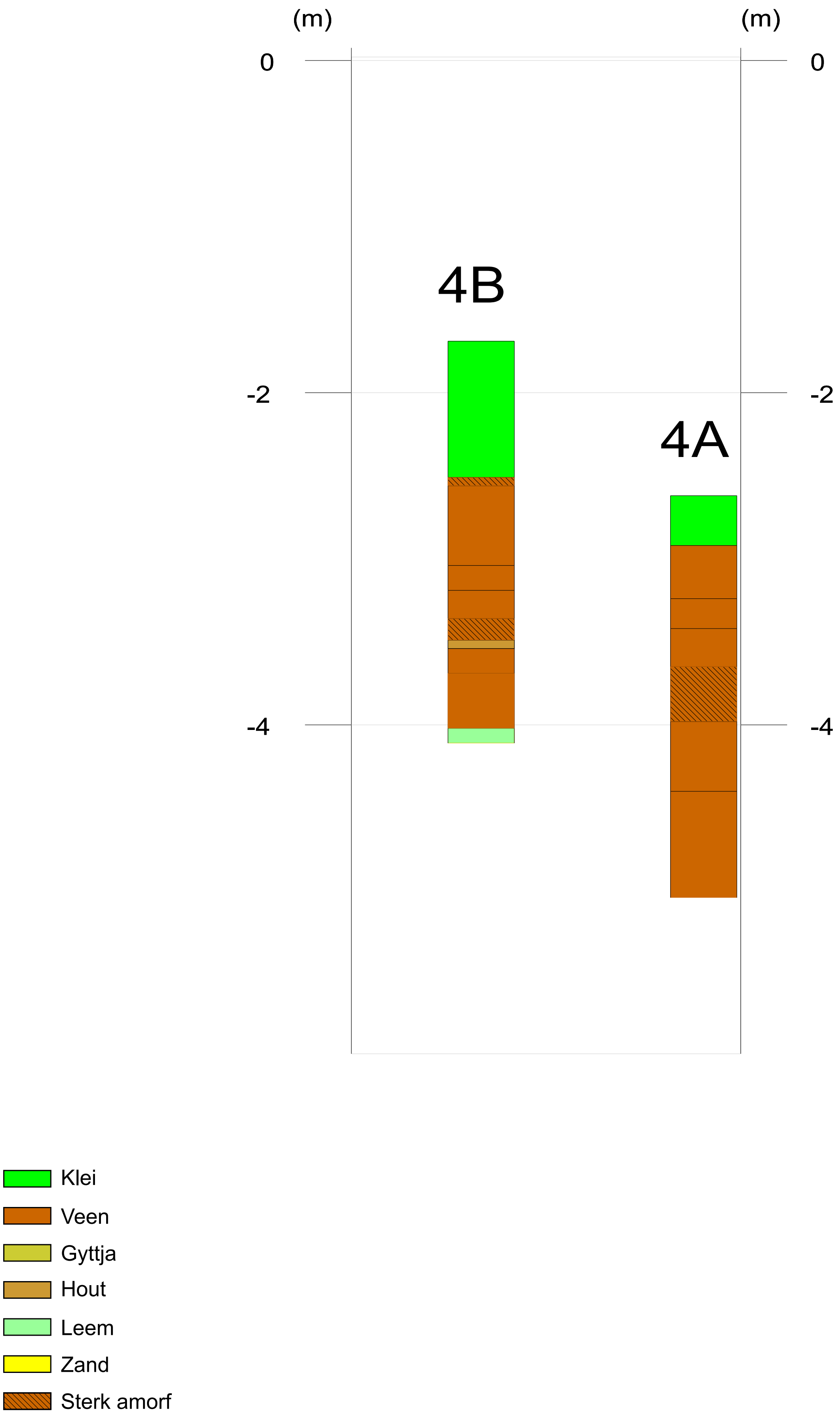

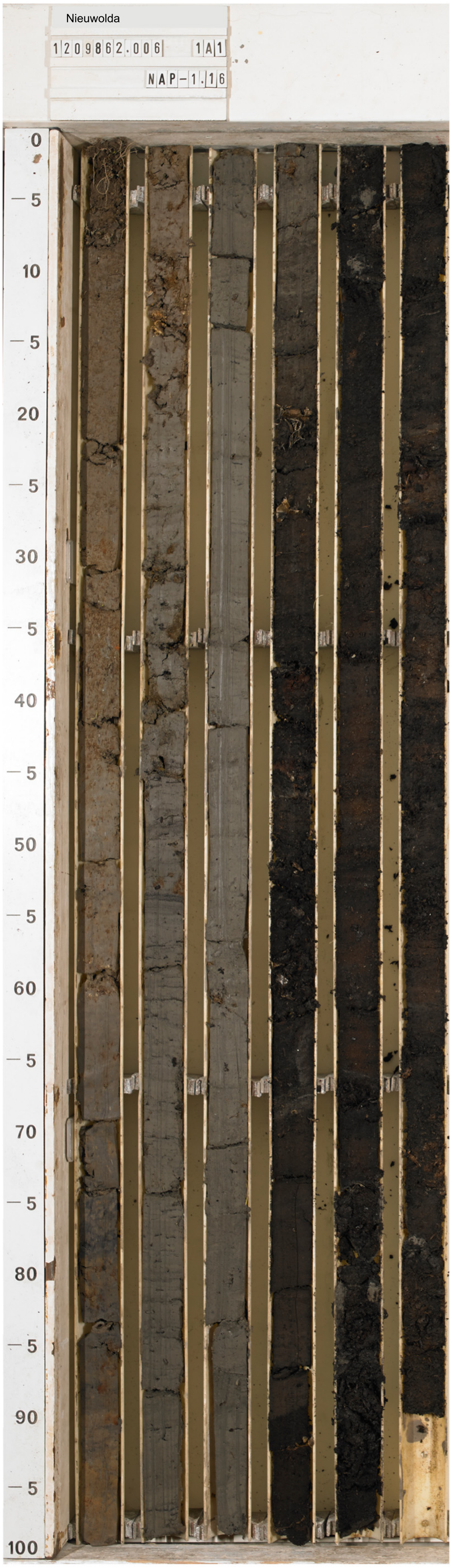

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datum 2016-02-09 | get. Mar

Nieuwolda

gez.

CO-1209862/006

FOTO BORING 1A-1

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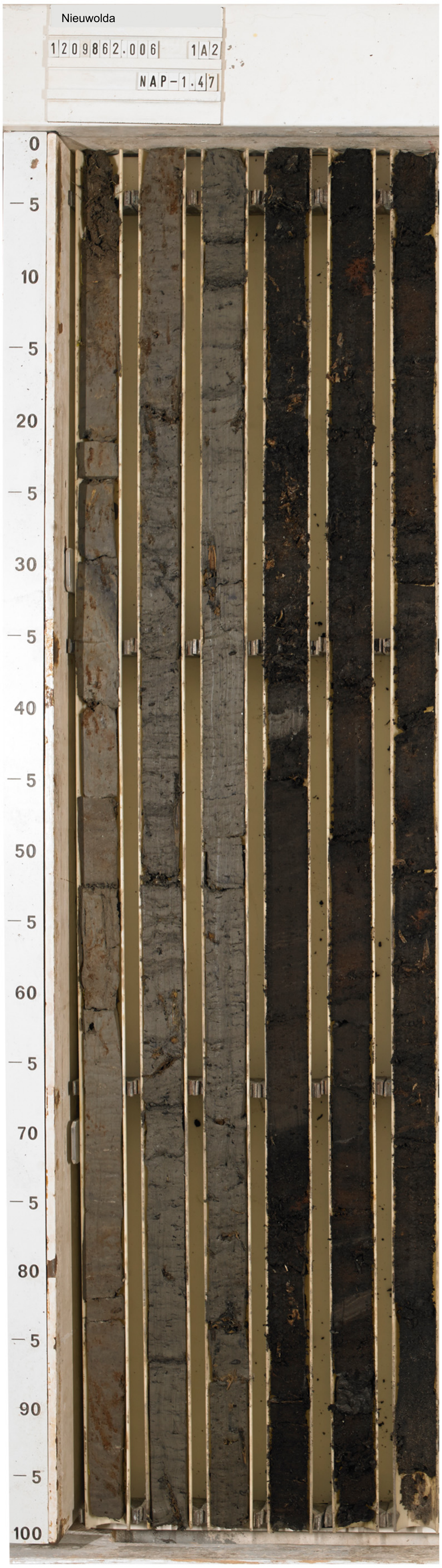

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Nieuwolda

CO-1209862/006

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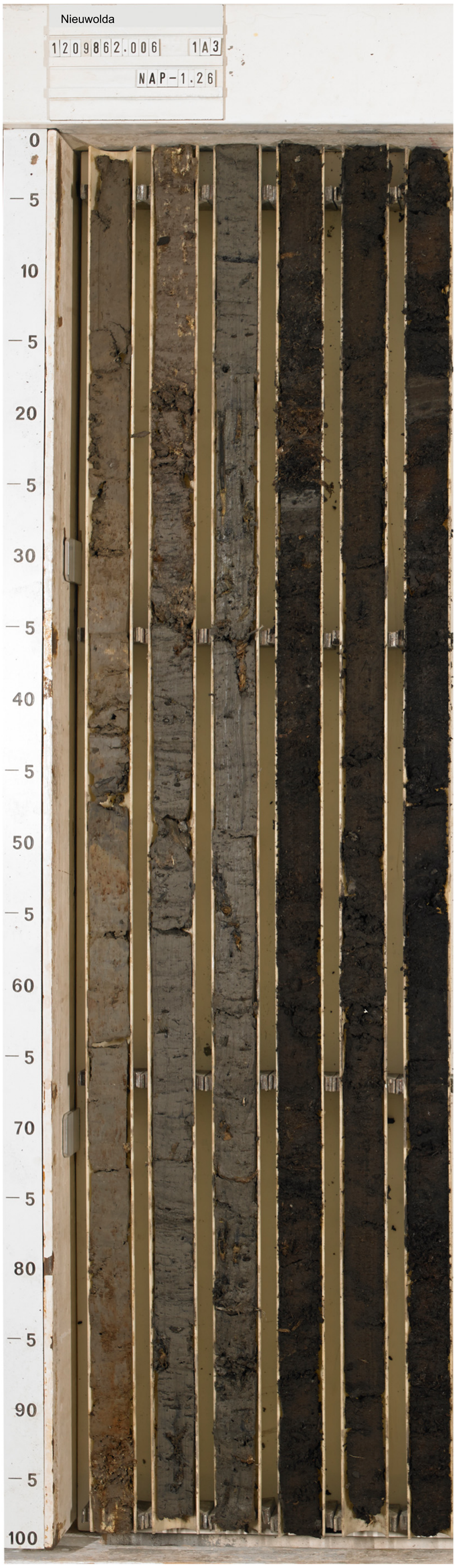

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Nieuwolda

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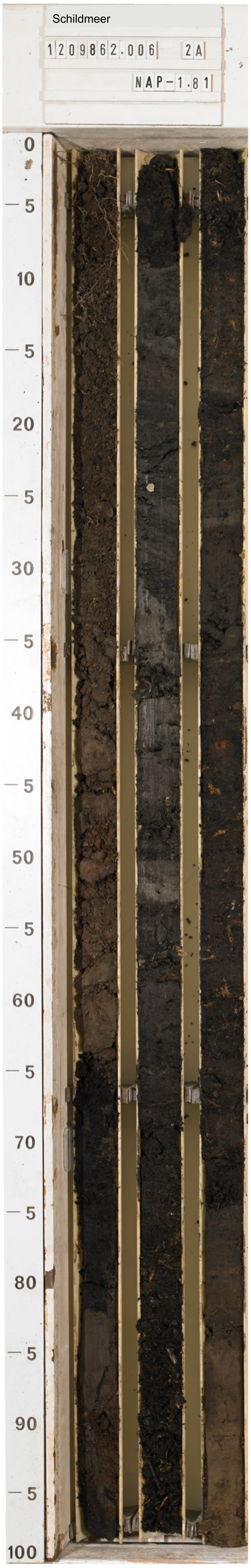

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info@deltares.nl

datum 2016-02-09

get. Mar

gez.

Schildmeer

CO-1209862/006

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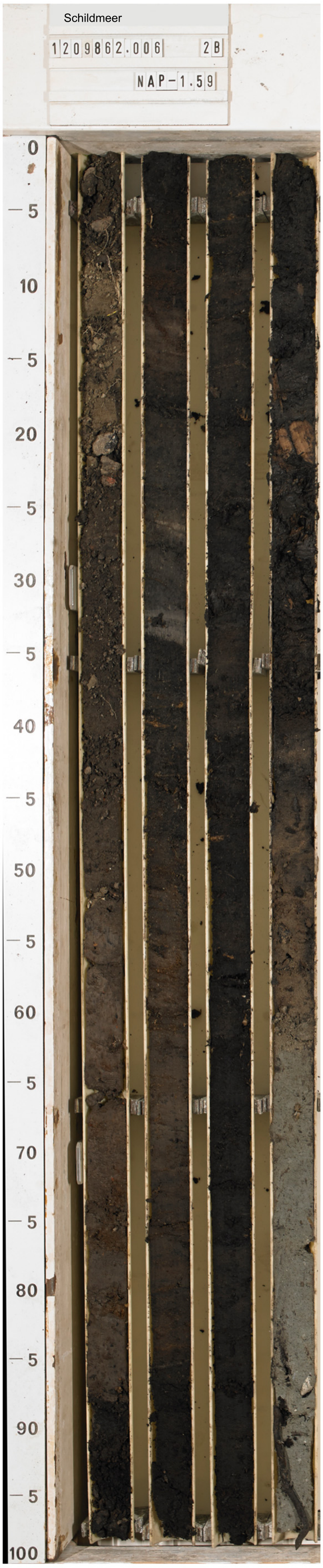

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Telefoon (0)88 335 8273
Telefax (0)88 335 8582
www.deltares.nl
info@deltares.nl

datum 2016-02-09

get. Mar

Schildmeer

gez.

CO-1209862/006

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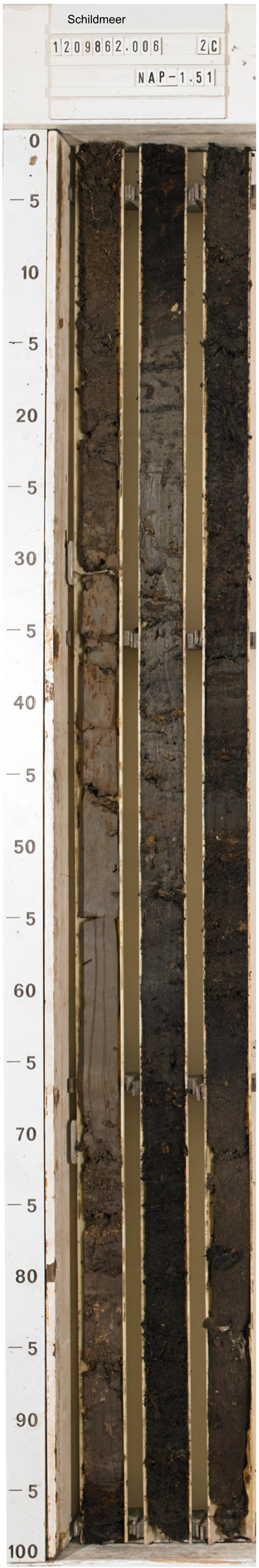

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Boussinesqweg 1 2629 HV Delft, Telefax (0)88 335 8582 info@deltares.nl

datum 2016-02-09

get. Mar

gez.

Schildmeer

CO-1209862/006

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www.deltares.nl info@deltares.nl

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Scheemda

gez.

CO-1209862/006

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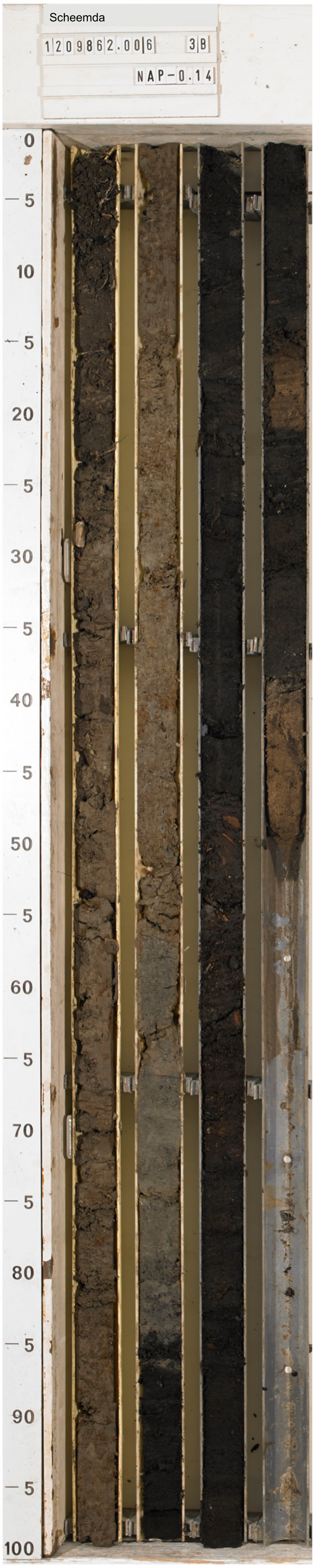

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Scheemda

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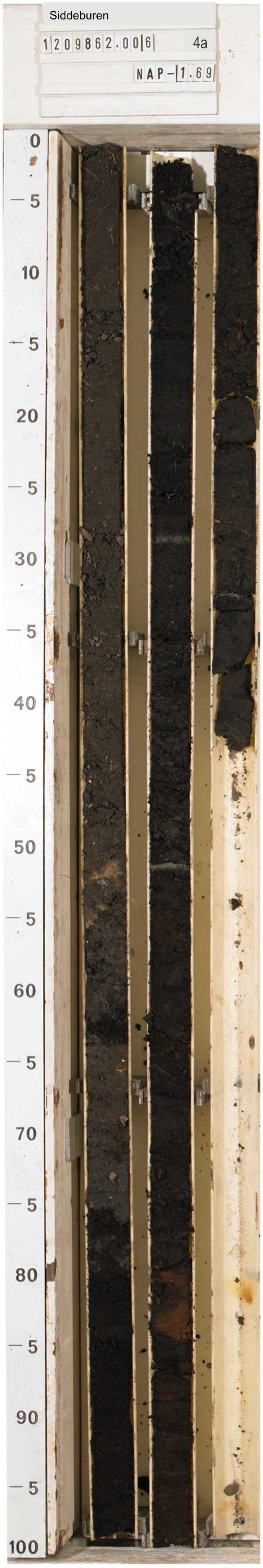

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datum 2016-02-09

get. Mar

gez.

Dynamic peat properties
Siddeburen

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CO-1209862/006

BIJL. 4A

form. A4

BESCHRIJVING: ZIE GETEKENDE VERSIE VAN BORING | Filenaam: 1209862.006-4B | Gewijzigd: 2016-00-00 | Blad 1/1

Deltares
Postbus 177 2600 MH Delft, Boussinesqweg 1 2629 HV Delft,
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www.deltares.nl info@deltares.nl

datum 2016-02-09
get. Mar
gez.

Dynamic peat properties
Siddeburen

CO-1209862/006

FOTO BORING 4B

Type: Handboring

coördinaten
X = 254860.17
Y = 583418.56
NAP -2.61

BIJL. 4B

form. A4

C Piston Samples

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datum 2016-03-02

get. Mar

Dynamic peat properties
Nieuwolda

gez.

CO-1209862/011

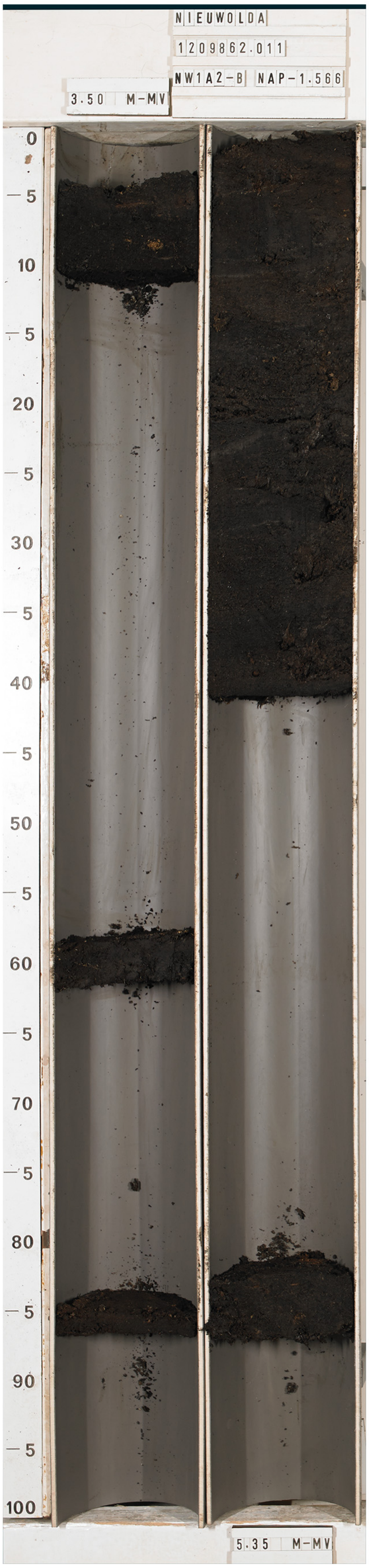
FOTO BORING NW1A2-A

Type: Piston sample

coördinaten
X = 260167.797
Y = 584506.106
NAP -1.528

BIJL. NW1A2-A

form. A4



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datum 2016-03-02
get. Mar

Dynamic peat properties
Nieuwolda

gez.

CO-1209862/011

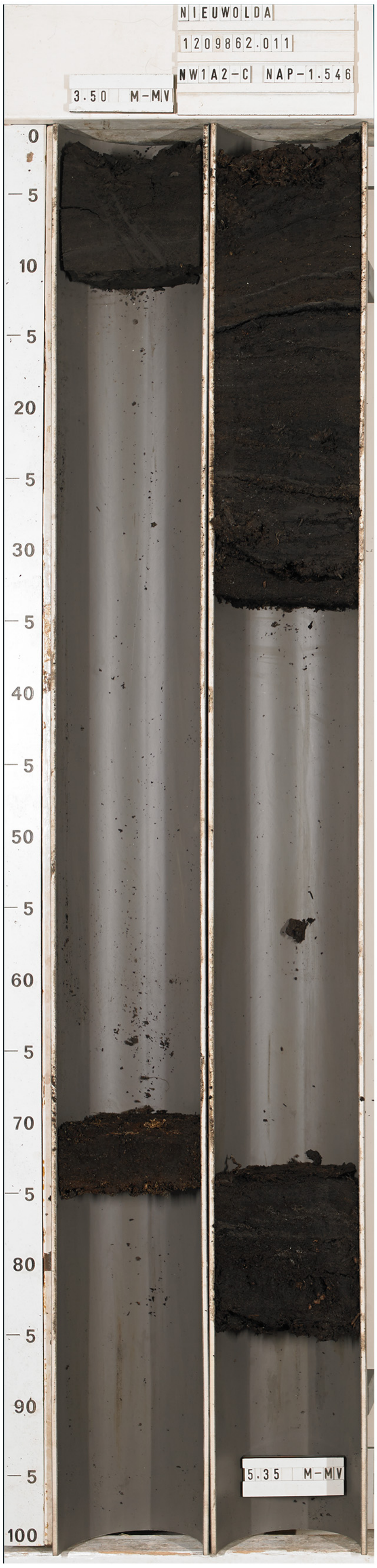
FOTO BORING NW1A2-B

Type: Piston sample

coördinaten
X = 260167.112
Y = 584506.524
NAP -1.566

BIJL. NW1A2-B

form. A4



BESCHRIJVING: ZIE GETEKENDE VERSIE VAN BORING	Filenaam: 1209862_NW1a2-c	Gewijzigd: 2016-00-00	Blad 1/1

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datum 2016-03-02
get. Mar
gez.

Dynamic peat properties
Nieuwolda

CO-1209862/011

FOTO BORING NW1A2-C

Type: Piston sample

coördinaten
X = 260167.639
Y = 584507.438
NAP -1.546

BIJL. NW1A2-C

form. A4

BESCHRIJVING: ZIE GETEKENDE VERSIE VAN BORING | Filenaam: 1209862_NW1a2-d | Gewijzigd: 2016-00-00 | Blad 1/1

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datum 2016-03-02 | get. Mar

Dynamic peat properties
Nieuwolda

gez.

CO-1209862/011

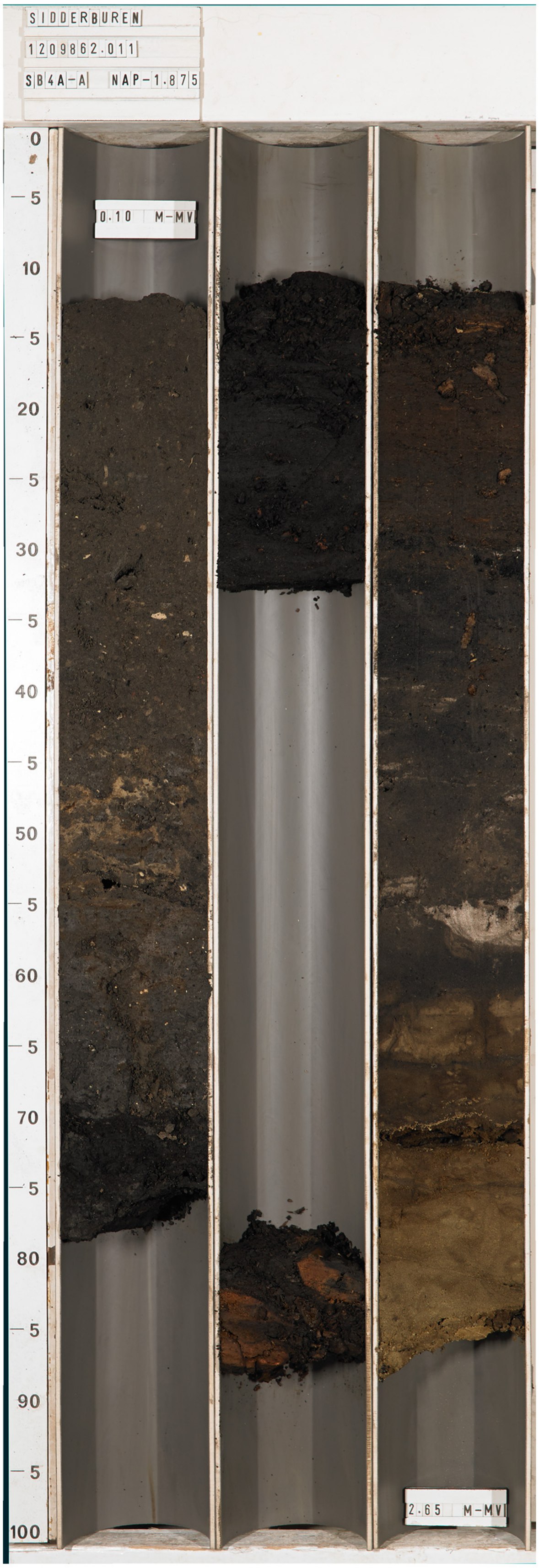
coördinaten
X = 260168.404
Y = 584507.154
NAP -1.541

FOTO BORING NW1A2-D

Type: Piston sample

BIJL. NW1A2-D

form. A4



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datum 2016-03-02

get. Mar

gez.

Dynamic peat properties

Siddeburen

CO-1209862/011

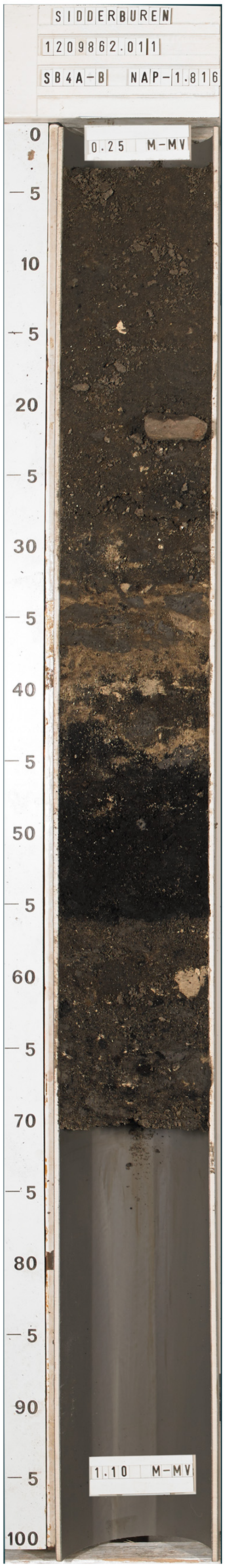
FOTO BORING SB4A-A

Type: Piston sample

coördinaten
X = 254673.413
Y = 583348.284
NAP -1.875

BIJL. SB4A-A

form. A4



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get. Mar

Dynamic peat properties
Siddeburen

gez.

CO-1209862/011

FOTO BORING SB4A-B

Type: Piston sample

coördinaten
X = 254673.701
Y = 583349.280
NAP -1.816

BIJL. SB4A-B

form. A4

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datum 2016-03-02

get. Mar

gez.

Dynamic peat properties
Siddeburen

CO-1209862/011

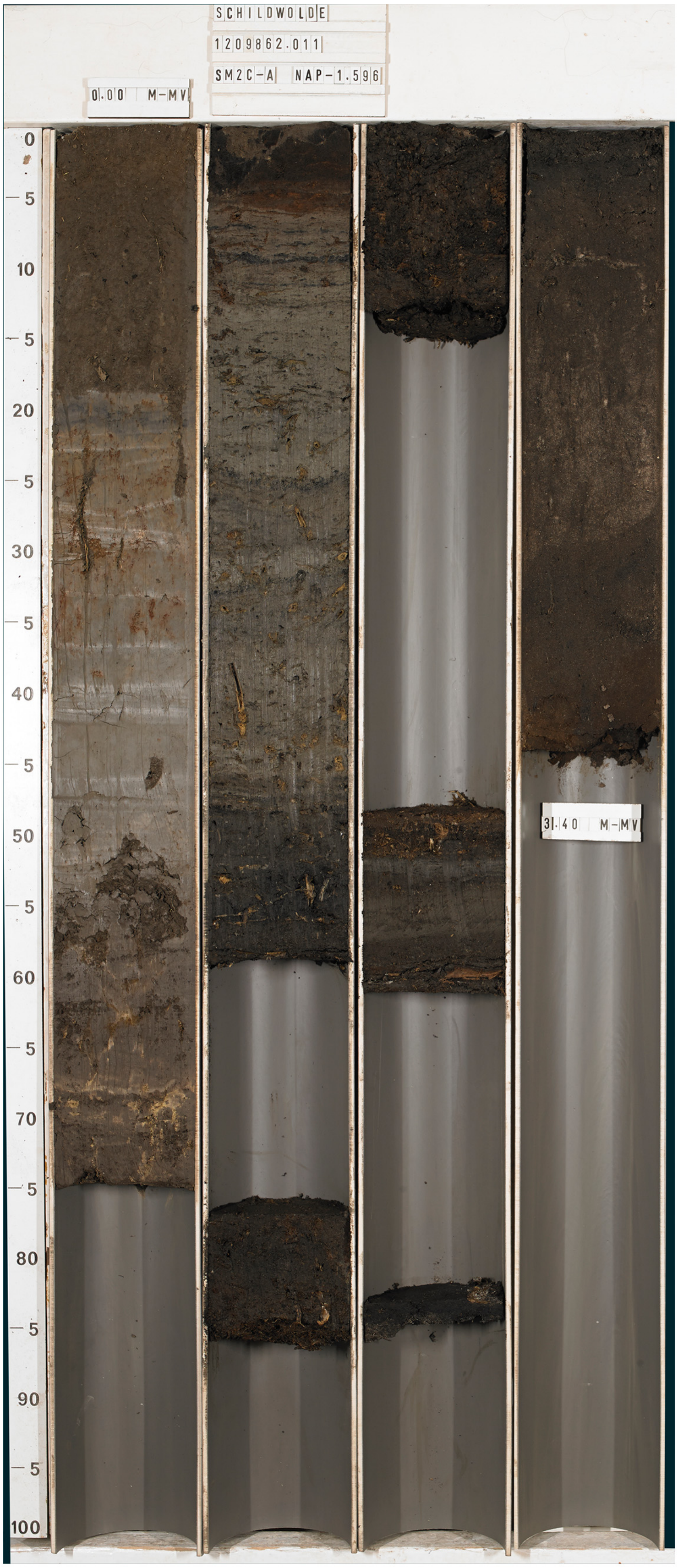
FOTO BORING SB4A-C

Type: Piston sample

coördinaten
X = 254672.545
Y = 583348.509
NAP -1.796

BIJL. SB4A-C

form. A4



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datum 2016-03-02
get. Mar

Dynamic peat properties
Schildwolde

gez.

CO-1209862/011

FOTO BORING SM2C-A

Type: Piston sample

coördinaten
X = 248925.612
Y = 587243.255
NAP -1.596

BIJL. SM2C-A

form. A4

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datum 2016-03-02

get. Mar

Dynamic peat properties
Schildwolde

gez.

CO-1209862/011

FOTO BORING SM2C-B

Type: Piston sample

coördinaten
X = 248926.379
Y = 587242.934
NAP -1.548

BIJL. SM2C-B

form. A4

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datum 2016-03-02

get. Mar

Dynamic peat properties
Schildwolde

gez.

CO-1209862/011

FOTO BORING SM2C-C

Type: Piston sample

coördinaten
X = 248925.655
Y = 587242.203
NAP -1.530

BIJL. SM2C-C

form. A4

D Testing procedure

Memo

To
...

Date	**Reference**	**Number of pages**
29 February 2016	1209862-011-GEO-0001	3
From	**Direct line**	**E-mail**
Cor Zwanenburg	+31(0)88335 7290	cor.zwanenburg@deltares.nl

Subject
Guidelines on the laboratory testing procedure_Tests on Groningen peat samples

---

Introduction

For assessing the dynamic properties of Groningen peat a cooperative laboratory testing program is scheduled among Deltares, Ruhr University Bochum and NGI. Guidelines on the sample preparation and testing procedure per type of test of this program are specified herein to ensure consistency of the test results among the three laboratories.

(A) Storage of the samples

Up on arrival, samples should be stored at in a humid and temperature controlled room. Temperature should be approximately 10±2 degrees Celsius.

(B) Specimen Preparation

Samples 15 cm long and with a diameter of 10cm will be transported to the Bochum University and to the NGI lab. The sample diameter will need to be trimmed/reduced to the required diameter of the resonant column tests. This can be done by using the trimming turntable device as illustrated in the photo on the right.

For minimizing the disturbance of the samples it is suggested to reduce its diameter in two steps. In the first step a sharp knife/aiding tools can be used to rough cut the surface of the sample to a diameter in between the initial 10 cm and the required one. In step 2 by using the trimming turntable a complete perimeter cut can be done to obtain the final diameter.

After obtaining the required diameter the sample needs to be trimmed to the final height by using a wire saw (or other suitable device) to cut of the slices of soil from both ends of the sample. Top and bottom surfaces need to be flat and perpendicular to the specimen sides.

Precautions must be taken to roots or hearty portions not be pulled when trimming. These kinds of parts have to be careful cut off with sharp blades.

Before placing the sample in the resonant column cell its dimensions (diameter and height) and its mass need to be measured. For determination of Moisture Content (Test Method D2216_refer to Table 1) soil from the remaining of cuttings is used.

(C) Testing Procedure / Equipment / Calculations

- ✓ It is of importance to ensure that the sample at the shearing stage does not slip along the end platens. To facilitate proper coupling of the ends of the specimen to the specimen cap and base it is proposed that active-end and passive-end platens **with pins** are used.

- ✓ Particular care should be taken such as an excessive axial load is not applied to the peat specimens due to the weight of the top-cap. The top-cap imposed axial pressure should not exceed the effective stress level of the peat sample under consideration.

- ✓ Information on the properties of the rubber membrane used to encase the specimen (diameter, thickness and stiffness) shall be provided to Deltares. Tests will be performed without the use of drainage strips.

- ✓ Specimens will be tested fully saturated. To ensure saturation a back pressure of 300 kPa will be applied to the samples. Specimens shall be considered to be saturated if the value of B is equal to or greater than 0.96. Measurement of the B factor is done by measuring the change in the specimen pore pressure that occurs as a result of the change of cell pressure. B-measurements should be taken for increments of cell pressure of at least 25 kPa.

- ✓ Specimens will be isotropically consolidated to their estimated in situ conditions. The in situ effective stress conditions will be provided for each sample by Deltares prior to the start of testing.

- ✓ Volumetric strain measurements need to be recorded to track the sample's consolidation during and after application of the in situ stresses. Samples will be consolidated for 24 hours after the last increment of cell pressure is applied.

- ✓ Bender element measurements will be taken before and after the application of a back pressure, after the end of consolidation and during the shearing of the sample.

- ✓ For the Bender Element tests we suggest to determine the travel time of the sinusoidal shear wave according to the first major peak-to-peak method[1] (e.g. Viggiani & Atkinson, 1995; Chan, 2007).

- ✓ We recommend termination of the resonant column testing up on reaching the apparatus feasible maximum strain level or a maximum strain level of at least 0.5% as outlined in ASTM D4015-07.

- ✓ After the end of the test the final moist mass of the sample should be measured and the water content and dry mass of solids should be determined according to ASTM D 2216 and ASTM D 7263 (refer to Table 1).

[1] The method of determination of the shear arrival time which will produce the most reliable results is an item that requires further discussion before any final decision is taken.

- ✓ The samples will be tested following a 'sample testing priority list' provided by Deltares to ensure a simultaneous progress of the testing programme on adjacent samples and an early identification of potential inconsistencies in the test results.

The laboratory tests will be performed in accordance to the test procedures/standards presented in Table 1 below.

Table 1: Overview of laboratory testing standards and procedures

a/a	Type of Test	Test Procedure/Standard	Additional Comments
Index Classification Tests			
1	Moisture Content	ASTM D2216-10	To be determined (a) over the entire sample and (b) over the trimming cuttings
2	Dry and Wet density	NEN 5110 and ASTM D 7263-09	To be determined over the entire sample
3	Solid density	ASTM D 5550-14	After determination of water content, dry and wet density the remaining sample is split in two. The first part is used to determine the organic content and the second part will be used to determine the solid density
4	Organic Content	ASTM D 2974-07 (Method C)	
Dynamic Tests			
1	Direct simple shear tests	ASTM D 6528-07 and NORSOK standard G-0001, Annex D: Laboratory testing, Rev.2, October 2004	-
2	Ko-CRS tests	ASTM D 4186-06	-
3	Resonant column tests	ASTM D 4015-07	-
4	Bender element tests	Ruhr-University Bochum and NGI in-house procedure	-

E Report RUB

GEO | RUHR
Ingenieurgesellschaft für Geotechnik
Univ. Prof. Dr.-Ing. habil. Tom Schanz
Am alten Wasserwerk 12
45886 Gelsenkirchen

Small and intermediate strain properties of Groningen peat

Projekt: "Small and intermediate strain properties of Groningen peat "

Auftraggeber: Deltares
Postbus 177, 2600 MH DElft

Bearbeiter: GEO|RUHR
Ingenieurgesellschaft für Geotechnik
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Bochum, October 2016

Contents

1 Introduction

Experimental and analytical studies in the last few decades show that the mechanical properties of geo-materials strongly depend on the amplitude of deformation or vibration generated by dynamic events, e.g. earthquake, traffic, machine foundations. For example, during an earthquake, compression and shear waves propagate through the soil mass from the bedrock to the designed structures. The goal is to analyze the effect of waves on the stability of structures located on the soil mass. The structures are usually safe against compression waves because of the weight of the structure. Therefore, the shear component of seismic waves is usually the most critical component because of the susceptibility of structures to horizontal motions and ground settlement during vibration (Goudarzy 2015).

Shear stiffness and damping ratio are significantly affected by amplitude of shear strain which is important in deposited soils as the stiffness and damping in each layer are related to the amplitude of shear strain in that layer. As it is apparent from literature, the shear modulus decreases with an increase in the amplitude of shear strain. Damping ratio increases with an increase in the amplitude of shear strain. Previous studies using resonant column and torsional shear device, e.g. Hardin and Drnevich (1972*b*), Drnevich (1978), Seed et al. (1986) and Wichtmann and Triantafyllidis (2013*a*), confirm that shear modulus in small strain region has maximum value which is called maximum shear modulus, G_{max}. In this region soil behavior is linear. With further increase in the amplitude of shear strain soil behaves nonlinearly. Material damping ratio at small strain region has the minimum value which is called minimum damping ratio, D_{min} and it increases with further increase in the amplitude of shear strain. In analyzing the response of soil elements when these elements are subjected to small deformations or vibrations, elastic parameters (G_{max} and D_{min}) are applicable for analyzing the response of soils. By increasing the amplitude of deformations, shear modulus, G, and damping ratio, η, will be different in comparison with the initial values. The mechanical properties of soils at medium strain region is so-called intermediate strain properties in the present research work. Small and intermediate strain properties (G_{max}, $G(\gamma)$, $D(\gamma)$) of geo-materials are key parameters to analyze the mechanical response of soil elements subjected to small deformation or vibration (Benz 2007). To perform an accurate analysis, especially for deposited soils, stiffness and damping ratio must be accurately determined at different level of deformation or vibration. As an example, equivalent linear procedure proposed by Schnable et al. (1972) and developed by Idriss and Sun (1992) is one of the concepts applicable to account for the nonlinearity of soils using an iterative procedure to obtain values of modulus and damping.

In the last few decades, a number of cyclic and dynamic laboratory measurements have been conducted for determining the stress-strain properties of granular arrays and natural sands at small to intermediate strain regions. The small and intermediate strain properties include: i) maximum shear modulus at small strains, G_{max}; ii) the variation of shear modulus with shear strain, $G(\gamma)$; iii) the variation of damping ratio with strain, D.

The effect of various parameters on the small and intermediate strain properties of geomaterials have been studied in previous works. However, by reviewing the literature, studies on the small and intermediate strain properties of soft soils, e.g. peat, are rare.

In this report, a series of resonant column tests performed on the peat samples provided by Deltares is described. This report includes four main chapters: chapter 1 is a short introduction for this report. In chapter 2, first the Bochum Resonant Column device is described. For doing tests on soft materials, e.g. peats, modification of actuator is necessary. Therefore, the modification and validation of the Bochum resonant column device and performed tests on trial peat samples are also described in this chapter. In chapter three, the experimental procedure and experimental results on all peat samples received from Deltares, will be presented and the results will be compared with the published data in literature on inorganic and organic soils. In chapter four, empirical relationships will be described to predict the small and intermediate properties of peat samples.

2 Bochum resonant column device

2.1 Description of device

The Bochum resonant column device is used to study the small and intermediate strain properties of peat samples. In the Bochum resonant column device sinusoidal vibration is applied on the top of the sample using two Mini-Shakers. Signals are monitored using oscilloscope device to detect the value of resonant frequency. Finally, the value of shear strain and shear stiffness can be calculated from the measurements. This device was designed for tests on granular materials with minimum confining pressure of 50 kPa because of the weight of actuator. The successful application of the Bochum resonant column device to measure the small and intermediate strain properties of granular materials has been confirmed through the performed researches using this device (e.g. Wichtmann et al. 2001, Wichtmann and Triandafilidis 2005, Wichtmann and Triantafyllidis 2009, Wichtmann and Triantafyllidis 2013b, Wichtmann and Triantafyllidis 2013a, Wichtmann and Triantafyllidis 2014, Wichtmann et al. 2015, Goudarzy et al. 2014, Goudarzy 2015, Goudarzy, König and Schanz 2016 and Goudarzy, Rahman, König and Schanz 2016).
The Bochum resonant column device is free-free device, i.e. top and bottom of the sample are free in vibration. Based on the boundary conditions of RC apparatus and dynamic relationships, following relations are applicable to predict maximum shear modulus using free-free RC apparatus:

$$atan(a) - \frac{J^2}{J_0 J_l}\frac{tan(a)}{a} = \frac{J}{J_0} + \frac{J}{J_l} \tag{2.1}$$

where:

$$a = \frac{\omega l}{c} = \frac{2\pi f_r L}{\sqrt{\frac{G}{\rho}}} \rightarrow f_r = \frac{a}{2\pi l}\sqrt{\frac{G}{\rho}} \tag{2.2}$$

$$G = \big(\frac{2\pi L f_r}{a}\big)^2 \rho$$

where, J is the mass moment of inertia of sample, J_0 is the mass moment of inertia of bottom part, J_l is the mass moment of inertia of top part, f_r is the resonant frequency, L

is the height of sample and G is the shear stiffness.
Before preforming tests using RC device the values of mass moment of inertia must be determined accurately because they have a direct effect on the measurements.
Three mass moment of inertia are defined for free-free resonant column apparatus:

1. Mass moment of inertia of sample (J)
   The adopted samples in RC test using the Bochum resonant column device have a cylindrical shape (Figure 2.1). Therefore, the mass moment of inertia of samples, J, can be easily calculated, $J = 1/32\pi\rho hd^4$, where, d is the diameter of sample and h is the height of sample (Figure 2.1). To measure the size of samples, samples were divided into 5 levels (A, B,... and E in Figure 2.1), afterwards, diameter of sample was measured in three directions (A-1, A-2 and A-3 in Figure 2.1) for each level. The average of d was used for initial estimation of J value. The height of sample was also measured in three sides of sample and the average value was taken as initial h of sample.

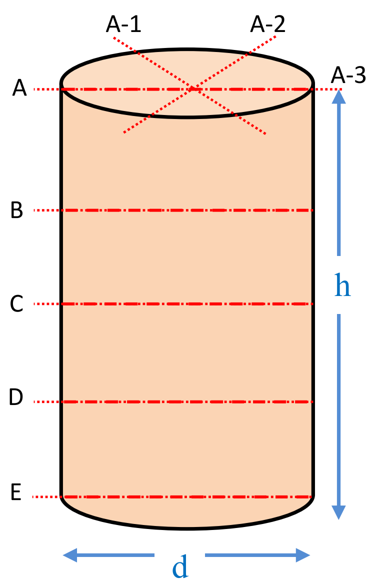


Figure 2.1: Geometry of the adopted samples

2. Mass moment of inertia of bottom part (J_0)
   The bottom part of the Bochum resonant column device composes 3 parts (Figure 2.2). These parts have a cylindrical shapes, therefore, the mass moment of inertia can be easily calculated, $J_0 = \Sigma J_{0i}$ ($J_{0i} = 1/32\pi\rho hd^4$). The value of J_0 for the Bochum resonant column device is 1.1743 kgm^2.

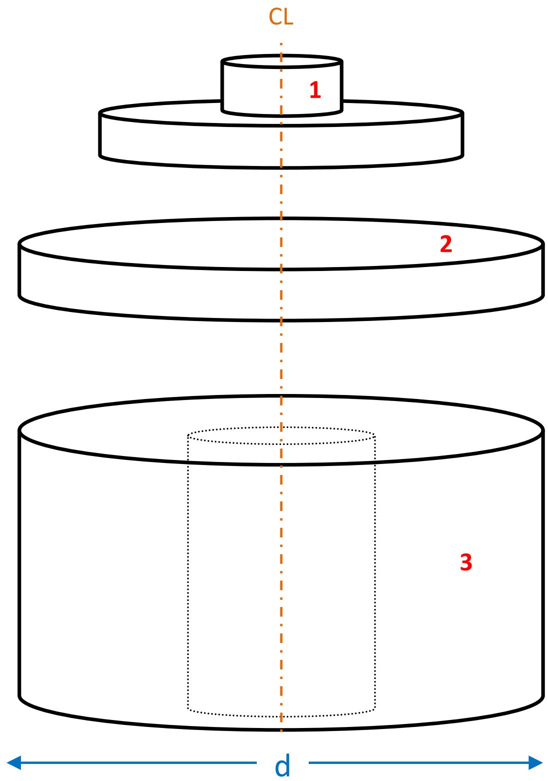


Figure 2.2: Geometry of bottom part of the Bochum resonant column

3. Mass moment of inertia of top part (J_l)

In order to perform tests on peat material, modifications had to be implemented. This modification of the Bochum Resonant column device was mainly the construction of a new lighter actuator. With this new actuator the vertical stress on top of the sample decreases in comparison with the older one. In the following sections the new actuator and validation of device will be explained. First try on organic soils, peat, using the Bochum resonant column device was done on December 2015 which was not successful, because: 1- due to the weight and shape of actuator (10 kg), top part of sample was not stable during tests 2- tests were only limited to small strain region (G_{max}). It must be noted that in this region, the signals were noisy and resonant frequency was also not detected accurately. Therefore, different methods were considered to solve these problems and finally we decided to decrease the weight of actuator. The modified parts were received on 27.01.2016 and tests were started immediately. In following the details of old and new actuator are explained.

2.2 Mass moment of inertia of top part (J_l)

2.2.1 Old actuator

Sample and bottom of the RC device have a cylindrical shape and their mass moment of inertia can be determined accurately. However, top part of resonant column has a complex shape (Figure 2.3, old actuator) which must be determined accurately before performing tests. Performed analytical and practical methods showed that the mass moment of inertia for the old actuator was about 0.064 kgm^2. The same analyses were done for the new actuator.

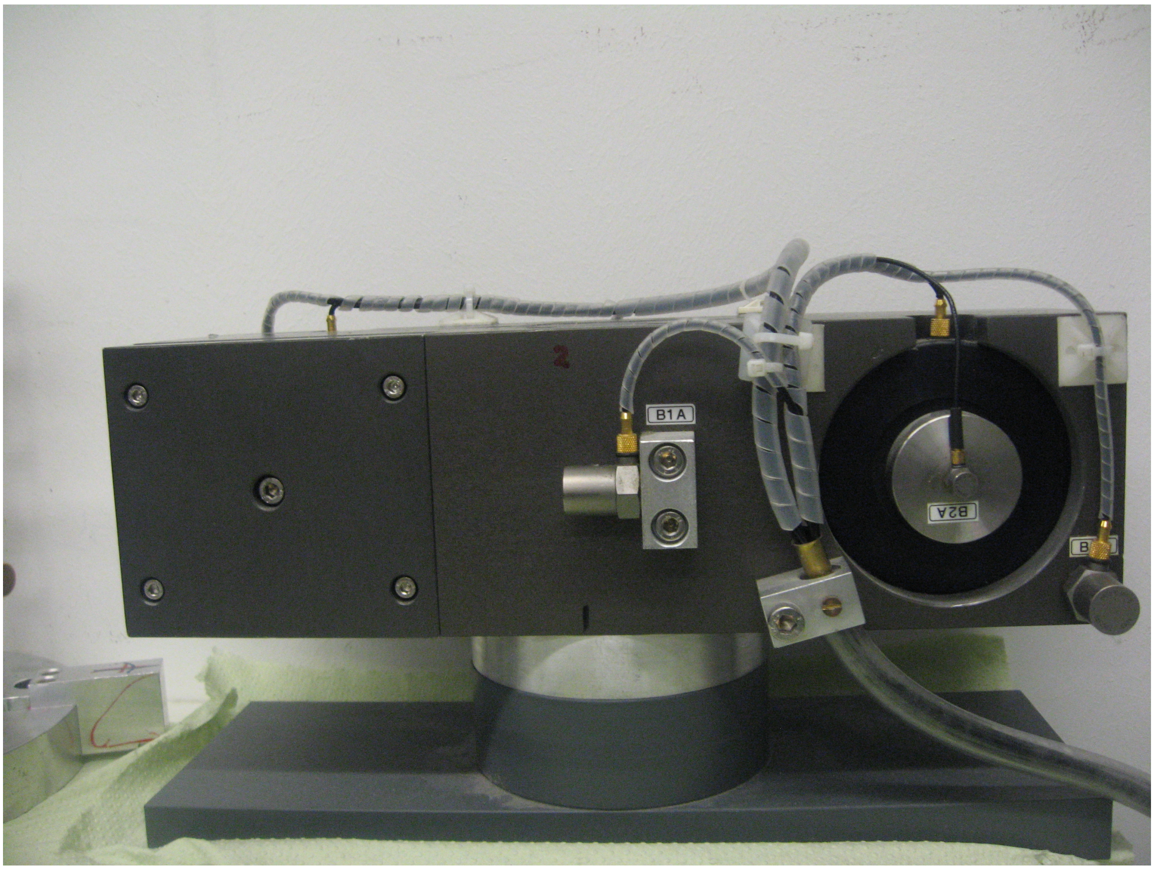


Figure 2.3: Geometry of top part of Bochum resonant column

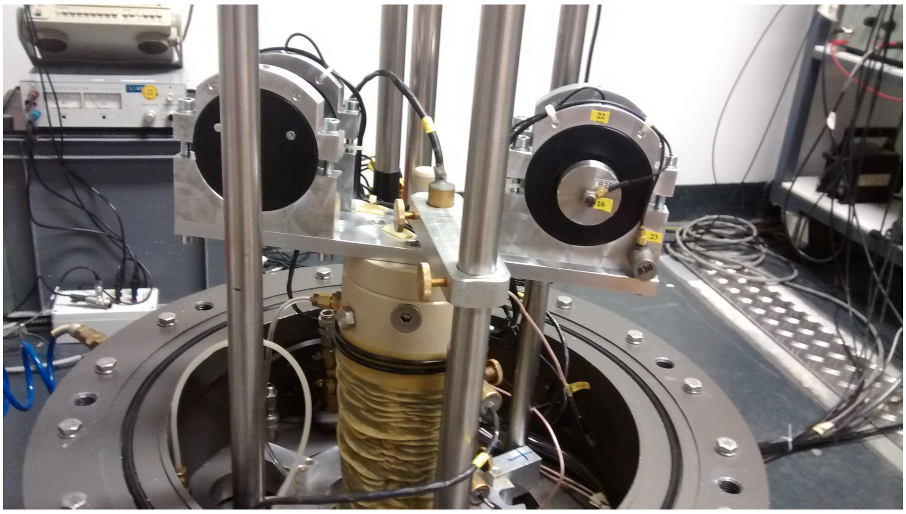
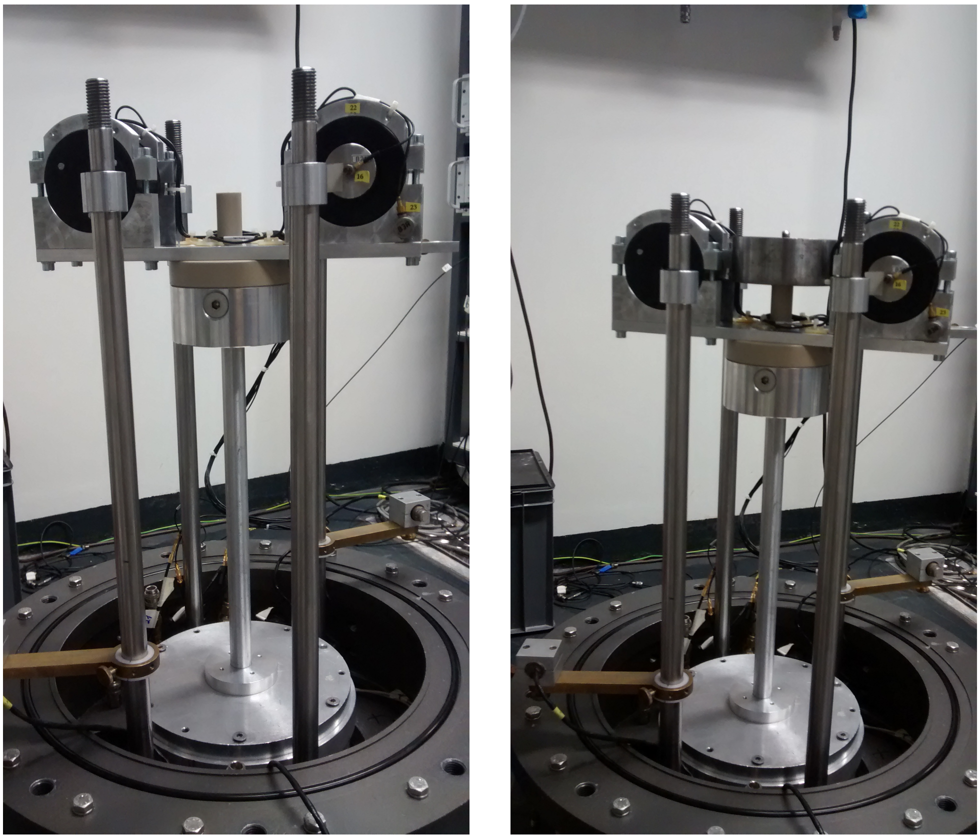


Figure 2.4: Geometry of new actuator of Bochum resonant column device



(a)

(b)

Figure 2.5: Determination of J_l for new actuator using Aluminum sample (d=2cm): a) without extra mass b) with extra mass

2.2.2 New actuator

The new actuator has a simple shape including two main parts: base plate and four frames to hold shakers (Figure 2.4). The weight of new actuator is about 5 kg which is about half of old actuator. However, before performing tests the value of J_l must be determined accurately. Two method were used to determine the value of J_l. In the first method, the geometry of actuator was divided into 9 parts and mass moment of inertia was determined for each part and total mass moment of inertia was the sum of them which is about 0.043 kgm^2.

Another method was also used to determine the value of J_l. In this method, RC tests were conducted with the aluminum sample (d=2 cm) with extra mass (extra mass has a given mass moment of inertia) and without extra mass (Figure 2.6). Afterwards, the value of J_l and a were determined by solving Equations (details can be found in Goudarzy 2015). The obtained value for J_l from this method will be used for all measurements. The obtained value for J_l with this method was 0.044 kgm^2. The value obtained from the experimental procedure will be used in all other tests.

2.3 Validation of results

2.3.1 Hostun sand sample

A sample with a relative density of 65% was prepared using raining method. The sample was subjected to the cell pressure of 55, 80, 110, 140, 170 and 200 kPa. These isotropic pressures have been also used in the previous tests using old actuator on Hostun Sand with the Bochum Resonant Column device (black points). The results are presented in the following figures (Figures 2.6a, 2.6b, 2.6c and 2.6d). These figures confirm that modification has been done successfully.

It is worthwhile to mention that the existing scatter between the results from new and old actuator is due to the difference in weight of the actuator. The cell pressure acts as an isotropic loading in all sides of the sample (horizontal and vertical sides). Additionally, the weight of actuator generates an extra stress in the vertical direction of sample in the RC cell. This means that due to the weight of actuator, anisotropic stress state is created inside the sample. Therefore, the old actuator with weight of 10 kg leads to higher vertical stress in the sample in comparison to the tests using the new actuator (weight of 5kg). This causes differences in the test results.

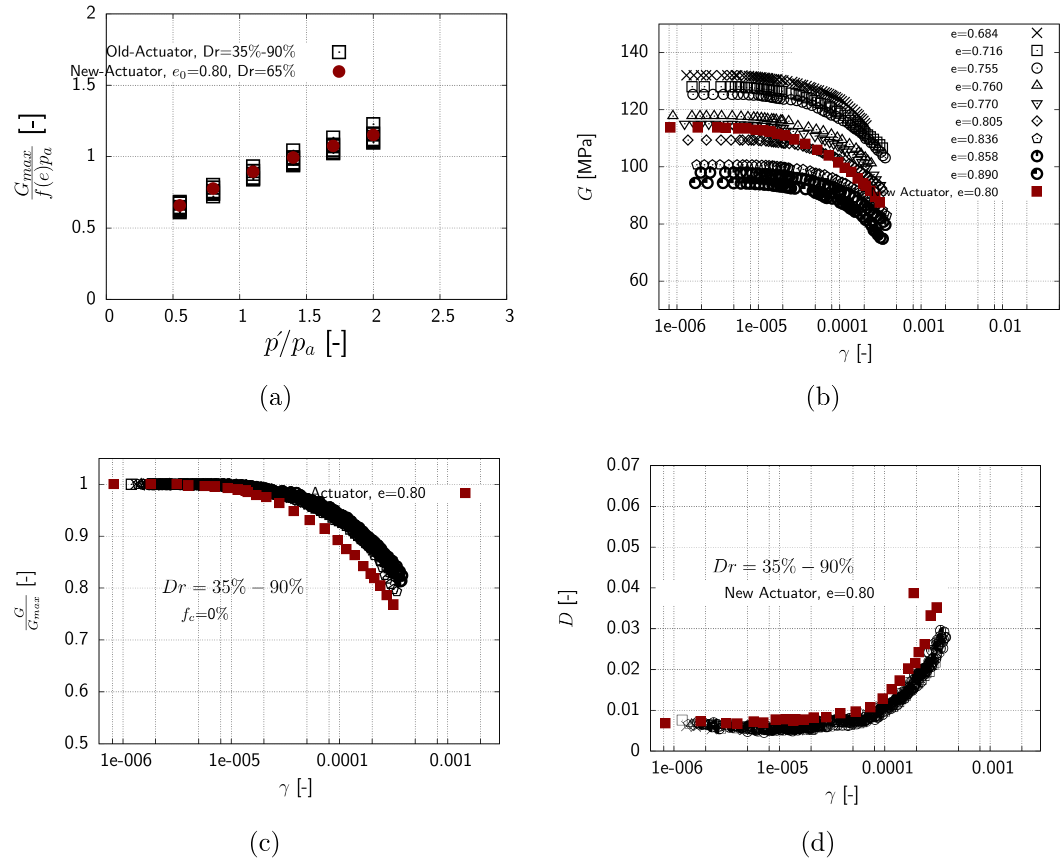


Figure 2.6: The experimental results of Clean Hostun sand, solid points is the results with new actuator and black points are results with old actuator: a) $\frac{G_{max}}{f(e)p_a}$ versus $p\acute{}/pa$, where, p_a is atmospheric pressure (assumed to be 100 kPa); b) G versus γ for cell pressure of 200 kPa; c) $\frac{G}{G_{max}}$ versus γ for cell pressure of 200 kPa; d) Damping ratio D versus γ for cell pressure of 200 kPa

2.3.2 Resonant column test on trial peat samples

2.3.2.1 Test program

After calibration and validation of the device a series of resonant column tests were conducted on the peat samples from Deltares. These samples were called: Bus-13-1 and Bus-13-2. The results are explained in following.

- Test on sample: Bus-13-1

Sample number Bus-13-1 had an initial height of 19.4 cm, diameter of 10 cm and total weight of 1.57 kg. The initial density of the sample was 1.028 g/cm^2. Trial tests were conducted for the isotropic confining pressures of 30, 50 and 67 kPa (loading path). Afterwards the confining pressure was decreased to 27 kPa (unloading) and RC test were also conducted for this confining pressure. The contact between top and bottom caps of resonant column device and sample were improved using steel nails (Figure 2.7) with minimum disturbance of sample. The main results are presented in the following sections.

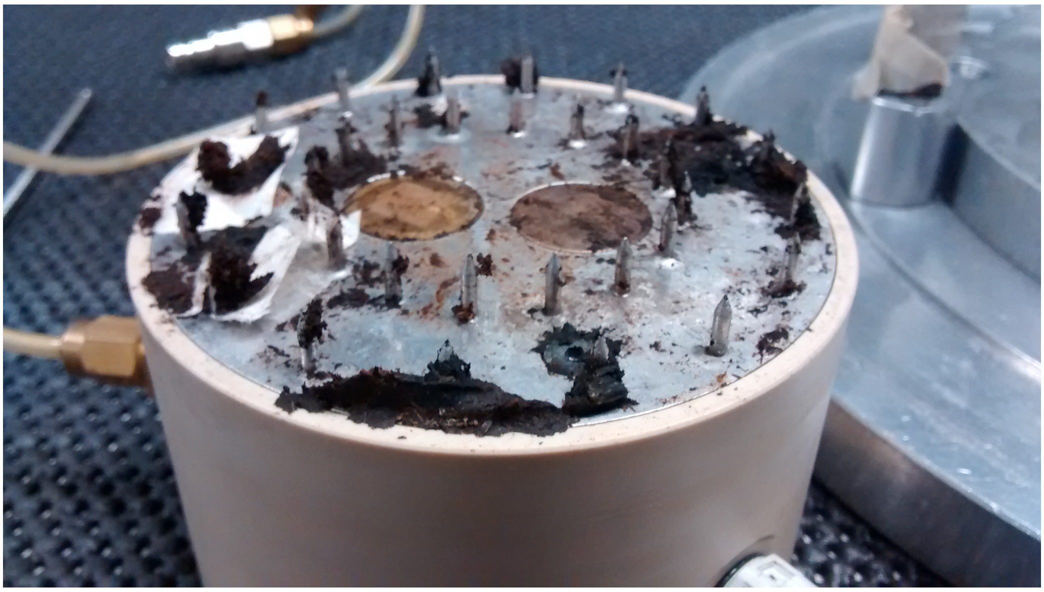


Figure 2.7: Photo of modified top cap to improve the interlocking or contact between top cap and sample using nails, after test on sample Bus-13-1

The measured maximum shear modulus, G_{max}, for loading and unloading stress state are presented in Figure 2.8. This figure shows the significant effect of confining pressure on G_{max}. Furthermore, this figure shows that G_{max} was slightly affected by unloading. However, it is worthwhile to mention that the time of consolidation (time between applying confining pressure and RC test) was 24 hours for all stress steps but, time for unloading was about 68 hours. Therefore, the results for unloading path cloud be affected by time. The measured G_{max} from current experiment was compared with the results presented by Kishida et al. (2009) in Figure 2.8.

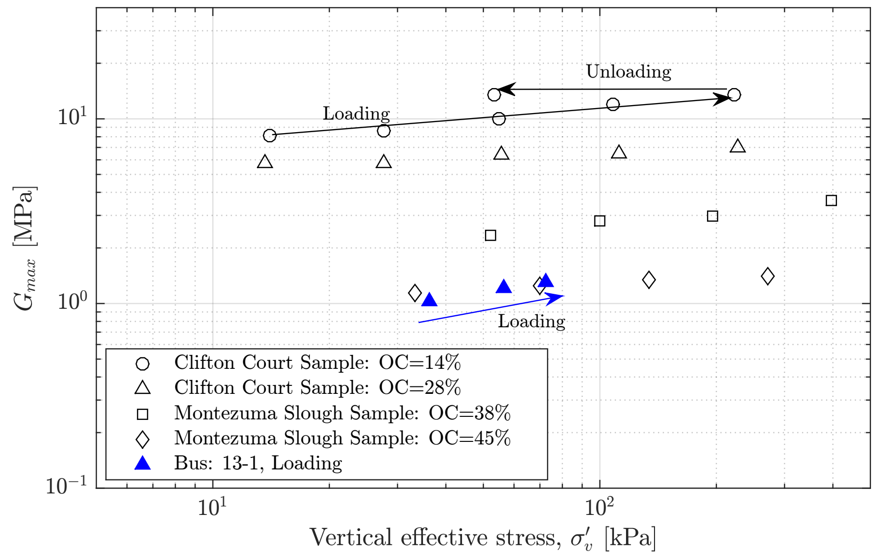


Figure 2.8: G_{max} versus σ_v´ for loading and unloading in comparison with the data published by Kishida et al. (2009) for highly organic soils from Montezuma and Clifton Court. The solid points are results from the current experiment.

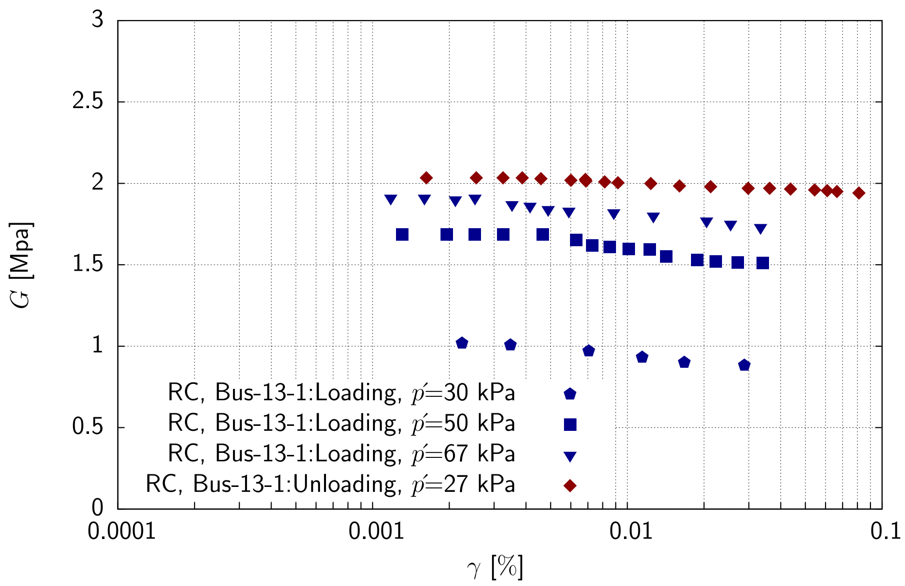


Figure 2.9: G versus γ for adopted peat sample

Figure 2.9 shows that shear modulus decreases slightly with an increase in the amplitude of shear strain in comparison with the observed results for sand or granular material. Figure 2.10 shows the effect of confining pressure on $\frac{G}{G_{max}}$. It can be observed that the

effect of confining pressure on $\frac{G}{G_{max}}$ is not significant which agrees with the results reported by Kishida et al. (2009) for highly organic soils.
Figure 2.11 shows the effect of confining pressure and shear strain on damping ratio. The results reveal that damping ratio is slightly affected by shear strain and confining pressure up to shear strain of 4E-2 %.

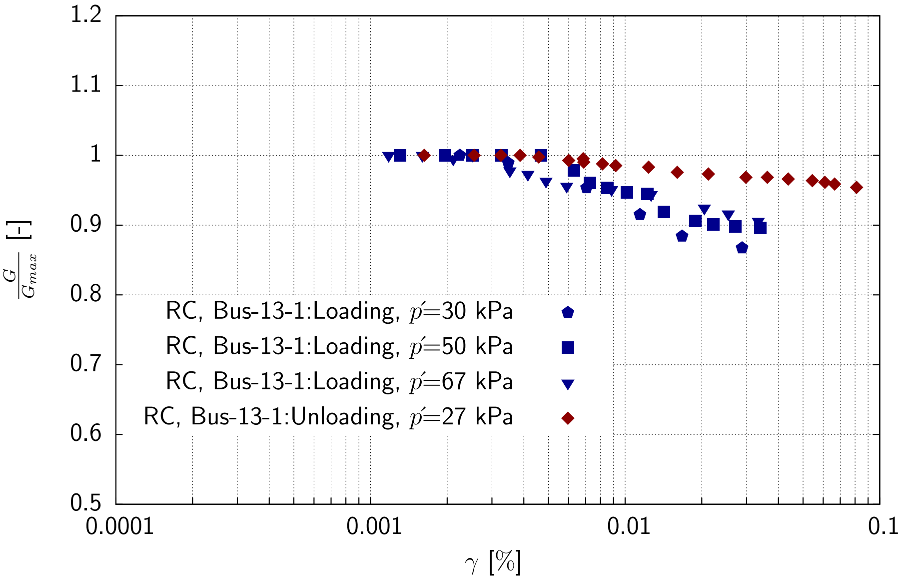


Figure 2.10: $\frac{G}{G_{max}}$ versus γ for adopted peat sample

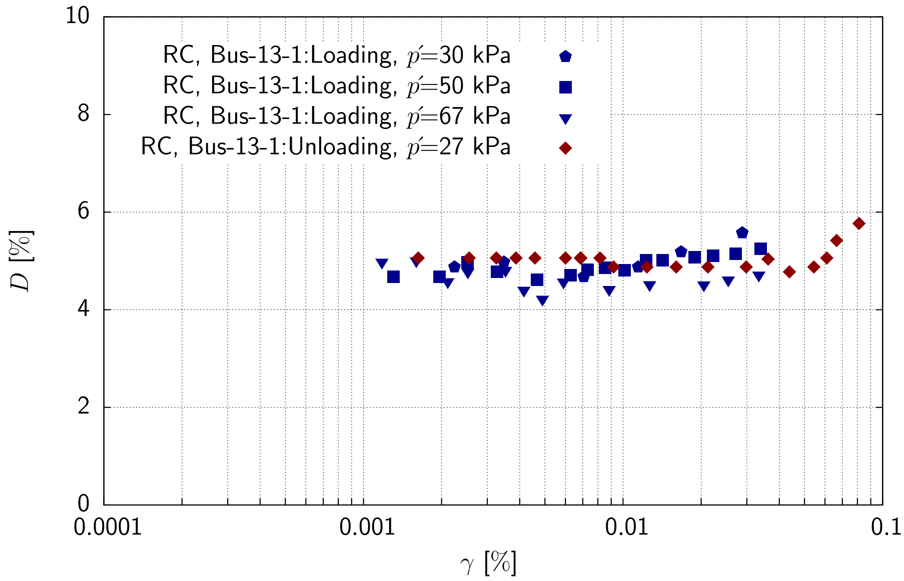


Figure 2.11: Damping ratio, D, versus γ for adopted peat sample

- Test on sample: Bus-13-2

The sample had an initial height of 18.48 cm, diameter of 9.77 cm and total weight of 1.57 kg. The initial density of the sample was 1.128 g/cm^3. Trial tests were conducted for the mean effective stresses of 17, 18 and 23 kPa (loading path) and the isotropic confining pressure of 9 kPa (unloading path). For this test, thin wings were also added between nails to improve the contact between top cap and sample during RC test (Figure 2.12). The results from this experiment are presented in following:

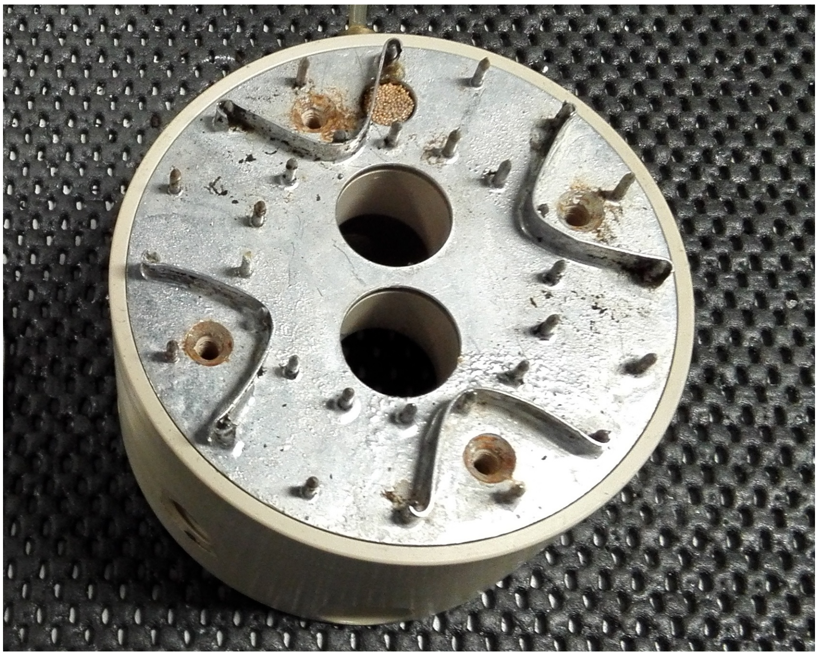


Figure 2.12: Photograph of modified top cap to improve the interlocking or contact between top cap and sample using nails and wings, test on sample Bus-13-2

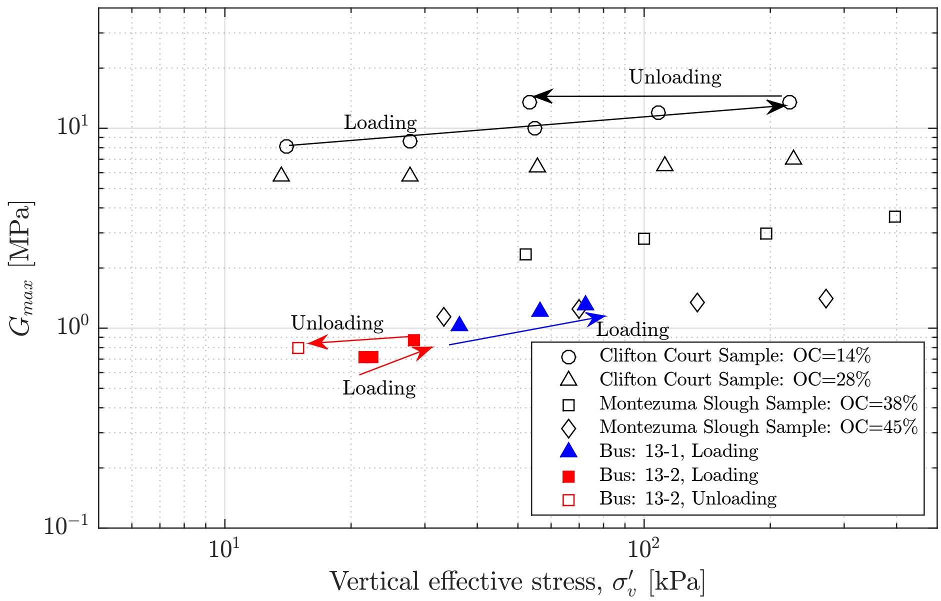


Figure 2.13: G_{max} versus $\sigma_v{'}$ for loading and unloading in comparison with the data published by Kishida et al. (2009) for highly organic soils from Montezuma and Clifton Court

The bandwidth method was used to calculate the value of resonant frequency and damping ratio. For example, Figure 2.14 shows the effect of frequency on the amplitude of excitation for the mean effective stress on 24 kPa. As can be seen from this Figure, resonant frequency, f_r, and consequently shear stiffness, G, decreases slightly with increasing the shear strain. This effect can also be seen in Figure 2.15 for the other mean effective stresses.

The same as sample Bus-13-1, Figure 2.16 shows that the effect of mean effective stress on $\frac{G}{G_{max}}$ is not significant which agrees with the results reported by Kishida et al. (2009) for highly organic soils. It is worthwhile to mention that the value of organic content for Bus-13-2 was 72.8%, this means that the sample was categorized as highly organic soil.

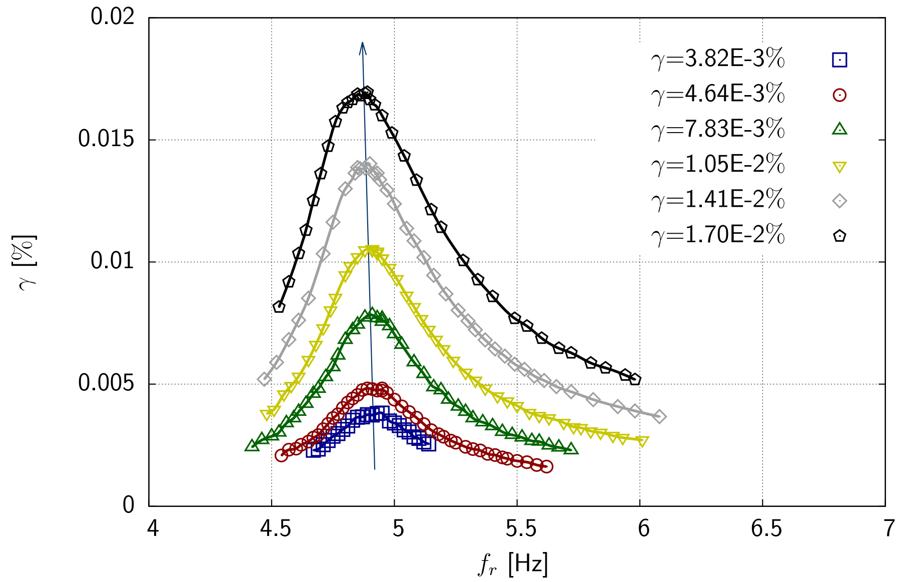


Figure 2.14: γ versus resonant frequency for mean effective stress of 24 kPa, sample:Bus-13-2

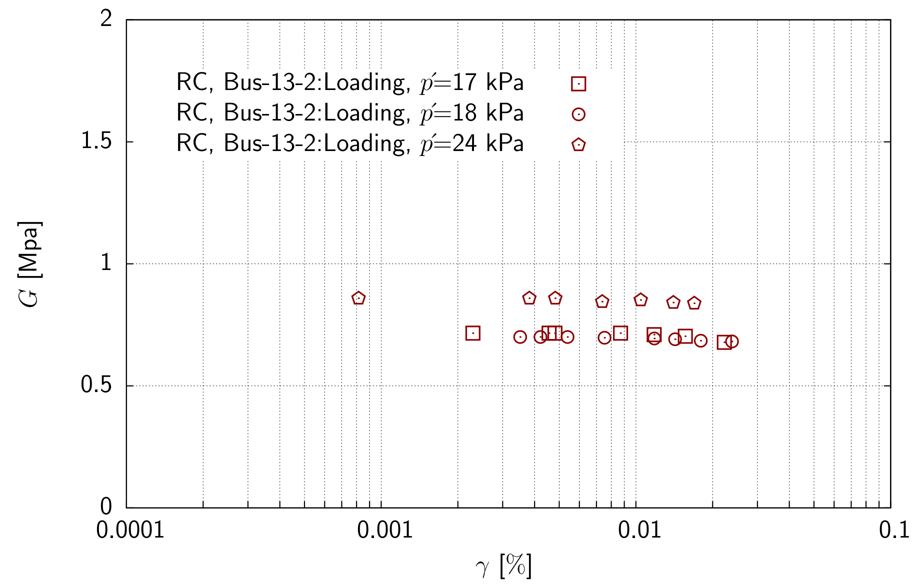


Figure 2.15: Shear modulus versus γ for adopted peat, sample:Bus-13-2

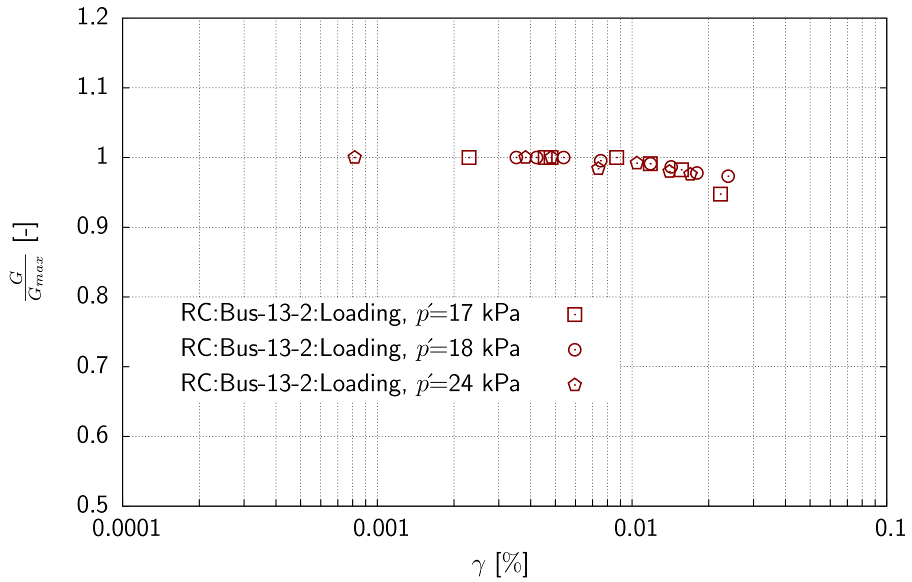


Figure 2.16: G/G_{max} versus shear strain for sample:Bus-13-2

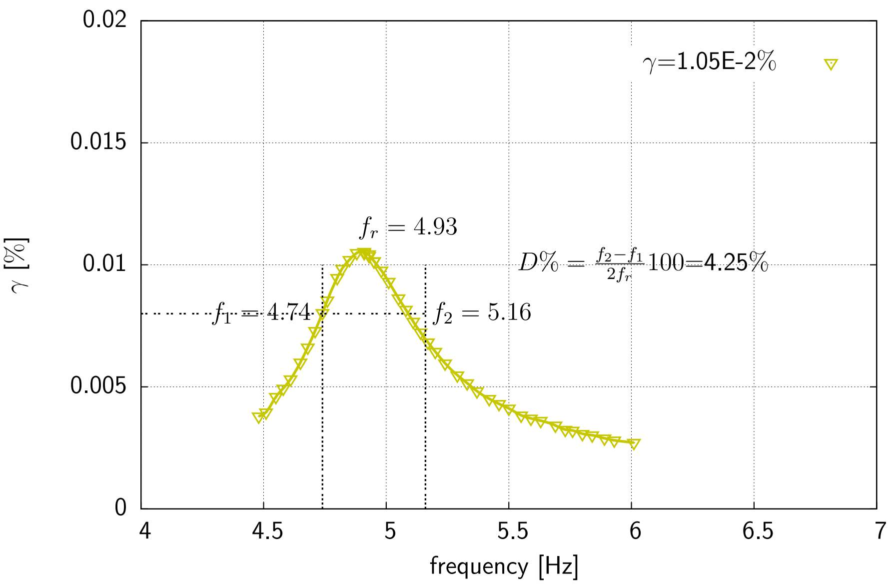


Figure 2.17: γ versus resonant frequency for mean effective stress of 24 kPa and shear strain of 1.05E-5, sample:Bus-13-2, f_1 and f_2 are frequencies at γ=0.707 γ_{peak} and they called: lower and upper half power frequencies

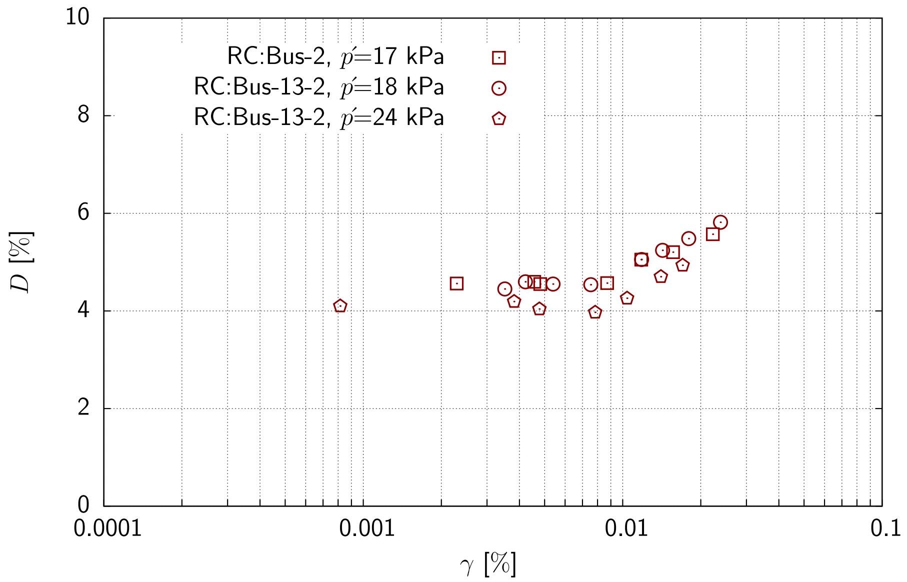


Figure 2.18: Damping ratio versus shear strain for sample:Bus-13-2

Bandwidth method was used to calculate the value of damping ratio for sample Bus-13-2. As an example, Figure 2.17 shows the measured damping ratio for mean effective stress on 24 kPa at shear strain of 1.05E-5. This method were extended for the mean effective stresses. Figure 2.18 shows the summary of results with respect to the amplitude of shear strain.

2.3.2.2 Comparison with the published data

The experimental data for these samples are compared with the results from Sherman Island in California (Boulanger et al. 1998 and Wehling et al. 2003) and Montezuma Slough and Clifton Court in Sacramento-Sab Joaquin Delta (Kishida et al. 2009) and results for sample Bus-13-1.

- **Inorganic clays**

The curves proposed by Vucetic and Dobry (1991) for G/G_{max}-γ and D-γ are presented in Figures 2.19 and 2.20. The recommended lines in their study are used to take into account the effect of plasticity on nonlinear behavior of clays. The recommended lines in their study are compared with the measured data from this experiment and published data by Kishida et al. (2009) in Figures 2.19 and 2.20.

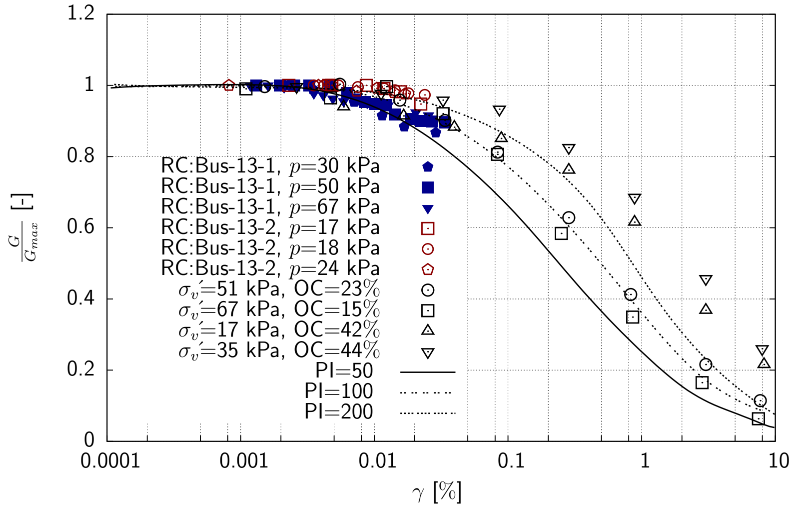


Figure 2.19: Comparison of modulus degradation for adopted peat with the lines recommended for inorganic clays by Vucetic and Dobry (1991)

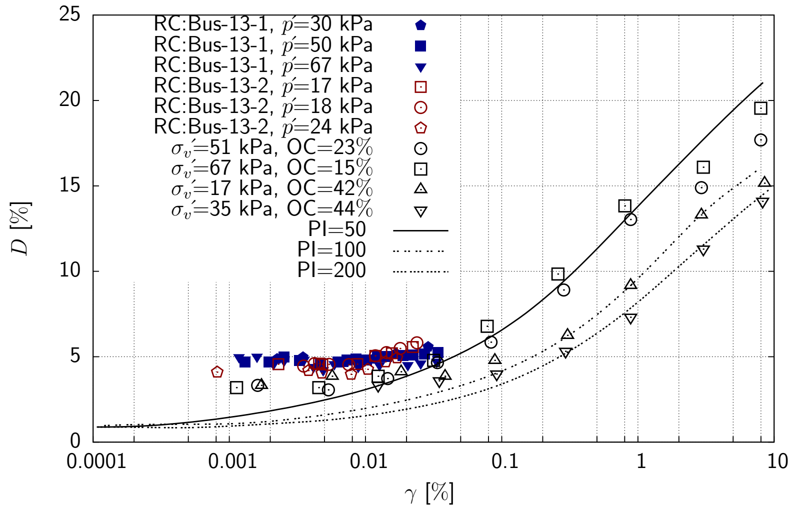


Figure 2.20: Comparison of damping ratio for adopted peat with the lines recommended for inorganic clays by Vucetic and Dobry (1991)

- **Inorganic clays and organic soils**

The effect of various parameters on G and D of inorganic clays and organic soils were evaluated by Stokoe et al. (1999) in the laboratory using combined RC-TS device. Stokoe et al. (1999) reported the linearity behaviour of peat (Figures 2.21 and 2.22). The results from our experiment are compared with the recommended lines by Stokoe et al. (1999) for various soils in Figures 2.21 and 2.22.

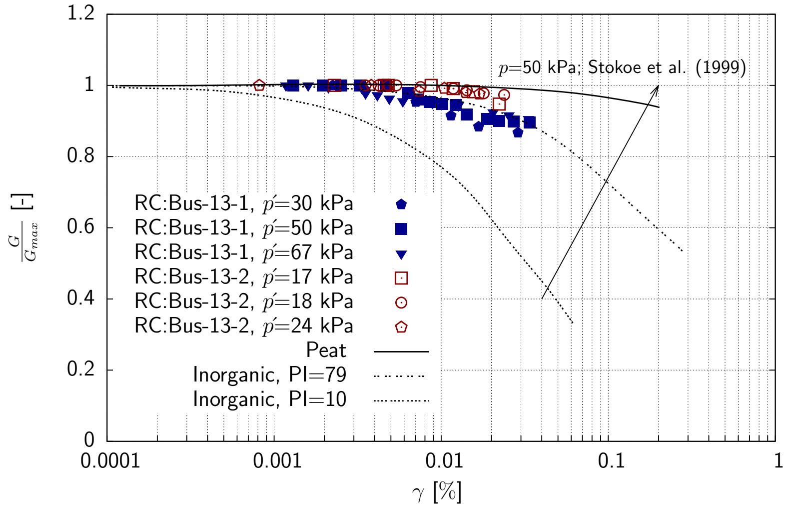


Figure 2.21: Comparison of modulus degradation for adopted peat with the lines recommended for peat and inorganic clays by Stokoe et al. (1999)

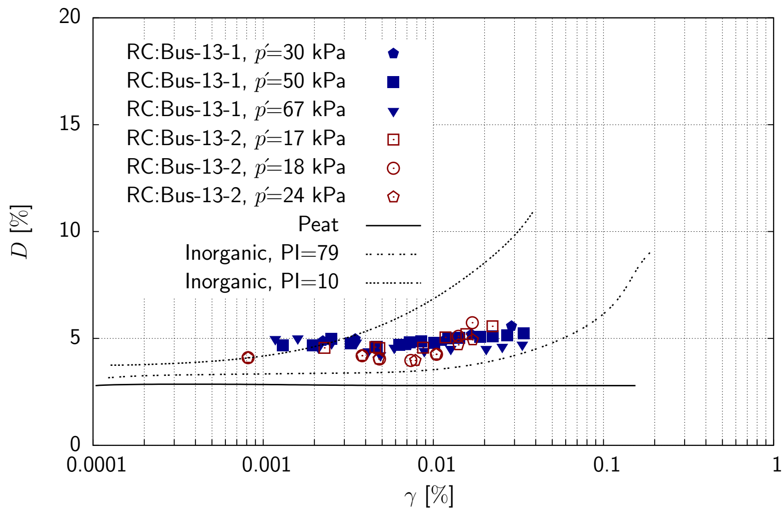


Figure 2.22: Comparison of damping ratio for adopted peat with the lines recommended for peat and inorganic clays by Stokoe et al. (1999))

- **Highly organic soils**

Kishida et al. (2009) conducted RC and torsional shear tests to assess dynamic properties of highly organic soils (OC≈ 15%-61%). Samples were compiled from the Montezuma Slough and Clifton Court in their experiment.
The results of current experiment on trial peat samples, blue solid points, are compared

with the published data by Kishida et al. (2009), black points, in Figures 2.23, 2.24 and 2.25. Furthermore, Wehling et al. (2003) proposed a lower and upper curve for modulus degradation and damping ratio of the experimental data on undisturbed samples compiled from free field of Sherman Island. Experimental results on trial samples were also compared with the proposed curves by Wehling et al. (2003) in Figures 2.24 and 2.25.

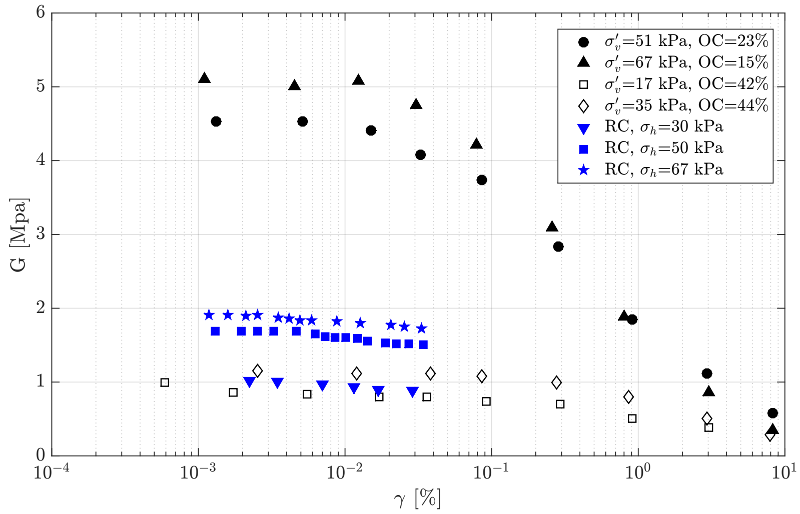


Figure 2.23: Comparison of shear modulus versus γ for adopted peat, blue points, in comparison with the results presented by Kishida et al. (2009)

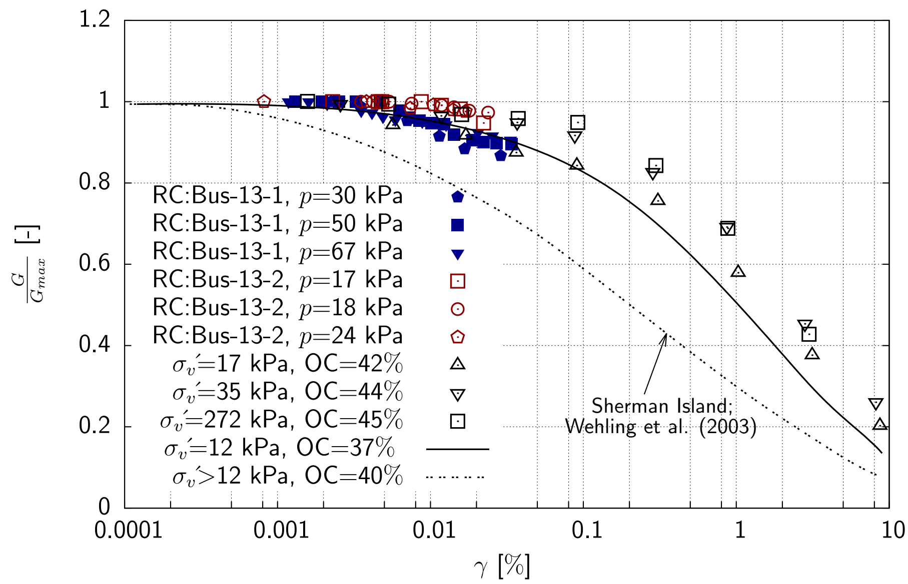


Figure 2.24: Comparison of modulus degradation for adopted peat with the lines recommended by Wehling et al. (2003) and Kishida et al. (2009)

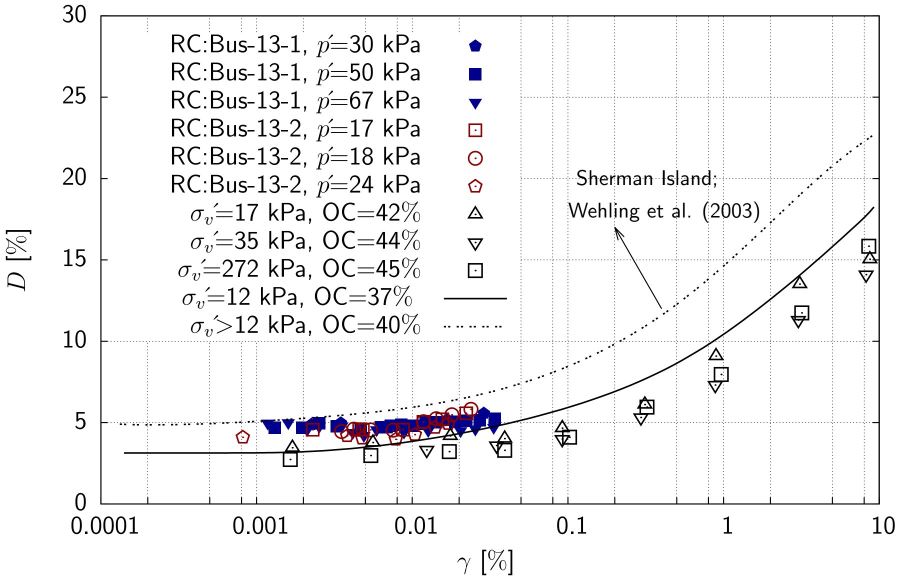


Figure 2.25: Comparison of damping ratio for adopted peat with the lines recommended by Wehling et al. (2003) and Kishida et al. (2009)

2.4 Summary

The resonant column device at Ruhr Universität Bochum was modified for performing tests on soft soils, e.g. peats. After modification and validation of device, a series of tests were conducted on the samples provided by Deltares. The results revealed that the effect of mean effective stress on intermediate strain properties of the samples, $G/Gmax$ and D curves, have been slightly effected by stress induced anisotropy, this could be due to the high amount of the organic contents inside the samples (as it was also observed and reported by Kishida et al. 2009 for Sherman Island, Montezuma Slough and Clifton Court peat). However, the result showed a significant effect of mean effective stress on G_{max} and $G(\gamma)$. The results were also compared with the previous works on organic soils, peat. The results confirmed that the modification of device has been done successfully.

3 Experimental program on Groningen peat samples

Experimental studies were conducted on the peat samples provided by Deltares. The study is divided into two parts:

i) classification tests, in accordance with ASTM standards, including water content, ω_c, organic content, OC, density of solid particles, ρ_s and fall cone tests to determine the undrained shear strength, S_{su}. It is worthwhile to mention that fall cone tests were conducted as an evidence for the measured stiffness using RC device which was helpful for interpretation of measured results using RC device

ii) RC and BE tests on the samples with natural water content under drained conditions to determine the small and intermediate properties of peat samples.

Table 3.1 shows details of the experimental program.

Table 3.1: Experimental program for samples 1-20

Samples			classification					Boundary conditions of RC and BE test			RC tests				BE tests
No.	name	Depth [m]	ρ $[g/cm^3]$	ρ_s $[g/cm^3]$	ω_c [%]	OC [%]	S_{su} [kPa]	σ_h' [kPa]	σ_v' [kPa]	K_0	G_{max} [Mpa]	$G(\gamma)$ [Mpa]	D_{min} [%]	$D(\gamma)$ [%]	G_{max} [Mpa]
1	NW1A2-A5-1D	3.95-4.11	×	×	×	×	×	6.40	25.60	0.25	×	×	×	×	×
2	NW1A2-A6-1A	4.3-4.46	×	×	×	×	×	6.60	26.50	0.25	×	×	×	×	×
3	NW1A2-B1-2B	3.85-4.0	×	×	×	×	×	6.50	26.10	0.25	×	×	×	×	×
4	NW1A2-C1-1A	3.6-3.76	×	×	×	×	×	6.30	25.30	0.25	×	×	×	×	×
5	NW1A2-D1-1A	3.67-3.82	×	×	×	×	×	6.50	25.90	0.25	×	×	×	×	×
6	NW1A2-D2-2A	5-5.15	×	×	×	×	×	6.90	27.50	0.25	×	×	×	×	×
7	NW1A2-a7-1A	5.25-5.4	×	×	×	×	×	7.00	27.70	0.25	×	×	×	×	×
8	NW1A2-d1-2	4.15-4.3	×	×	×	×	×	6.60	26.30	0.25	×	×	×	×	×
9	NW1A2-d2-1C	4.85-5	×	×	×	×	×	6.80	27.30	0.25	×	×	×	×	×
10	NW1A2-B1-3A	4.1-4.25	×	×	×	×	×	6.60	26.40	0.25	×	×	×	×	×
11	NW1A2-B2-2A	5.1-5.25	×	×	×	×	×	6.90	27.60	0.25	×	×	×	×	×
12	NW1A2-C1-2B	4.2-4.35	×	×	×	×	×	6.60	26.50	0.25	×	×	×	×	×
13	NW1A2-C2-1B	4.9-5.05	×	×	×	×	×	6.80	27.30	0.25	×	×	×	×	×
14	NW1A2-C2-2B	5.2-5.35	×	×	×	×	×	6.90	27.70	0.25	×	×	×	×	×
15	SM2C-B1-1A	1.77-1.92	×	×	×	×	×	3.30	13.30	0.25	×	×	×	×	×
16	SM2C-A2-1B	1.47-1.62	×	×	×	×	×	3.30	13.30	0.25	×	×	×	×	×
17	SB4A-A2-2A	1.4-1.55	×	×	×	×	×	3.30	13.30	0.25	×	×	×	×	×
			×	×	×	×	×	6.50	26.00	0.25	×	×	×	×	×
18	SM2C-C1-1A	1.8-1.95	×	×	×	×	×	3.30	13.30	0.25	×	×	×	×	×
19	SM2C-A3-1A	1.9-2.05	×	×	×	×	×	3.30	13.30	0.25	×	×	×	×	×
								6.50	26.00	0.25	×	×	×	×	×
								9.00	36.00	0.25	×	×	×	×	×
20	SB4A-A2-1B	1.18-1.35	×	×	×	×	×	3.30	13.30	0.25	×	×	×	×	×
								7.50	30.00	0.25	×	×	×	×	×

3.1 Classification tests

ASTM standard were used to determine water content, ω_c and organic content, OC, of samples. Also, fall cone test was conducted to measure the value of penetration of cone in side of sample based on the DIN EN ISO 17892-6 standard. This value used to determine the value of undrained shear strength, S_{su}, of soil samples. Table 3.2 shows a summary of measured results for all the samples.

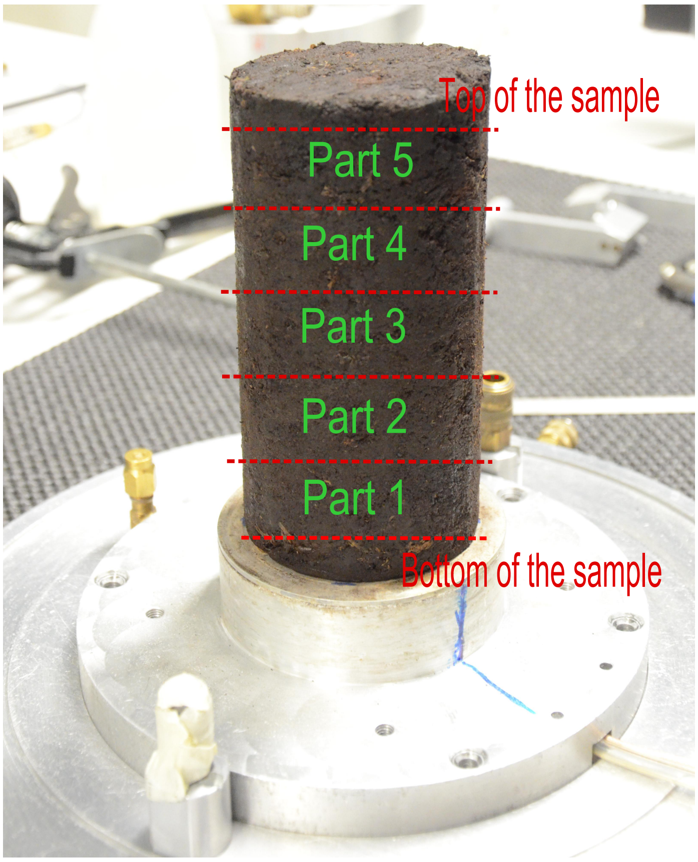


Figure 3.1: Sketch of sample for classification tests

Classification tests were conducted on the samples after RC test. Samples were divided into 5 parts (Figure 3.1). The top and bottom parts, in Figure 3.1, are removed from the sample. Afterwards, parts 1, 3 and 5 were chosen for fall cone, water content and organic content tests. Firstly, 3 fall cone tests were conducted on part 1. Afterwards, water content and organic content of this part were determined. This process was also repeated for parts 3 and 5. This means, 3 fall cone, water content and organic content tests were conducted for upper, middle and lower parts of each sample. The average values have been summarized in Table 3.2 and the details can be found in Appendix. Part 4 of samples have been send to Deltares for grain density tests and part 2 is still available in Bochum. The value of density was calculated from RC test after consolidation of sample.

Table 3.2: Experimental results for samples 1-14

		classification				
Sample No.	Sample name	ρ $[g/cm^3]$	ρ_s $[g/cm^3]$	ω_c [%]	OC [%]	S_{su} [kPa]
1	NW1A2-A5-1D	1.093		471.220	82.280	39.740
2	NW1A2-A6-1A	1.057		523.340	79.640	28.850
3	NW1A2-B1-2B	1.047		468.900	81.910	33.450
4	NW1A2-C1-1A	1.034		463.980	83.480	40.960
5	NW1A2-D1-1A	1.077		484.340	85.170	56.380
6	NW1A2-D2-2A	1.053		579.580	89.520	43.520
7	NW1A2-a7-1A	1.058		486.910	73.150	33.450
8	NW1A2-d1-2	1.009		508.440	88.230	38.440
9	NW1A2-d2-1C	1.029		606.620	91.310	35.300
10	NW1A2-B1-3A	1.032		549.120	91.320	39.820
11	NW1A2-B2-2A	1.037		539.540	90.040	30.710
12	NW1A2-C1-2B	1.028		579.220	91.550	27.000
13	NW1A2-C2-1B	1.044		608.110	92.640	37.890
14	NW1A2-C2-2B	1.031		632.970	89.720	30.880
15	SM2C-B1-1A	0.993		746.850	87.510	13.710
16	SM2C-A2-1B	1.051		659.840	87.870	13.360
17	SB4A-A2-2A	1.017		513.870	88.730	25.070
18	SM2C-C1-1A	1.180		689.370	86.550	12.120
19	SM2C-A3-1A	1.050		556.640	79.880	24.590
20	SB4A-A2-1B	1.005		542.480	93.990	27.810

3.2 RC and BE tests

24 RC and BE tests were conducted on 20 peat samples provided by Deltares to determine the small and intermediate properties of the adopted samples. 14 samples had approximately the same stress state, where $\sigma_h{}'$ was between 6-7 kPa and $\sigma_v{}'$ was between 24-32 kPa. However, 6 samples were subjected to low stress state ($\sigma_h{}'$=3.3 kPa and $\sigma_v{}'$=13.3 kPa), this is worthwhile to mention that the tests were conducted for two or three dif-

ferent stress levels on these samples. However, for all these tests the K_0 value remain constant (K_0=0.25) and that the effective vertical and horizontal stresses were raised simultaneously to higher stress levels under the condition of keeping the K_0 value constant. According to Table 3.1 tests at different stress levels (other than σ_h'=3.3 kPa and σ_v'=13.30 kPa) were conducted on three out of the six "low stress state" samples. Therefore, the results have been presented into two sections in this report: i) the results for samples 1-14 with the same boundary conditions and; ii) results for samples 15-20 under low stress level.

3.2.1 Initial and boundary conditions

3.2.1.1 Resonant column test

The initial conditions and and boundary conditions of the performed RC and BE tests are summarized in following:

Geometry of samples:
RC and BE tests were conducted on the cylindrical peat samples with diameter of 8-8.3 cm and height of 15-16 cm.

Degree of saturation:
RC and BE tests were conducted on the samples containing natural water content.

Consolidation time:
After sample preparation and applying the target stress on the sample, the sample was left under target stress for 24 hr. Afterwards, RC and BE tests were conducted. As an example, Figure 3.2 shows the vertical deformation of sample number 13 (NW1A2-C2-1B) versus time for the 24 hr consolidation period.

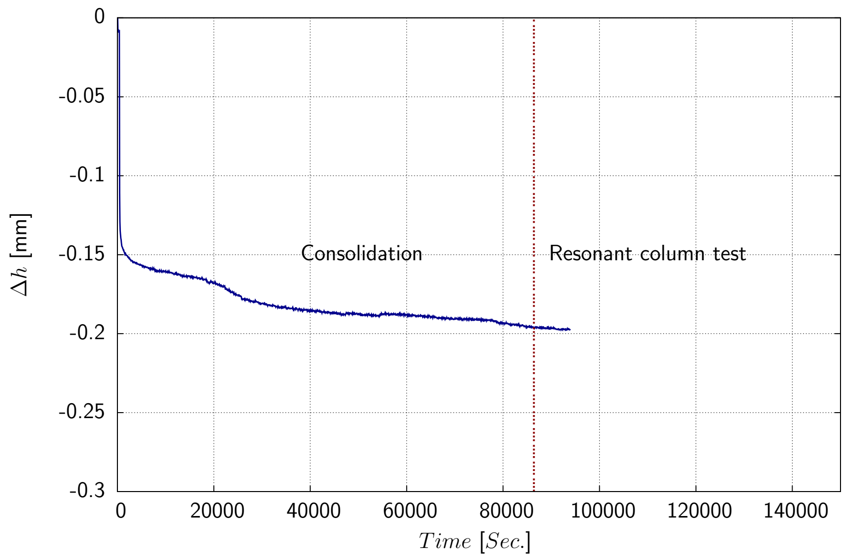


Figure 3.2: Vertical deformation of sample 13, NW1A2-C2-1B versus time

Amplitude of vibration:
RC tests were conducted on the samples with the maximum possible amplitude. Due to the compliance of samples, connection between sample and top and bottom caps and actuator achieved shear strain was limited to γ=5-7E-2%.

3.2.1.2 Bender Element tests

Traveling time:
The first arrival or deflection method (Goudarzy, König and Schanz 2016) was adopted to detect the travel time, t_s. Therefore, the shear wave velocity (v_s) is equal to length of the sample at the time of bender element test over the travel time. It must be noted that the length of 3 mm, which corresponds to the length of one bender element, was subtracted from the height of sample, assuming that the signal is transmitted over the half length of one bender element. Furthermore, the delay time, t_d, was also measured and subtracted from the measured traveling time. t_d is a traveling time when the bender elements are in direct contact with each other. t_d is due to the adopted cover for elements and its thickness, the value of t_d for the adopted bender elements was equal to 0.8 μs (Figure 3.3).

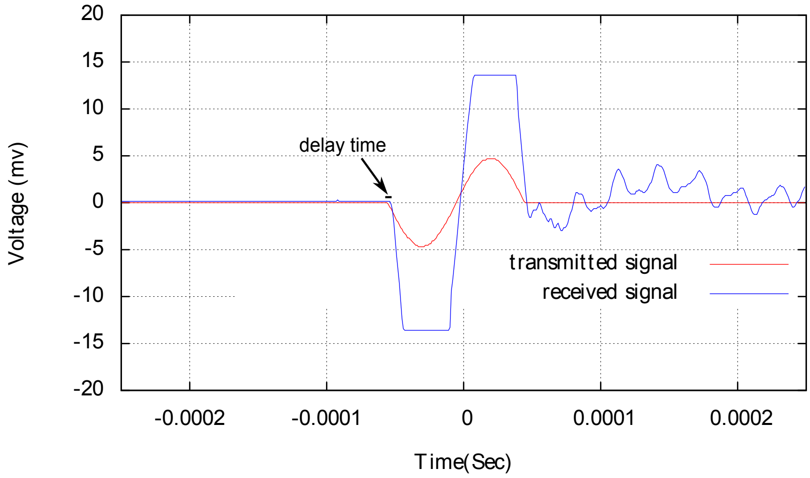
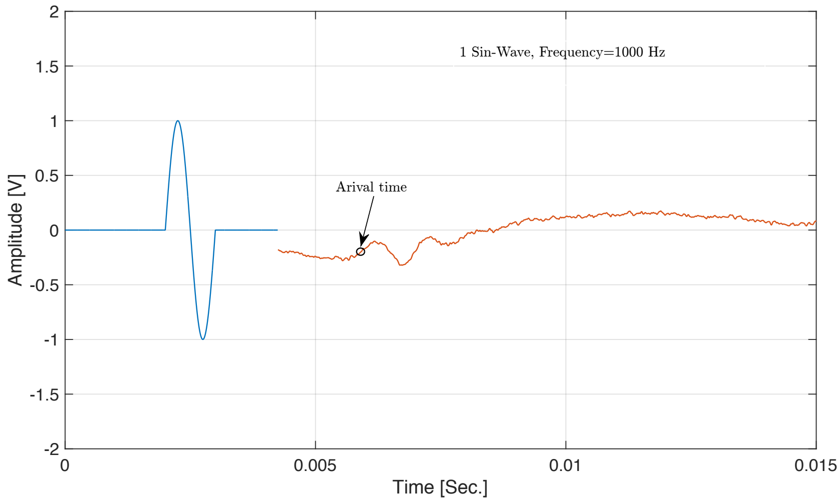


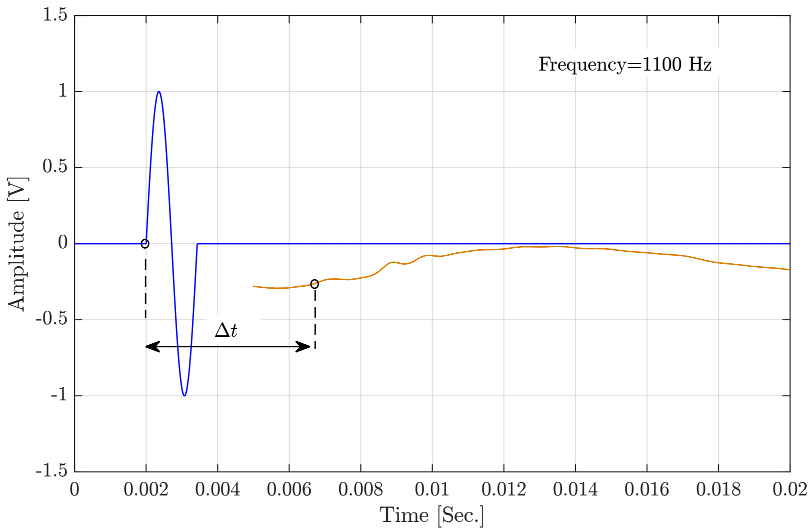
Figure 3.3: The value of delay time, t_d, for the adopted bender elements in this experiment

Frequency of signals:
Sinusoidal signals were sent with different frequencies to detect the arrival signals with higher quality (Figure 3.4). There is no direct relation to find a optimum frequency for signals in BE tests. The frequency depends on the boundary conditions, size and type of materials. Therefore, the optimum frequency must be determined using test with different frequencies to find the best frequency. These experiment revealed that the optimum frequency for adopted materials was between 900-1100 HZ.

Type of signals:
Triangle and sinusoidal signals were used to find the best type of signals for BE tests (Figure 3.5). The results revealed that sinusoidal signals have better quality in comparison to others.

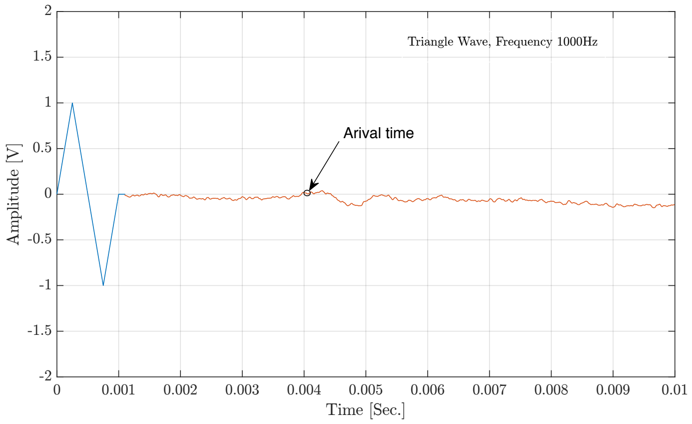


(a)

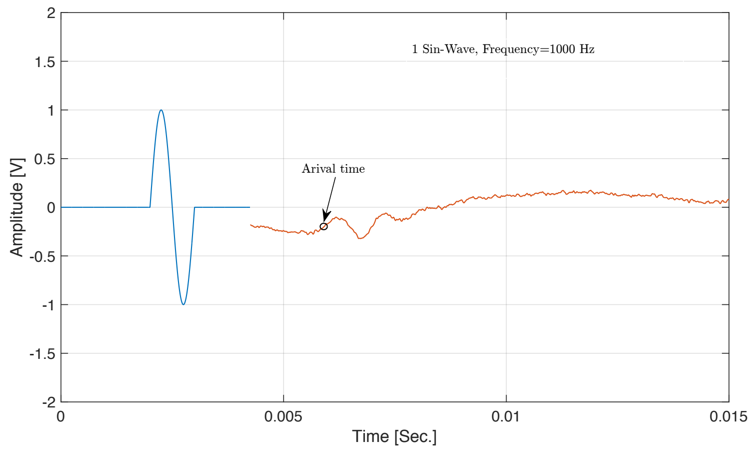


(b)

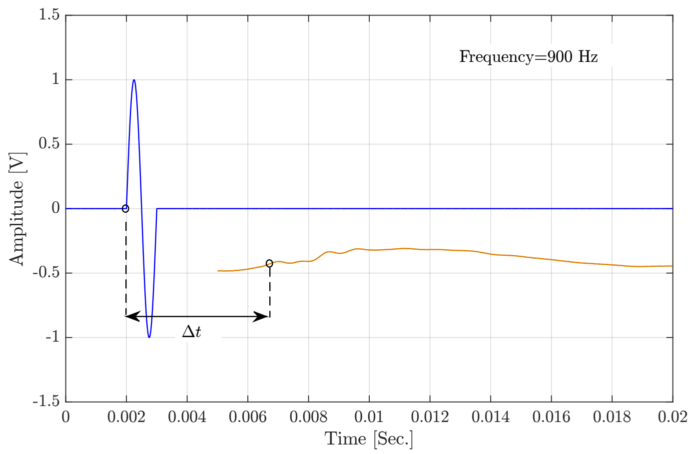
Figure 3.4: Frequency of signals in BE tests: a) sinusoidal signal, f=1000 Hz; b) sinusoidal signal, f=1100 Hz



(a)



(b)

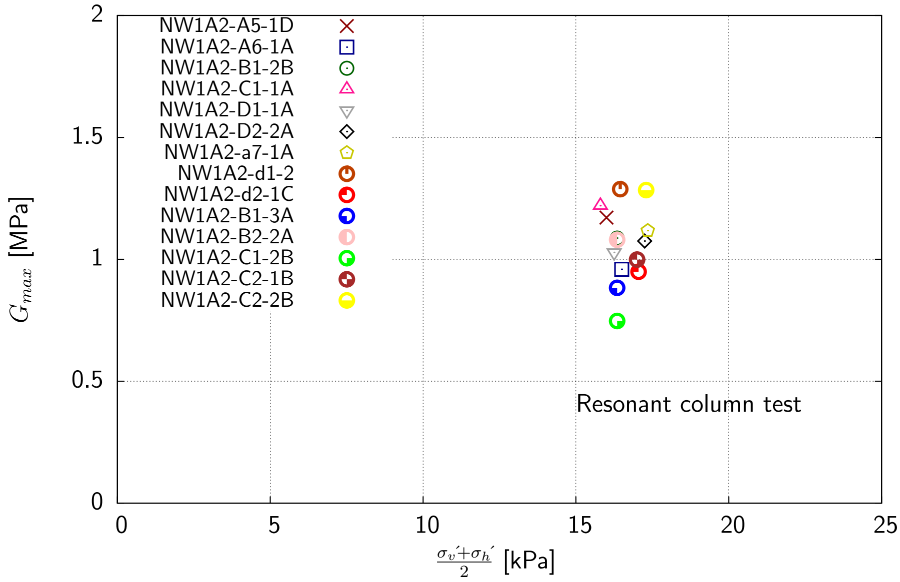


(c)

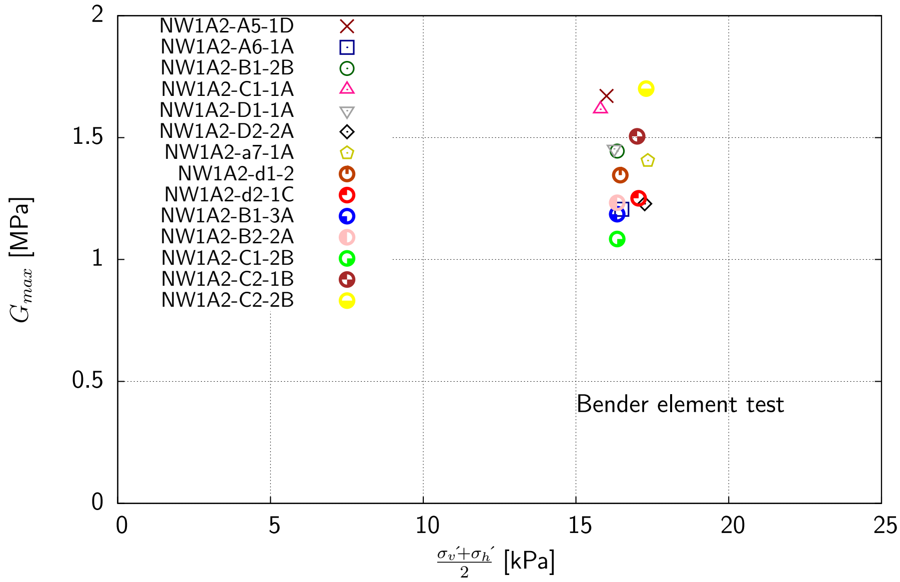
Figure 3.5: Type of signals in BE tests: a) triangle signal, f=1000 Hz; b) one sinusoidal signal, f=1000 Hz; c) one sinusoidal signal, f=900 Hz

3.2.2 Results for samples 1-14

Figure 3.6 shows the measured G_{max} using the resonant column device for samples 1 to 14 (Table 6.1). The details of results and the results from BE tests are presented in Tables 6.1 and 6.2 in Appendix.



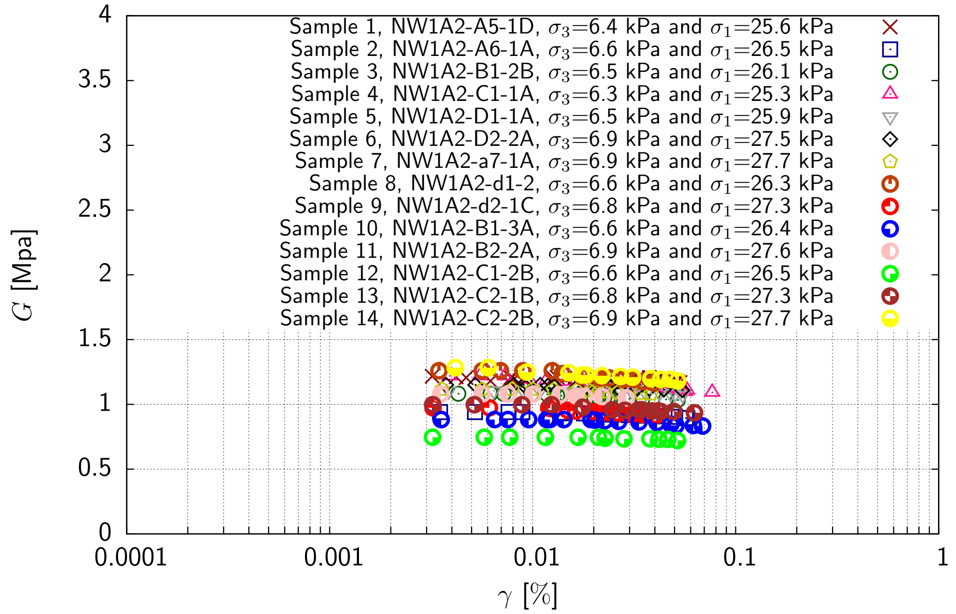
(a)



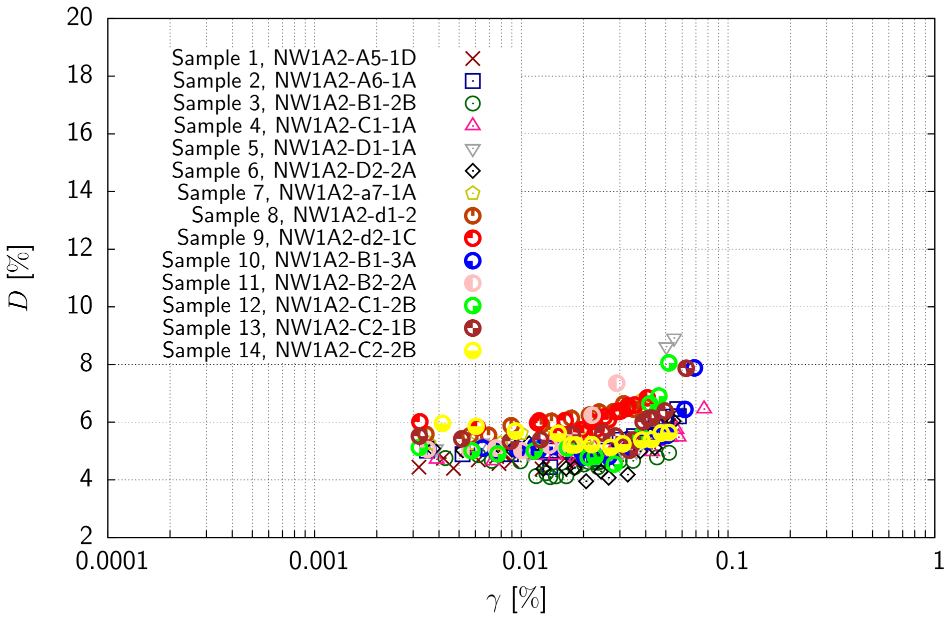
(b)

Figure 3.6: G_{max} versus $\frac{\sigma_v' + \sigma_h'}{2}$ for loading path for samples with subjected to σ_h'=6-7 kPa, samples 1 to 14 Table 6.1: a) RC test; b) BE test

Figure 3.7 shows the effect of shear strain on shear modulus and damping ration. As it is apparent from these Figures, shear stiffness decreases and damping ratio increases slightly with an increase in the amplitude of shear strain.



(a)

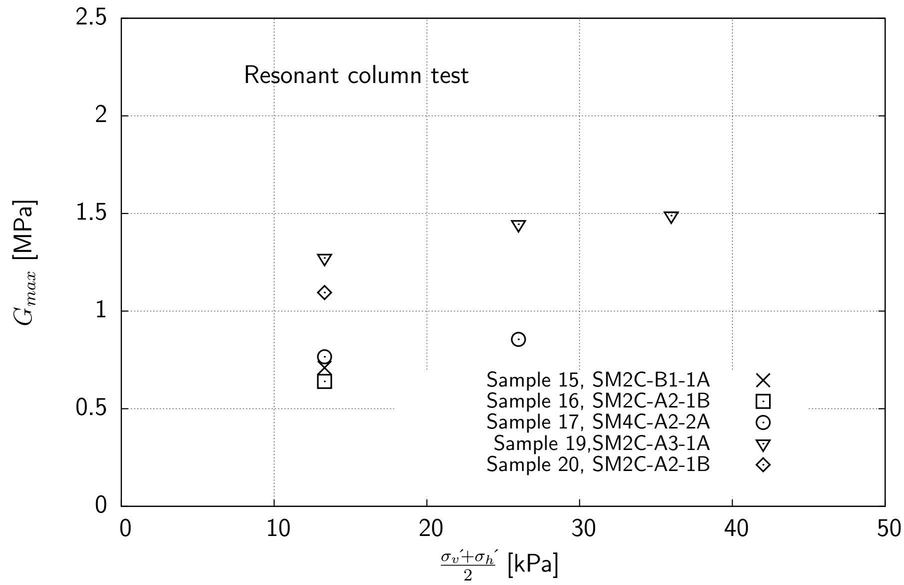


(b)

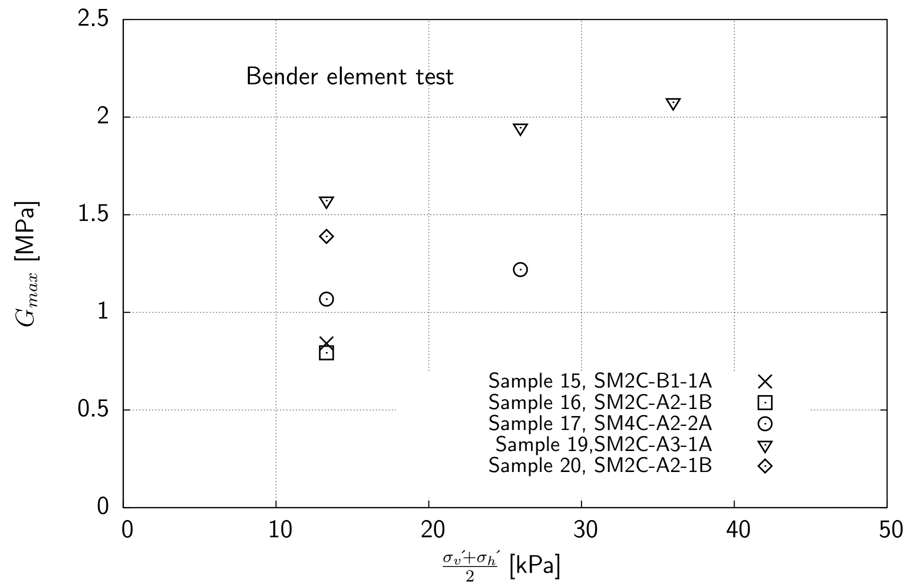
Figure 3.7: Small and intermediate properties of peat: a) shear modulus versus shear strain; b) damping ratio versus shear strain

3.2.3 Results for samples 15-20, low stress level

Figure 3.8 shows the measured G_{max} using the resonant column device for samples 15 to 20 (Table 6.2).



(a)



(b)

Figure 3.8: G_{max} versus $\frac{\sigma_v' + \sigma_h'}{2}$ for loading path for samples subjected to σ_h'=3.3-9 kPa, samples 15 to 20 Table 6.2: a) RC test; b) BE test

As it is apparent from Figure 3.8, G_{max} increases with an increase $\frac{\sigma_v' + \sigma_h'}{2}$ for the adopted materials. The details of these results and the results from BE tests are presented in Table 6.2 in Appendix. Figure 3.10 shows the effect of shear strain on shear modulus and damping ratio. As it is apparent from these figures, shear stiffness decreases and damping ratio increases slightly with an increase in the amplitude of shear strain.

3.8 shows that G_{max} increases with an increase in mean effective stress, $\frac{\sigma_v' + \sigma_h'}{2}$. The trend of data is the same as the curve proposed by Hardin and Drnevich (1972*a*) ($G_{max} = Kf(p') = K(p'/p_a)^n$) for geo-materials and the trend of G_{max} versus mean effective stress is in agreement with the published works (e.g. see Figure 3.12). Furthermore, damping ratio, D, as showed in Figure 3.10b, for this sample is constant up to shear strain of 0.05%. This means, the shear strain for which damping ratio starts to increase is much higher for this sample compared to the other samples. This confirms that the stiffness of this sample was higher compared to the stiffness of other samples. However, the test results on sample 20 show different behaviour. Shear stiffness decreased in comparison with sample 19 (Figures 3.8 and 3.10a). Again, Figure 3.8 revealed that G_{max} increases with an increase in the mean effective stress and the trend is the same as shown by other results. But, damping ratio starts to increase at a shear strain less than observed by the other samples (Figure 3.10b). BE tests on this sample showed the same trend of wave velocity like the RC tests. Additional tests were also conducted for unloading path on this sample (e.g. see Figure 3.9). The results of these additional tests confirm the measured values for G_{max} and $D(\gamma)$. However, it is worthwhile to mention that peats are not homogeneous and the results may be affected by natural fibers and woods inside the sample.

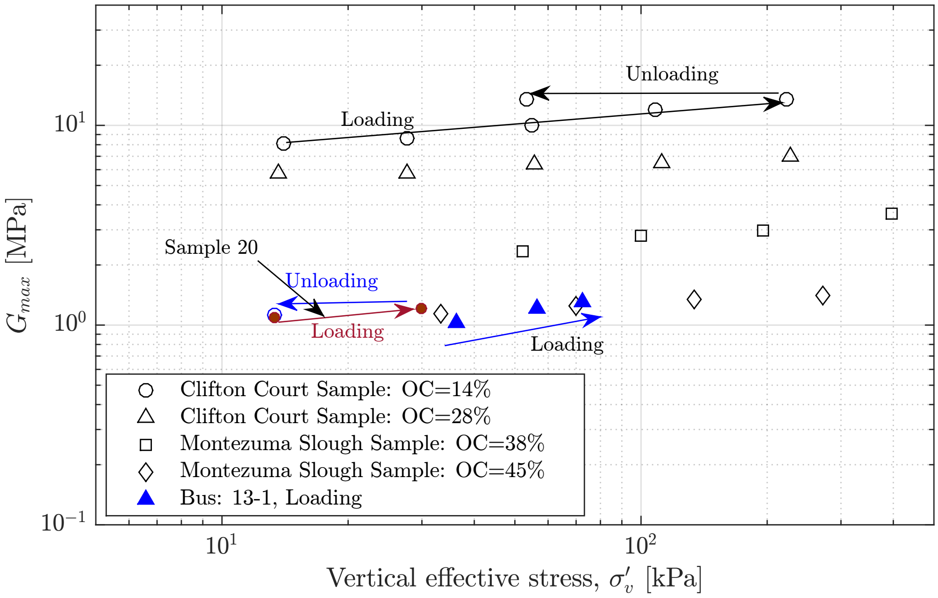
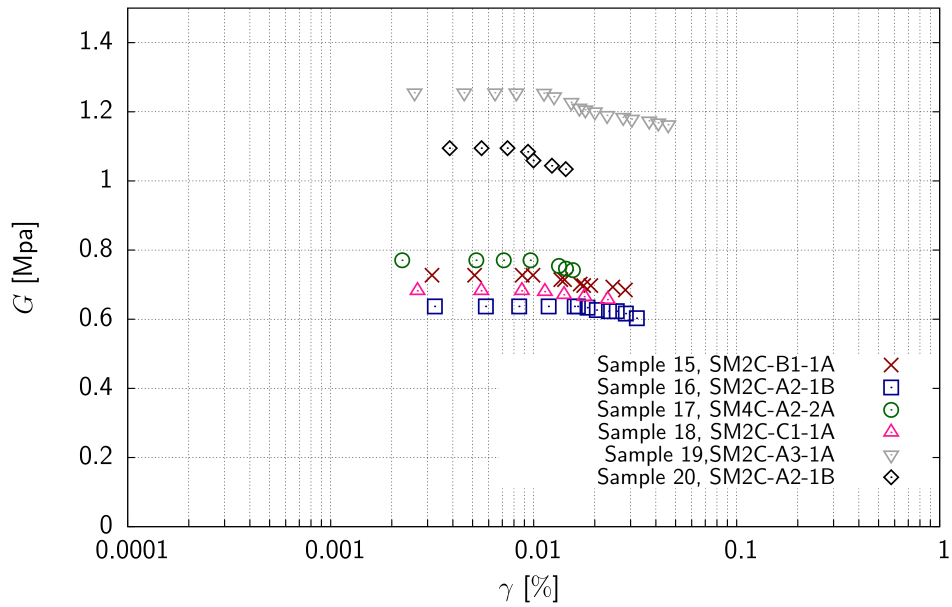
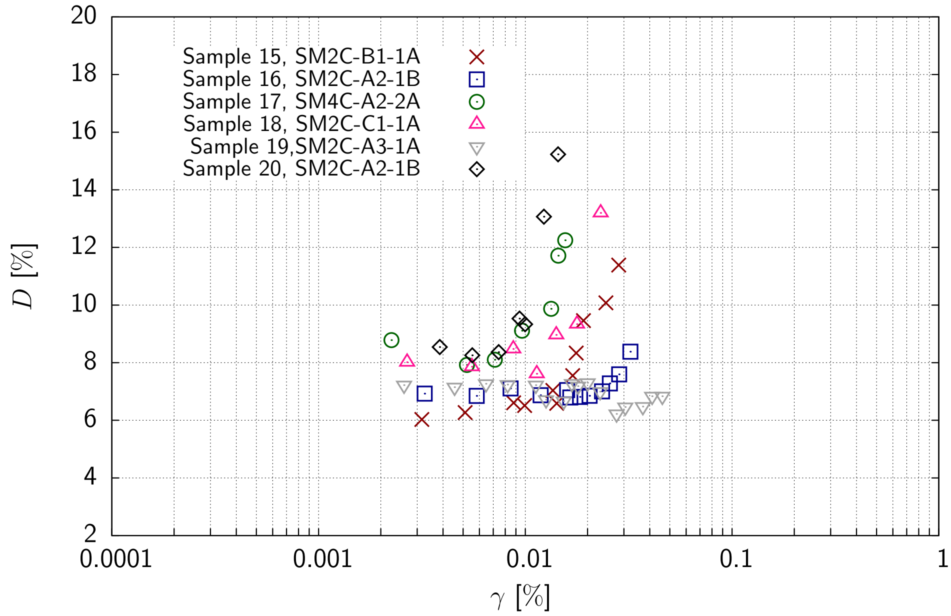


Figure 3.9: G_{max} versus σ_v´ for sample 20 subjected to loading and unloading in comparison with the data published data by Kishida et al. (2009) for highly organic soils from Montezuma and Clifton Court



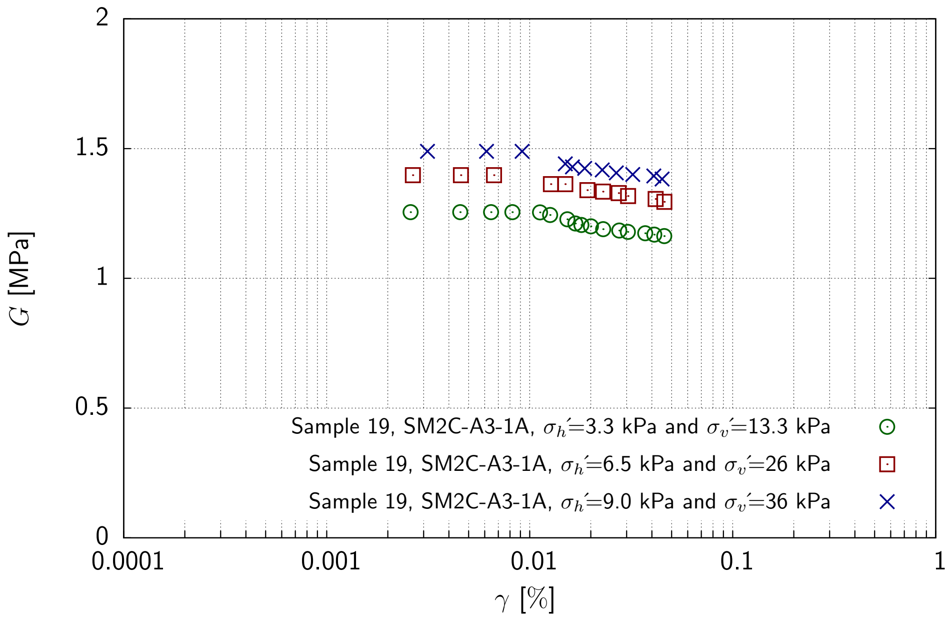
(a)



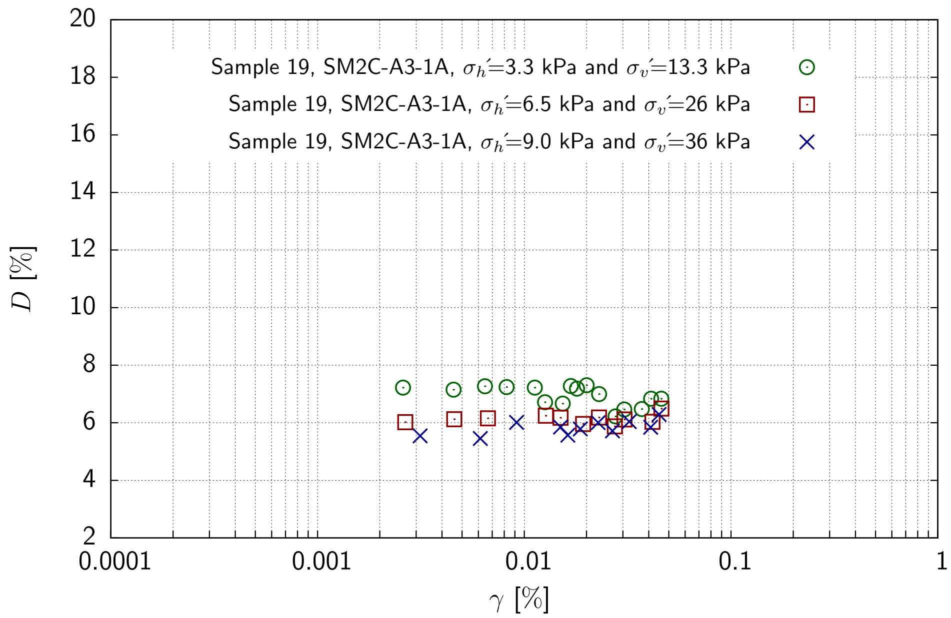
(b)

Figure 3.10: Small and intermediate properties of peat: a) shear modulus versus shear strain; b) damping ratio versus shear strain

Figure 3.11 shows the effect of shear strain and mean effective stress on shear modulus and damping ration. As it is apparent from these Figures, shear stiffness decreases and damping ratio increases slightly with an increase in the amplitude of shear strain. However, this Figure shows a significant effect of mean effective stress on minimum damping ratio, D_{min} and shear stiffness.



(a)



(b)

Figure 3.11: Small and intermediate properties of sample 19, SM2C-A3-1A : a) shear modulus versus shear strain; b) damping ratio versus shear strain

3.2.4 Comparison with published data

The measured maximum shear modulus, G_{max} of all samples are presented in comparison with the published data by Kishida et al. (2009) in Figure 3.12. The arrows in this Figure shows the loading path for samples 17, 19 and 20. Therefore,this figure shows the significant effect of vertical effective stress on G_{max}.

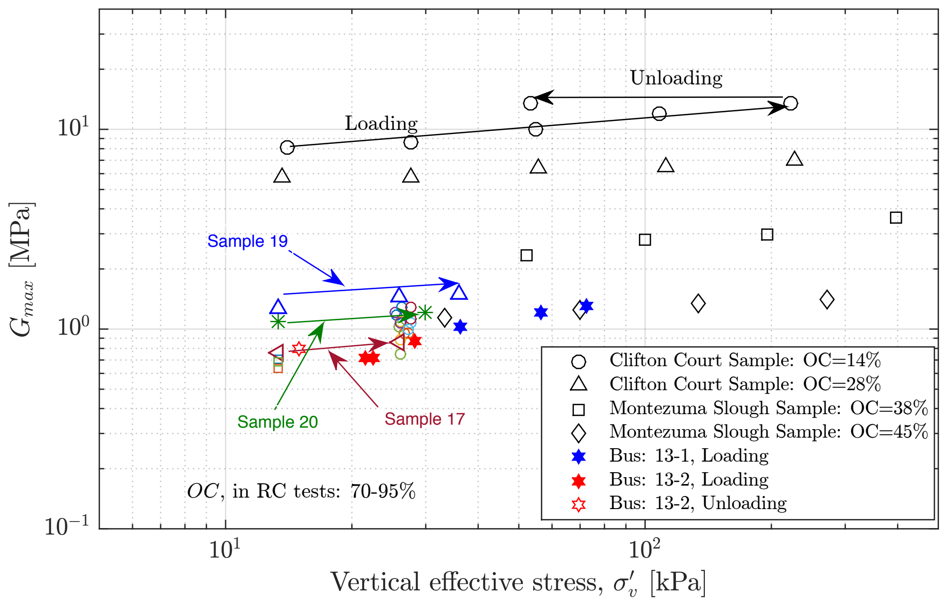


Figure 3.12: G_{max} versus σ_v´ for loading and unloading in comparison with the data published data by Kishida et al. (2009) for highly organic soils from Montezuma and Clifton Court

The results of current experiment, colored points were also compared with the curves proposed by Vucetic and Dobry (1991) for G/G_{max}-γ and D-γ of inorganic soils, and the recommended lines by Stokoe et al. (1999) and Kishida et al. (2009) for organic soils in Figure 3.13. In this Figure black points are the measured results for samples 15-20. These points show a deviation in comparison with the other results. This deviation could be due to the loose fabric of sample which has been subjected to low pressure.

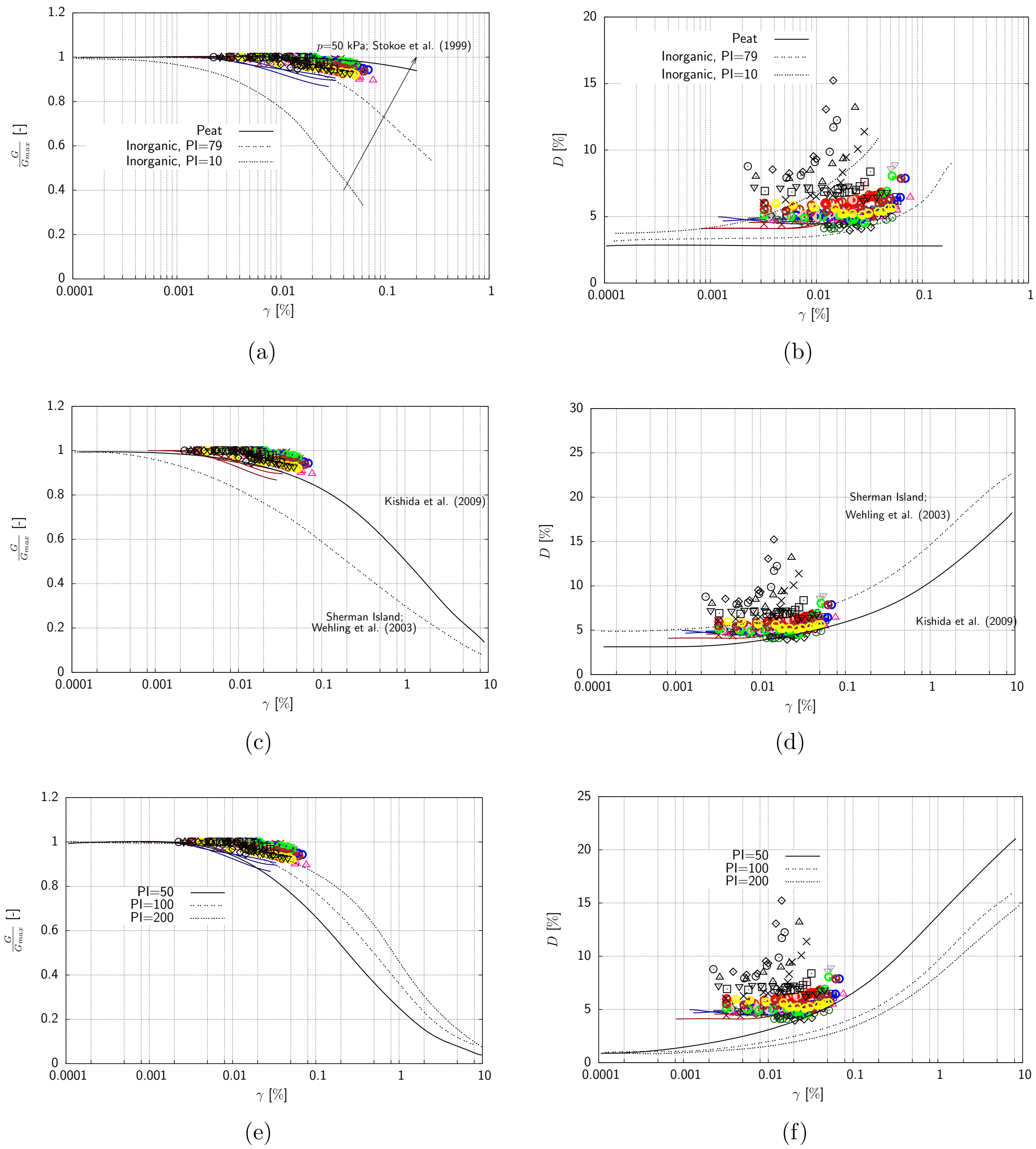


Figure 3.13: Small and intermediate properties of peat samples in comparison with the published data: a) shear modulus versus shear strain by Stokoe et al. (1999); b) damping ratio versus shear strain by Stokoe et al. (1999); c) shear modulus versus shear strain by Kishida et al. (2009); d) damping ratio versus shear strain by Kishida et al. (2009); e) shear modulus versus shear strain by Vucetic and Dobry (1991); f) damping ratio versus shear strain by Vucetic and Dobry (1991)

4 Empirical relationships

4.1 Derivation of empirical relationships

Empirical relationships have been also developed to predict modulus degradation, G, and damping ratio, D, of soils. Hardin and Drnevich (1972a) proposed an well known empirical relation 4.1 to predict the G/G_{max} curve. Hardin's relationship is based on two main parts: maximum shear modulus and reference shear strain.

$$\frac{G}{G_{max}} = \frac{1}{1 + \frac{\gamma}{\gamma_r}} \tag{4.1}$$

Where G_{max} is maximum shear modulus, γ is a shear strain and γ_r is the reference shear strain. Empirical relationships to predict γ_r (Seed and Idriss 1970) are not applicable to predict γ_r in samples subjected to anisotropic loading (Tatsuoka et al. 1979 and Goudarzy 2015). However Goudarzy (2015) reported that the value of γ_r for samples subjected to anisotropic loading could be estimated through Equation 4.2:

$$\gamma_r = \gamma_{r100}\left(\sigma_v/p_a\right)^{m_v}\left(\sigma_h/p_a\right)^{m_h} \tag{4.2}$$

where, γ_{r100} is the reference shear strain for sample subjected to 100 kPa isotropic cell pressure, p_a is atmospheric pressure. However, this function can not be also applicable for the adopted peat samples to predict the value of γ_r, because, reference shear strain is not available. Two method could be used to estimate the value of γ_r:

1) Fitting the curve from Equation 4.1 to the test data in Figure G/G_{max} versus shear strain and estimate the value of γ_r (Goudarzy 2015) 2) γ_r can be assumed as a point that G/G_{max} is equal to 0.5 (Stokoe et al. 1999).

The second method was used to determine the value of γ_r for samples. The data by Deltares for large strain level was used for this analysis. The G_{max} was assumed as an average value for experimental data for samples 1-14 (G_{max}=1 Mpa). If we normalize the data from Deltares by average G_{max} the value of γ_r could be determined (Figure 4.1). Therefore, from this Figure the value of γ_r is approximately 1%.

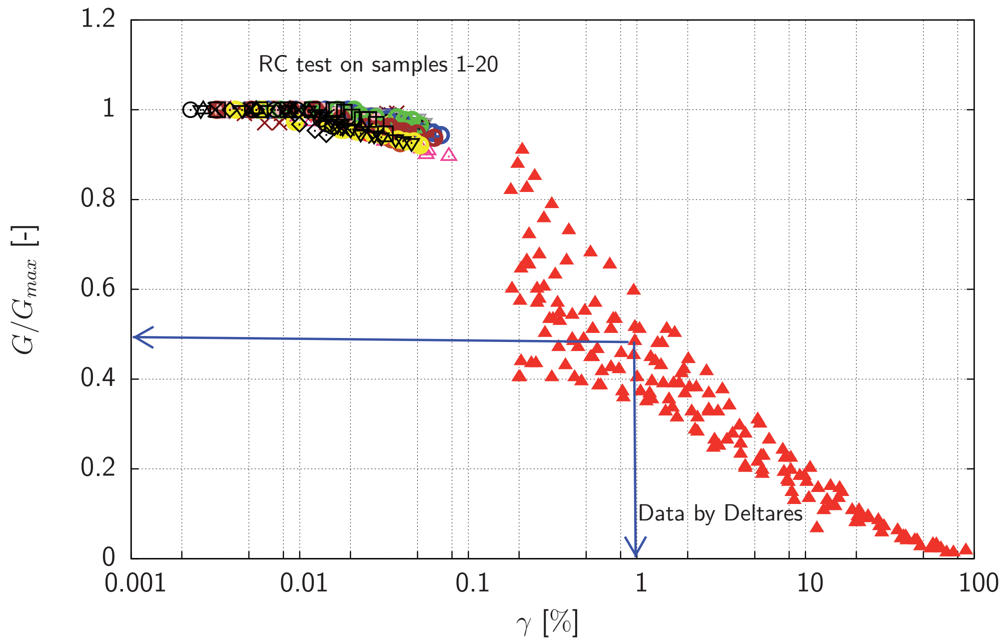


Figure 4.1: G/G_{max} versus shear strain for all data

Darendeli (2001) and Hashash (2009) proposed a modified form of Equation 4.1 as Equation 4.3:

$$\frac{G}{G_{max}} = \frac{1}{1 + \beta(\frac{\gamma}{\gamma_r})^{\alpha}} \tag{4.3}$$

where, γ is the shear strain, γ_r is the reference shear strain, and α, β are curve fitting parameters.

Hardin and Drnevich (1972*b*) defined a hyperbolic strain,γ_h and proposed 4.4 to predict the modulus degradation.

$$\frac{G}{G_{max}} = \frac{1}{1 + \frac{\gamma}{\gamma_r}[1 + a\exp(-b\frac{\gamma}{\gamma_r})]} \tag{4.4}$$

Where a and b are fitting curve parameters and γ_r is reference strain.

From the analysis the fitting parameters of Equations 4.3 and 4.4 can be determined (Figure 4.2).

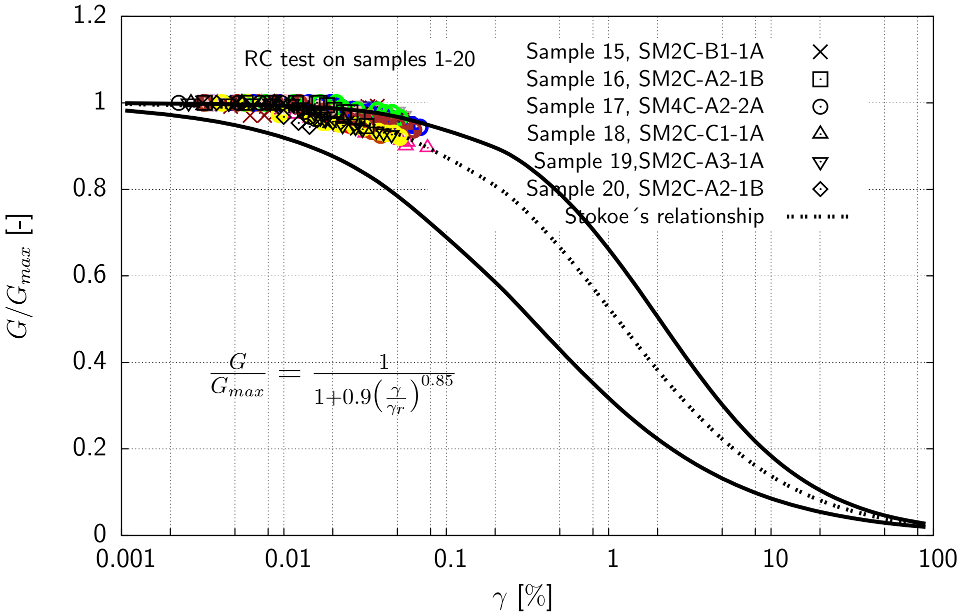


Figure 4.2: G/G_{max} versus shear strain for all data and fitting parameters of Equation 4.3

Hardin and Drnevich (1972*a*) and Hardin and Drnevich (1972*b*) proposed the Equation 4.5 to predict damping ratio respect to shear strain.

$$\frac{D}{D_{max}} = \frac{\frac{\gamma}{\gamma_r}}{1+\frac{\gamma}{\gamma_r}} \tag{4.5}$$

Where D_{max} is maximum value damping ratio which is suggested as between 25% to 33% for sands. However, the value of D_{max} is an unkown value and this Equation is not applicable to estimate the value of D.
Damping ratio can be estimated through Equation 4.6:

$$\frac{D}{D_{min}} = A\Big(\frac{\frac{\gamma}{\gamma_r}}{1+\frac{\gamma}{\gamma_r}}\Big)^B + 1 \tag{4.6}$$

where, D_{min} is the minimum damping ratio and A and B are fitting parameters.
This model was used to predict damping ratio in peat samples. The results revealed that for adopted material the values of A and B must be equal to 4.7 and 0.9 respectively (black solid and dashed lines in Figure 4.3). Also, minimum damping ratio, D_{min}, is equal to 4.75 for samples 1-14 and 9 for samples 15-20. It is worthwhile to mention that all analysis to determine the fitting parameters were conducted on samples 1-14, analysis

will be developed for all data.

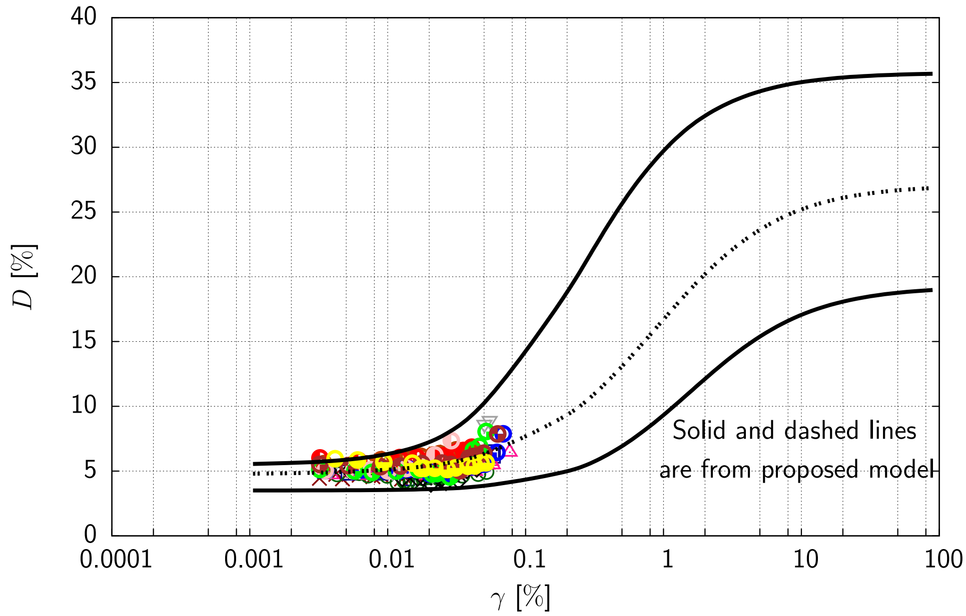
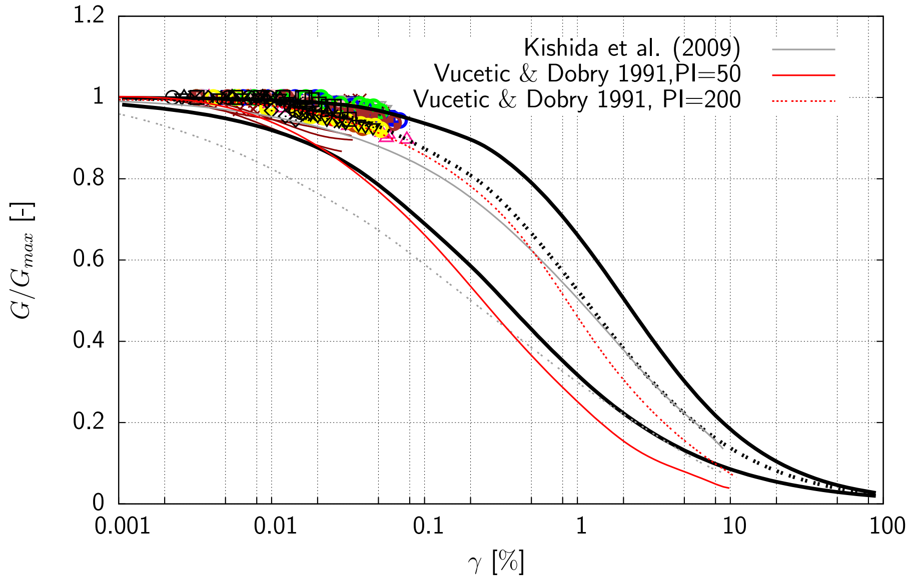


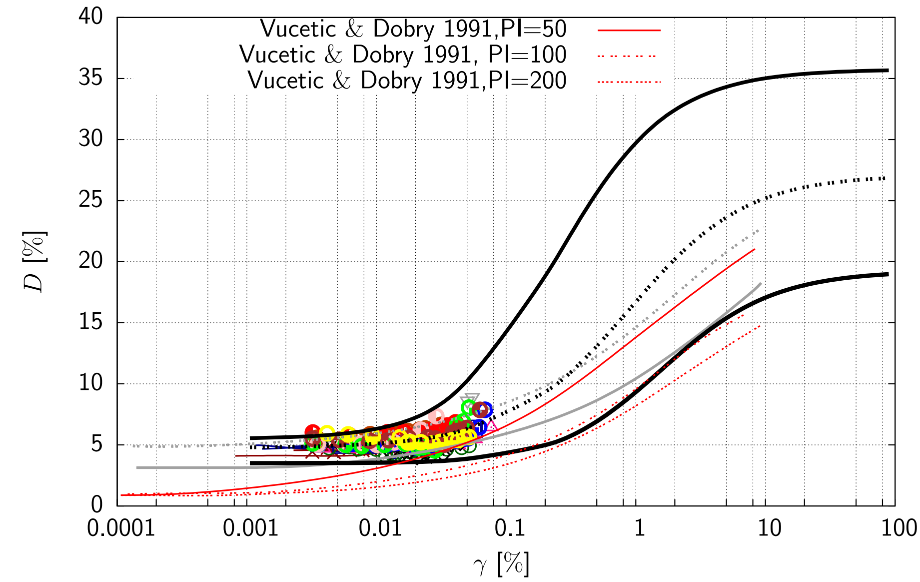
Figure 4.3: D versus shear strain for all data and fitting parameters of Equation 4.6 for samples 1-14, D_{min}=4.75 %

4.2 Comparison of derived empirical relationships with published data

Experimental data obtained from the current study on peat samples and the proposed curves regarding the experimental data were compared with the curves proposed by Vucetic and Dobry (1991) for inorganic soils and Kishida et al. (2009) for organic soils in Figure 4.4.



(a)



(b)

Figure 4.4: Small and intermediate properties of peat samples in comparison with the published data: a) shear modulus versus shear strain; b) damping ratio versus shear strain the solid and dashed black lines are curves from Equations 4.2 and 4.3 using the determined fitting parameters from this experiment for samples 1-14, D_{min}=4.75 %

5 Conclusion

Resonant column and Bender element tests were conducted on the peat samples. The tests have been performed on samples with natural water content under drained conditions. In addition classification tests have been carried out to determine water content, organic content and undrained shear strength, S_{su}. S_{su} was determined using fall cone test.
Resonant column and Bender element test were conducted to get the shear wave velocity and maximum shear stiffness of the peat samples. Samples were consolidated under anisotropic stress state, K=σ_h'/σ_v'=0.25, where, the confining pressure, σ_h', was between 3.3 to 9 kPa. Furthermore, the amplitude of shear strain was increased up to 3E-2% to assess the effect of shear strain on shear modulus and damping ratio. The experimental results show that G decreases and D increases with an increase in the amplitude of shear strain. The experimental results show a good agreement with the published data for organic and inorganic soil samples. In addition, the results show that G/G_{max} and damping ratio are slightly affected by pre-consolidation stress which is also in agreement with the published data for high organic peat samples.

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6 Appendix

6.1 Water content

Ruhr - Universität Bochum

Lehrstuhl für Grundbau, Boden- und Felsmechanik

Bestimmung des natürlichen Wassergehaltes

nach DIN 18121

Projekt:		Proben Nr.:	NW1A2-A5-1D
Probe:	Nr.1	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	21.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	3,95-4,11 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	176,47	181,23	183,43		
Trockenmasse+Tara	[g]	112,05	115,83	116,14		
Tara Behälter	[g]	97,92	102,21	102,05		
Masse Wasser	[g]	64,42	65,40	67,29		
Trockenmasse	[g]	14,13	13,62	14,09		
Wassergehalt	[%]	455,91	480,18	477,57		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

471,22

Figure 6.1: Laboratory results for water content of sample number 1

Ruhr - Universität Bochum

Lehrstuhl für Grundbau, Boden- und Felsmechanik

RUB

Bestimmung des natürlichen Wassergehaltes

nach DIN 18121

Projekt:		Proben Nr.:	NW1A2-A6-1A
Probe:	Nr.2	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	21.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	4,30-4,46 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	194,60	179,50	194,08		
Trockenmasse+Tara	[g]	128,39	110,55	125,72		
Tara Behälter	[g]	111,56	98,83	114,10		
Masse Wasser	[g]	66,21	68,95	68,36		
Trockenmasse	[g]	16,83	11,72	11,62		
Wassergehalt	[%]	393,40	588,31	588,30		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

523,34

Figure 6.2: Laboratory results for water content of sample number 2

Ruhr - Universität Bochum

Lehrstuhl für Grundbau, Boden- und Felsmechanik

RUB

Bestimmung des natürlichen Wassergehaltes

nach DIN 18121

Projekt:		Proben Nr.:	NW1A2-B1-2B
Probe:	Nr.3	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	20.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	3,85-4,00m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	192,03	178,54	188,05		
Trockenmasse+Tara	[g]	126,11	112,05	121,05		
Tara Behälter	[g]	112,06	98,13	106,48		
Masse Wasser	[g]	65,92	66,49	67,00		
Trockenmasse	[g]	14,05	13,92	14,57		
Wassergehalt	[%]	469,18	477,66	459,85		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

468,90

Figure 6.3: Laboratory results for water content of sample number 3

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Projekt:		Proben Nr.:	NW1A2-C1-1A
Probe:	Nr.4	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	22.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	3,60-3,76 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	159,67	188,80	162,61		
Trockenmasse+Tara	[g]	94,41	123,68	98,96		
Tara Behälter	[g]	80,43	109,55	85,25		
Masse Wasser	[g]	65,26	65,12	63,65		
Trockenmasse	[g]	13,98	14,13	13,71		
Wassergehalt	[%]	466,81	460,86	464,26		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

463,98

Figure 6.4: Laboratory results for water content of sample number 4

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nach DIN 18121

Projekt:		Proben Nr.:	NW1A2-D1-1A
Probe:	Nr.5	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	20.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	3,67-3,82 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	173,69	192,43	163,24		
Trockenmasse+Tara	[g]	111,07	126,71	98,94		
Tara Behälter	[g]	98,26	112,68	85,97		
Masse Wasser	[g]	62,62	65,72	64,30		
Trockenmasse	[g]	12,81	14,03	12,97		
Wassergehalt	[%]	488,84	468,42	495,76		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

484,34

Figure 6.5: Laboratory results for water content of sample number 5

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Projekt:		Proben Nr.:	NW1A2-D2-2A		
Probe:	Nr.6	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	22.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	5,00-5,15 m	Bemerkung:			

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	159,18	192,82	195,62		
Trockenmasse+Tara	[g]	90,79	125,56	126,86		
Tara Behälter	[g]	79,20	114,34	114,34		
Masse Wasser	[g]	68,39	67,26	68,76		
Trockenmasse	[g]	11,59	11,22	12,52		
Wassergehalt	[%]	590,08	599,47	549,20		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

579,58

Figure 6.6: Laboratory results for water content of sample number 6

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Projekt:		Proben Nr.:	NW1A2-a7-1A
Probe:	Nr.7	Bodenart:	Totf
Entnahmestelle:	Holland	Datum:	22.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	5,25-5,40 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	187,94	180,82	197,10		
Trockenmasse+Tara	[g]	120,37	114,38	128,81		
Tara Behälter	[g]	104,57	100,41	116,56		
Masse Wasser	[g]	67,57	66,44	68,29		
Trockenmasse	[g]	15,80	13,97	12,25		
Wassergehalt	[%]	427,66	475,59	557,47		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

486,91

Figure 6.7: Laboratory results for water content of sample number 7

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Projekt:		Proben Nr.:	NW1A2-d1-2
Probe:	Nr.8	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	27.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	4,15-4,30 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	158,69	163,12	179,44		
Trockenmasse+Tara	[g]	93,48	98,68	113,30		
Tara Behälter	[g]	80,43	85,69	100,81		
Masse Wasser	[g]	65,21	64,44	66,14		
Trockenmasse	[g]	13,05	12,99	12,49		
Wassergehalt	[%]	499,69	496,07	529,54		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

508,44

Figure 6.8: Laboratory results for water content of sample number 8

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Projekt:		Proben Nr.:	NW1A2-d2-1C		
Probe:	Nr.9	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,85-5,00 m	Bemerkung:			

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	180,39	191,99	181,45		
Trockenmasse+Tara	[g]	111,47	124,32	114,21		
Tara Behälter	[g]	99,87	113,10	103,41		
Masse Wasser	[g]	68,92	67,67	67,24		
Trockenmasse	[g]	11,60	11,22	10,80		
Wassergehalt	[%]	594,14	603,12	622,59		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

606,62

Figure 6.9: Laboratory results for water content of sample number 9

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Projekt:		Proben Nr.:	NW1A2-B1-3A
Probe:	Nr.10	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	25.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	4,10-4,25 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	179,98	176,19	180,65		
Trockenmasse+Tara	[g]	112,62	109,48	112,48		
Tara Behälter	[g]	100,61	97,25	99,88		
Masse Wasser	[g]	67,36	66,71	68,17		
Trockenmasse	[g]	12,01	12,23	12,60		
Wassergehalt	[%]	560,87	545,46	541,03		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

549,12

Figure 6.10: Laboratory results for water content of sample number 10

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Projekt:		Proben Nr.:	NW1A2-B2-2A
Probe:	Nr.11	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	25.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	5,10-5,25 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	194,77	183,33	186,48		
Trockenmasse+Tara	[g]	126,37	116,53	113,57		
Tara Behälter	[g]	113,12	103,41	101,28		
Masse Wasser	[g]	68,40	66,80	72,91		
Trockenmasse	[g]	13,25	13,12	12,29		
Wassergehalt	[%]	516,23	509,15	593,25		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

539,54

Figure 6.11: Laboratory results for water content of sample number 11

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nach DIN 18121

Projekt:		Proben Nr.:	NW1A2-C1-2B
Probe:	Nr.12	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	25.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	4,20-4,35 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	175,46	198,53	183,69		
Trockenmasse+Tara	[g]	106,68	130,44	116,73		
Tara Behälter	[g]	94,74	119,08	104,82		
Masse Wasser	[g]	68,78	68,09	66,96		
Trockenmasse	[g]	11,94	11,36	11,91		
Wassergehalt	[%]	576,05	599,38	562,22		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

579,22

Figure 6.12: Laboratory results for water content of sample number 12

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Projekt:		Proben Nr.:	NW1A2-C2-1B
Probe:	Nr.13	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	25.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	4,90-5,05 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	195,35	184,57	185,08		
Trockenmasse+Tara	[g]	127,41	116,57	114,44		
Tara Behälter	[g]	116,37	105,02	103,05		
Masse Wasser	[g]	67,94	68,00	70,64		
Trockenmasse	[g]	11,04	11,55	11,39		
Wassergehalt	[%]	615,40	588,74	620,19		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

608,11

Figure 6.13: Laboratory results for water content of sample number 13

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Projekt:		Proben Nr.:	NW1A2-C2-2B
Probe:	Nr.14	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	26.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	5,20-5,35 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	175,66	169,28	188,38		
Trockenmasse+Tara	[g]	107,00	101,13	120,51		
Tara Behälter	[g]	94,07	92,16	109,35		
Masse Wasser	[g]	68,66	68,15	67,87		
Trockenmasse	[g]	12,93	8,97	11,16		
Wassergehalt	[%]	531,01	759,75	608,15		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

632,97

Figure 6.14: Laboratory results for water content of sample number 14

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Projekt:		Proben Nr.:	SM2C-B1-1A
Probe:	Nr.15	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	26.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	1,77-1,92 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	191,71	175,11	163,11		
Trockenmasse+Tara	[g]	125,01	108,78	95,45		
Tara Behälter	[g]	115,03	100,14	87,04		
Masse Wasser	[g]	66,70	66,33	67,66		
Trockenmasse	[g]	9,98	8,64	8,41		
Wassergehalt	[%]	668,34	767,71	804,52		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

746,85

Figure 6.15: Laboratory results for water content of sample number 15

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Projekt:		Proben Nr.:	SM2C-A2-1B
Probe:	Nr.16	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	26.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	1,47-1,62 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	179,65	178,47	173,45		
Trockenmasse+Tara	[g]	111,98	112,37	108,24		
Tara Behälter	[g]	102,21	102,06	98,14		
Masse Wasser	[g]	67,67	66,10	65,21		
Trockenmasse	[g]	9,77	10,31	10,10		
Wassergehalt	[%]	692,63	641,13	645,64		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

659,80

Figure 6.16: Laboratory results for water content of sample number 16

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nach DIN 18121

Projekt:		Proben Nr.:	SB4A-A2-2A
Probe:	Nr.17	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	26.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	1,40-1,55 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	187,62	191,02	178,99		
Trockenmasse+Tara	[g]	124,24	126,93	111,28		
Tara Behälter	[g]	111,54	114,09	98,82		
Masse Wasser	[g]	63,38	64,09	67,71		
Trockenmasse	[g]	12,70	12,84	12,46		
Wassergehalt	[%]	499,06	499,14	543,42		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

513,87

Figure 6.17: Laboratory results for water content of sample number 17

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Projekt:		Proben Nr.:	SM2C-C1-1A
Probe:	Nr.18	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	27.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	1,80-1,95 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	186,51	171,44	180,61		
Trockenmasse+Tara	[g]	121,85	106,86	115,92		
Tara Behälter	[g]	112,06	97,92	106,48		
Masse Wasser	[g]	64,66	64,58	64,69		
Trockenmasse	[g]	9,79	8,94	9,44		
Wassergehalt	[%]	660,47	722,37	685,28		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

689,37

Figure 6.18: Laboratory results for water content of sample number 18

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Bestimmung des natürlichen Wassergehaltes

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Projekt:		Proben Nr.:	SM2C-A3-1A
Probe:	Nr.19	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	27.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	1,90-2,05 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	198,09	182,65	173,10		
Trockenmasse+Tara	[g]	129,01	117,57	107,86		
Tara Behälter	[g]	116,55	104,57	97,25		
Masse Wasser	[g]	69,08	65,08	65,24		
Trockenmasse	[g]	12,46	13,00	10,61		
Wassergehalt	[%]	554,41	500,62	614,89		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

556,64

Figure 6.19: Laboratory results for water content of sample number 19

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Projekt:		Proben Nr.:	SB4A-A2-1B
Probe:	Nr.20	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	27.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	1,18-1,35 m	Bemerkung:	

		Oben	Mitte	Unten		
Feuchtmasse+Tara	[g]	185,02	182,36	181,83		
Trockenmasse+Tara	[g]	114,75	112,63	113,43		
Tara Behälter	[g]	101,29	100,60	100,42		
Masse Wasser	[g]	70,27	69,73	68,40		
Trockenmasse	[g]	13,46	12,03	13,01		
Wassergehalt	[%]	522,07	579,63	525,75		

Feuchtmasse+Tara	[g]					
Trockenmasse+Tara	[g]					
Tara Behälter	[g]					
Masse Wasser	[g]					
Trockenmasse	[g]					
Wassergehalt	[%]					

542,48

Figure 6.20: Laboratory results for water content of sample number 20

6.2 Organic content, OC

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Bestimmung des Glühverlustes

nach DIN 18128

Projekt:		Proben Nr.:	NW1A2-A5-1D
Probe:	Nr.1	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	21.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	3,95-4,11 m	Bemerkung:	

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	176,47	181,23	183,43
Tara	[g]	97,92	102,21	102,05
feuchte Masse	[g]	78,55	79,02	81,38
Trockenmasse + Tara	[g]	112,05	115,83	116,14
Trockenmasse	[g]	14,13	13,62	14,09
Masse Wasser	[g]	64,42	65,40	67,29
Wassergehalt	[%]	455,91	480,18	477,57
geglühte Masse + Tara	[g]	100,71	104,52	104,37
geglühte Masse	[g]	2,79	2,31	2,32
Gewichtsverlust	[g]	11,34	11,31	11,77
Glühverlust	[%]	80,25	83,04	83,53
Mittelwert	[%]		82,28	

Figure 6.21: Laboratory results for organic content of sample number 1

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Bestimmung des Glühverlustes

nach DIN 18128

Projekt:		Proben Nr.:	NW1A2-A6-1A		
Probe:	Nr.2	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	21.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,30-4,46 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	194,60	179,50	194,08
Tara	[g]	111,56	98,83	114,10
feuchte Masse	[g]	83,04	80,67	79,98
Trockenmasse + Tara	[g]	128,39	110,55	125,72
Trockenmasse	[g]	16,83	11,72	11,62
Masse Wasser	[g]	66,21	68,95	68,36
Wassergehalt	[%]	393,40	588,31	588,30
geglühte Masse + Tara	[g]	118,58	100,01	115,18
geglühte Masse	[g]	7,02	1,18	1,08
Gewichtsverlust	[g]	9,81	10,54	10,54
Glühverlust	[%]	58,29	89,93	90,71
Mittelwert	[%]		79,64	

Figure 6.22: Laboratory results for organic content of sample number 2

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Bestimmung des Glühverlustes

nach DIN 18128

Projekt:		Proben Nr.:	NW1A2-B1-2B		
Probe:	N.r3	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	20.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	3,85-4,00 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	192,03	178,54	188,05
Tara	[g]	112,06	98,13	106,48
feuchte Masse	[g]	79,97	80,41	81,57
Trockenmasse + Tara	[g]	126,11	112,05	121,05
Trockenmasse	[g]	14,05	13,92	14,57
Masse Wasser	[g]	65,92	66,49	67,00
Wassergehalt	[%]	469,18	477,66	459,85
geglühte Masse + Tara	[g]	114,51	100,58	109,28
geglühte Masse	[g]	2,45	2,45	2,80
Gewichtsverlust	[g]	11,60	11,47	11,77
Glühverlust	[%]	82,56	82,40	80,78
Mittelwert	[%]		**81,91**	

Figure 6.23: Laboratory results for organic content of sample number 3

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Projekt:		Proben Nr.:	NW1A2-C1-1A
Probe:	Nr.4	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	22.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	3,60-3,76 m	Bemerkung:	

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	159,67	188,80	162,61
Tara	[g]	80,43	109,55	85,25
feuchte Masse	[g]	79,24	79,25	77,36
Trockenmasse + Tara	[g]	94,41	123,68	98,96
Trockenmasse	[g]	13,98	14,13	13,71
Masse Wasser	[g]	65,26	65,12	63,65
Wassergehalt	[%]	466,81	460,86	464,26
geglühte Masse + Tara	[g]	83,09	112,10	86,96
geglühte Masse	[g]	2,66	2,55	1,71
Gewichtsverlust	[g]	11,32	11,58	12,00
Glühverlust	[%]	80,97	81,95	87,53
Mittelwert	[%]		**83,48**	

Figure 6.24: Laboratory results for organic content of sample number 4

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Projekt:		Proben Nr.:	NW1A2-D1-1A		
Probe:	Nr.5	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	20.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	3,67-3,82 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	173,69	192,43	163,24
Tara	[g]	98,26	112,68	85,97
feuchte Masse	[g]	75,43	79,75	77,27
Trockenmasse + Tara	[g]	111,07	126,71	98,94
Trockenmasse	[g]	12,81	14,03	12,97
Masse Wasser	[g]	62,62	65,72	64,30
Wassergehalt	[%]	488,84	468,42	495,76
geglühte Masse + Tara	[g]	99,51	115,29	88,06
geglühte Masse	[g]	1,25	2,61	2,09
Gewichtsverlust	[g]	11,56	11,42	10,88
Glühverlust	[%]	90,24	81,40	83,89
Mittelwert	[%]		**85,17**	

Figure 6.25: Laboratory results for organic content of sample number 5

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Projekt:		Proben Nr.:	NW1A2-D2-2A		
Probe:	Nr.6	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	22.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	5,00-5,15 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	159,18	192,82	195,62
Tara	[g]	79,20	114,34	114,34
feuchte Masse	[g]	79,98	78,48	81,28
Trockenmasse + Tara	[g]	90,79	125,56	126,86
Trockenmasse	[g]	11,59	11,22	12,52
Masse Wasser	[g]	68,39	67,26	68,76
Wassergehalt	[%]	590,08	599,47	549,20
geglühte Masse + Tara	[g]	80,86	115,39	115,31
geglühte Masse	[g]	1,66	1,05	0,97
Gewichtsverlust	[g]	9,93	10,17	11,55
Glühverlust	[%]	85,68	90,64	92,25
Mittelwert	[%]		**89,52**	

Figure 6.26: Laboratory results for organic content of sample number 6

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Projekt:		Proben Nr.:	NW1A2-A7-1A		
Probe:	Nr.7	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	22.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	5,25-5,40 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	187,94	180,82	197,10
Tara	[g]	104,57	100,41	116,56
feuchte Masse	[g]	83,37	80,41	80,54
Trockenmasse + Tara	[g]	120,37	114,38	128,81
Trockenmasse	[g]	15,80	13,97	12,25
Masse Wasser	[g]	67,57	66,44	68,29
Wassergehalt	[%]	427,66	475,59	557,47
geglühte Masse + Tara	[g]	109,24	104,34	119,36
geglühte Masse	[g]	4,67	3,93	2,80
Gewichtsverlust	[g]	11,13	10,04	9,45
Glühverlust	[%]	70,44	71,87	77,14
Mittelwert	[%]		**73,15**	

Figure 6.27: Laboratory results for organic content of sample number 7

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Projekt:		Proben Nr.:	NW1A-D1-2		
Probe:	Nr.8	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,15-4,30 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	158,69	163,12	179,44
Tara	[g]	80,43	85,69	100,81
feuchte Masse	[g]	78,26	77,43	78,63
Trockenmasse + Tara	[g]	93,48	98,68	113,30
Trockenmasse	[g]	13,05	12,99	12,49
Masse Wasser	[g]	65,21	64,44	66,14
Wassergehalt	[%]	499,69	496,07	529,54
geglühte Masse + Tara	[g]	82,26	86,98	102,23
geglühte Masse	[g]	1,83	1,29	1,42
Gewichtsverlust	[g]	11,22	11,70	11,07
Glühverlust	[%]	85,98	90,07	88,63
Mittelwert	[%]		**88,23**	

Figure 6.28: Laboratory results for organic content of sample number 8

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Projekt:		Proben Nr.:	NW1A2-d2-1C		
Probe:	Nr.9	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,85-5,00 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	180,39	191,99	181,45
Tara	[g]	99,87	113,10	103,41
feuchte Masse	[g]	80,52	78,89	78,04
Trockenmasse + Tara	[g]	111,47	124,32	114,21
Trockenmasse	[g]	11,60	11,22	10,80
Masse Wasser	[g]	68,92	67,67	67,24
Wassergehalt	[%]	594,14	603,12	622,59
geglühte Masse + Tara	[g]	100,83	114,14	104,33
geglühte Masse	[g]	0,96	1,04	0,92
Gewichtsverlust	[g]	10,64	10,18	9,88
Glühverlust	[%]	91,72	90,73	91,48
Mittelwert	[%]		**91,31**	

Figure 6.29: Laboratory results for organic content of sample number 9

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Projekt:		Proben Nr.:	NW1A2-B1-3A		
Probe:	Nr.10	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	25.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,10-4,25 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	179,98	176,19	180,65
Tara	[g]	100,61	97,25	99,88
feuchte Masse	[g]	79,37	78,94	80,77
Trockenmasse + Tara	[g]	112,62	109,48	112,48
Trockenmasse	[g]	12,01	12,23	12,60
Masse Wasser	[g]	67,36	66,71	68,17
Wassergehalt	[%]	560,87	545,46	541,03
geglühte Masse + Tara	[g]	101,59	98,29	101,06
geglühte Masse	[g]	0,98	1,04	1,18
Gewichtsverlust	[g]	11,03	11,19	11,42
Glühverlust	[%]	91,84	91,50	90,63
Mittelwert	[%]		**91,32**	

Figure 6.30: Laboratory results for organic content of sample number 10

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Projekt:		Proben Nr.:	NW1A2-B2-2A		
Probe:	Nr.11	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	25.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	5,10-5,25 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	194,77	183,33	186,48
Tara	[g]	113,12	103,41	101,28
feuchte Masse	[g]	81,65	79,92	85,20
Trockenmasse + Tara	[g]	126,37	116,53	113,57
Trockenmasse	[g]	13,25	13,12	12,29
Masse Wasser	[g]	68,40	66,80	72,91
Wassergehalt	[%]	516,23	509,15	593,25
geglühte Masse + Tara	[g]	114,96	104,41	102,31
geglühte Masse	[g]	1,84	1,00	1,03
Gewichtsverlust	[g]	11,41	12,12	11,26
Glühverlust	[%]	86,11	92,38	91,62
Mittelwert	[%]		**90,04**	

Figure 6.31: Laboratory results for organic content of sample number 11

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Projekt:		Proben Nr.:	NW1A2-C1-2B		
Probe:	Nr.12	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	25.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,2-4,35 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	175,46	198,53	183,69
Tara	[g]	94,74	119,08	104,82
feuchte Masse	[g]	80,72	79,45	78,87
Trockenmasse + Tara	[g]	106,68	130,44	116,73
Trockenmasse	[g]	11,94	11,36	11,91
Masse Wasser	[g]	68,78	68,09	66,96
Wassergehalt	[%]	576,05	599,38	562,22
geglühte Masse + Tara	[g]	95,81	119,95	105,86
geglühte Masse	[g]	1,07	0,87	1,04
Gewichtsverlust	[g]	10,87	10,49	10,87
Glühverlust	[%]	91,04	92,34	91,27
Mittelwert	[%]		**91,55**	

Figure 6.32: Laboratory results for organic content of sample number 12

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Projekt:		Proben Nr.:	NW1A2-C2-1B		
Probe:	Nr.13	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	25.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,90-5,05 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	195,35	184,57	185,08
Tara	[g]	116,37	105,02	103,05
feuchte Masse	[g]	78,98	79,55	82,03
Trockenmasse + Tara	[g]	127,41	116,57	114,44
Trockenmasse	[g]	11,04	11,55	11,39
Masse Wasser	[g]	67,94	68,00	70,64
Wassergehalt	[%]	615,40	588,74	620,19
geglühte Masse + Tara	[g]	117,20	105,86	103,88
geglühte Masse	[g]	0,83	0,84	0,83
Gewichtsverlust	[g]	10,21	10,71	10,56
Glühverlust	[%]	92,48	92,73	92,71
Mittelwert	[%]		**92,64**	

Figure 6.33: Laboratory results for organic content of sample number 13

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Projekt:		Proben Nr.:	NW1A2-C2-2B
Probe:	Nr.14	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	26.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	5,20-5,35 m	Bemerkung:	

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	175,66	169,28	188,38
Tara	[g]	94,07	92,16	109,35
feuchte Masse	[g]	81,59	77,12	79,03
Trockenmasse + Tara	[g]	107,00	101,13	120,51
Trockenmasse	[g]	12,93	8,97	11,16
Masse Wasser	[g]	68,66	68,15	67,87
Wassergehalt	[%]	531,01	759,75	608,15
geglühte Masse + Tara	[g]	95,02	93,11	110,79
geglühte Masse	[g]	0,95	0,95	1,44
Gewichtsverlust	[g]	11,98	8,02	9,72
Glühverlust	[%]	92,65	89,41	87,10
Mittelwert	[%]		**89,72**	

Figure 6.34: Laboratory results for organic content of sample number 14

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Projekt:		Proben Nr.:	SM2C-B1-1A
Probe:	Nr.15	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	26.07.2016 Bearbeiter: Skubisch
Entnahmetiefe:	1,77-1,92 m	Bemerkung:	

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	191,71	175,11	163,11
Tara	[g]	115,03	100,14	87,04
feuchte Masse	[g]	76,68	74,97	76,07
Trockenmasse + Tara	[g]	125,01	108,78	95,45
Trockenmasse	[g]	9,98	8,64	8,41
Masse Wasser	[g]	66,70	66,33	67,66
Wassergehalt	[%]	668,34	767,71	804,52
geglühte Masse + Tara	[g]	116,23	101,24	88,11
geglühte Masse	[g]	1,20	1,10	1,07
Gewichtsverlust	[g]	8,78	7,54	7,34
Glühverlust	[%]	87,98	87,27	87,28
Mittelwert	[%]		**87,51**	

Figure 6.35: Laboratory results for organic content of sample number 15

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Projekt:		Proben Nr.:	SM2C-A2-1B		
Probe:	Nr.16	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	26.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,47-1,62 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	179,65	178,47	173,45
Tara	[g]	102,21	102,06	98,14
feuchte Masse	[g]	77,44	76,41	75,31
Trockenmasse + Tara	[g]	111,98	112,37	108,24
Trockenmasse	[g]	9,77	10,31	10,10
Masse Wasser	[g]	67,67	66,10	65,21
Wassergehalt	[%]	692,63	641,13	645,64
geglühte Masse + Tara	[g]	103,38	103,24	99,45
geglühte Masse	[g]	1,17	1,18	1,31
Gewichtsverlust	[g]	8,60	9,13	8,79
Glühverlust	[%]	88,02	88,55	87,03
Mittelwert	[%]		**87,87**	

Figure 6.36: Laboratory results for organic content of sample number 16

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Projekt:		Proben Nr.:	SB4A-A2-2A		
Probe:	Nr.17	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	26.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,40-1,55 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	187,62	191,02	178,99
Tara	[g]	111,54	114,09	98,82
feuchte Masse	[g]	76,08	76,93	80,17
Trockenmasse + Tara	[g]	124,24	126,93	111,28
Trockenmasse	[g]	12,70	12,84	12,46
Masse Wasser	[g]	63,38	64,09	67,71
Wassergehalt	[%]	499,06	499,14	543,42
geglühte Masse + Tara	[g]	113,18	115,43	100,16
geglühte Masse	[g]	1,64	1,34	1,34
Gewichtsverlust	[g]	11,06	11,50	11,12
Glühverlust	[%]	87,09	89,56	89,25
Mittelwert	[%]		**88,63**	

Figure 6.37: Laboratory results for organic content of sample number 17

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Projekt:		Proben Nr.:	SM2C-C1-1A		
Probe:	Nr.18	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,80-1,95 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	186,51	171,44	180,61
Tara	[g]	112,06	97,92	106,48
feuchte Masse	[g]	74,45	73,52	74,13
Trockenmasse + Tara	[g]	121,85	106,86	115,92
Trockenmasse	[g]	9,79	8,94	9,44
Masse Wasser	[g]	64,66	64,58	64,69
Wassergehalt	[%]	660,47	722,37	685,28
geglühte Masse + Tara	[g]	113,44	99,13	107,68
geglühte Masse	[g]	1,38	1,21	1,20
Gewichtsverlust	[g]	8,41	7,73	8,24
Glühverlust	[%]	85,90	86,47	87,29
Mittelwert	[%]		**86,55**	

Figure 6.38: Laboratory results for organic content of sample number 18

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Projekt:		Proben Nr.:	SM2C-A3-1A		
Probe:	Nr.19	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.02.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,90-2,05 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	198,09	182,65	173,10
Tara	[g]	116,55	104,57	97,25
feuchte Masse	[g]	81,54	78,08	75,85
Trockenmasse + Tara	[g]	129,01	117,57	107,86
Trockenmasse	[g]	12,46	13,00	10,61
Masse Wasser	[g]	69,08	65,08	65,24
Wassergehalt	[%]	554,41	500,62	614,89
geglühte Masse + Tara	[g]	119,21	108,05	98,55
geglühte Masse	[g]	2,66	3,48	1,30
Gewichtsverlust	[g]	9,80	9,52	9,31
Glühverlust	[%]	78,65	73,23	87,75
Mittelwert	[%]		**79,88**	

Figure 6.39: Laboratory results for organic content of sample number 19

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Projekt:		Proben Nr.:	SB4A-A2-1B		
Probe:	Nr.20	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,18-1,35 m	Bemerkung:			

Versuch Nr.		Oben	Mitte	Unten
feucht Masse + Tara	[g]	185,02	182,36	181,83
Tara	[g]	101,29	100,60	100,42
feuchte Masse	[g]	83,73	81,76	81,41
Trockenmasse + Tara	[g]	114,75	112,63	113,43
Trockenmasse	[g]	13,46	12,03	13,01
Masse Wasser	[g]	70,27	69,73	68,40
Wassergehalt	[%]	522,07	579,63	525,75
geglühte Masse + Tara	[g]	102,06	101,11	101,47
geglühte Masse	[g]	0,77	0,51	1,05
Gewichtsverlust	[g]	12,69	11,52	11,96
Glühverlust	[%]	94,28	95,76	91,93
Mittelwert	[%]		**93,99**	

Figure 6.40: Laboratory results for organic content of sample number 20

6.3 Fall cone test

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Projekt:		Proben Nr.:	NW1A2-A5-1D
Probe:	Nr.1	Bodenart:	Torf
Entnahmestelle:	Holland	Datum:	19.07.2016 Bearbeiter: Sku/Lan
Entnahmetiefe:	3,95-4,11 m	Bemerkung:	Unten

Wassergehalt	477,57	%	Masse	81,57	[g]
Einbaudichte feucht ρ	1,068	[g/cm³]	Volumen	76,366	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	8	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	49,37	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert	**39,74**	[kPa]

Figure 6.41: The results of fall cone test, for sample number 1

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Projekt:		Proben Nr.:	NW1A2-A6-1A		
Probe:	Nr.2	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	19.07.2016	Bearbeiter:	Sku/Lan
Entnahmetiefe:	4,3-4,46 m	Bemerkung:	Unten		

Wassergehalt	588,30	%	Masse	80,22	[g]
Einbaudichte feucht ρ	1,045	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **28,85** [kPa]

Figure 6.42: The results of fall cone test, for sample number 2

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Projekt:		Proben Nr.:	NW1A2-B1-2B		
Probe:	Nr.3	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	20.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	3,85-4,00 m	Bemerkung:	Oben		

Wassergehalt	469,18	%	Masse	80,23	[g]
Einbaudichte feucht ρ	1,045	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **33,45** [kPa]

Figure 6.43: The results of fall cone test, for sample number 3

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Projekt:		Proben Nr.:	NW1A2-C1-1A		
Probe:	Nr.4	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	22.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	3,60-3,76 m	Bemerkung:	Oben		

Wassergehalt	466,8	%	Masse	79,5	[g]
Einbaudichte feucht ρ	1,041	[g/cm³]	Volumen	76,366	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	0,8
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	9,8
Eindringtiefe i	[mm]	8	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	49,37	ungestörte Probe c_{ufc}	[kPa]	#DIV/0!
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	0,8
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	9,8
Eindringtiefe i	[mm]	8	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	49,37	ungestörte Probe c_{ufc}	[kPa]	#DIV/0!
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	0,8
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	9,8
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	#DIV/0!
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	0,8
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	9,8
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	#DIV/0!

Mittelwert **40,96** [kPa]

Figure 6.44: The results of fall cone test, for sample number 4

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Projekt:		Proben Nr.:	NW1A2-D1-1A		
Probe:	Nr.5	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	20.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	3,67-3,82 m	Bemerkung:	Unten		

Wassergehalt	495,8	%	Masse	77,48	[g]
Einbaudichte feucht ρ	1,015	[g/cm³]	Volumen	76,366	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	6	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	87,76	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	8	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	49,37	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	8	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	49,37	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **56,38** [kPa]

Figure 6.45: The results of fall cone test, for sample number 5

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Projekt:		Proben Nr.:	NW1A2-D2-2A	
Probe:	Nr.6	Bodenart:	Torf	
Entnahmestelle:	Holland	Datum:	22.07.2016	Bearbeiter: Skubisch
Entnahmetiefe:	5,00-5,15 m	Bemerkung:	Unten	

Wassergehalt	549,2	%	Masse	81,43	[g]
Einbaudichte feucht ρ	1,061	[g/cm³]	Volumen	76,749	[cm^3]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	7	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	64,48	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **43,52** [kPa]

Figure 6.46: The results of fall cone test, for sample number 6

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Projekt:		Proben Nr.:	NW1A2-a7-A1		
Probe:	Nr.7	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	22.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	5,25-5,40 m	Bemerkung:	Oben		

Wassergehalt	427,66	%	Masse	83,53	[g]
Einbaudichte feucht ρ	1,088	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **33,45** [kPa]

Figure 6.47: The results of fall cone test, for sample number 7

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Projekt:		Proben Nr.:	NW1A2-d1-2		
Probe:	Nr.8	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,15-4,30 m	Bemerkung:	Oben		

Wassergehalt	499,69	%	Masse	78,63	[g]
Einbaudichte feucht ρ	1,025	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	7	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	64,48	ungestörte Probe c_{ufc}	[kPa]	
Mittelwert		**38,44**	[kPa]		

Figure 6.48: The results of fall cone test, for sample number 8

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Projekt:		Proben Nr.:	NW1A2-d2-1C		
Probe:	Nr.9	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,85-5,00 m	Bemerkung:	Unten		

Wassergehalt	622,59	%	Masse	78,45	[g]
Einbaudichte feucht ρ	1,022	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **35,30** [kPa]

Figure 6.49: The results of fall cone test, for sample number 9

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Projekt:		Proben Nr.:	NW1A2-B1-3A		
Probe:	Nr.10	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	25.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,10-4,25 m	Bemerkung:	Unten		

Wassergehalt	541,03	%	Masse	80,95	[g]
Einbaudichte feucht ρ	1,055	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			**5. Versuch**		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	7	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	64,48	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			**6. Versuch**		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			**7. Versuch**		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			**8. Versuch**		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **39,82** [kPa]

Figure 6.50: The results of fall cone test, for sample number 10

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Projekt:		Proben Nr.:	NW1A2-B2-2A		
Probe:	Nr.11	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	25.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	5,10-5,25	Bemerkung:	Unten		

Wassergehalt	593,25	%	Masse	85,38	[g]
Einbaudichte feucht ρ	1,118	[g/cm³]	Volumen	76,366	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	

2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	

3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	

4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **30,71** [kPa]

Figure 6.51: The results of fall cone test, for sample number 11

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Projekt:			Proben Nr.:	NW1A2-C1-2B		
Probe:	Nr.12		Bodenart:	Torf		
Entnahmestelle:	Holland		Datum:	25.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,20-4,35 m		Bemerkung:	Unten		
Wassergehalt	562,22	%		Masse	79	[g]
Einbaudichte feucht ρ	1,034	[g/cm³]		Volumen	76,366	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	13	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	18,69	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
Mittelwert		**27,00**	[kPa]		

Figure 6.52: The results of fall cone test, for sample number 12

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Projekt:		Proben Nr.:	NW1A2-C2-B1		
Probe:	Nr.13	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	25.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	4,90-5,05 m	Bemerkung:	Unten		

Wassergehalt	620,19	%	Masse	82,18	[g]
Einbaudichte feucht ρ	1,071	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	9	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	39,01	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	8	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	49,37	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **37,89** [kPa]

Figure 6.53: The results of fall cone test, for sample number 13

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Projekt:			Proben Nr.:	NW1A2-C1-2B		
Probe:	Nr.14		Bodenart:	Torf		
Entnahmestelle:	Holland		Datum:	26.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	5,20-5,35 m		Bemerkung:	Unten		
Wassergehalt	608,15	%		Masse	79,22	[g]
Einbaudichte feucht ρ	1,080	[g/cm³]		Volumen	73,366	[cm³]
1. Versuch			5. Versuch			
Masse	[g]	402,58	Masse		[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°		c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g		[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i		[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}		[kPa]	
2. Versuch			6. Versuch			
Masse	[g]	402,58	Masse		[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°		c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g		[m/s²]	
Eindringtiefe i	[mm]	8	Eindringtiefe i		[mm]	
ungestörte Probe c_{ufc}	[kPa]	49,37	ungestörte Probe c_{ufc}		[kPa]	
3. Versuch			7. Versuch			
Masse	[g]	402,58	Masse		[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°		c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g		[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i		[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}		[kPa]	
4. Versuch			8. Versuch			
Masse	[g]	402,58	Masse		[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°		c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g		[m/s²]	
Eindringtiefe i	[mm]	12	Eindringtiefe i		[mm]	
ungestörte Probe c_{ufc}	[kPa]	21,94	ungestörte Probe c_{ufc}		[kPa]	
Mittelwert		**30,88**	[kPa]			

Figure 6.54: The results of fall cone test, for sample number 14

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Projekt:		Proben Nr.:	SM2C-B1-1A		
Probe:	Nr.15	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	26.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,77-1,92 m	Bemerkung:	Unten		

Wassergehalt	804,52	%	Masse	76,48	[g]
Einbaudichte feucht ρ	0,996	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	16	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	12,34	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	14	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	16,12	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	16	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	12,34	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	15	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	14,04	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **13,71** [kPa]

Figure 6.55: The results of fall cone test, for sample number 15

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Projekt:		Proben Nr.:	SM2-A2-1B		
Probe:	Nr.16	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	26.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,47- 1,62 m	Bemerkung:	Oben		

Wassergehalt	692,63	%	Masse	77,79	[g]
Einbaudichte feucht ρ	1,014	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	16	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	12,34	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	14	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	16,12	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	15	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	14,04	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	17	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	10,93	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **13,36** [kPa]

Figure 6.56: The results of fall cone test, for sample number 16

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Projekt:		Proben Nr.:	SB4A-A2-2A		
Probe:	Nr.17	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	26.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,40-1,55 m	Bemerkung:	Oben		

Wassergehalt	499,06	%	Masse	76,43	[g]
Einbaudichte feucht ρ	1,001	[g/cm³]	Volumen	76,366	[cm^3]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	12	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	21,94	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **25,07** [kPa]

Figure 6.57: The results of fall cone test, for sample number 17

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Projekt:		Proben Nr.:	SM2C-C1-1A		
Probe:	Nr.18	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,80-1,95 m	Bemerkung:	Unten		

Wassergehalt	685,28	%	Masse	74,38	[g]
Einbaudichte feucht ρ	0,974	[g/cm³]	Volumen	76,366	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	16	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	12,34	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	16	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	12,34	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	15	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	14,04	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	18	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	9,75	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **12,12** [kPa]

Figure 6.58: The results of fall cone test, for sample number 18

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RUB

Fallkegelversuch

nach DIN EN ISO 17892-6

Projekt:		Proben Nr.:	SM2C-A3-1A		
Probe:	Nr.19	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,90-2,05 m	Bemerkung:	Unten		

Wassergehalt	614,89	%	Masse	76,39	[g]
Einbaudichte feucht ρ	1,000	[g/cm³]	Volumen	76,366	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	0,8
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	9,8
Eindringtiefe i	[mm]	13	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	18,69	ungestörte Probe c_{ufc}	[kPa]	#DIV/0!
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	0,8
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	9,8
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	#DIV/0!
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	0,8
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	9,8
Eindringtiefe i	[mm]	12	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	21,94	ungestörte Probe c_{ufc}	[kPa]	#DIV/0!
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	0,8
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	9,8
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	#DIV/0!

Mittelwert **24,59** [kPa]

Figure 6.59: The results of fall cone test, for sample number 19

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Fallkegelversuch

nach DIN EN ISO 17892-6

Projekt:		Proben Nr.:	SB4A-A2-1B		
Probe:	Nr.20	Bodenart:	Torf		
Entnahmestelle:	Holland	Datum:	27.07.2016	Bearbeiter:	Skubisch
Entnahmetiefe:	1,18-1,35 m	Bemerkung:	Mitte		

Wassergehalt	579,63	%	Masse	82,14	[g]
Einbaudichte feucht ρ	1,070	[g/cm³]	Volumen	76,749	[cm³]

1. Versuch			5. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	12	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	21,94	ungestörte Probe c_{ufc}	[kPa]	
2. Versuch			6. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	11	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	26,11	ungestörte Probe c_{ufc}	[kPa]	
3. Versuch			7. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	
4. Versuch			8. Versuch		
Masse	[g]	402,58	Masse	[g]	
Öffnungswinkel 30°	c =	0,8	Öffnungswinkel 30°	c =	
Erdbeschleunigung g	[m/s²]	9,8	Erdbeschleunigung g	[m/s²]	
Eindringtiefe i	[mm]	10	Eindringtiefe i	[mm]	
ungestörte Probe c_{ufc}	[kPa]	31,59	ungestörte Probe c_{ufc}	[kPa]	

Mittelwert **27,81** [kPa]

Figure 6.60: The results of fall cone test, for sample number 20

6.4 RC and BE test results

6.4.1 Results for G_{max}

Table 6.1: Experimental results for samples 1-14

Sample			Boundary conditions			RC tests		BE tests		Classification				
No.	Name	Depth [m]	σ_h' [kPa]	σ_v' [kPa]	K_0 [kPa]	V_s [m/s]	G_{max} [MPa]	V_s [m/s]	G_{max} [MPa]	ρ [g/cm^3]	ρ_s [g/cm^3]	ω_c [%]	OC [%]	S_{su} [kPa]
1	NW1A2-A5-1D	3.95-4.11	6.40	25.60	0.25	32.724	1.171	39.090	1.671	1.093		471.220	82.280	39.740
2	NW1A2-A6-1A	4.3-4.46	6.60	26.50	0.25	30.120	0.959	33.775	1.206	1.057		523.340	79.640	28.850
3	NW1A2-B1-2B	3.85-4	6.50	26.10	0.25	32.213	1.087	37.136	1.445	1.047		468.900	81.910	33.450
4	NW1A2-C1-1A	3.6-3.76	6.30	25.30	0.25	34.345	1.220	39.531	1.616	1.034		463.980	83.480	40.960
5	NW1A2-D1-1A	3.673.82	6.50	25.9	0.25	31.971	1.028	38.020	1.454	1.077		484.340	85.170	56.380
6	NW1A2-D2-2A	5.0-5.15	6.9	27.50	0.25	31.939	1.075	34.160	1.229	1.053		579.580	89.520	43.520
7	NW1A2-a7-1A	5.25-5.04	7.00	27.70	0.25	32.511	1.118	36.457	1.406	1.058		486.910	73.150	33.450
8	NW1A2-d1-2	4.15-4.30	6.60	26.30	0.25	35.726	1.288	36.347	1.346	1.009		508.440	88.230	38.440
9	NW1A2-d2-1C	4.85-5.0	6.80	27.30	0.25	30.361	0.949	34.864	1.251	1.029		606.620	91.310	35.300
10	NW1A2-B1-3A	4.1-4.25	6.60	26.40	0.25	29.250	0.883	33.896	1.186	1.032		549.120	91.320	39.820
11	NW1A2-B2-2A	5.1-5.25	6.90	27.60	0.25	32,.275	1.080	34.476	1.233	1.037		539.540	90.040	30.710
12	NW1A2-C1-2B	4.2-4.35	6.60	26.50	0.25	26.967	0.747	32.482	1.084	1.028		579.220	91.550	27.000
13	NW1A2-C2-1B	4.9-5.05	6.80	27.30	0.25	30.932	0.999	37.964	1.505	1.044		608.110	92.640	37.890
14	NW1A2-C2-2B	5.2-5.35	6.90	27.70	0.25	35.293	1.284	40.620	1.701	1.031		632.970	89.720	30.880

Table 6.2: Experimental results for samples 15-20

Sample			boundary conditions			RC tests		BE tests		classification				
No.	Name	Depth [kPa]	σ_h' [m]	σ_v' [kPa]	$(\sigma_h' + \sigma_v')/2$ [kPa]	V_s $[m/s]$	G_{max} [MPa]	t_v m/s	G_{max} [MPa]	ρ $[g/cm^3]$	ρ_s $[g/cm^3]$	ω_c [%]	OC [%]	S_{su} [kPa]
15	SM2C-B1-1A	1.77-1.92	3.30	13.30	0.25	26.739	0.710	29.101	0.841	0.993		746.850	87.510	13.710
16	SM2C-A2-1B	1.47-1.62	3.30	13.30	0.25	24.681	0.640	27.458	0.793	1.051		659.840	87.870	13.360
17	SB4A-A2-2A	1.4-1.55	3.30	13.30	0.25	27.447	0.766	32.394	1.068	1.017		513.870	88.730	25.070
			6.50	26.00	0.25	29.059	0.855	34.702	1.219	1.013				
18	SM2C-C1-1A	1.8-1.95	3.30	13.30	0.25	24.052	0.682	28.184	0.937	1.180		689.370	86.550	12.120
19	SM2C-A3-1A	1.9-2.05	3.30	13.30	0.25	34.784	1.272	38.669	1.572	1.050		556.640	79.880	24.590
			6.50	26.00	0.25	37.039	1.445	42.988	1.946	1.052				
			9.00	36.00	0.25	37.597	1.489	44.389	2.076	1.054				
20	SB4A-A2-1B	1.18-1.35	3.30	13.30	0.25	33.007	1.095	37.181	1.389	1.005		542.480	93.990	27.810
			7.50	30.00	0.25	34.608	1.206	39.667	1.584	1.007				

6.4.2 Results for $G(\gamma)\&D(\gamma)$

Sample- 1 NW1A2-A5-1D					
gamma	gamma%	Vs	G	G/Gmax	D%
3,19E-05	3,19E-03	34,084	1,217	1,000	4,440
4,18E-05	4,18E-03	33,024	1,213	0,997	4,748
4,70E-05	4,70E-03	34,084	1,207	0,992	4,400
6,23E-05	6,23E-03	32,267	1,182	0,971	4,690
7,58E-05	7,58E-03	32,267	1,182	0,971	4,808
7,75E-05	7,75E-03	34,084	1,207	0,992	4,566
8,13E-05	8,13E-03	32,494	1,197	0,984	4,907
8,98E-05	8,98E-03	33,857	1,191	0,979	4,655
1,26E-04	1,26E-02	34,084	1,207	0,992	4,380
1,32E-04	1,32E-02	34,539	1,209	0,994	4,553
1,44E-04	1,44E-02	34,842	1,201	0,987	4,957
1,62E-04	1,62E-02	34,993	1,212	0,996	4,740
1,83E-04	1,83E-02	34,084	1,207	0,992	4,580
1,94E-04	1,94E-02	34,539	1,209	0,994	4,772
2,35E-04	2,35E-02	33,933	1,196	0,983	4,810
2,89E-04	2,89E-02	34,009	1,202	0,987	4,882
2,91E-04	2,91E-02	34,312	1,203	0,989	5,071
3,10E-04	3,10E-02	33,782	1,186	0,974	5,113
3,29E-04	3,29E-02	34,084	1,207	0,992	5,252
3,39E-04	3,39E-02	34,312	1,203	0,989	5,236
3,76E-04	3,76E-02	34,236	1,208	0,992	5,246
3,99E-04	3,99E-02	33,706	1,180	0,970	5,306
4,09E-04	4,09E-02	33,706	1,180	0,970	5,528
4,09E-04	4,09E-02	33,706	1,180	0,970	5,528
5,03E-04	5,03E-02	33,630	1,175	0,966	5,880
5,16E-04	5,16E-02	33,630	1,175	0,966	5,883
5,31E-04	5,31E-02	34,084	1,169	0,961	6,222

Figure 6.61: The results from RC test, for sample number 1

Sample-2 NW1A2-A6-1A					
gamma	gamma%	Vs	G	G/Gmax	D%
3,55E-05	3,55E-03	29,833	0,941	1,000	5,015
5,15E-05	5,15E-03	29,833	0,941	1,000	4,889
7,56E-05	7,56E-03	29,833	0,941	1,000	4,982
8,88E-05	8,88E-03	29,825	0,941	1,000	4,891
1,38E-04	1,38E-02	29,752	0,936	0,995	4,444
1,38E-04	1,38E-02	29,678	0,931	0,990	5,016
1,79E-04	1,79E-02	29,678	0,931	0,990	4,955
1,79E-04	1,79E-02	29,678	0,931	0,990	5,013
2,46E-04	2,46E-02	29,531	0,922	0,980	4,722
2,53E-04	2,53E-02	29,531	0,922	0,980	5,010
2,99E-04	2,99E-02	29,457	0,918	0,975	5,121
2,99E-04	2,99E-02	29,457	0,918	0,975	5,389
3,46E-04	3,46E-02	29,604	0,927	0,985	5,402
3,51E-04	3,51E-02	29,383	0,913	0,970	5,514
4,09E-04	4,09E-02	29,383	0,913	0,970	5,514
4,14E-04	4,14E-02	29,310	0,908	0,965	5,565
4,46E-04	4,46E-02	29,310	0,908	0,965	5,852
5,03E-04	5,03E-02	29,236	0,904	0,960	6,190
5,68E-04	5,68E-02	29,089	0,895	0,951	6,456
5,78E-04	5,78E-02	29,089	0,895	0,951	6,203

Figure 6.62: The results from RC test, for sample number 2

Sample-3 NW1A2-B1-2B					
gamma	gamma%	Vs	G	G/Gmax	D%
4,25E-05	4,25E-03	32,139	1,082	1,000	4,754
6,24E-05	6,24E-03	32,139	1,082	1,000	4,855
7,24E-05	7,24E-03	32,139	1,082	1,000	4,659
9,93E-05	9,93E-03	32,139	1,082	1,000	4,639
1,18E-04	1,18E-02	32,066	1,077	0,995	4,129
1,32E-04	1,32E-02	31,919	1,067	0,986	4,230
1,38E-04	1,38E-02	31,919	1,067	0,986	4,093
1,47E-04	1,47E-02	31,919	1,067	0,986	4,123
1,65E-04	1,65E-02	31,846	1,062	0,982	4,125
1,81E-04	1,81E-02	31,846	1,062	0,982	4,439
2,01E-04	2,01E-02	31,772	1,057	0,977	4,534
2,11E-04	2,11E-02	31,699	1,053	0,973	4,624
2,25E-04	2,25E-02	31,699	1,053	0,973	4,609
2,35E-04	2,35E-02	31,626	1,048	0,968	4,439
2,36E-04	2,36E-02	31,626	1,048	0,968	4,593
2,42E-04	2,42E-02	31,626	1,048	0,968	4,639
2,99E-04	2,99E-02	31,552	1,043	0,964	4,650
3,47E-04	3,47E-02	31,552	1,043	0,964	4,660
4,53E-04	4,53E-02	31,479	1,038	0,959	4,779
5,19E-04	5,19E-02	31,405	1,033	0,955	4,939

Figure 6.63: The results from RC test, for sample number 3

Sample-4 NW1A2-C1-1A					
gamma	gamma%	Vs	G	G/Gmax	D%
3,89E-05	3,89E-03	34,345	1,220	1,000	4,713
5,48E-05	5,48E-03	34,345	1,220	1,000	4,955
7,35E-05	7,35E-03	34,345	1,220	1,000	4,654
9,58E-05	9,58E-03	33,964	1,193	0,978	4,968
1,17E-04	1,17E-02	33,887	1,187	0,974	4,842
1,46E-04	1,46E-02	33,735	1,177	0,965	4,855
1,83E-04	1,83E-02	33,658	1,171	0,960	4,758
1,87E-04	1,87E-02	33,582	1,166	0,956	4,665
2,06E-04	2,06E-02	33,506	1,161	0,952	4,965
2,26E-04	2,26E-02	33,353	1,150	0,943	5,106
2,68E-04	2,68E-02	33,353	1,150	0,943	4,920
3,18E-04	3,18E-02	33,124	1,134	0,930	5,100
3,41E-04	3,41E-02	33,200	1,140	0,934	4,965
4,30E-04	4,30E-02	33,048	1,129	0,926	4,965
4,57E-04	4,57E-02	32,971	1,124	0,922	5,324
5,26E-04	5,26E-02	32,819	1,114	0,913	5,465
5,77E-04	5,77E-02	32,742	1,108	0,909	5,478
5,63E-04	5,63E-02	32,590	1,098	0,900	5,738
7,66E-04	7,66E-02	32,513	1,093	0,896	6,455

Figure 6.64: The results from RC test, for sample number 4

Sample-5 NW1A2-D1-1A					
gamma	gamma%	Vs	G	G/Gmax	D%
3,86E-05	3,86E-03	33,194	1,105	1,000	5,080
6,44E-05	6,44E-03	33,194	1,105	1,000	5,280
9,01E-05	9,01E-03	33,194	1,105	1,000	5,281
1,09E-04	1,09E-02	33,194	1,105	1,000	4,916
1,60E-04	1,60E-02	33,115	1,100	0,995	5,156
2,12E-04	2,12E-02	33,115	1,100	0,995	4,688
2,57E-04	2,57E-02	33,115	1,100	0,995	4,916
2,72E-04	2,72E-02	33,115	1,100	0,995	4,928
3,09E-04	3,09E-02	33,035	1,095	0,990	4,988
3,61E-04	3,61E-02	32,956	1,089	0,986	5,000
4,22E-04	4,22E-02	32,956	1,089	0,986	5,314
4,79E-04	4,79E-02	32,877	1,084	0,981	5,797
5,03E-04	5,03E-02	32,877	1,084	0,981	8,620
5,49E-04	5,49E-02	32,718	1,074	0,971	8,920

Figure 6.65: The results from RC test, for sample number 5

Sample-6 NW1A2-D2-2A					
gamma	gamma%	Vs	G	G/Gmax	D%
3,75E-05	3,75E-03	33,048	1,151	1,000	5,086
5,22E-05	5,22E-03	33,048	1,151	1,000	5,025
8,06E-05	8,06E-03	33,048	1,151	1,000	5,072
9,01E-05	9,01E-03	33,048	1,151	1,000	5,045
9,48E-05	9,48E-03	33,048	1,151	1,000	5,163
1,09E-04	1,09E-02	33,048	1,151	1,000	5,264
1,19E-04	1,19E-02	32,974	1,145	0,996	5,257
1,28E-04	1,28E-02	32,900	1,140	0,991	4,382
1,65E-04	1,65E-02	32,752	1,130	0,982	4,402
1,81E-04	1,81E-02	32,752	1,130	0,982	4,412
2,06E-04	2,06E-02	32,752	1,130	0,982	3,950
2,43E-04	2,43E-02	32,826	1,135	0,987	4,289
2,65E-04	2,65E-02	32,678	1,125	0,978	4,072
3,27E-04	3,27E-02	32,605	1,120	0,973	4,186
3,76E-04	3,76E-02	32,605	1,120	0,973	4,989
4,42E-04	4,42E-02	32,531	1,115	0,969	5,114
5,46E-04	5,46E-02	32,457	1,110	0,965	6,036

Figure 6.66: The results from RC test, for sample number 6

Sample-7 NW1A2-a7-1A					
gamma	gamma%	Vs	G	G/Gmax	D%
3,57E-05	3,57E-03	32,511	1,118	1,000	5,264
5,65E-05	5,65E-03	32,511	1,118	1,000	5,264
7,91E-05	7,91E-03	32,511	1,118	1,000	5,264
9,99E-05	9,99E-03	32,511	1,118	1,000	5,609
1,27E-04	1,27E-02	32,435	1,113	0,995	5,568
1,64E-04	1,64E-02	32,360	1,107	0,991	5,275
1,92E-04	1,92E-02	32,285	1,102	0,986	5,305
2,01E-04	2,01E-02	32,285	1,102	0,986	5,264
2,12E-04	2,12E-02	32,210	1,097	0,982	5,473
2,29E-04	2,29E-02	32,210	1,097	0,982	5,678
2,61E-04	2,61E-02	32,134	1,092	0,977	5,742
3,41E-04	3,41E-02	32,059	1,087	0,972	6,502
3,83E-04	3,83E-02	31,984	1,082	0,968	6,789

Figure 6.67: The results from RC test, for sample number 7

Sample-8 NW1A2-d1-2					
gamma	gamma%	Vs	G	G/Gmax	D%
3,45E-05	3,45E-03	34,935	1,260	1,000	5,579
5,65E-05	5,65E-03	34,935	1,260	1,000	5,531
6,94E-05	6,94E-03	34,935	1,260	1,000	5,543
8,94E-05	8,94E-03	34,935	1,260	1,000	5,876
1,25E-04	1,25E-02	34,935	1,260	1,000	5,914
1,40E-04	1,40E-02	34,624	1,237	0,982	6,028
1,75E-04	1,75E-02	34,313	1,215	0,965	6,131
2,14E-04	2,14E-02	34,157	1,204	0,956	6,243
2,38E-04	2,38E-02	34,157	1,204	0,956	6,351
2,81E-04	2,81E-02	34,002	1,193	0,947	6,366
3,13E-04	3,13E-02	34,002	1,193	0,947	6,636
3,49E-04	3,49E-02	33,768	1,177	0,934	6,452
3,95E-04	3,95E-02	33,613	1,166	0,926	6,567

Figure 6.68: The results from RC test, for sample number 8

Sample-9 NW1A2-d2-1C					
gamma	gamma%	Vs	G	G/Gmax	D%
3,23E-05	3,23E-03	30,988	0,974	1,000	6,013
6,12E-05	6,12E-03	30,988	0,974	1,000	5,825
1,20E-04	1,20E-02	30,988	0,974	1,000	5,975
1,22E-04	1,22E-02	30,678	0,969	0,995	6,045
1,49E-04	1,49E-02	30,441	0,954	0,979	5,512
1,63E-04	1,63E-02	30,591	0,949	0,975	6,057
1,96E-04	1,96E-02	30,512	0,944	0,969	5,743
2,02E-04	2,02E-02	30,203	0,939	0,964	5,618
2,17E-04	2,17E-02	30,203	0,939	0,964	6,007
2,30E-04	2,30E-02	30,432	0,939	0,964	5,744
2,52E-04	2,52E-02	30,194	0,925	0,949	6,184
2,64E-04	2,64E-02	30,045	0,929	0,954	6,085
2,92E-04	2,92E-02	30,273	0,929	0,954	6,366
3,02E-04	3,02E-02	29,966	0,924	0,949	6,385
3,24E-04	3,24E-02	29,887	0,919	0,944	6,481
3,28E-04	3,28E-02	30,114	0,920	0,944	6,562
3,54E-04	3,54E-02	29,887	0,919	0,944	6,596
4,07E-04	4,07E-02	29,808	0,915	0,939	6,842

Figure 6.69: The results from RC test, for sample number 9

Sample-10 NW1A2-B1-3A					
gamma	gamma%	Vs	G	G/Gmax	D%
3,54E-05	3,54E-03	29,250	0,883	1,000	5,052
6,50E-05	6,50E-03	29,250	0,883	1,000	5,101
7,55E-05	7,55E-03	29,250	0,883	1,000	5,049
9,55E-05	9,55E-03	29,250	0,883	1,000	5,062
1,17E-04	1,17E-02	29,250	0,883	1,000	5,178
1,22E-04	1,22E-02	29,250	0,883	1,000	5,037
1,42E-04	1,42E-02	29,250	0,883	1,000	5,156
1,94E-04	1,94E-02	29,250	0,883	1,000	5,025
2,03E-04	2,03E-02	29,173	0,878	0,995	4,786
2,26E-04	2,26E-02	29,097	0,874	0,990	4,798
2,65E-04	2,65E-02	29,021	0,869	0,984	4,810
3,34E-04	3,34E-02	28,944	0,865	0,979	5,076
4,10E-04	4,10E-02	28,868	0,860	0,974	5,344
4,79E-04	4,79E-02	28,639	0,846	0,959	5,513
5,08E-04	5,08E-02	28,486	0,837	0,948	5,541
6,19E-04	6,19E-02	28,486	0,837	0,948	6,443
6,87E-04	6,87E-02	28,410	0,833	0,943	7,881

Figure 6.70: The results from RC test, for sample number 10

Sample-11 NW1A2-B2-2A					
gamma	gamma%	Vs	G	G/Gmax	D%
3,52E-05	3,52E-03	32,288	1,080	1,000	5,052
5,64E-05	5,64E-03	32,288	1,080	1,000	5,021
7,54E-05	7,54E-03	32,288	1,080	1,000	5,102
1,01E-04	1,01E-02	32,288	1,080	1,000	5,011
1,37E-04	1,37E-02	32,214	1,075	0,995	5,199
1,64E-04	1,64E-02	32,067	1,065	0,986	5,111
1,80E-04	1,80E-02	31,993	1,060	0,982	5,345
2,20E-04	2,20E-02	31,993	1,060	0,982	6,242
2,89E-04	2,89E-02	31,846	1,050	0,973	7,351

Figure 6.71: The results from RC test, for sample number 11

Sample-12 NW1A2-C1-2B					
gamma	gamma%	Vs	G	G/Gmax	D%
3,22E-05	3,22E-03	26,982	0,747	1,000	5,122
5,77E-05	5,77E-03	26,982	0,747	1,000	5,006
7,70E-05	7,70E-03	26,982	0,747	1,000	4,901
1,15E-04	1,15E-02	26,982	0,747	1,000	5,001
1,67E-04	1,67E-02	26,982	0,747	1,000	5,101
2,11E-04	2,11E-02	26,982	0,747	1,000	4,781
2,27E-04	2,27E-02	26,829	0,738	0,989	4,808
2,82E-04	2,82E-02	26,752	0,734	0,983	4,545
3,78E-04	3,78E-02	26,752	0,734	0,983	5,510
4,19E-04	4,19E-02	26,675	0,730	0,977	6,630
4,63E-04	4,63E-02	26,675	0,730	0,977	6,906
5,17E-04	5,17E-02	26,521	0,722	0,966	8,056

Figure 6.72: The results from RC test, for sample number 12

Sample-13 NW1A2-C2-1B					
gamma	gamma%	Vs	G	G/Gmax	D%
3,22E-05	3,22E-03	30,969	0,998	1,000	5,516
5,15E-05	5,15E-03	30,969	0,998	1,000	5,421
8,85E-05	8,85E-03	30,969	0,998	1,000	5,338
1,24E-04	1,24E-02	30,969	0,998	1,000	5,390
1,77E-04	1,77E-02	30,668	0,979	0,981	5,575
2,48E-04	2,48E-02	30,366	0,959	0,961	5,622
2,85E-04	2,85E-02	30,291	0,955	0,957	5,516
3,33E-04	3,33E-02	30,366	0,959	0,961	5,024
3,45E-04	3,45E-02	30,366	0,959	0,961	5,383
3,88E-04	3,88E-02	30,216	0,950	0,952	6,010
4,14E-04	4,14E-02	30,216	0,950	0,952	6,130
4,27E-04	4,27E-02	30,140	0,945	0,947	6,145
4,96E-04	4,96E-02	30,140	0,945	0,947	6,386
6,27E-04	6,27E-02	29,990	0,936	0,938	7,869

Figure 6.73: The results from RC test, for sample number 13

Sample-14 NW1A2-C2-2B					
gamma	gamma%	Vs	G	G/Gmax	D%
4,16E-05	4,16E-03	35,293	1,284	1,000	5,957
6,04E-05	6,04E-03	35,293	1,284	1,000	5,857
9,37E-05	9,37E-03	34,818	1,250	0,973	5,692
1,51E-04	1,51E-02	34,739	1,244	0,969	5,617
1,75E-04	1,75E-02	34,502	1,227	0,956	5,211
1,84E-04	1,84E-02	34,502	1,227	0,956	5,211
2,19E-04	2,19E-02	34,423	1,221	0,951	5,222
2,71E-04	2,71E-02	34,343	1,216	0,947	5,122
3,10E-04	3,10E-02	34,264	1,210	0,943	5,246
3,83E-04	3,83E-02	34,106	1,199	0,934	5,381
4,27E-04	4,27E-02	34,027	1,193	0,930	5,393
4,75E-04	4,75E-02	34,027	1,193	0,930	5,618
5,18E-04	5,18E-02	33,869	1,182	0,921	5,643

Figure 6.74: The results from RC test, for sample number 14

Sample-15 SM2C-B1-1A					
gamma	gamma%	Vs	G	G/Gmax	D%
3,16E-05	3,16E-03	27,060	0,727	1,000	6,027
5,12E-05	5,12E-03	27,060	0,727	1,000	6,270
8,78E-05	8,78E-03	27,060	0,727	1,000	6,606
9,93E-05	9,93E-03	27,060	0,727	1,000	6,513
1,36E-04	1,36E-02	26,819	0,714	0,982	7,036
1,42E-04	1,42E-02	26,819	0,714	0,982	6,587
1,69E-04	1,69E-02	26,578	0,702	0,965	7,553
1,76E-04	1,76E-02	26,498	0,697	0,959	8,333
1,91E-04	1,91E-02	26,498	0,697	0,959	9,459
2,45E-04	2,45E-02	26,418	0,693	0,953	10,076
2,83E-04	2,83E-02	26,257	0,685	0,942	11,386

Figure 6.75: The results from RC test, for sample number 15

Sample-16 SM2C-A2-1B					
gamma	gamma%	Vs	G	G/Gmax	D%
3,26E-05	3,26E-03	24,615	0,637	1,000	6,925
5,82E-05	5,82E-03	24,615	0,637	1,000	6,846
8,48E-05	8,48E-03	24,615	0,637	1,000	7,105
1,19E-04	1,19E-02	24,615	0,637	1,000	6,870
1,59E-04	1,59E-02	24,615	0,637	1,000	7,046
1,65E-04	1,65E-02	24,615	0,637	1,000	6,793
1,84E-04	1,84E-02	24,548	0,633	0,995	6,812
2,05E-04	2,05E-02	24,414	0,627	0,984	6,849
2,35E-04	2,35E-02	24,347	0,623	0,978	7,005
2,56E-04	2,56E-02	24,347	0,623	0,978	7,280
2,84E-04	2,84E-02	24,213	0,616	0,968	7,597
3,22E-04	3,22E-02	23,946	0,603	0,946	8,380

Figure 6.76: The results from RC test, for sample number 16

Sample-17- SB4A-A2-2A -s33=3,3 kPa					
gamma	gamma%	Vs	G	G/Gmax	D%
2,25E-05	2,25E-03	27,521	0,771	1,000	8,781
5,22E-05	5,22E-03	27,521	0,771	1,000	7,921
7,12E-05	7,12E-03	27,521	0,771	1,000	8,103
9,64E-05	9,64E-03	27,521	0,771	1,000	9,108
1,33E-04	1,33E-02	27,227	0,754	0,979	9,870
1,44E-04	1,44E-02	27,080	0,746	0,968	11,714
1,56E-04	1,56E-02	27,007	0,742	0,963	12,247

Sample-17- SB4A-A2-2A -S33=6,5 kPa					
gamma	gamma%	Vs	G	G/Gmax	D%
2,55E-05	2,55E-03	29,059	0,855	1,000	6,150
5,22E-05	5,22E-03	29,059	0,855	1,000	6,525
7,82E-05	7,82E-03	29,059	0,855	1,000	6,985
1,00E-04	1,00E-02	29,059	0,855	1,000	7,127
1,05E-04	1,05E-02	29,059	0,855	1,000	7,494
1,39E-04	1,39E-02	28,765	0,838	0,980	10,985
1,57E-04	1,57E-02	28,618	0,829	0,970	12,995
1,91E-04	1,91E-02	28,471	0,821	0,960	14,370

Figure 6.77: The results from RC test, for sample number 17

Sample-18-SM2C-C1-1A-s33=3,3 kPa					
gamma	gamma%	Vs	G	G/Gmax	D%
2,68E-05	2,68E-03	24,052	0,682	1,000	8,015
5,52E-05	5,52E-03	24,052	0,682	1,000	7,859
8,74E-05	8,74E-03	24,052	0,682	1,000	8,475
1,14E-04	1,14E-02	24,001	0,680	0,996	7,616
1,41E-04	1,41E-02	23,848	0,671	0,983	8,966
1,78E-04	1,78E-02	23,746	0,665	0,975	9,339
2,32E-04	2,32E-02	23,593	0,657	0,962	13,199

Figure 6.78: The results from RC test, for sample number 18

Sample-19-SM2C-A3-1A-s33=3,3 kPa					
gamma	gamma%	Vs	G	G/Gmax	D%
2,59E-05	2,59E-03	34,556	1,255	1,000	7,223
4,55E-05	4,55E-03	34,556	1,255	1,000	7,152
6,45E-05	6,45E-03	34,556	1,255	1,000	7,268
8,21E-05	8,21E-03	34,556	1,255	1,000	7,242
1,12E-04	1,12E-02	34,556	1,254	0,999	7,220
1,26E-04	1,26E-02	34,404	1,244	0,991	6,713
1,53E-04	1,53E-02	34,176	1,228	0,978	6,667
1,68E-04	1,68E-02	33,948	1,211	0,965	7,277
1,80E-04	1,80E-02	33,872	1,206	0,961	7,184
2,00E-04	2,00E-02	33,796	1,200	0,957	7,303
2,30E-04	2,30E-02	33,644	1,190	0,948	6,998
2,76E-04	2,76E-02	33,568	1,184	0,944	6,222
3,05E-04	3,05E-02	33,492	1,179	0,939	6,463
3,70E-04	3,70E-02	33,417	1,174	0,935	6,477
4,11E-04	4,11E-02	33,341	1,168	0,931	6,834
4,60E-04	4,60E-02	33,265	1,163	0,927	6,834

Sample-19-SM2C-A3-1A-s33=6,5 kPa					
gamma	gamma%	Vs	G	G/Gmax	D%
2,66E-05	2,66E-03	36,432	1,398	1,000	6,022
4,59E-05	4,59E-03	36,432	1,398	1,000	6,122
6,67E-05	6,67E-03	36,432	1,398	1,000	6,153
1,27E-04	1,27E-02	35,976	1,363	0,975	6,245
1,50E-04	1,50E-02	35,976	1,363	0,975	6,173
1,93E-04	1,93E-02	35,673	1,340	0,959	5,957
2,30E-04	2,30E-02	35,597	1,334	0,955	6,183
2,74E-04	2,74E-02	35,521	1,329	0,951	5,876
3,05E-04	3,05E-02	35,369	1,317	0,943	6,116
4,17E-04	4,17E-02	35,217	1,306	0,934	6,034
4,61E-04	4,61E-02	35,066	1,295	0,926	6,494

Sample-19-SM2C-A3-1A-s33=9 kPa					
gamma	gamma%	Vs	G	G/Gmax	D%
3,14E-05	3,14E-03	37,597	1,489	1,000	5,546
6,13E-05	6,13E-03	37,597	1,489	1,000	5,456
9,17E-05	9,17E-03	37,597	1,489	1,000	6,013
1,50E-04	1,50E-02	36,989	1,441	0,968	5,852
1,62E-04	1,62E-02	36,837	1,430	0,960	5,567
1,87E-04	1,87E-02	36,761	1,424	0,956	5,785
2,28E-04	2,28E-02	36,685	1,418	0,952	6,004
2,67E-04	2,67E-02	36,533	1,406	0,944	5,717
3,22E-04	3,22E-02	36,457	1,400	0,940	6,042
4,09E-04	4,09E-02	36,381	1,394	0,936	5,846
4,49E-04	4,49E-02	36,229	1,383	0,929	6,289

Figure 6.79: The results from RC test, for sample number 19

Sample-20-SB4A-A2-1B-s33=3,3 kPa					
gamma	gamma%	Vs	G	G/Gmax	D%
3,85E-05	3,85E-03	33,007	1,095	1,000	8,541
5,54E-05	5,54E-03	33,007	1,095	1,000	8,255
7,43E-05	7,43E-03	33,007	1,095	1,000	8,368
9,38E-05	9,38E-03	32,853	1,084	0,991	9,529
9,97E-05	9,97E-03	32,466	1,059	0,967	9,333
1,23E-04	1,23E-02	32,234	1,044	0,954	13,067
1,44E-04	1,44E-02	32,080	1,034	0,945	15,231

Sample-20-SB4A-A2-1B-s33=7,5 kPa					
gamma	gamma%	Vs	G	G/Gmax	D%
3,75E-05	3,75E-03	34,608	1,206	1,000	6,125
5,49E-05	5,49E-03	34,608	1,206	1,000	6,056
7,85E-05	7,85E-03	34,608	1,206	1,000	6,042
8,49E-05	8,49E-03	34,453	1,195	0,991	7,740
1,17E-04	1,17E-02	34,376	1,190	0,987	7,753
1,65E-04	1,65E-02	34,221	1,179	0,978	8,042
1,74E-04	1,74E-02	34,144	1,174	0,973	8,199
2,14E-04	2,14E-02	33,912	1,158	0,960	8,617
2,47E-04	2,47E-02	33,758	1,147	0,951	9,442
2,95E-04	2,95E-02	33,603	1,137	0,943	10,805

Figure 6.80: The results from RC test, for sample number 20

F Report NGI

Technical note

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Resonant Column Tests of Peat

Contents

Appendix

Appendix A: Photographs of test specimens

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FS 32989/EMS 612006

Summary

NGI performed 6 resonant column tests as well as bender element and index texts on peat samples from the Groningen area of The Netherlands. The specimens had organic contents ranging from 73 % to 90 %, water contents from 467 % to 620 %, and total unit weights of 9.97 kN/m^3 to 10.15 kN/m^3. NGI performed five anisotropic tests with vertical effective stresses from 25 kPa to 27 kPa and K_0 = 0.25. NGI performed one isotropic test with confining pressure equal to 7 kPa.

The small strain shear modulus ranged from 650 kPa to 1050 kPa, and the small strain damping ranged from 7 % to 14%. Shear modulus and damping ratios were measured for strain ranges of 0.0001 % to 0.17 %, and small strain shear modulus and damping were measured versus time until a maximum time of 1488 (24.8 hours) minutes to 5575 minutes (92.9 hours). The results of the resonant column, bender element, and index tests are also provided digitally in the Excel file "20150598_Lab_Data.xlsx".

1 Introduction

Deltares contracted NGI to perform the following tests for each of six peat samples from the Groningen area of The Netherlands:

- Resonant column; to estimate shear modulus (G) and damping (D) versus shear strain (γ), and small strain shear modulus (G_{max}) versus time over one day
- Piezo ceramic bender element measurements of G_{max}
- Index tests, specifically;
    - Water content
    - Organic content
    - Soil density
    - Density of solid particles

Deltares sent additional samples to Ruhr University Bochum, Germany, for more resonant column tests. This report presents the results of the laboratory tests conducted at NGI.

2 Test specifications

NGI received six peat samples from Deltares on 31 March, 2016. The samples appeared in good condition upon arrival. NGI stored the samples in a humid and temperature controlled room, with a temperature of approximately 10±2 degrees Celsius. NGI received the test specifications from Deltares on 4 April, 2016. All of the peat samples tested at NGI are from shallow layers and were tested at in-situ conditions. Table 1 lists the test number, sample ID, start and end depth of the sample, the vertical effective confining pressure (σ'_{vc}), horizontal effective confining pressure (σ'_{hc}), and the coefficient of earth pressure at rest ($K_0 = \sigma'_{hc} / \sigma'_{vc}$) specified by Deltares for each test.

Table 1. Resonant column test specifications

Test No.	Sample ID	Start Depth (m)	End Depth (m)	σ_{vc}' (kPa)	σ_{hc}' (kPa)	K_0 -
1	SM2C-C1-2	-2.13	-2.31	7.60	7.60	1.00
2	NW1A2-A5-1A	-3.7	-3.85	25.80	6.50	0.25
3	NW1A2-A6-2A	-4.8	-4.95	27.10	6.80	0.25
4	NW1A2-B1-2A	-3.7	-3.85	25.90	6.50	0.25
5	NW1A2-B2-1	-4.9	-5.08	27.00	6.80	0.25
6	NW1A2-C1-1E	-3.95	-4.1	26.20	6.60	0.25

3 Testing methodology

3.1 Index tests

NGI performed water content, organic content, soil density, and density of solid particles tests for all six test specimens. NGI estimated the water content according to ASTM standard D2216-10 method A from the sample cuttings. NGI calculated the total soil density according to ASTM standard D7263-09 based on the measured specimen used in the resonant column tests. After the end of the resonant column tests the specimen was split in two and one half was used for the organic content test and one half for the density of solid particles tests. NGI estimated the organic content using ASTM standard D2974-07 method C, and the density of solid particles using ASTM standard D5550-14.

3.2 Resonant column tests

The resonant column device used at NGI was designed by Dr. B.O. Hardin and manufactured by V.P. Drnevich (Drnevich et al, 1978). This device was mounted into a modified Geonor triaxial cell. The configuration is of the fixed-free type with the oscillator attached to the top of the specimen. The device is capable of anisotropic consolidation and triaxial shear. For a detailed description of equipment and procedures, see ASTM D4015-15.

3.2.1 Mounting

NGI trimmed all specimens to 54 mm diameter. Due to the possible existence of a negative pore pressure in a specimen, special care was taken to avoid swelling due to the presence of free water during mounting. This was achieved by using dry porous stones at the start of the consolidation. Table 2 lists the membrane properties of each resonant column test. No filter paper was applied to the specimen.

Table 2. Membrane properties

Test No.	Sample ID	Diameter mm	Thickness mm	Stiffness c-value
1	SM2C-C1-2	54.43	0.72	1.35
2	NW1A2-A5-1A	54.63	0.75	1.32
3	NW1A2-A6-2A	54.91	0.67	1.15
4	NW1A2-B1-2A	54.11	0.64	1.16
5	NW1A2-B2-1	54.07	0.61	1.17
6	NW1A2-C1-1E	54.11	0.62	1.17

3.2.2 Saturation and consolidation

The specimens are first subjected to an isotropic stress equal to the estimated value of the initial negative pore pressure. Water is then flushed through the porous stones and immediately afterwards a 0-indicator is connected to the drainage lines. Any sign of volume change of the specimen is prevented by regulating the cell pressure until stable conditions have been reached. No back pressure was applied to the specimens.

From the isotropic stress, the horizontal confining stress was decreased and the vertical stress increased at about the same rate until the target values were reached, as specified in Table 1.

3.2.3 Measurement of shear modulus and damping

The device oscillates in torsion and is therefore used to measure the shear stiffness in torsion. The shear strains along the radius of the specimen vary from zero at the centre to a maximum value at the outer perimeter. Since these tests are typically performed within the elastic region for soils, the shear strain variation along the specimen radius is assumed to be linear and the reported shear strains are average values defined at 2/3 radius of the specimen. The methods for determining the shear wave velocities and the shear stiffnesses are derived from elastic theory. Damping is calculated from the dynamic magnification factor (i.e. from input excitation and output response magnitudes).

When determining the parameters G_{max} and D_{min} as functions of only time during a particular consolidation increment, all measurements (at different times during the entire increment) are taken at the same shear strain. This constant/common shear strain level is low enough to ensure that G and D are not functions of strain level (e.g. 10^{-3} % or lower).

When determining G and D as functions of shear strain, the time effect on these parameters is as small as possible. These measurements are done as quickly as possible at the very end of a consolidation increment, well into secondary compression. At this point, the changes in G_{max} and D_{min} are generally negligible over a short period of time. The measurement sequence starts with a determination at the lowest possible shear strain. A measurement is then taken at a somewhat larger shear strain, followed by another measurement at the lowest possible shear strain. This is repeated for progressively larger shear strains (all followed by a measurement at the same lowest possible shear strain, called the reference strain), until the maximum shear strain the equipment is capable of has been attained.

3.3 Bender element tests

NGI measures the small strain shear modulus (G_{max}) using piezo ceramic bender elements by placing one element at each end of a soil specimen. The bender element is an electro-mechanical transducer that is capable of converting mechanical energy (movement) either to or from electrical energy. The bender element at one end of the specimen is used to generate a sinusoidal shear wave pulse that propagates along the length of the specimen and the other element is used to determine the arrival time of the shear wave at the other end of the specimen. NGI measures bender element shear wave travel time by first peak to first peak with similar frequencies on the transmitter and receiver bender element signals. Given the travel time and height of the specimen one can calculate the shear wave velocity (V_s). The small strain shear modulus is then calculated as:

$$G_{max} = \rho * V_s^2$$

where ρ is the density of the soil. Dyvik and Madshus (1985) and Dyvik and Olsen (1989) provide more details.

4 Results

4.1 Index tests

Table 3 lists the results of the index tests. For each sample, Table 3 lists the total unit weight (γ_t), dry unit weight (γ_d), unit weight of solids (γ_s), water content (w), organic content (OC), specific gravity (G_s), and void ratio (e).

Table 3. Results of index tests

Test No.	Sample ID	γ_t kN/m^3	γ_d kN/m^3	γ_s kN/m^3	w %	OC %	Gs -	e -
1	SM2C-C1-2	10.15	1.53	14.47	565	72.7	1.48	8.46
2	NW1A2-A5-1A	10.03	1.77	15.36	467	85.4	1.57	7.68
3	NW1A2-A6-2A	9.98	1.39	14.73	620	89.8	1.50	9.60
4	NW1A2-B1-2A	9.98	1.7	14.51	487	86.6	1.48	7.54
5	NW1A2-B2-1	10.04	1.5	16.10	567	89.5	1.64	9.73
6	NW1A2-C1-1E	9.97	1.69	16.45	490	85.2	1.68	8.73

The total unit weight, unit weight of solids, water content and organic content were measured as specified in section 3.1. The dry unit weight, specific gravity, and void ratio were calculated as follows:

$$\gamma_d = \frac{\gamma_t}{1 + w}$$

$$G_s = \frac{\gamma_s}{\gamma_w}$$

$$e = \frac{\gamma_s}{\gamma_d} - 1$$

where γ_w is the unit weight of water (9.807 kN/m^3).

Appendix A contains photographs of all of the peat specimens, both intact and split in half. Appendix A and Table 3 show that all of the peat specimens had large amounts of organic material.

4.2 Bender element and resonant column

Table 4 through Table 9 list the results from the resonant column (RC) and bender element (BE) tests for all six specimens. They list the estimated small strain shear modulus (G_{max}) and small strain damping ratio (D_{min}) versus time calculated from the RC and BE tests, as well as the shear modulus (G) and damping ratio (D) versus shear strain (γ) calculated from the RC tests.

Figure 1 through Figure 6 show the results listed in Table 4 through Table 9 graphically, as well as plots for G/G_{max} and D without the intermediate measurements of the reference strain.

Table 4. Resonant column and bender element results for test 1 (SM2C-C1-2)

RC results vs time		
Time (min)	G_{max} (kPa)	D_{min} (%)
6	653	7.33
8	651	7.23
16	658	7.31
32	655	7.22
64	651	7.36
128	654	7.40
258	655	7.28
1003	626	8.48
1083	627	8.04
1263	629	7.80
1318	636	7.97
1468	632	7.61
2528	640	7.54
3893	644	7.87
5478	644	7.90
5513	644	7.80

RC results vs strain		
γ (%)	G (kPa)	D (%)
0.00036	644	7.80
0.00129	652	6.69
0.00038	650	7.94
0.00355	661	7.21
0.00035	642	7.71
0.01264	684	5.00
0.00036	648	7.88
0.03624	661	4.05
0.00036	648	7.89
0.12134	562	5.23
0.00037	631	7.33

BE results			
Time (min)	G_{max} (kPa)	Height (cm)	Volume (cm^3)
32	758	10.45	240.36
64	758	10.45	240.61
128	767	10.45	240.96
258	771	10.45	241.46
1003	784	10.45	242.46
1318	784	10.45	242.61
1468	784	10.45	242.61
2528	792	10.45	242.81
5513	810	10.45	243.36

Table 5. Resonant column and bender element results for test 2 (NW1A2-A5-1A)

RC results vs time		
Time (min)	G_{max} (kPa)	D_{min} (%)
2	1043	13.66
4	1044	13.58
8	1044	13.70
16	1043	13.76
32	1046	13.98
160	1057	14.64
260	1059	14.57
460	1073	14.87
545	1082	13.98
640	1077	14.39
775	1080	14.02
1535	1085	14.04
1605	1080	14.23

RC results vs strain		
γ (%)	G (kPa)	D (%)
0.00010	1080	14.23
0.00034	1078	14.35
0.00012	1078	14.32
0.00131	1118	13.20
0.00011	1098	14.66
0.00379	1156	9.85
0.00012	1085	14.52
0.01299	1133	6.47
0.00012	1073	14.21
0.01874	1111	5.53
0.00011	1080	14.09

BE results			
Time (min)	G_{max} (kPa)	Height (cm)	Volume (cm^3)
2	1201	10.77	257.77
4	1201	10.77	257.77
8	1201	10.77	257.72
16	1209	10.77	257.72
32	1208	10.77	257.67
160	1216	10.76	257.67
260	1215	10.76	257.67
460	1198	10.76	257.67
545	1198	10.76	257.67
1535	1213	10.75	257.87
1605	1229	10.75	257.87

Table 6. Resonant column and bender element results for test 3 (NW1A2-A6-2A)

RC results vs time		
Time (min)	G_{max} (kPa)	D_{min} (%)
3	759	7.90
7	759	7.94
17	759	7.94
25	766	7.94
43	764	8.61
75	756	7.69
139	759	7.72
1054	781	8.19
1474	782	8.42
2054	788	8.48
2879	785	8.74
3214	794	8.67
3329	794	8.67

RC results vs strain		
γ (%)	G (kPa)	D (%)
0.00015	794	8.67
0.00040	794	9.42
0.00013	800	9.15
0.00128	827	6.56
0.00013	823	6.37
0.00395	812	5.75
0.00013	823	6.38
0.01311	801	4.79
0.00013	824	6.41
0.02262	808	6.41
0.00013	826	6.36

BE results			
Time (min)	G_{max} (kPa)	Height (cm)	Volume (cm^3)
3	538	8.77	254.86
7	538	8.77	254.91
17	536	8.75	254.91
25	534	8.74	254.91
43	532	8.72	254.96
75	523	8.65	254.81
139	515	8.60	254.76
1054	477	8.16	254.51
1474	462	8.00	254.31
2504	444	7.81	254.31
3329	417	7.55	254.01
3329	421	7.55	254.01

Table 7. Resonant column and bender element results for test 4 (NW1A2-B1-2A)

RC results vs time		
Time (min)	G_{max} (kPa)	D_{min} (%)
2	986	12.55
4	975	12.53
10	976	12.45
21	990	12.51
40	990	12.43
98	992	12.41
203	993	12.55
273	992	12.41
423	993	12.45
1353	985	12.54
1488	987	12.63

RC results vs strain		
γ (%)	G (kPa)	D (%)
0.00037	987	12.63
0.00114	993	11.71
0.00038	986	12.50
0.00392	976	10.44
0.00038	995	12.19
0.01176	981	9.11
0.00038	989	12.37
0.03938	1012	5.87
0.00037	982	12.72
0.12173	953	5.52
0.00037	972	14.41
0.17422	947	5.31
0.00043	991	12.11

BE results			
Time (min)	G_{max} (kPa)	Height (cm)	Volume (cm^3)
2	1240	10.78	251.78
4	1258	10.78	251.78
10	1240	10.78	251.83
21	1257	10.77	251.88
40	1240	10.77	251.88
98	1239	10.77	251.98
203	1255	10.77	251.98
273	1255	10.77	252.08
423	1255	10.76	252.18
1353	1251	10.75	252.48
1488	1251	10.75	252.58

Table 8. Resonant column and bender element results for test 5 (NW1A2-B2-1)

RC results vs time		
Time (min)	G_{max} (kPa)	D_{min} (%)
2	824	11.34
5	824	11.34
10	824	11.34
23	824	11.34
45	820	11.04
100	824	11.15
154	822	11.17
1015	864	11.75
1175	854	11.91
1460	868	11.90
5330	888	12.70
5565	882	12.40
5575	884	12.25

RC results vs strain		
γ (%)	G (kPa)	D (%)
0.00039	884	12.25
0.00129	887	11.01
0.00039	895	12.15
0.00404	890	8.93
0.00043	891	12.24
0.01230	877	6.99
0.00039	888	12.21
0.04509	882	4.78
0.00040	901	11.95
0.12086	827	4.38
0.00042	884	11.59
0.17159	814	4.59
0.00040	894	11.75

BE results			
Time (min)	G_{max} (kPa)	Height (cm)	Volume (cm^3)
2	828	9.81	250.52
5	825	9.79	250.52
10	825	9.79	250.52
23	821	9.77	250.52
45	818	9.75	250.52
100	805	9.68	250.52
154	800	9.65	250.52
1015	773	9.39	250.82
1175	759	9.31	250.82
1460	765	9.29	250.82
5530	721	8.98	251.12
5565	714	8.95	251.12
5575	723	8.94	251.02

Table 9. Resonant column and bender element results for test 6 (NW1A2-C1-1E)

RC results vs time		
Time (min)	G_{max} (kPa)	D_{min} (%)
2	908	8.54
4	912	8.14
10	910	8.30
16	903	8.76
19	900	9.06
26	906	8.50
47	906	8.50
960	937	7.90
1385	936	7.74
1431	928	8.24
1453	925	8.18
2295	934	7.97
2635	928	8.39
2790	932	7.78
3835	930	7.62
3945	936	8.13

RC results vs strain		
γ (%)	G (kPa)	D (%)
0.00013	936	8.13
0.00036	933	8.41
0.00013	935	8.14
0.00123	935	9.13
0.00012	935	8.13
0.00375	1023	7.48
0.00012	941	8.13
0.01201	1022	5.04
0.00012	933	7.75
0.02025	1008	4.33
0.00012	939	8.12

BE results			
Time (min)	G_{max} (kPa)	Height (cm)	Volume (cm^3)
2	792	9.56	251.54
10	792	9.56	251.59
16	791	9.55	251.59
26	788	9.54	251.59
47	786	9.52	251.64
960	752	9.22	252.24
1385	738	9.14	252.39
1431	733	9.11	252.34
1453	731	9.10	252.34
2295	713	8.99	252.69
2635	704	8.94	252.74
2790	700	8.87	252.49
3835	682	8.76	252.64
3952	685	8.75	252.69

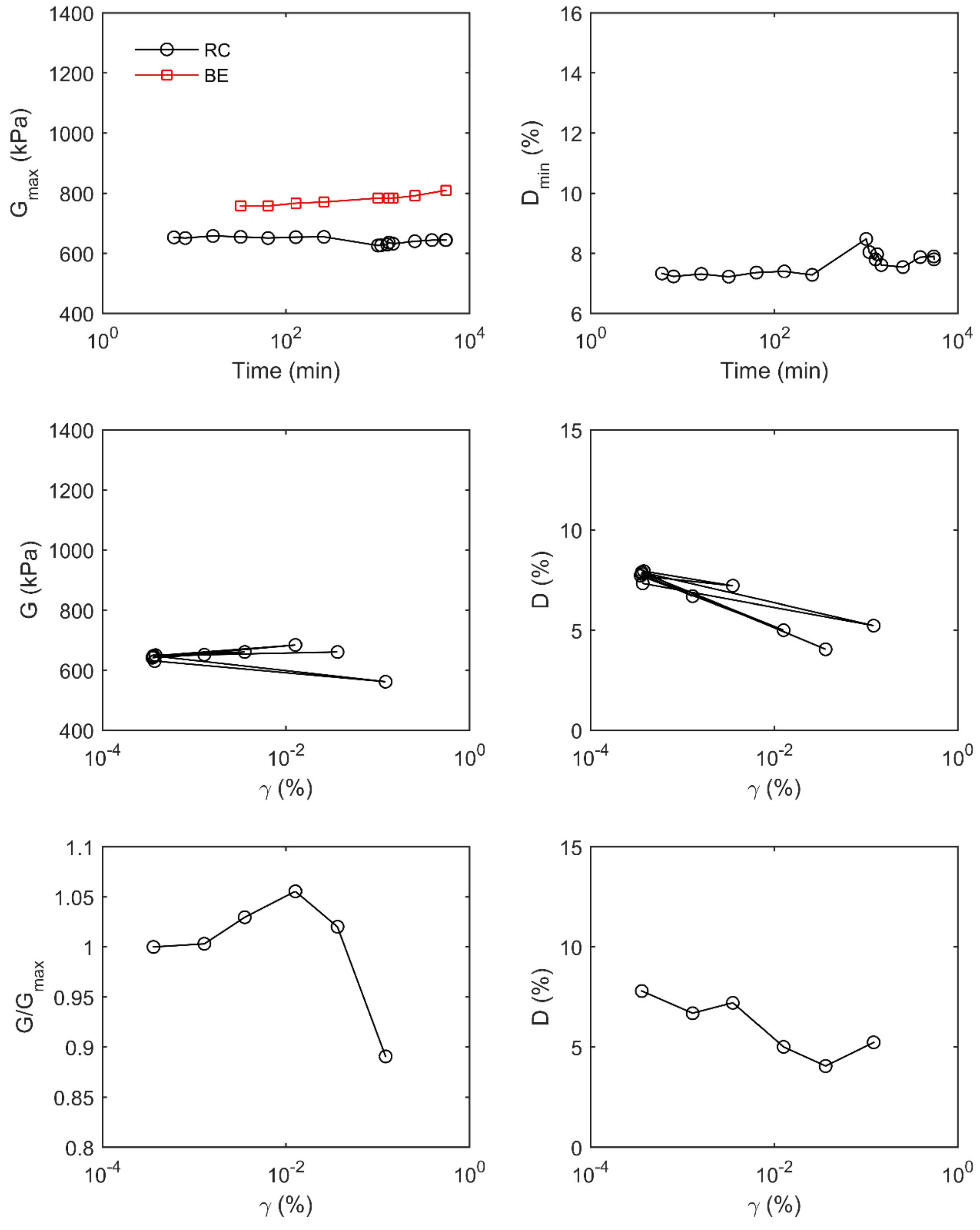

Figure 1. Resonant column and bender element results for test 1 (SM2C-C1-2)

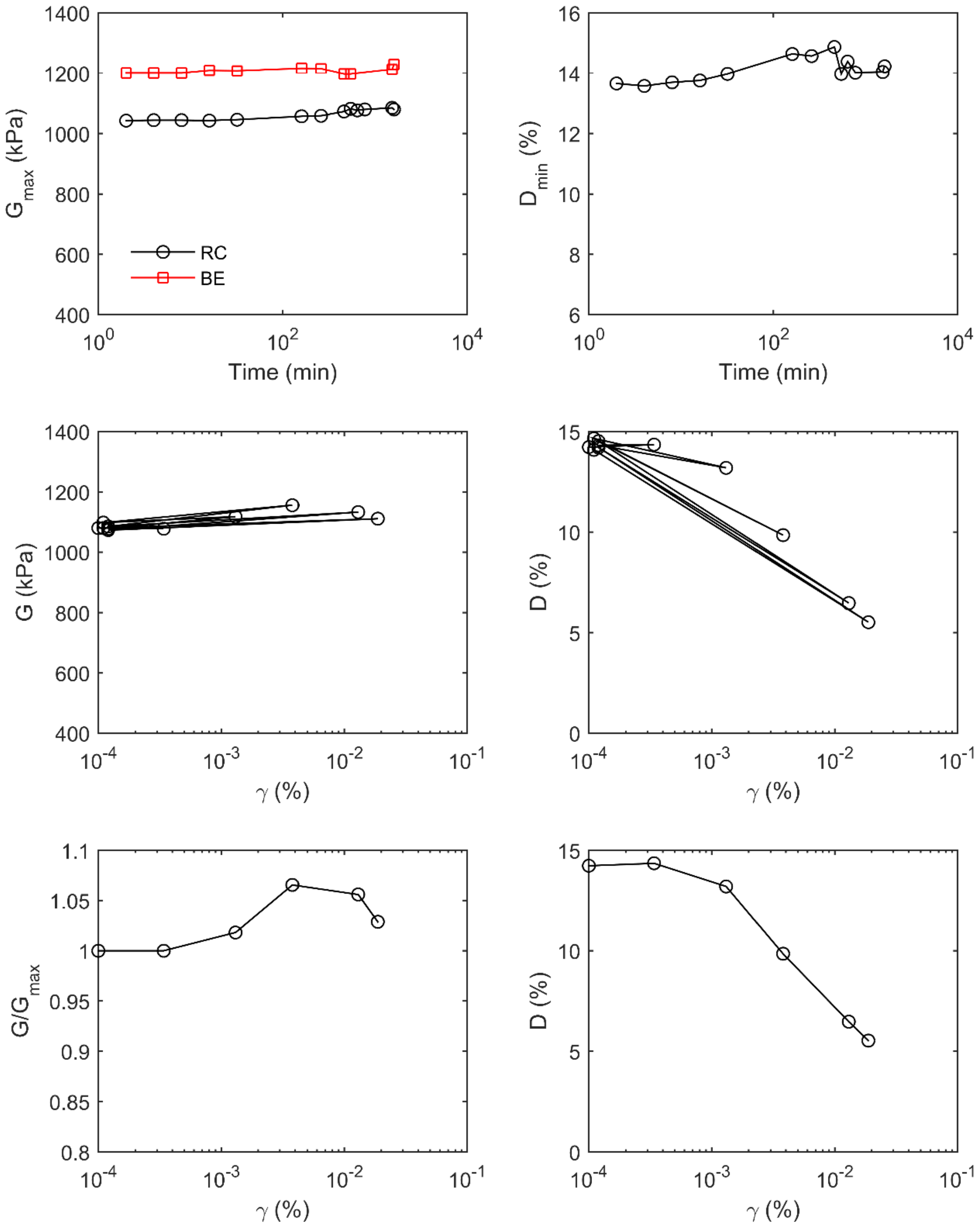

Figure 2. Resonant column and bender element results for test 2 (NW1A2-A5-1A)

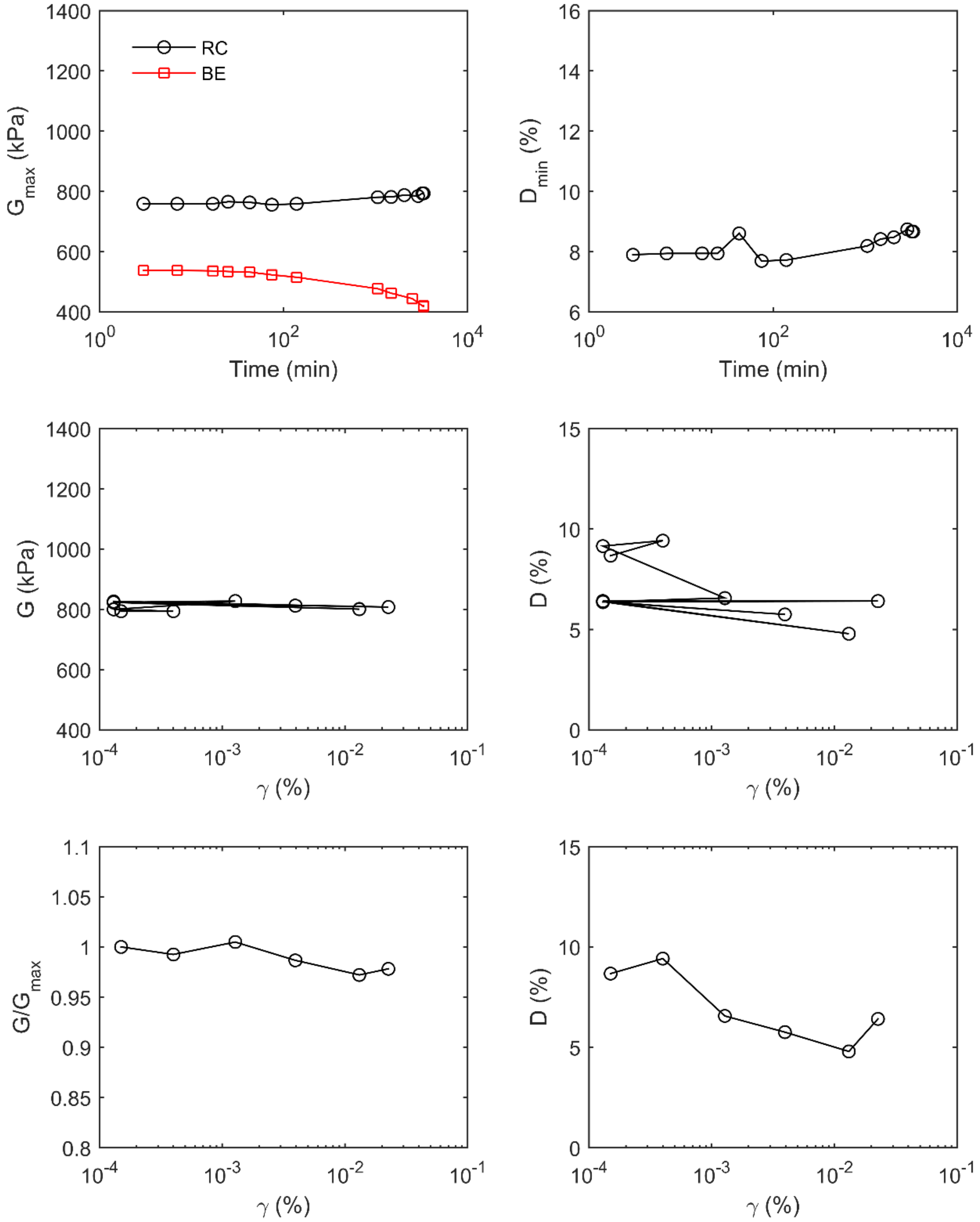

Figure 3. Resonant column and bender element results for test 3 (NW1A2-A6-2A)

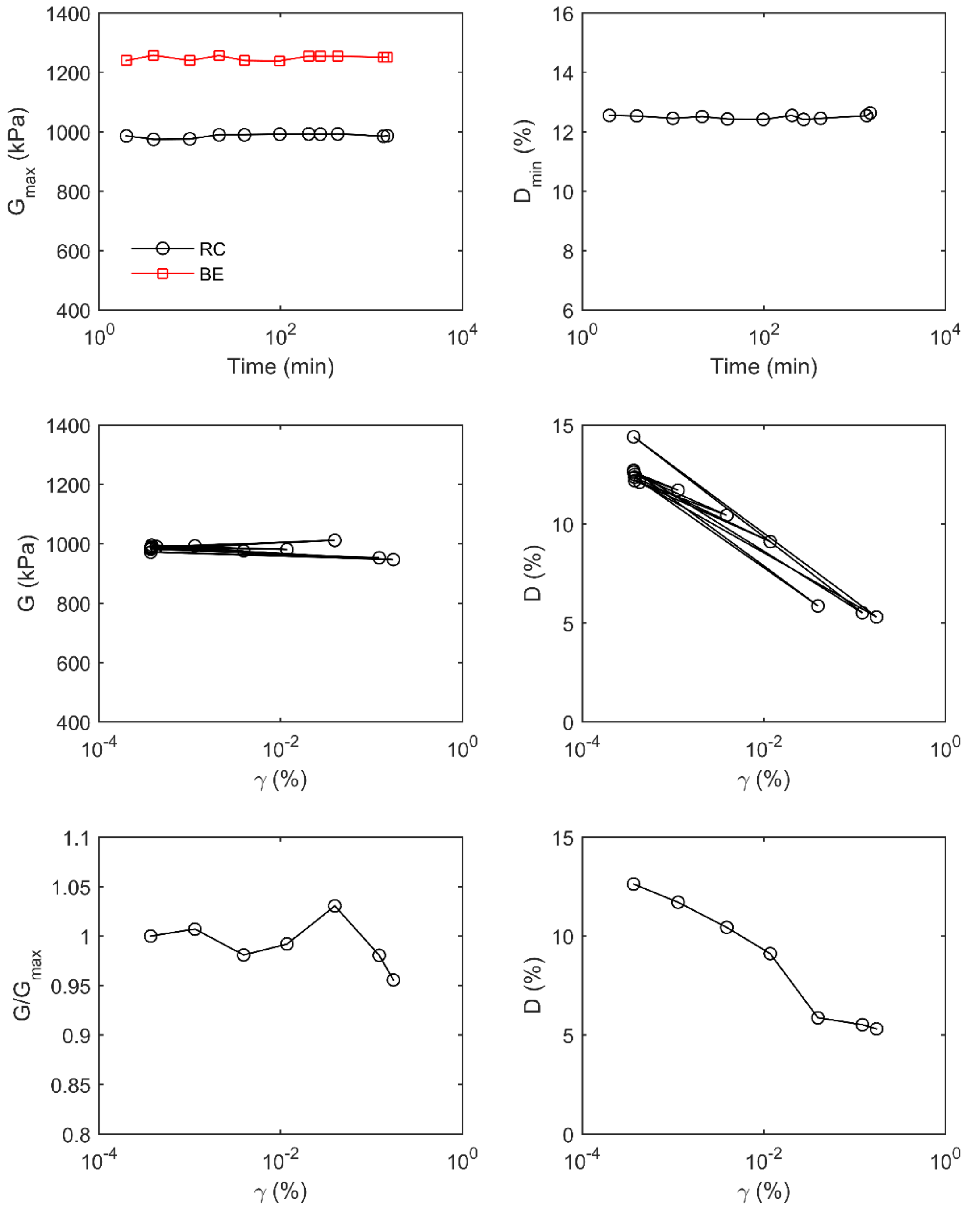

Figure 4. Resonant column and bender element results for test 4 (NW1A2-B1-2A)

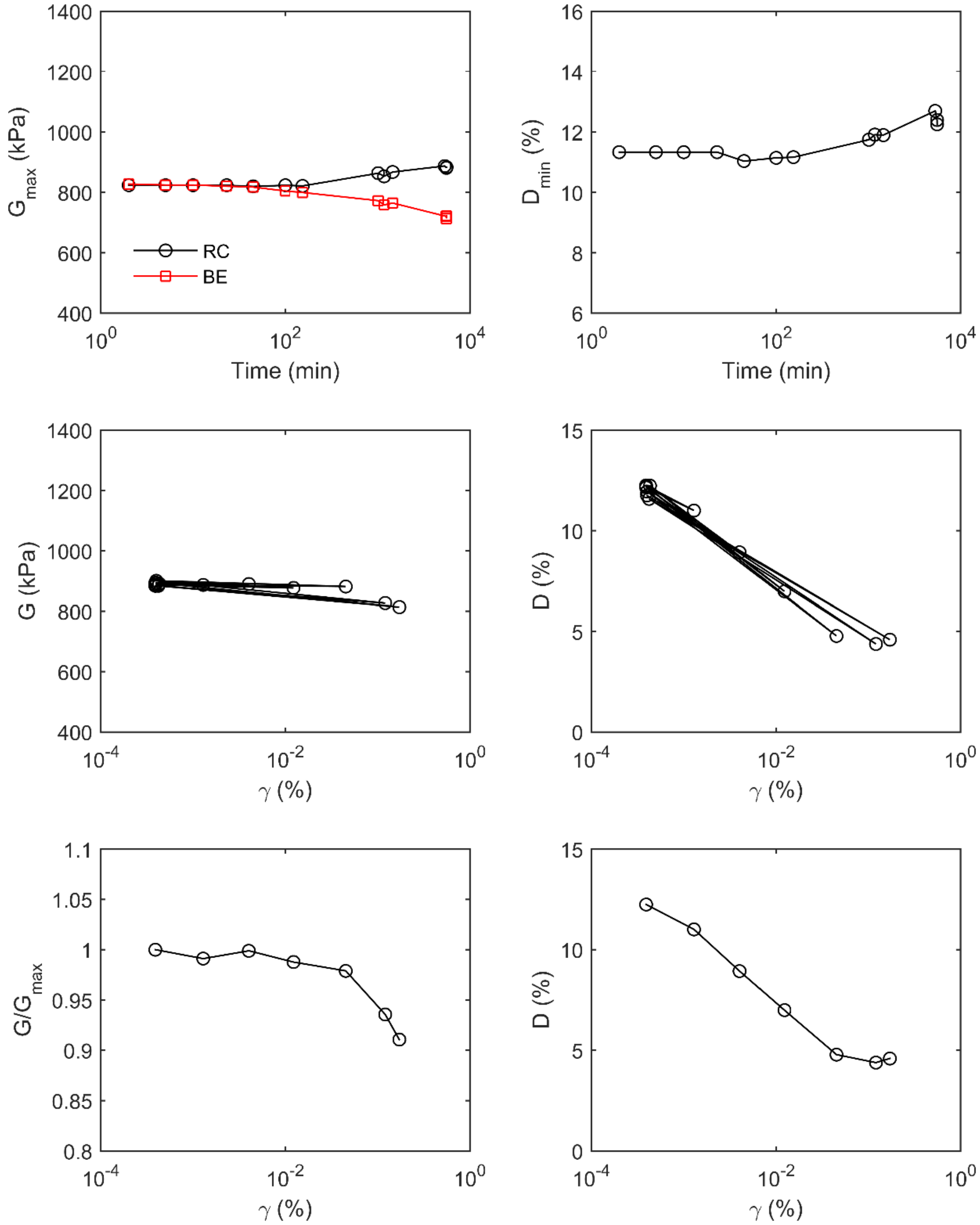

Figure 5. Resonant column and bender element results for test 5 (NW1A2-B2-1)

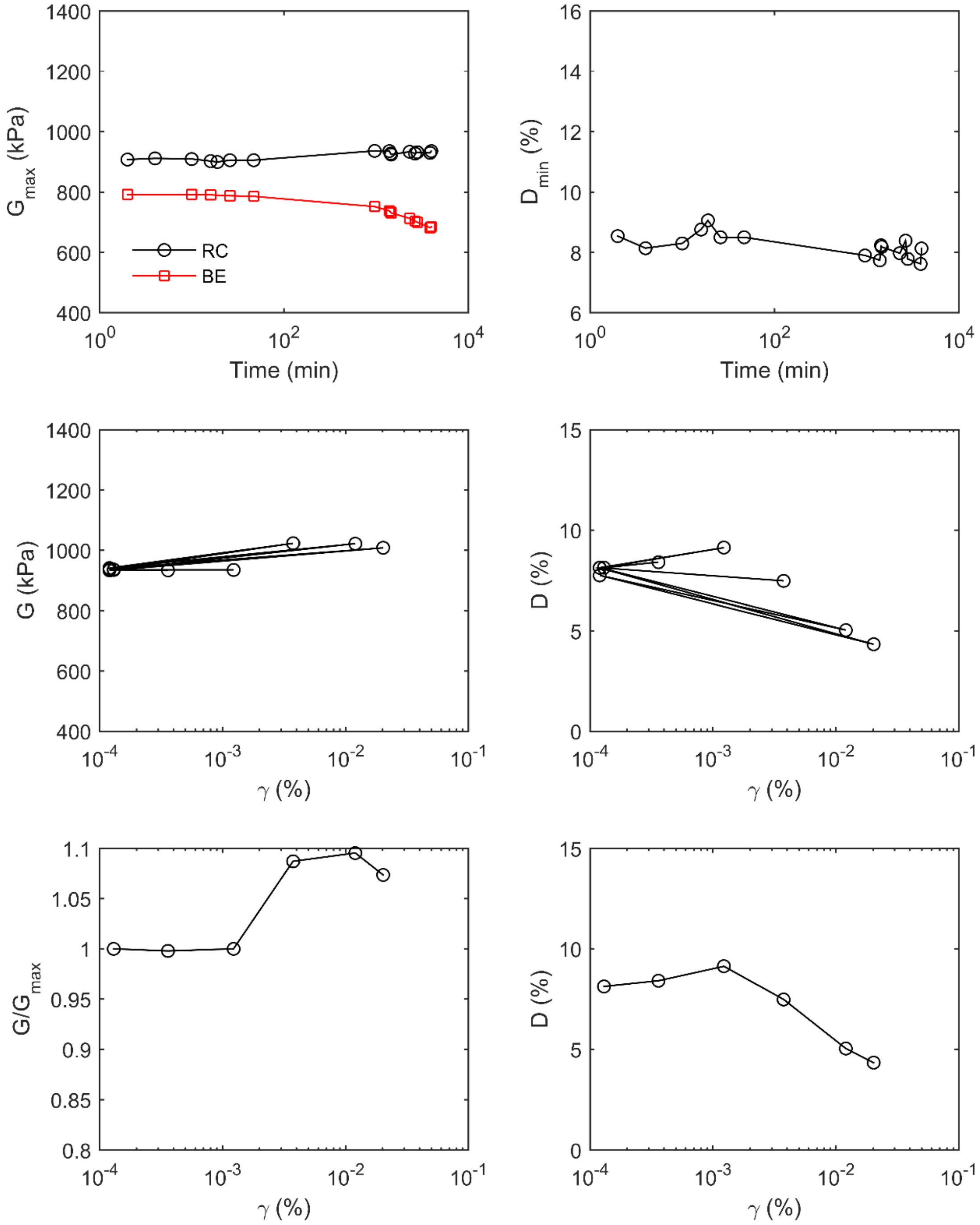

Figure 6. Resonant column and bender element results for test 6 (NW1A2-C1-1E)

5 Discussion

When calculating the stiffness and damping of a soil using a resonant column device, both the resonant frequency of the device with and without the soil specimen need to be calculated. The added mass (polar moment of inertia) of a soil specimen tends to reduce the system resonant frequency, but the added soil stiffness tends to increase the resonant frequency. For most soils, the effect of added stiffness is greater than the effect of the added mass and the resonant frequency of the system increases. However, for the peat specimens tested in this report, the resonant frequency of the system was lower with the soil specimen than it was without the soil specimen.

NGI tried but was unable to process the data from the resonant column tests according to ASTM D2015-07 using the specified FORTRAN program. The program could not calculate a result because the resonant frequency of the system with the soil specimen being lower than the resonant frequency of the system without the soil specimen resulted in negative numbers that the mathematics of the program could not handle. As a result, NGI tried the newly developed solver published in ASTM D4015-15. This solver calculates resonant column results in a different way than past solvers and was able to calculate results with no error message. This solver has been tested and verified by calculations on many different types of soils.

The calculated G values for the peat tests seem reasonable and are similar to the bender element results. However, the new solver calculated D_{min} values ranging from 7-14%, and decreasing D values with increasing shear strain for some tests. For most soils, D is around 1-4% at small strains and is usually relatively constant until it starts to increase after reaching the threshold strain. Using the relationship of Kishida et al (2009) for organic soils, NGI calculated D_{min} values of about 4% for the peats in this study, and that the D values remained constant until a shear strain of 0.01%. Therefore, NGI is not confident in the damping results.

To address this issue, NGI has been in contact with Dr. Vincent Drnevich, the developer of the new solver method and primary author of ASTM D4015 (Rune Dyvik, the technical lead for the geotechnical laboratory at NGI, is one of the three co-authors of ASTM D4015-15). NGI has discussed the results of the peat tests from this report with Dr. Drnevich on a confidential basis. Dr. Drnevich believes that the mathematics of the new ASTM D4015-15 solver, specifically the handling of imaginary numbers, may not be optimal for the very special case of these tests. Dr. Drnevich is investigating this problem and evaluating whether the solver should be improved. If it is established that the solver should be corrected, then NGI will use the modified solver to recalculate the resonant column results and resubmit them to Deltares.

For some of the bender element tests G_{max} decreases slightly with time. NGI does not know why this occurs. The G_{max} value could actually decrease with time, however, this is contrary to most laboratory data and NGI is therefore sceptical that this is actually the case. Typically, the value of G_{max} increases per log cycle of time about 0-5% for sand, 10% for overconsolidated cohesive material, and up to 20% for normally consolidated soft clay. This is the first time NGI has measured decreasing values of G_{max} with time.

Usually, shear wave travel times measured by bender element decrease with time as the specimen consolidates. This is because both the travel distance decreases as the specimen height diminishes and the soil becomes stiffer. In the tests on peat conducted for this report, the measured shear wave travel times were relatively constant during consolidation. With decreasing travel distance (diminishing specimen height) during consolidation, the calculated bender element shear wave velocity and G_{max} thereby decreased slightly over time. NGI takes into account the specimen volume change (and thereby density change, dimension, and mass change) in the resonant column results and in the bender element calculations of G_{max}.

6 References

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International Conference on Soil Mechanics and Foundation Engineering, 12. Rio de Janeiro 1989. Proceedings, Vol. 1, pp. 39-42.

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Regression models for dynamic properties of highly organic soils.
Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 135, p 533-534.

Appendix A

PHOTOGRAPHS OF TEST SPECIMENS

Date: 2016-05-02

Resonant Column Tests of Peat	Document No. 20150598-01-TN	
Sample SMC2C-C1-2	Figure No. A1	
	Date 2016-05-03	Drawn by BCa

P:\2015\05\20150598\Lab\Photos\Sample_01_Photo.grf

Date: 2016-05-02

Resonant Column Tests of Peat	Document No. 20150598-01-TN
Sample NW1A2-A5-1A	Figure No. A2
	Date 2016-05-03 / Drawn by BCa

P:\2015\05\20150598\Lab\Photos\Sample_02_Photo.grf

Date: 2016-05-02

Resonant Column Tests of Peat	Document No. 20150598-01-TN
Sample NW1A2-A6-2A	Figure No. A3
	Date 2016-05-03 / Drawn by BCa

P:\2015\05\20150598\Lab\Photos\Sample_03_Photo.grf

Date: 2016-05-02

Resonant Column Tests of Peat	Document No. 20150598-01-TN	
Sample NW1A2-B1-2A	Figure No. A4	
	Date 2016-05-03	Drawn by BCa

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Date: 2016-05-02

Resonant Column Tests of Peat	Document No. 20150598-01-TN	
Sample NW1A2-B2-1	Figure No. A5	
	Date 2016-05-03	Drawn by BCa

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Date: 2016-05-02

Resonant Column Tests of Peat	Document No. 20150598-01-TN	
Sample NW1A2-C1-1E	Figure No. A6	
	Date 2016-05-03	Drawn by BCa

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Review and reference page

Document information		
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Type of document Technical note	**Client** Deltares	**Original Date** 2016-05-11
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Distribution OPEN: To be published in open archives (BRAGE)		
Keywords Peat, Resonant Column, Dynamic soil properties		

Geographical information	
Country The Netherlands	**Offshore area**
Municipality Groningen	**Field name**
Location	**Location**
Map	**Field, Block No.**
UTM-coordinates **Zone: East: North:**	**Coordinates** **Projection, datum: East: North:**

Document control
Quality assurance according to NS-EN ISO9001

Rev.	**Reason for revision**	**Self review by:**	**Colleague review by:**	**Independent review by:**	**Interdisciplinary review by:**
0	Original document	2016-05-09 Brian Carlton	2016-05-10 Wing Shun Kwan	Select control date Type your name	Select control date Type your name
1	Comments from DELTARES	2016-06-01 Brian Carlton			

Document approved for release	**Date**	**Project Manager**
	1 June 2016	Morten Andreas Sjursen

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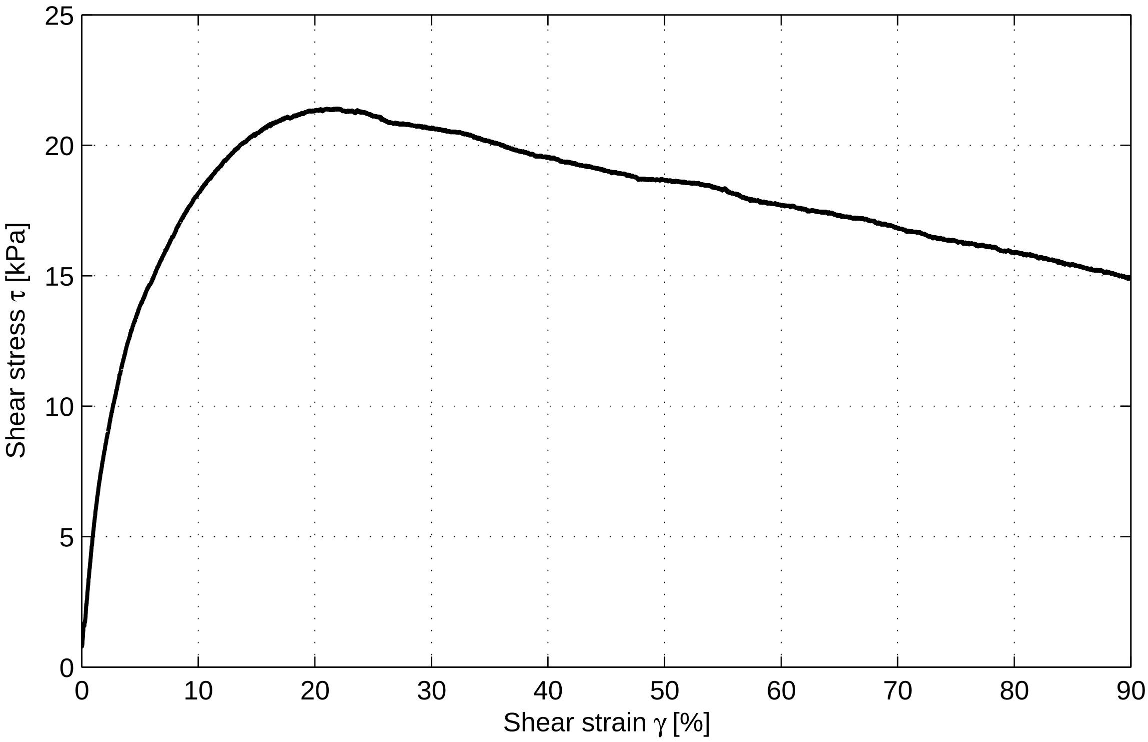
G Static DSS tests



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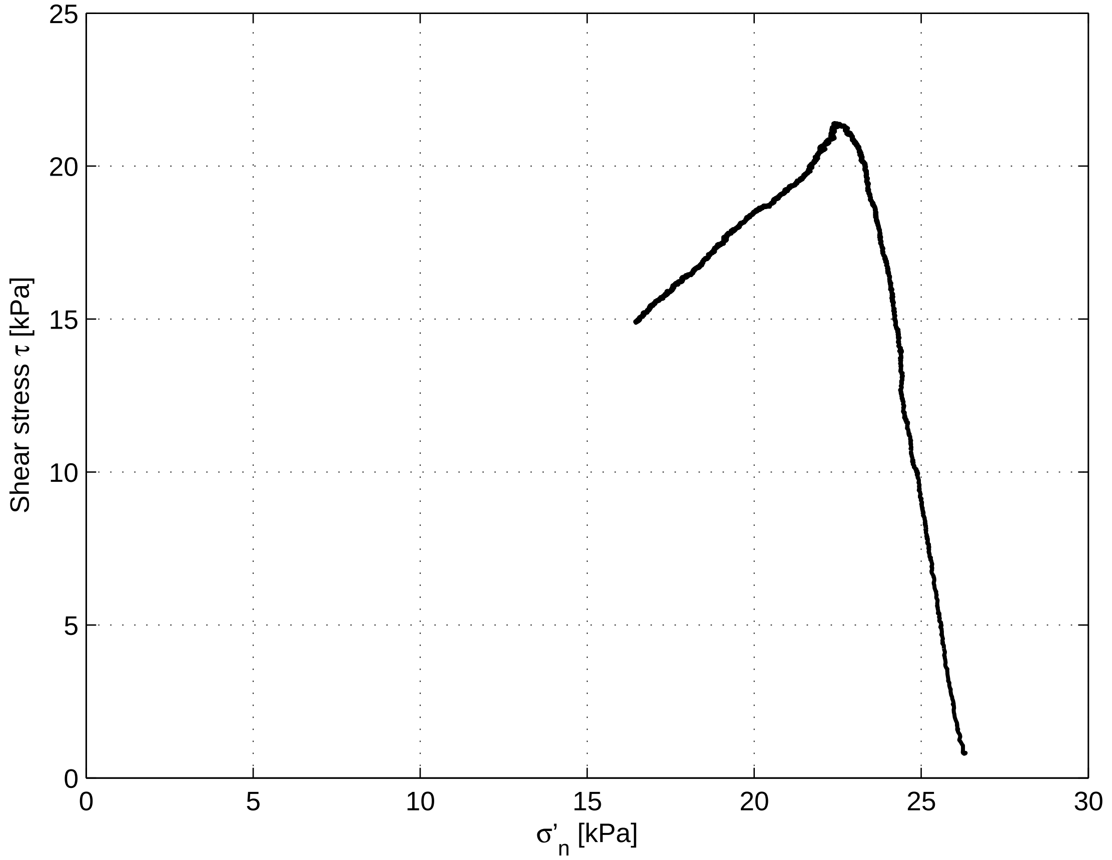
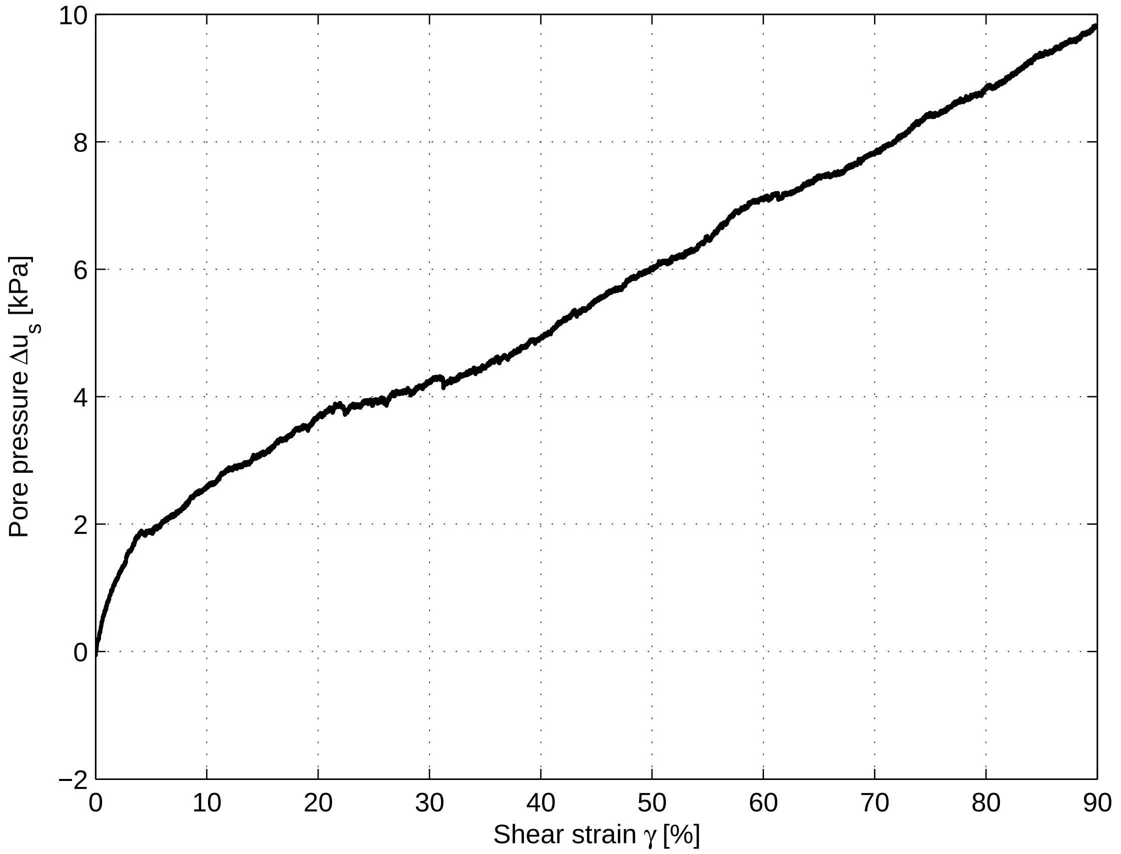
Soil classification	Peat, low−mineral content
Pressure area [cm²]	31.17
Mean temperature during shear [°C]	21.7
Test type	Constant height
Apparatus code	DSS−C
Sample name	NW1A2−A4−1B
Bore code	NW1A2−A
Depth top [m]	−4.78
Depth bottom [m]	−4.80
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm³]	1.0
S_0 [%]	−
Void ratio start shear [−]	0.99
w_0 [%]	507.9
w_{final} [%]	336.4
Consolidation stress [kPa]	26.3
Consolidation strain [%]	9.52
Strain rate [%/h]	8.0
Max shear stress [kPa]	21.4
Vert. stress at max shear stress [kPa]	22.4
Horz. strain at max shear stress [kPa]	21.9
σ_v at γ = 40% [kPa]	21.3
τ at γ = 40% [kPa]	19.5
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample's photos).





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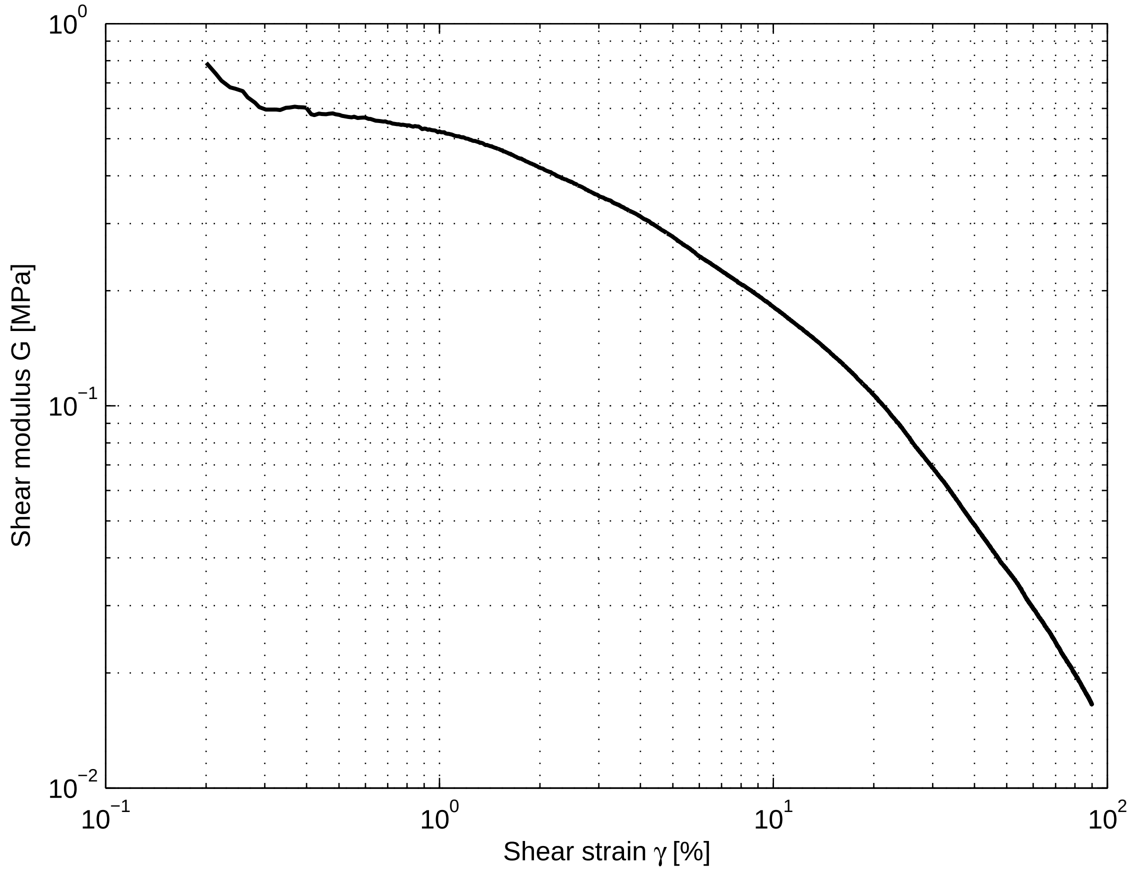
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−A4−1B				project 1209862.11	version 1.3
Direct Simple Shear Test				appendix NW1A2−A4−1B	page 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
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15% deformation	20.4	N.A	23.1	3.1	0.1
30% deformation	20.7	N.A	22.0	4.2	0.1
Maximum strain	14.9	N.A	16.5	9.8	0.0
Maximum τ	21.4	−0.00	22.4	3.9	0.1

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Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−A4−1B

Direct Simple Shear Test

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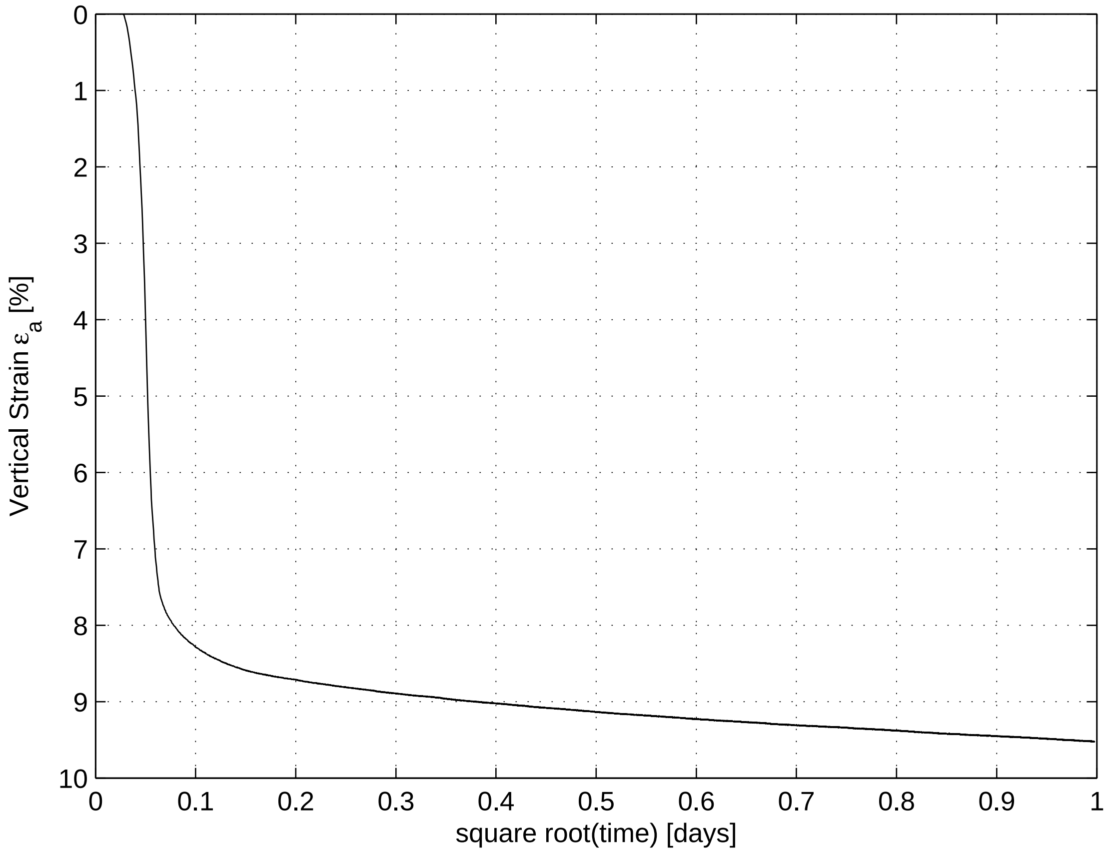
project	version
1209862.11	1.3
appendix	page
NW1A2−A4−1B	3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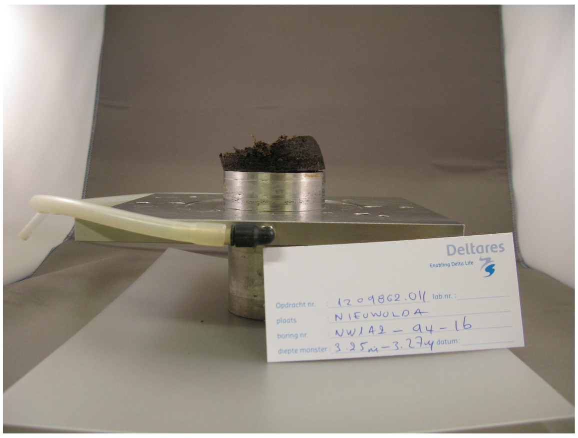
3
4
5
6
7
8
9
10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
square root(time) [days]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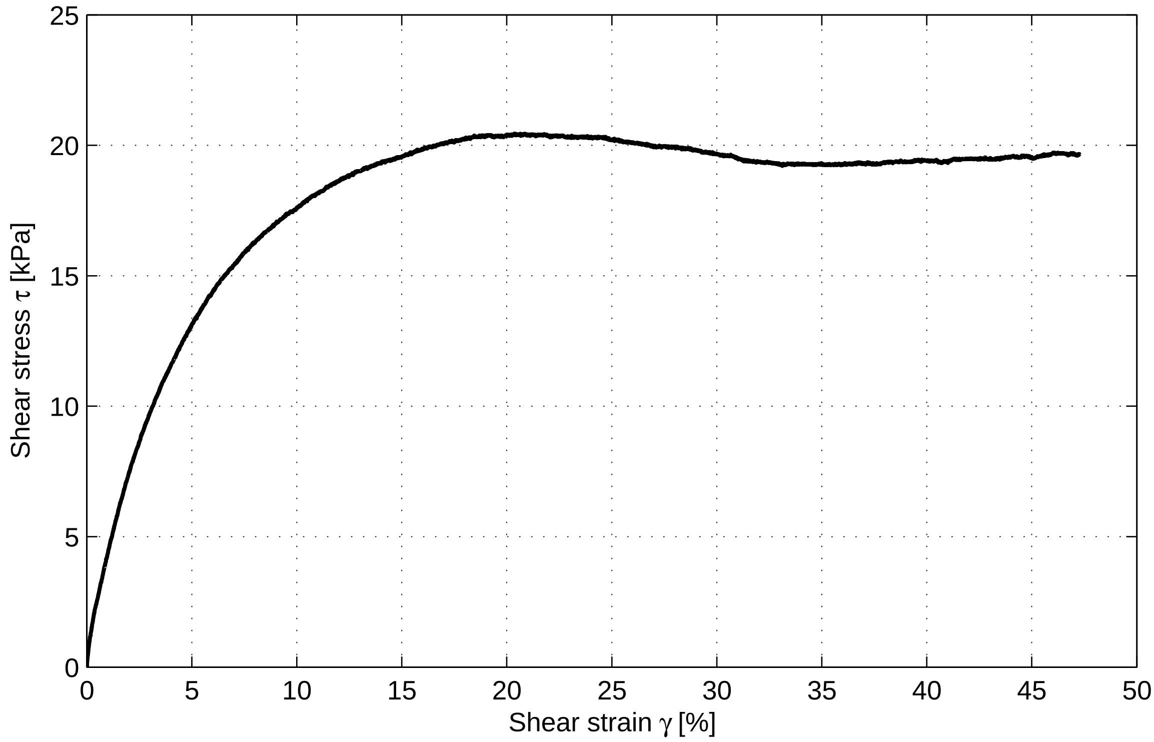
plaats : NIEUWOLDA
boring nr. : NW1A2 – A4 – 1B
diepte monster : 3.25m – 3.27m datum:



Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.7
Test type	Constant height
Apparatus code	DSS−D
Sample name	NW1A2−A5−1E
Bore code	NW1A2−A
Depth top [m]	−5.68
Depth bottom [m]	−5.70
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.92
w_0 [%]	479.4
w_{final} [%]	470.2
Consolidation stress [kPa]	27.4
Consolidation strain [%]	12.23
Strain rate [%/h]	8.0
Max shear stress [kPa]	20.4
Vert. stress at max shear stress [kPa]	22.9
Horz. strain at max shear stress [kPa]	20.6
σ_v at γ = 40% [kPa]	21.2
τ at γ = 40% [kPa]	19.4
Sample Disturbance Index [%]	−
SDI qualification	−

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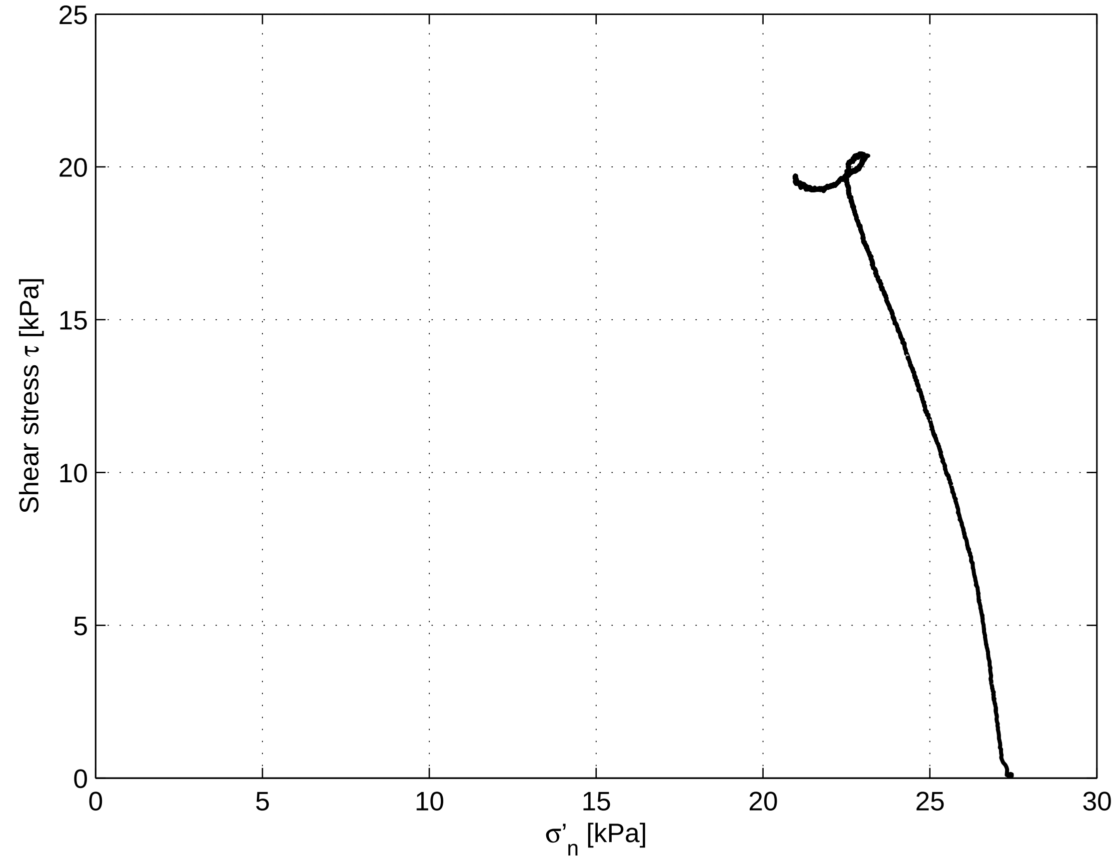
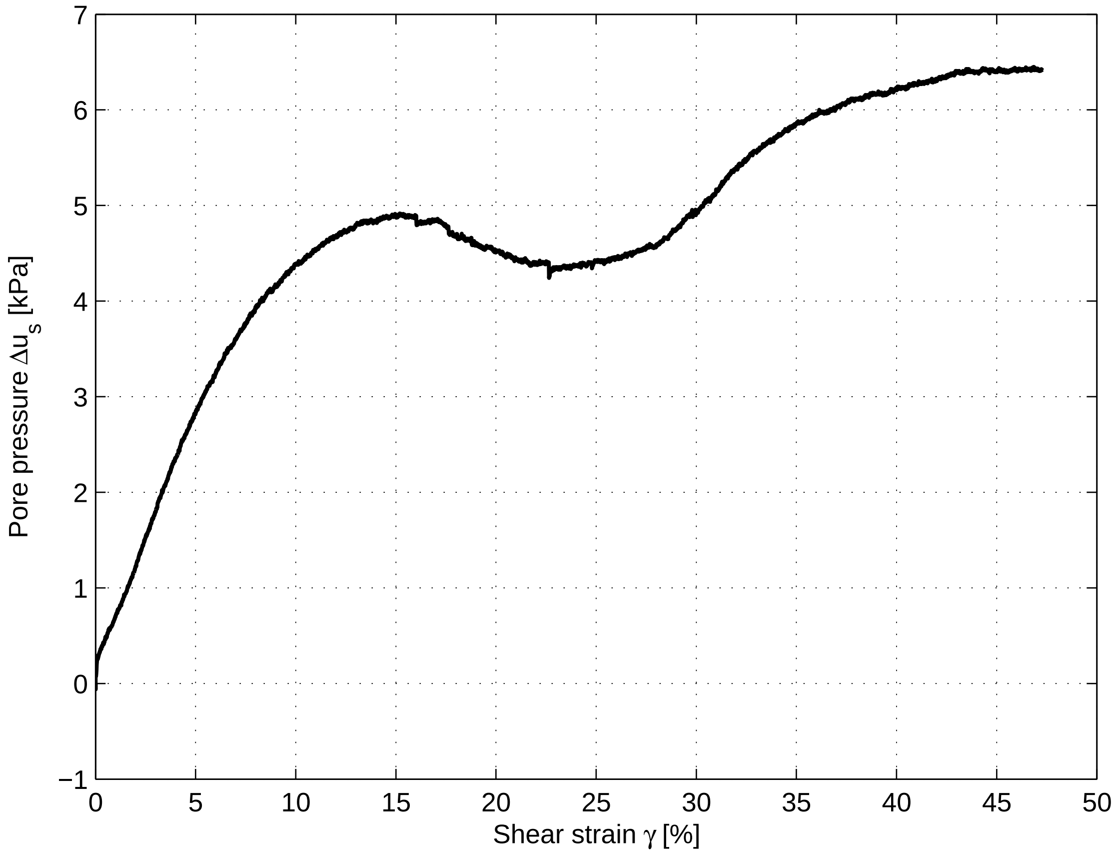
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−A5−1E	date 2016−04−15	signed konstad
	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−A5−1E	page 1





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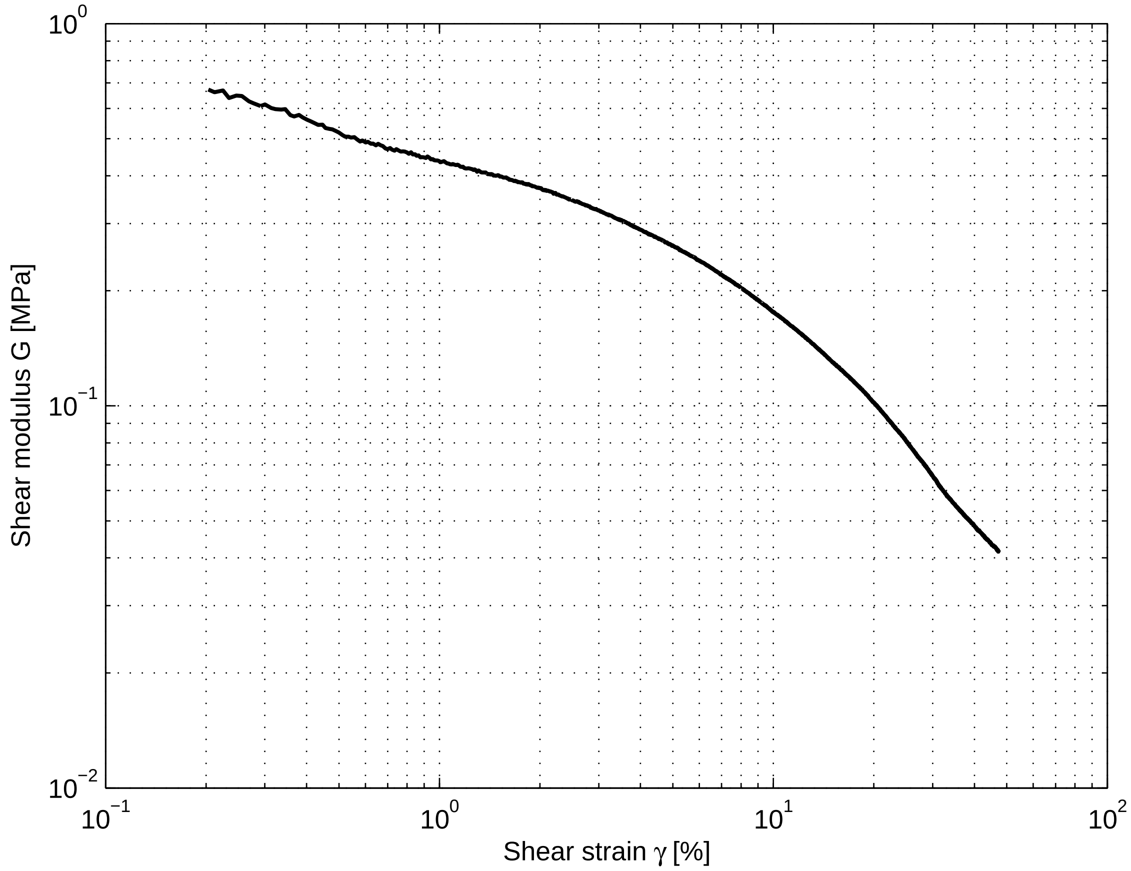
Shear degradation and damping curves for peat		date	signed
		2016−04−15	konstad
Direct Simple Shear test on sample NW1A2−A5−1E		project	version
		1209862.11	1.3
Direct Simple Shear Test		appendix	page
		NW1A2−A5−1E	2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	13.1	N.A	24.5	2.9	0.3
15% deformation	19.6	N.A	22.5	4.9	0.1
30% deformation	19.7	N.A	22.5	4.9	0.1
Maximum strain	19.6	N.A	21.0	6.4	0.0
Maximum τ	20.4	−0.00	22.9	4.5	0.1

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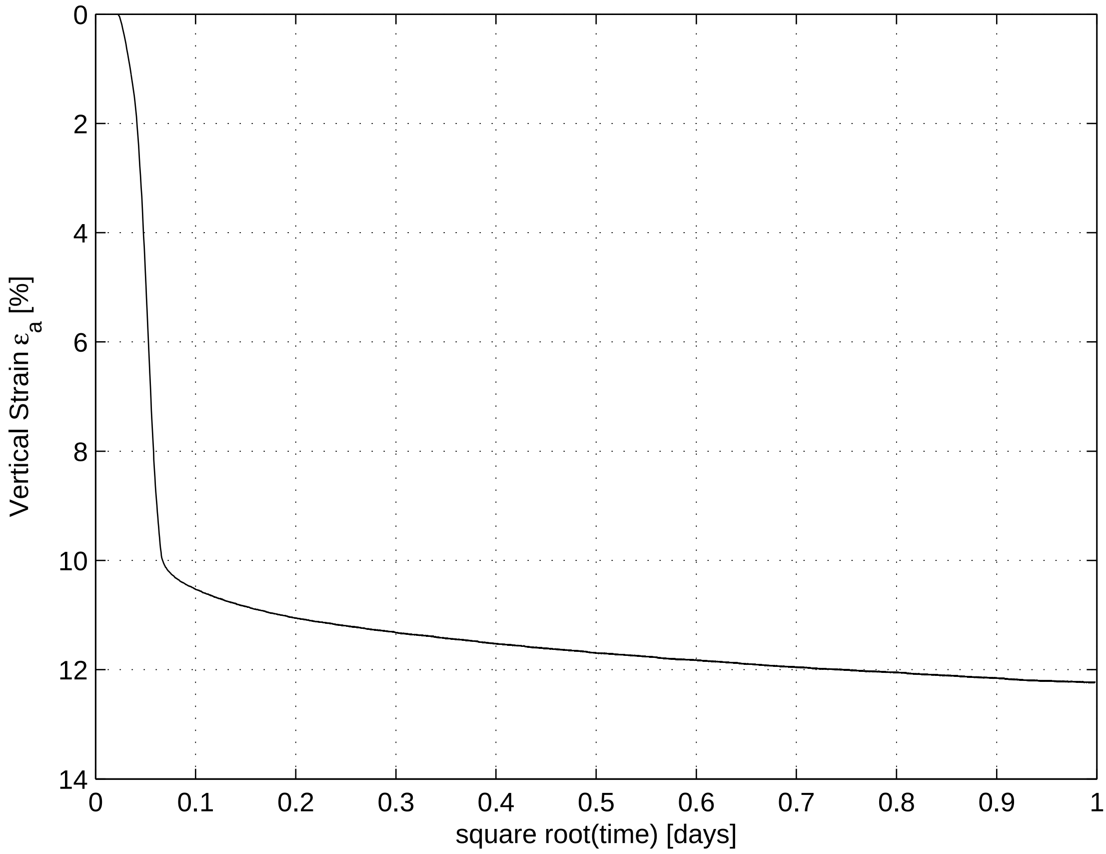
project	version
1209862.11	1.3
appendix	page
NW1A2−A5−1E	3

Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−A5−1E

Direct Simple Shear Test



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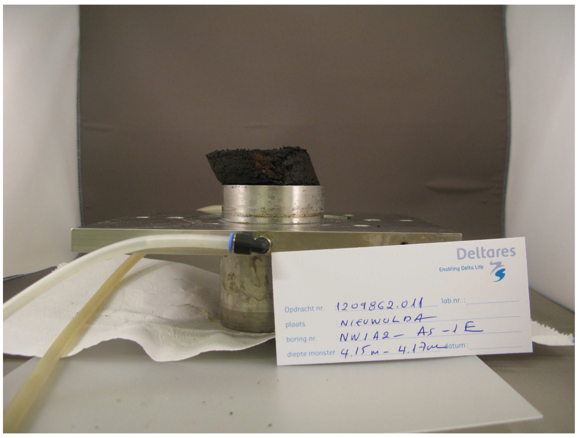
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−A5−1E	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−A5−1E	page 4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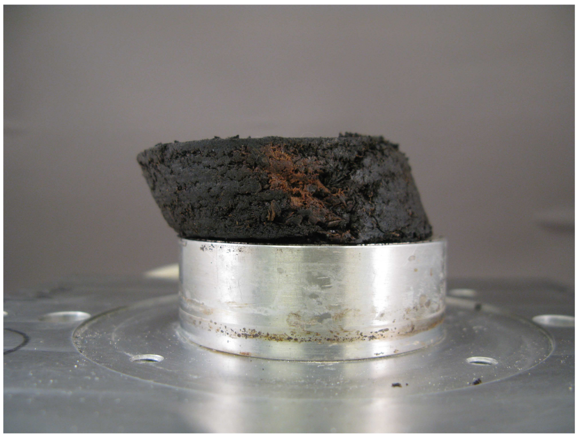
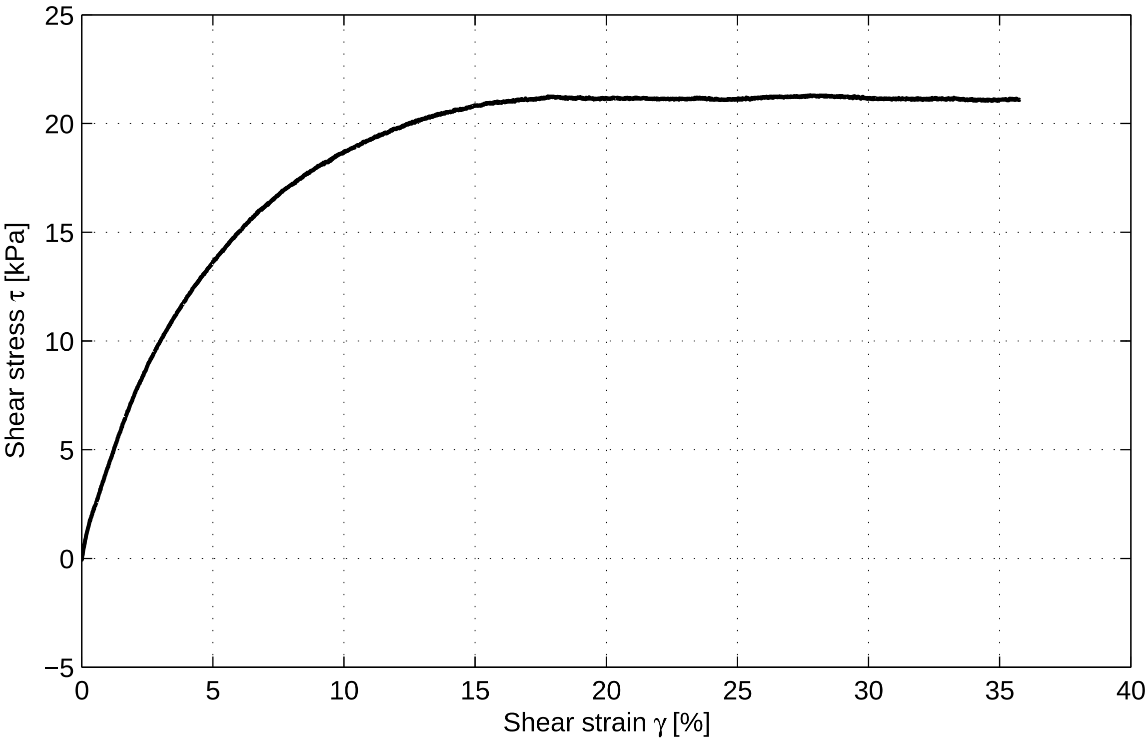
Opdracht nr. : 1209862.011
lab.nr. :
plaats : NIEUWOLDA
boring nr. : NW1A2- A5-1E
diepte monster : 4.15m - 4.17m
datum :





Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.7
Test type	Constant height
Apparatus code	DSS−D
Sample name	NW1A2−a6−1C
Bore code	NW1A2−A
Depth top [m]	−6.03
Depth bottom [m]	−6.05
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	1.0
S_0 [%]	−
Void ratio start shear [−]	0.98
w_0 [%]	569.2
w_{final} [%]	467.0
Consolidation stress [kPa]	27.8
Consolidation strain [%]	8.15
Strain rate [%/h]	8.0
Max shear stress [kPa]	21.3
Vert. stress at max shear stress [kPa]	26.7
Horz. strain at max shear stress [kPa]	27.8
σ_v at γ = 40% [kPa]	26.7
τ at γ = 40% [kPa]	21.2
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample’s photos).

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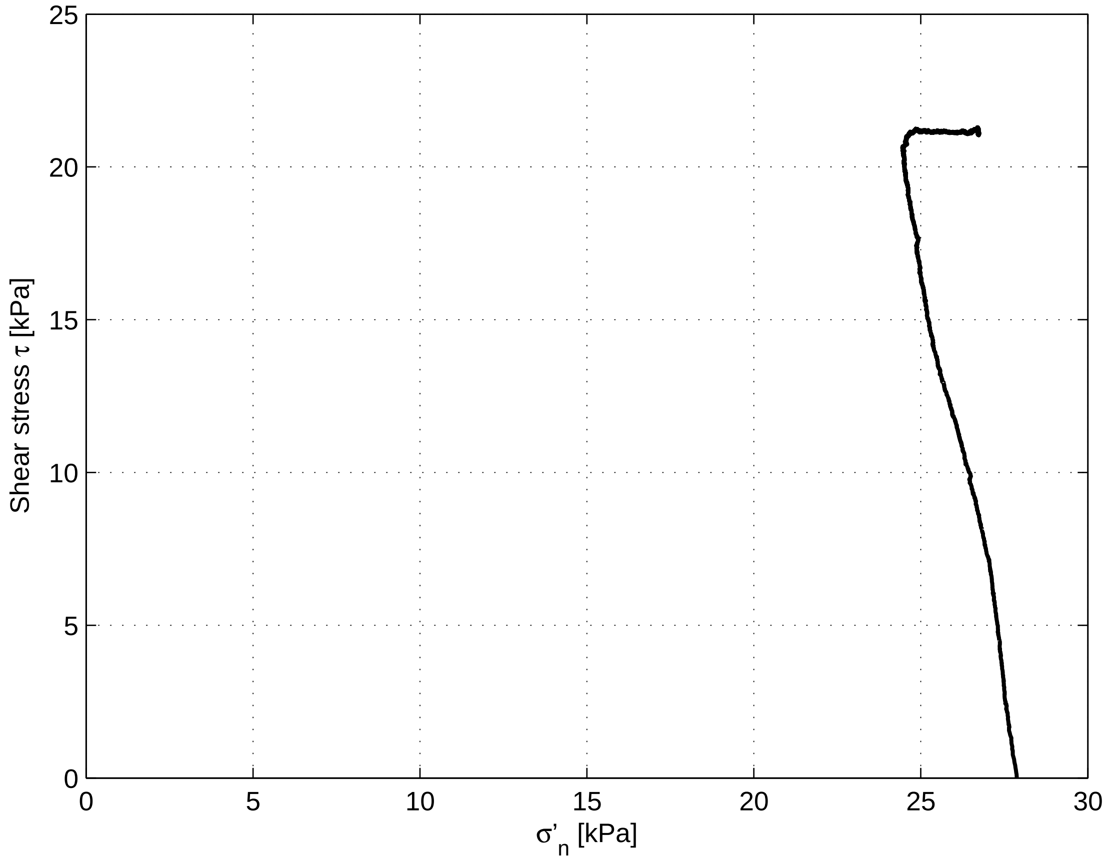
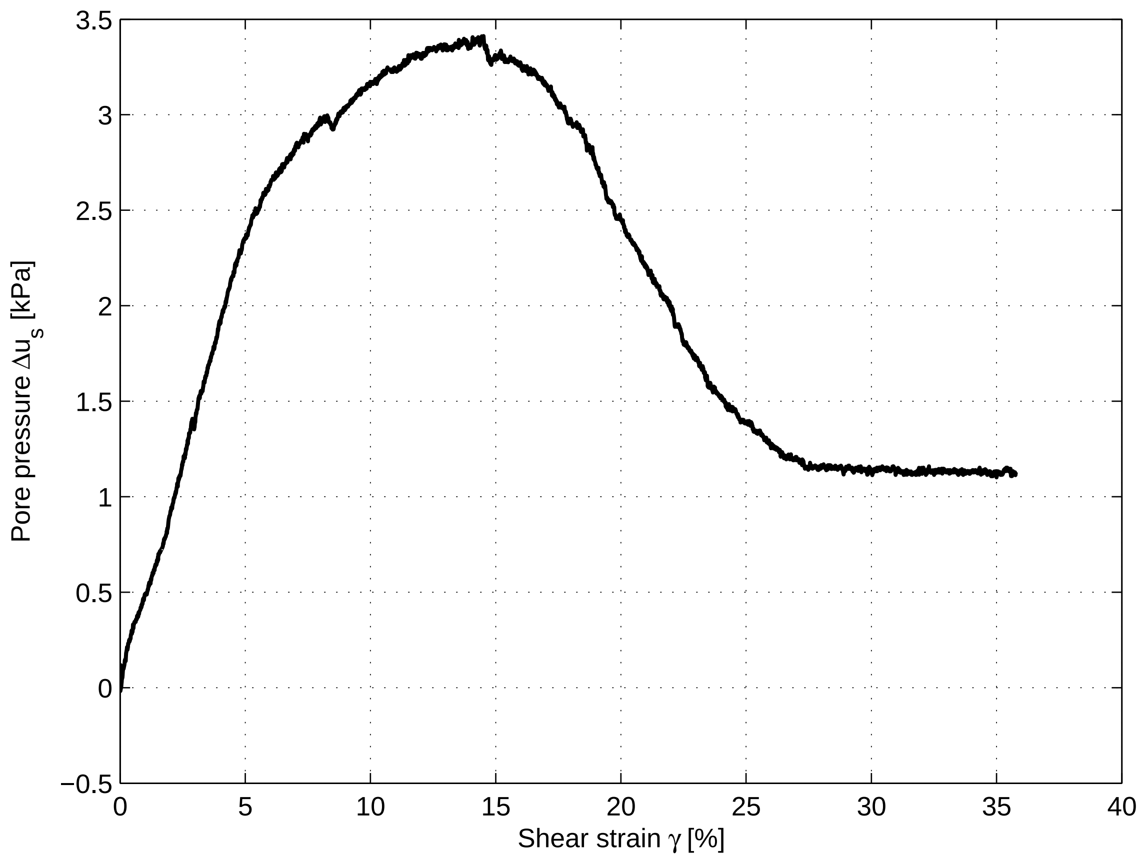
Shear degradation and damping curves for peat	date 2016−04−14	signed konstad
Direct Simple Shear test on sample NW1A2−a6−1C	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−a6−1C	page 1





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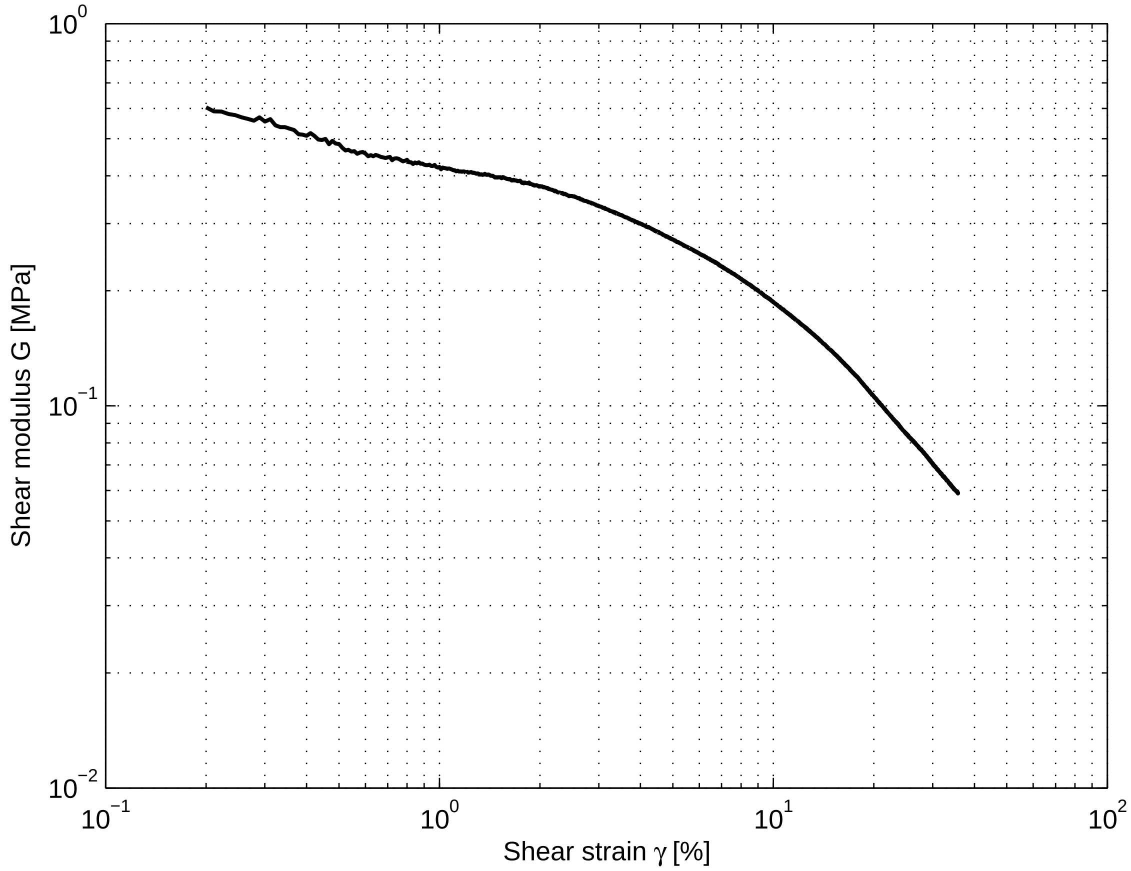
Direct Simple Shear test on sample NW1A2−a6−1C	project: 1209862.11	version: 1.3
Direct Simple Shear Test	appendix: NW1A2−a6−1C	page: 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	13.6	N.A	25.5	2.4	0.3
15% deformation	20.8	N.A	24.5	3.3	0.1
30% deformation	21.2	N.A	26.7	1.1	0.1
Maximum strain	21.1	N.A	26.7	1.1	0.1
Maximum τ	21.3	0.02	26.7	1.2	0.1

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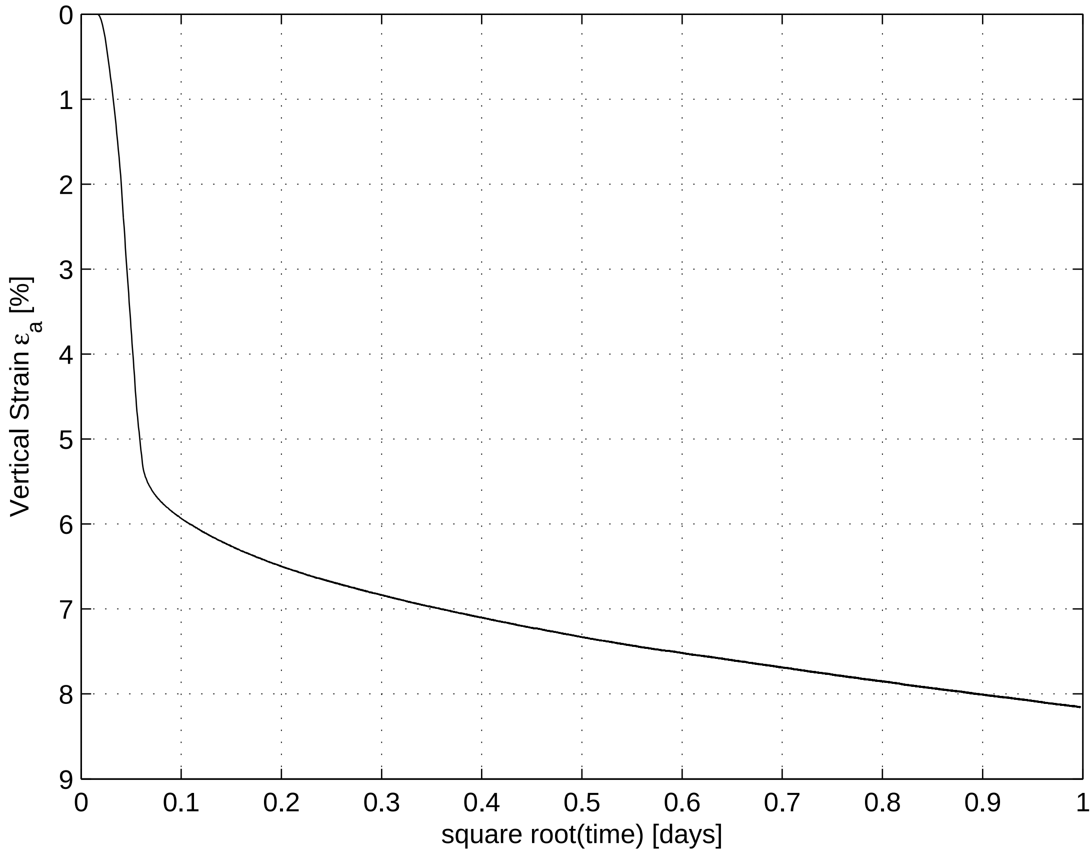
Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−a6−1C

Direct Simple Shear Test

date	signed
2016−04−14	konstad
project	**version**
1209862.11	1.3
appendix	**page**
NW1A2−a6−1C	3



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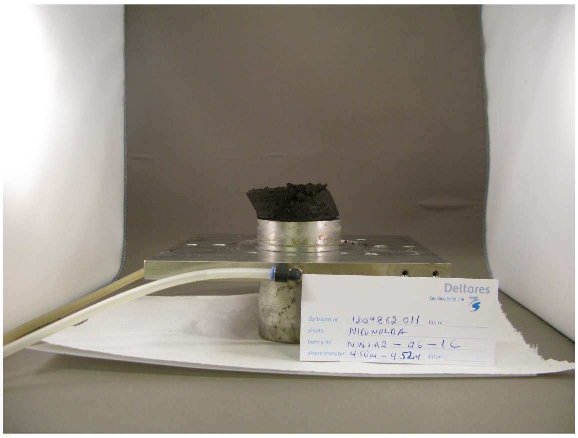
	date	signed
	2016−04−14	konstad
Shear degradation and damping curves for peat	project	version
Direct Simple Shear test on sample NW1A2−a6−1C	1209862.11	1.3
	appendix	page
Direct Simple Shear Test	NW1A2−a6−1C	4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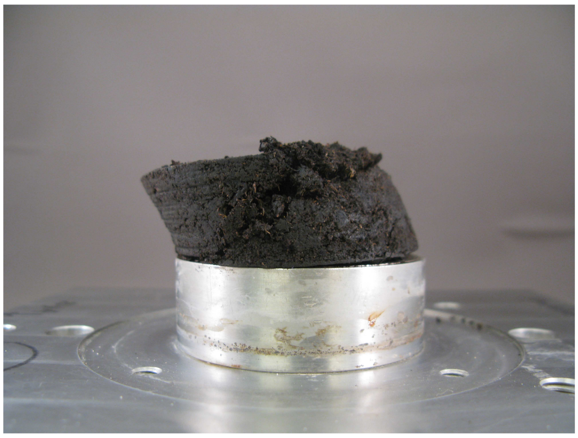
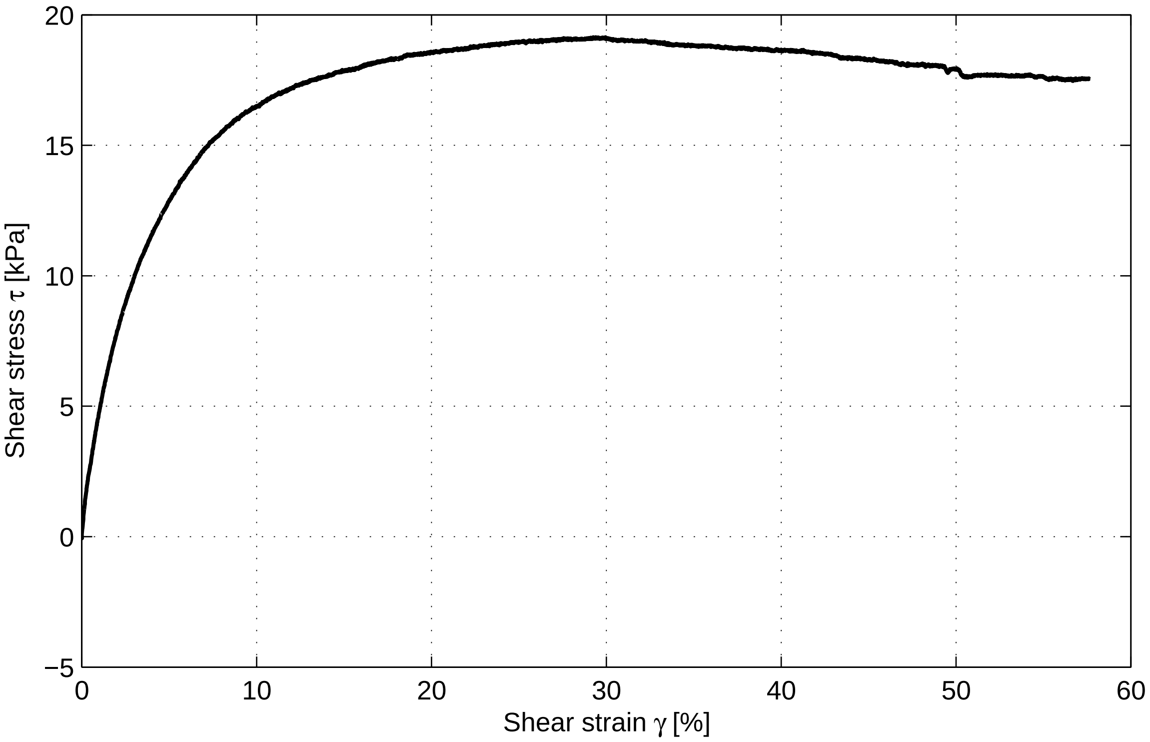
diepte monster : 4.50m – 4.52m
datum :





Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−D
Sample name	NW1A2−A7−1C
Bore code	NW1A2−A
Depth top [m]	−6.98
Depth bottom [m]	−7.00
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.91
w_0 [%]	653.9
w_{final} [%]	614.5
Consolidation stress [kPa]	28.8
Consolidation strain [%]	14.06
Strain rate [%/h]	8.0
Max shear stress [kPa]	19.1
Vert. stress at max shear stress [kPa]	18.4
Horz. strain at max shear stress [kPa]	29.3
σ_v at γ = 40% [kPa]	17.5
τ at γ = 40% [kPa]	18.7
Sample Disturbance Index [%]	−
SDI qualification	−

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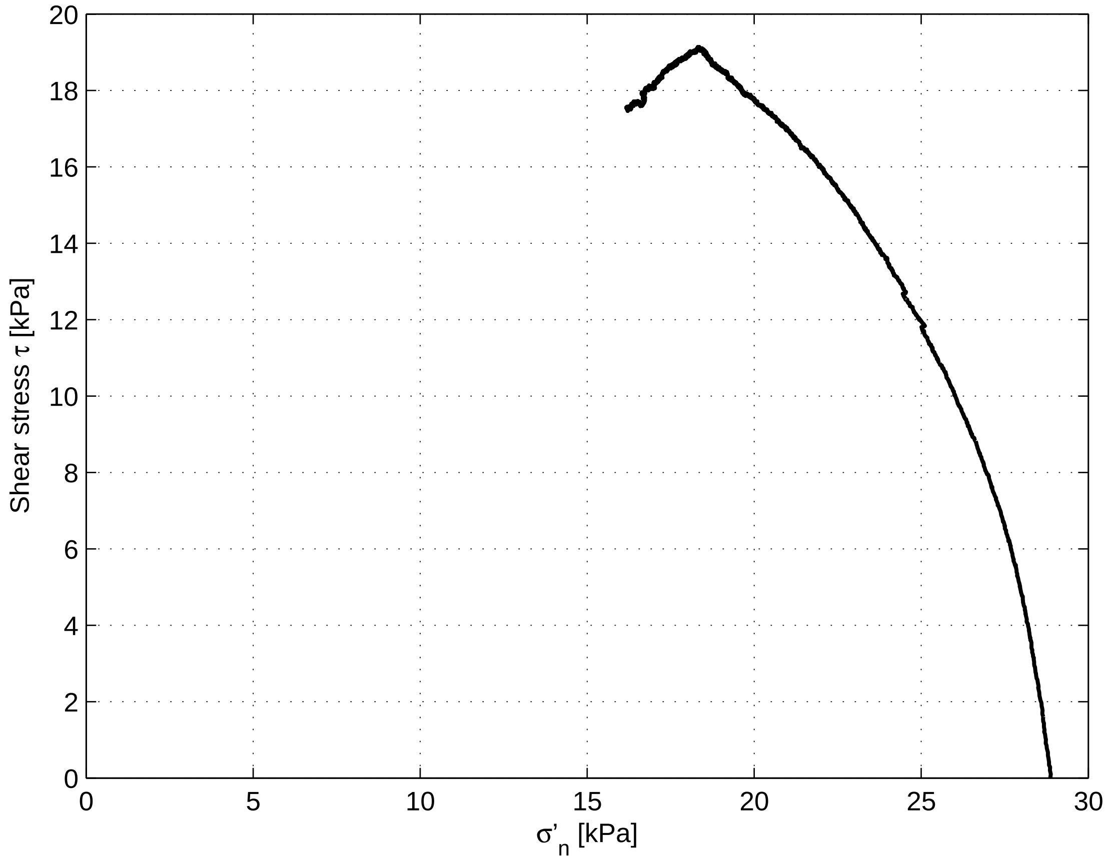
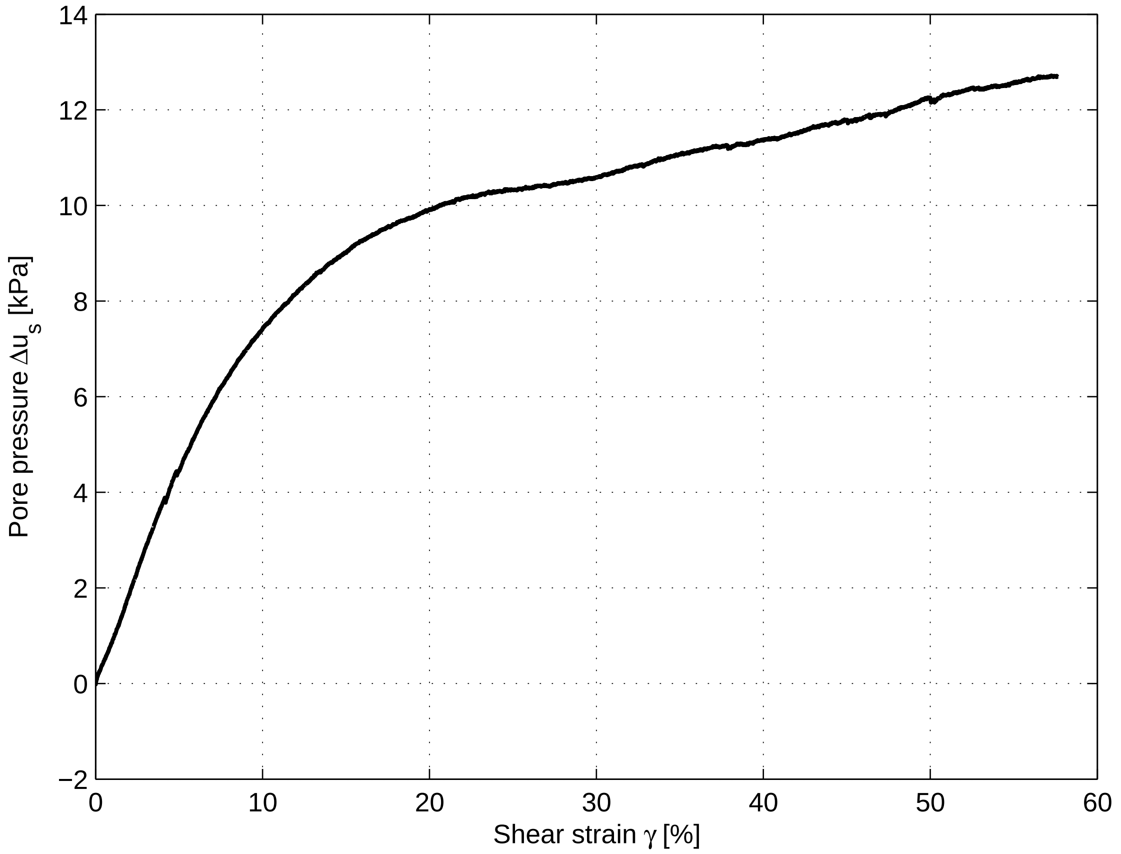
Shear degradation and damping curves for peat	date: 2016−04−18	signed: konstad
Direct Simple Shear test on sample NW1A2−A7−1C	project: 1209862.11	version: 1.3
Direct Simple Shear Test	appendix: NW1A2−A7−1C	page: 1





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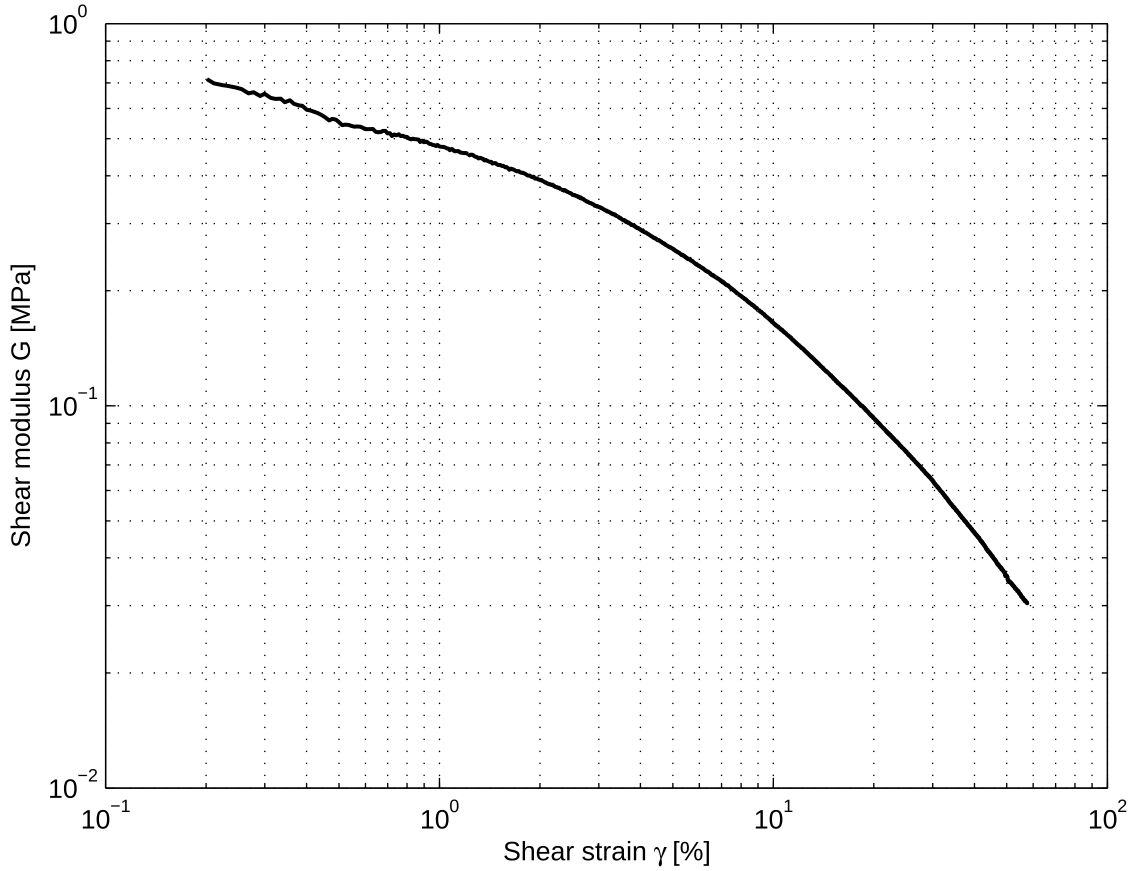
	date	signed
Shear degradation and damping curves for peat	2016−04−18	konstad
Direct Simple Shear test on sample NW1A2−A7−1C	project: 1209862.11	version: 1.3
Direct Simple Shear Test	appendix: NW1A2−A7−1C	page: 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	12.9	N.A	24.4	4.5	0.3
15% deformation	17.9	N.A	19.9	9.0	0.1
30% deformation	19.1	N.A	18.3	10.6	0.1
Maximum strain	17.5	N.A	16.2	12.7	0.0
Maximum τ	19.1	−0.00	18.3	10.5	0.1

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project	version
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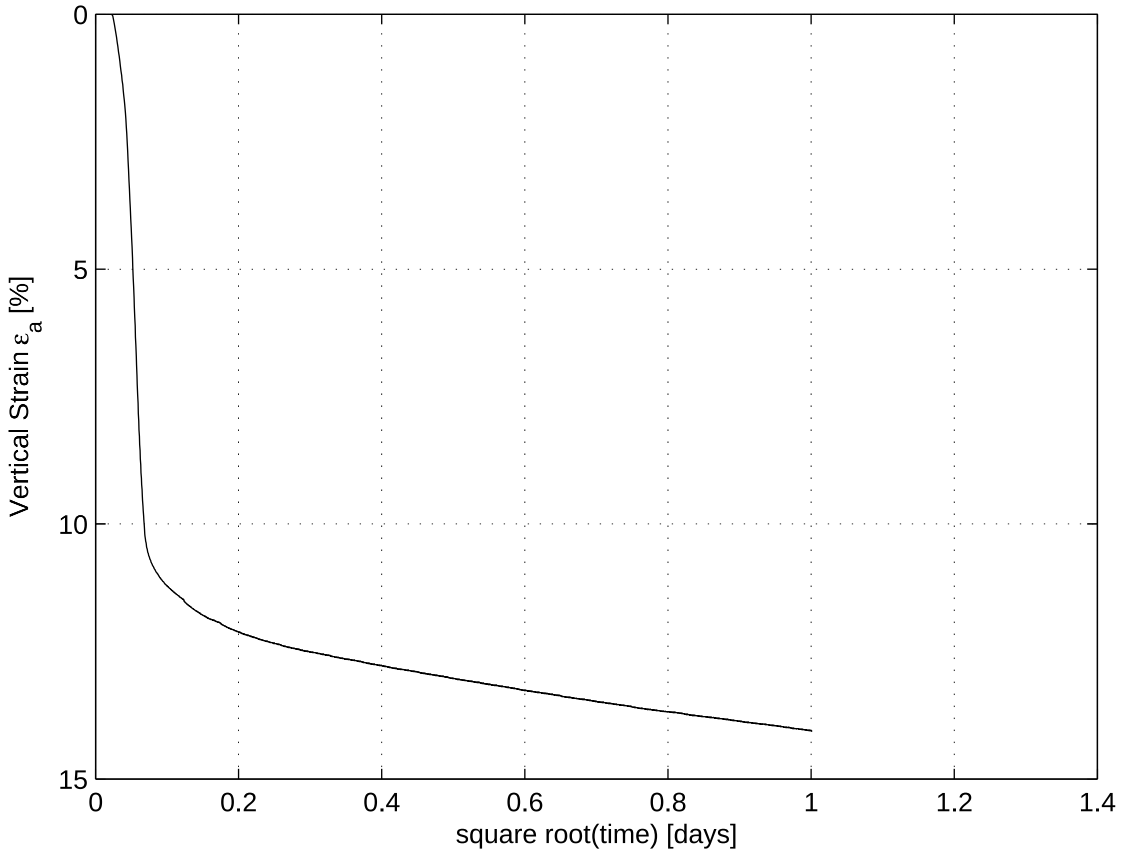
appendix	page
NW1A2−A7−1C	3

Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−A7−1C

Direct Simple Shear Test



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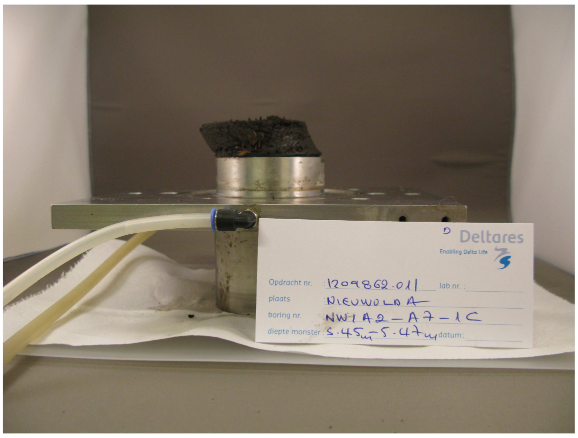
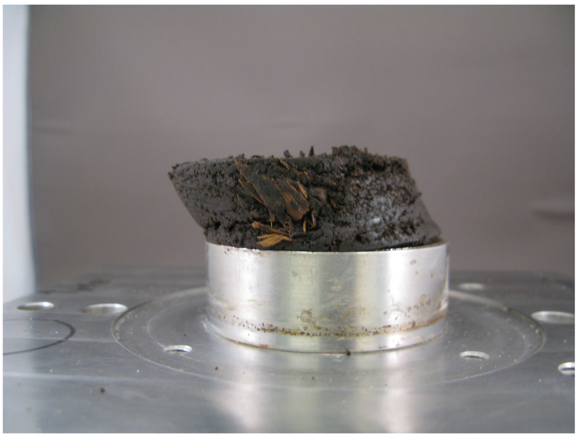
	date	signed
Shear degradation and damping curves for peat	2016−04−18	konstad
Direct Simple Shear test on sample NW1A2−A7−1C	project: 1209862.11	version: 1.3
Direct Simple Shear Test	appendix: NW1A2−A7−1C	page: 4





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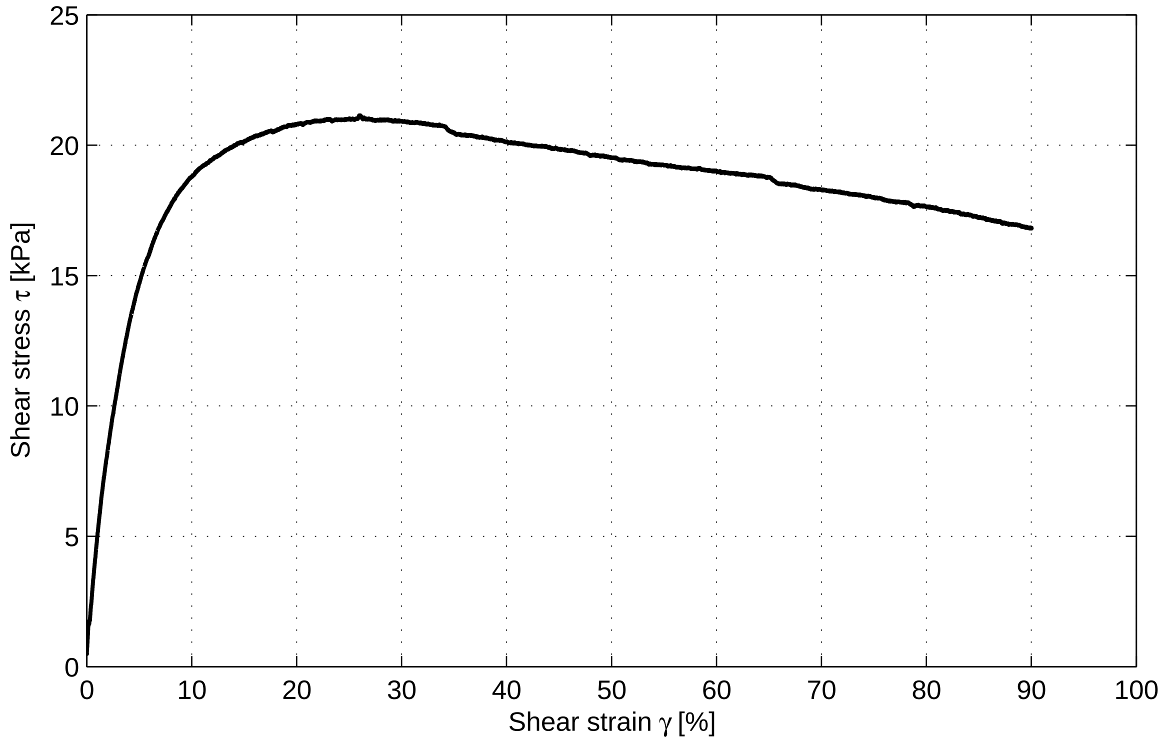
2016−04−18	konstadi
project	**version**
1209862.11	1.3
appendix	**page**
NW1A2−A7−1C	5

Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−A7−1C

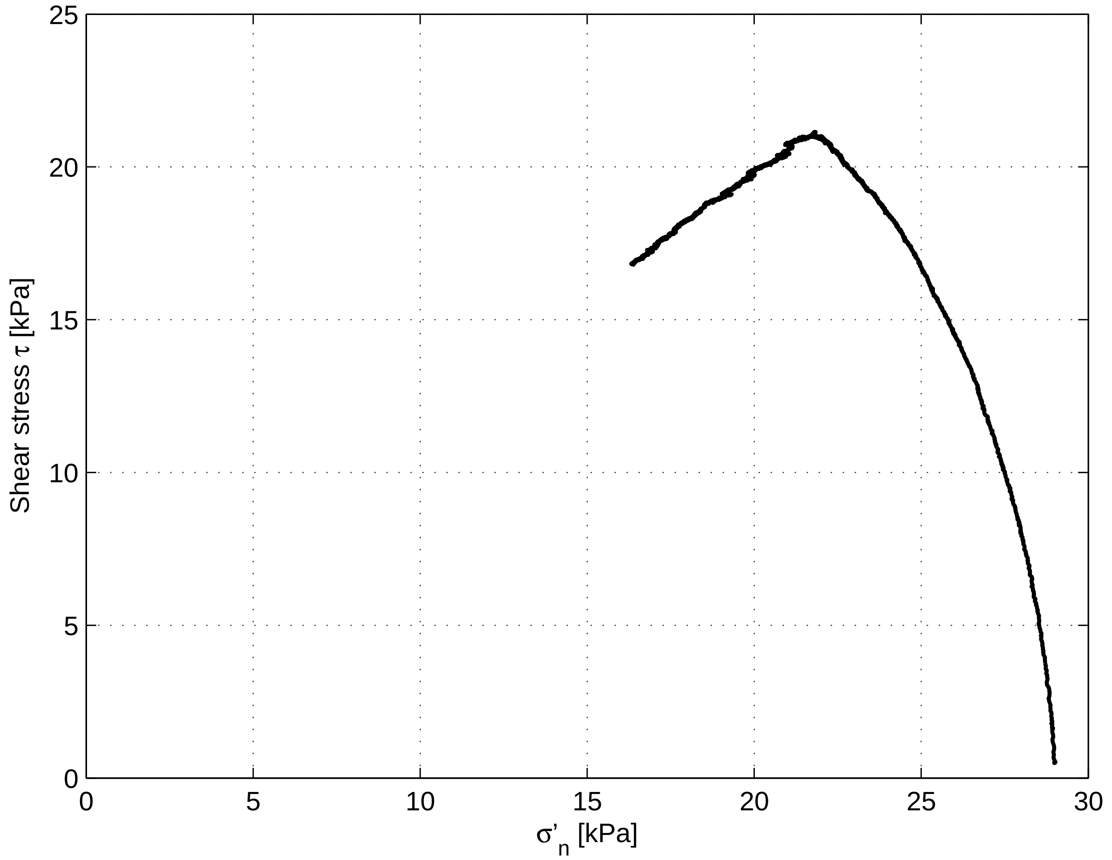
Direct Simple Shear Test

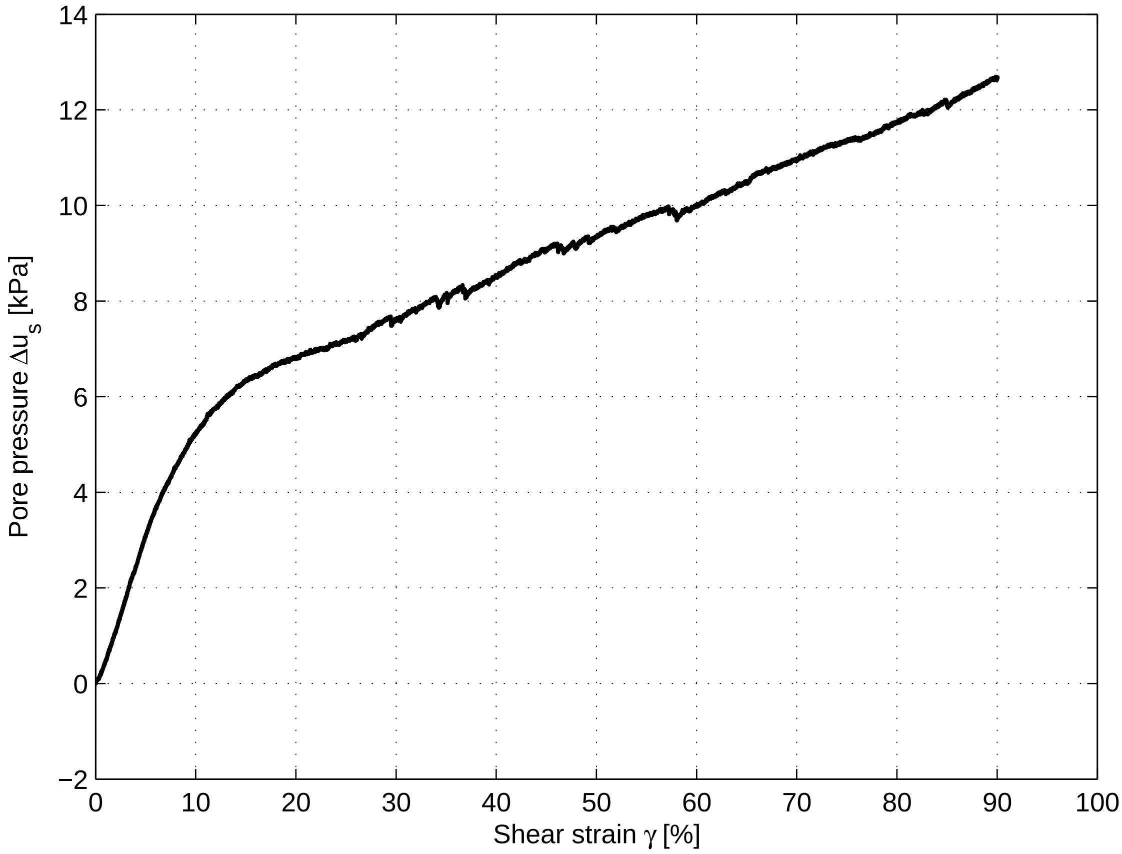


Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−C
Sample name	NW1A2−A7−2A
Bore code	NW1A2−A
Depth top [m]	−7.08
Depth bottom [m]	−7.10
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	1.0
S_0 [%]	−
Void ratio start shear [−]	0.96
w_0 [%]	524.5
w_{final} [%]	504.0
Consolidation stress [kPa]	29.0
Consolidation strain [%]	12.43
Strain rate [%/h]	8.0
Max shear stress [kPa]	21.1
Vert. stress at max shear stress [kPa]	21.8
Horz. strain at max shear stress [kPa]	26.1
σ_v at γ = 40% [kPa]	20.5
τ at γ = 40% [kPa]	20.1
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample's photos).





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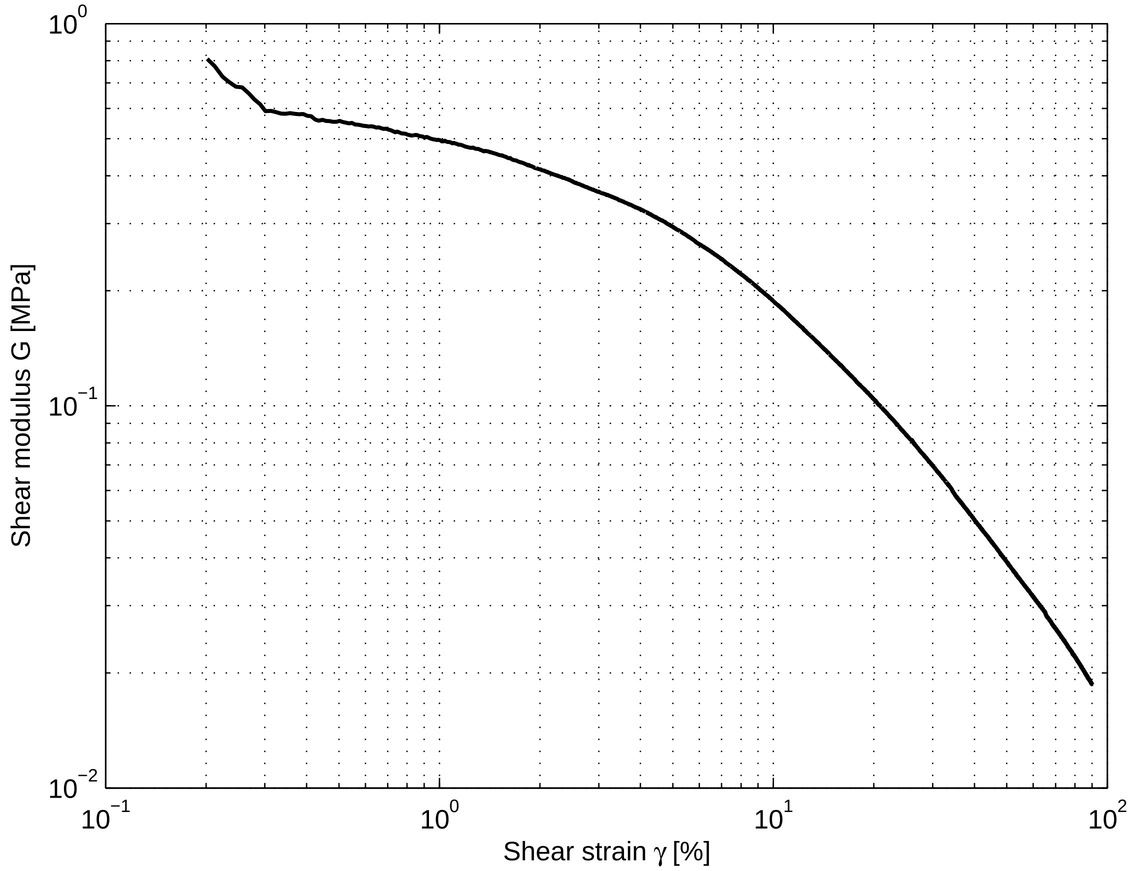
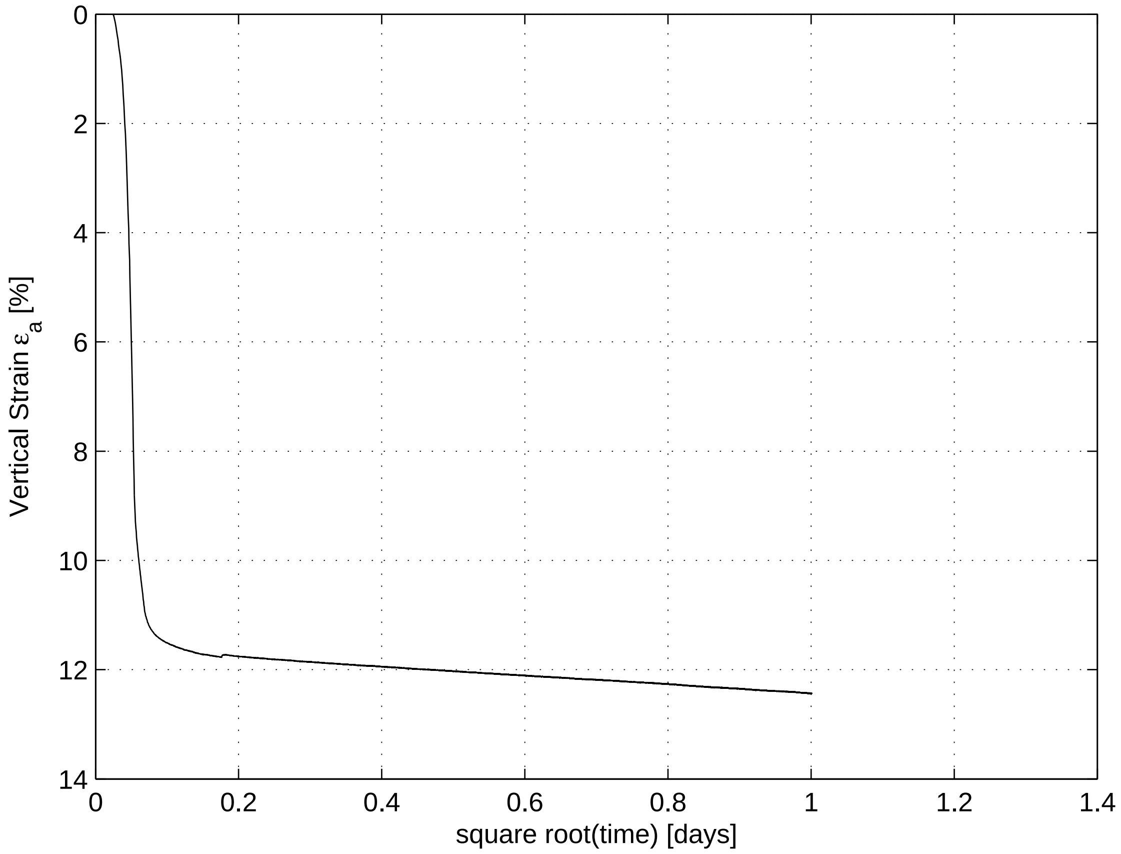
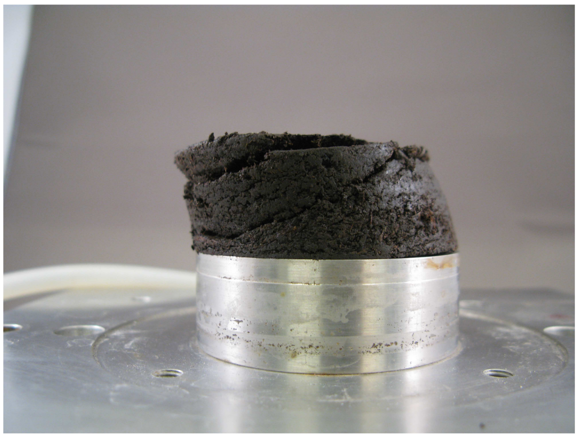
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−A7−2A	date 2016−04−15	signed konstad
	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−A7−2A	page 2



γ [%]	**τ [kPa]**	**ε_a [%]**	**σ'$_n$ [kPa]**	**Δu_s [kPa]**	**G [MPa]**
5% deformation	14.7	N.A	25.9	3.1	0.3
15% deformation	20.1	N.A	22.7	6.3	0.1
30% deformation	20.9	N.A	21.4	7.6	0.1
Maximum strain	16.8	N.A	16.4	12.6	0.0
Maximum τ	21.1	−0.00	21.8	7.2	0.1



Vertical Strain ε_a [%]
0
2
4
6
8
10
12
14
0
0.2
0.4
0.6
0.8
1
1.2
1.4
square root(time) [days]



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2016−04−15	konstad

Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−A7−2A

Direct Simple Shear Test

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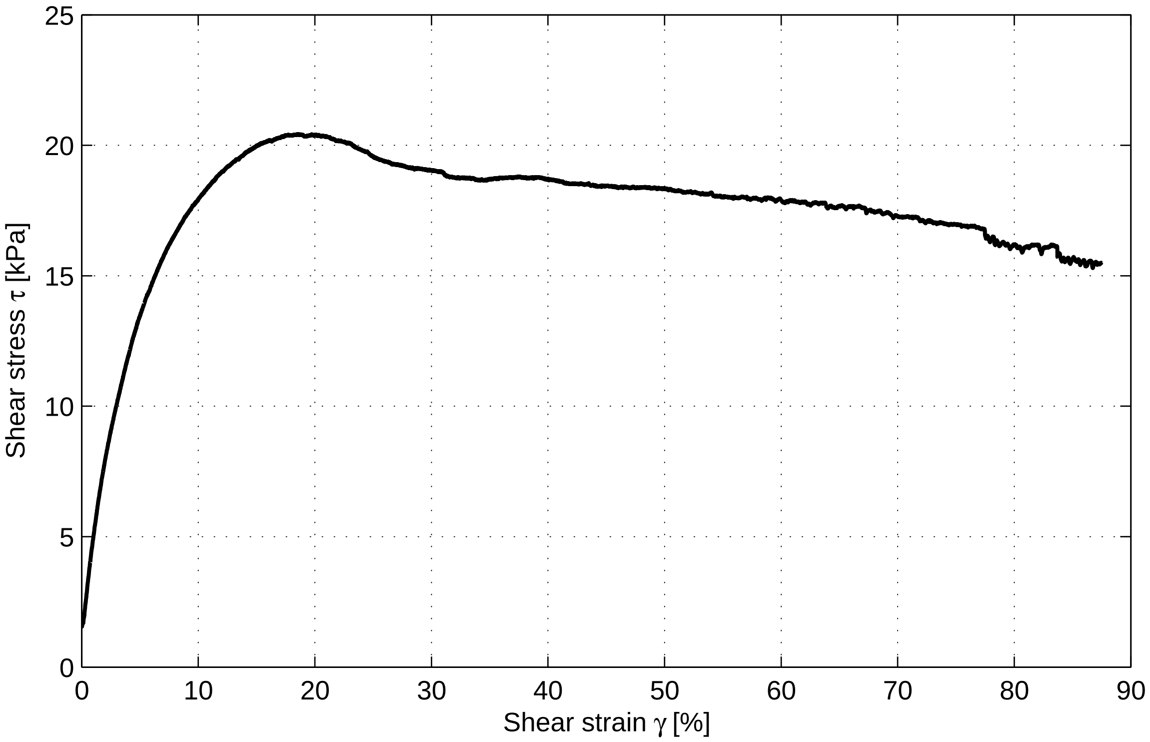
appendix	page
NW1A2−A7−2A	5



Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.7
Test type	Constant height
Apparatus code	DSS−C
Sample name	NW1A2−B1−2C
Bore code	NW1A2−B
Depth top [m]	−5.57
Depth bottom [m]	−5.59
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	1.0
S_0 [%]	−
Void ratio start shear [−]	0.99
w_0 [%]	469.9
w_{final} [%]	449.5
Consolidation stress [kPa]	27.2
Consolidation strain [%]	7.96
Strain rate [%/h]	7.9
Max shear stress [kPa]	20.4
Vert. stress at max shear stress [kPa]	25.4
Horz. strain at max shear stress [kPa]	18.5
σ_v at γ = 40% [kPa]	22.9
τ at γ = 40% [kPa]	18.7
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample's photos).

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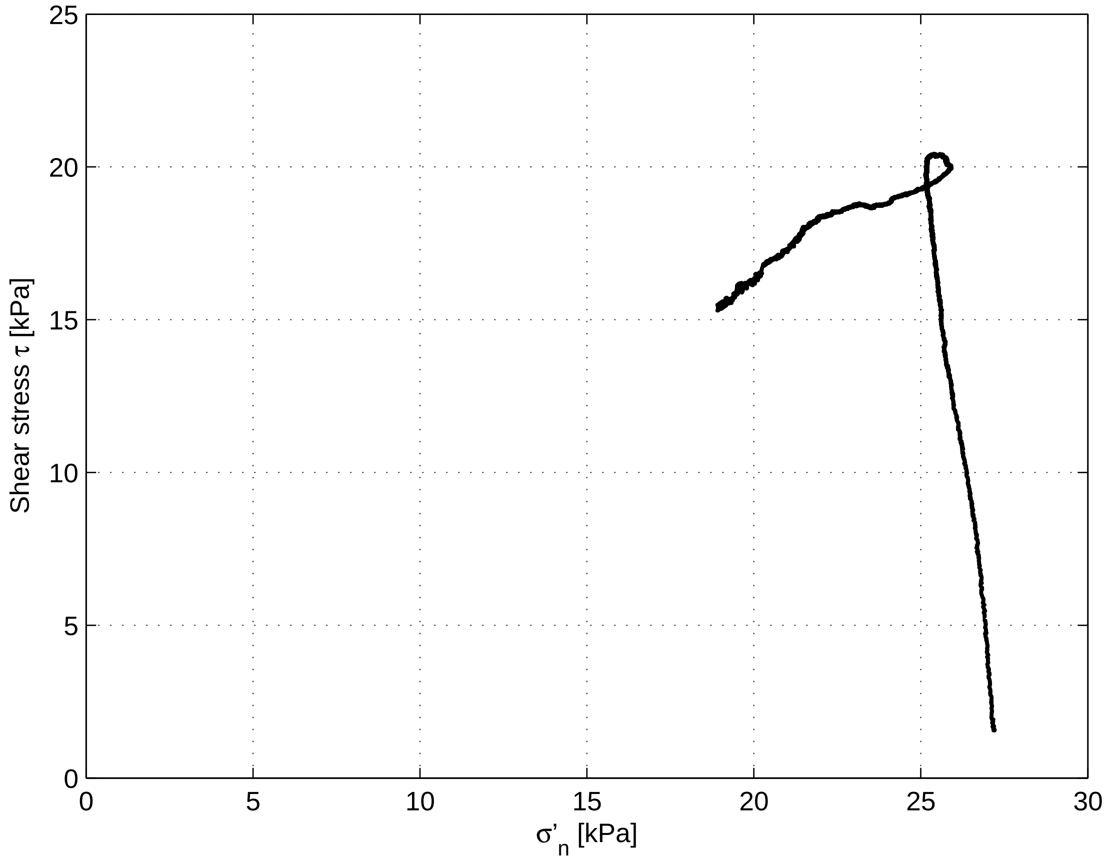
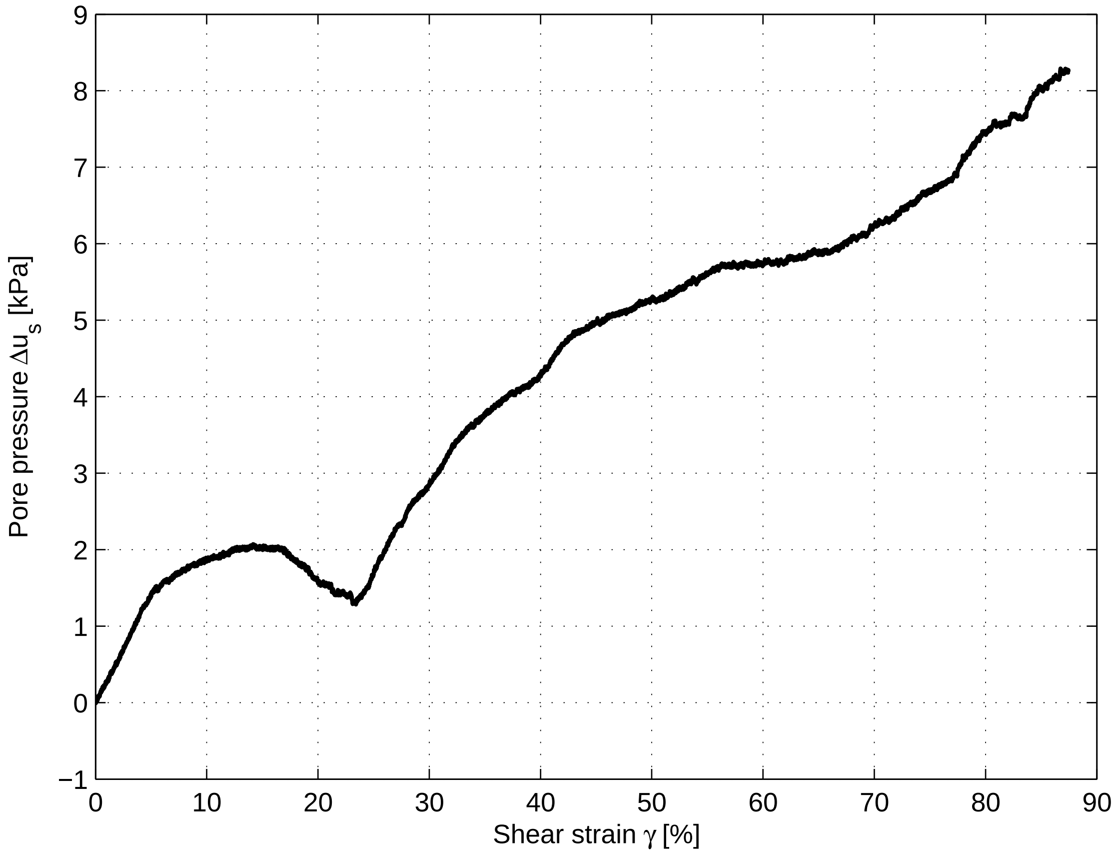
Shear degradation and damping curves for peat	date 2016−04−15	signed konstadi
Direct Simple Shear test on sample NW1A2−B1−2C	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−B1−2C	page 1





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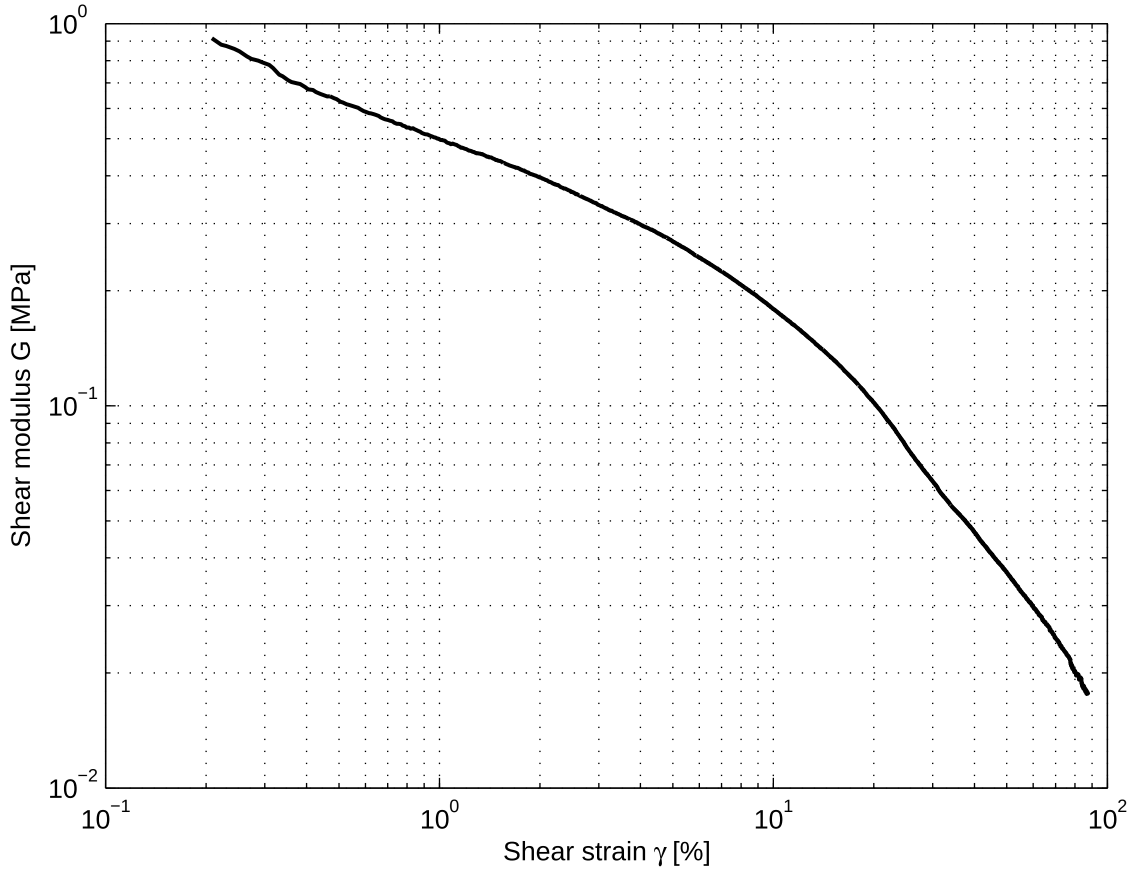
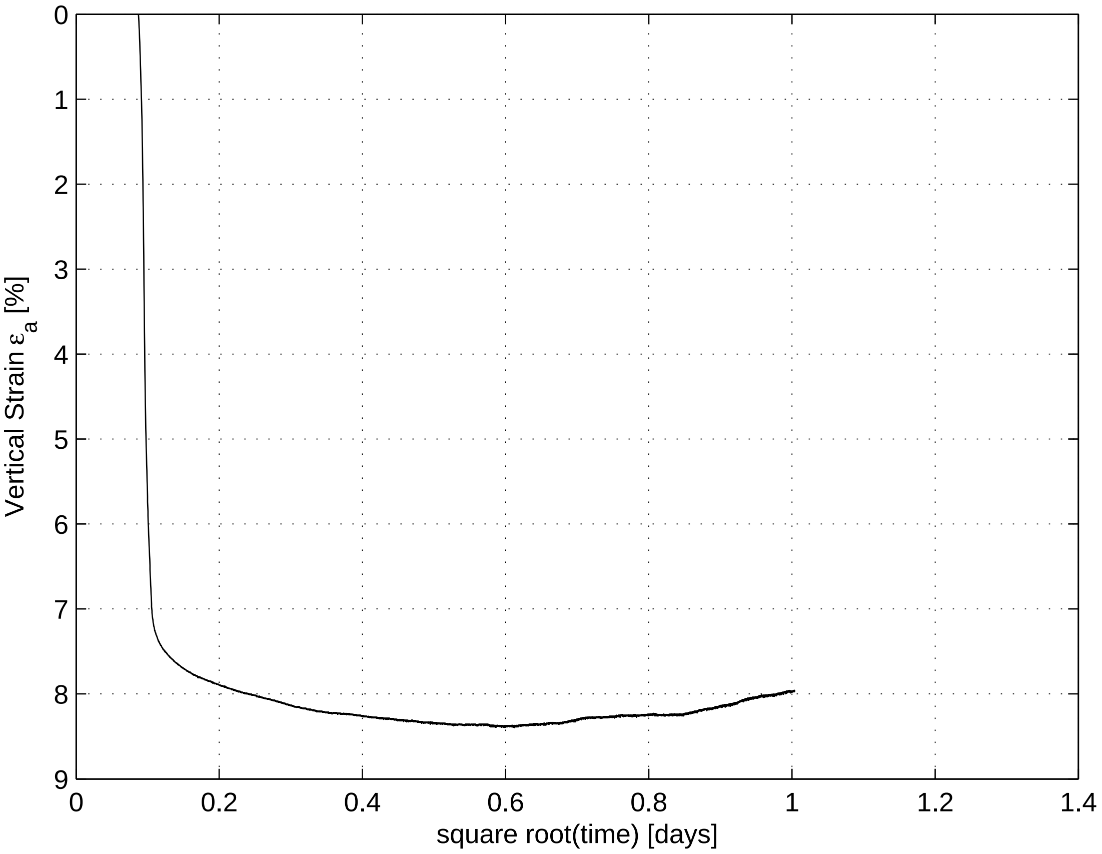
	date	signed
Shear degradation and damping curves for peat	2016−04−15	konstad
Direct Simple Shear test on sample NW1A2−B1−2C	project: 1209862.11	version: 1.3
Direct Simple Shear Test	appendix: NW1A2−B1−2C	page: 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	13.5	N.A	25.8	1.4	0.3
15% deformation	20.0	N.A	25.2	2.0	0.1
30% deformation	19.0	N.A	24.3	2.9	0.1
Maximum strain	15.5	N.A	18.9	8.3	0.0
Maximum τ	20.4	0.00	25.4	1.8	0.1



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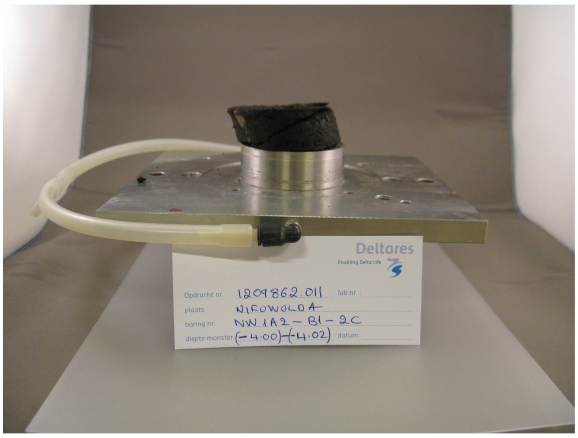
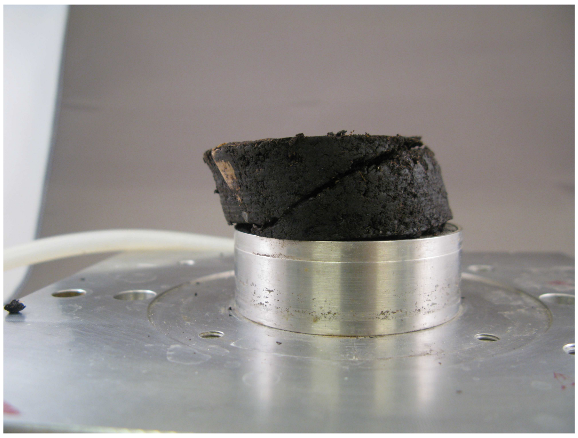
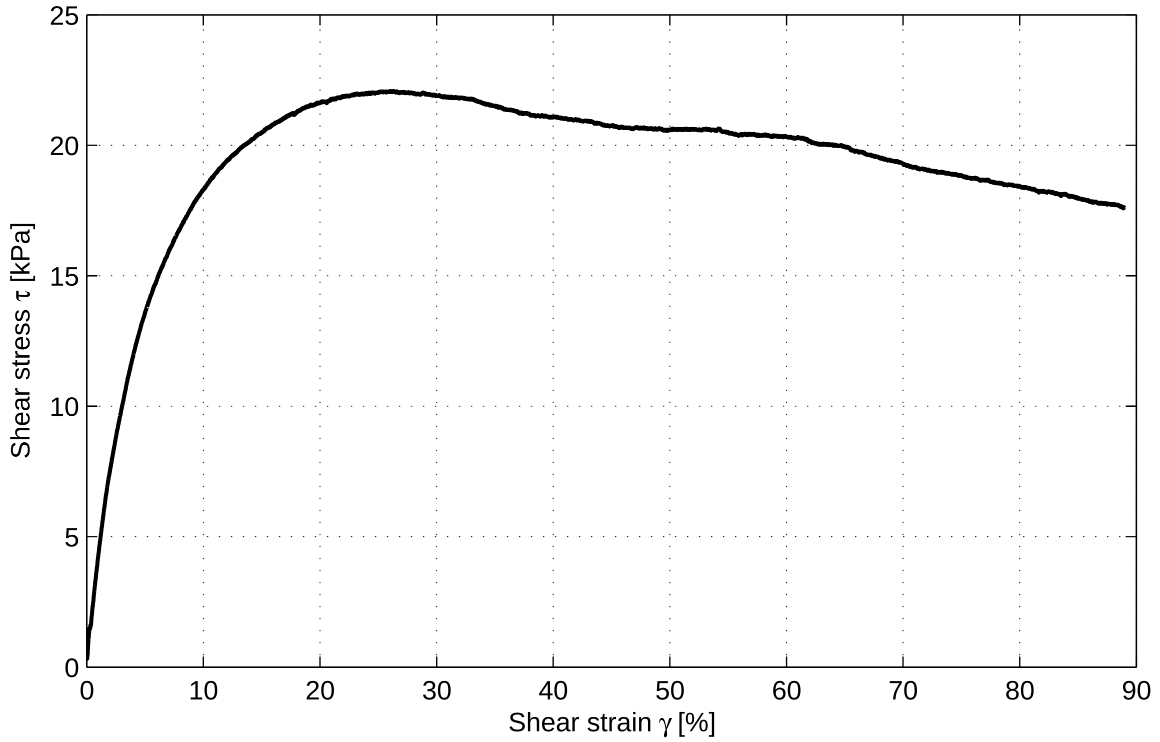
Shear degradation and damping curves for peat	date 2016−04−15	signed konstadi
Direct Simple Shear test on sample NW1A2−B1−2C	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−B1−2C	page 4


Deltares
Enabling Delta Life
Opdracht nr. : 1209862.011
lab.nr. :
plaats : NIEUWOLDA
boring nr. NW 1A2 – B1 – 2C
diepte monster (-4.00)-(-4.02)
datum :





Description of soil sample:

Soil classification	Gravel, silty
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−C
Sample name	NW1A2−B1−3B
Bore code	NW1A2−B
Depth top [m]	−5.82
Depth bottom [m]	−5.84
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.95
w_0 [%]	524.7
w_{final} [%]	493.8
Consolidation stress [kPa]	25.9
Consolidation strain [%]	8.60
Strain rate [%/h]	8.0
Max shear stress [kPa]	22.1
Vert. stress at max shear stress [kPa]	21.9
Horz. strain at max shear stress [kPa]	26.0
σ_v at γ = 40% [kPa]	21.2
τ at γ = 40% [kPa]	21.1
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample's photos).

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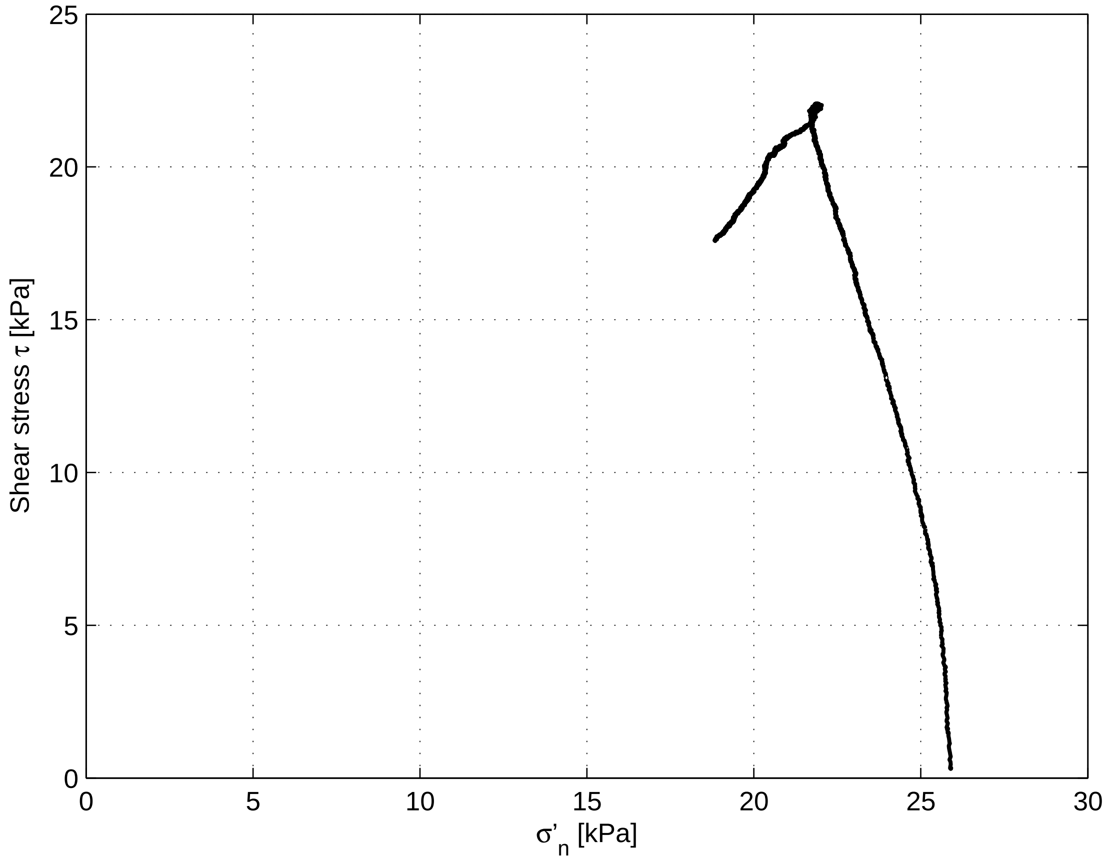
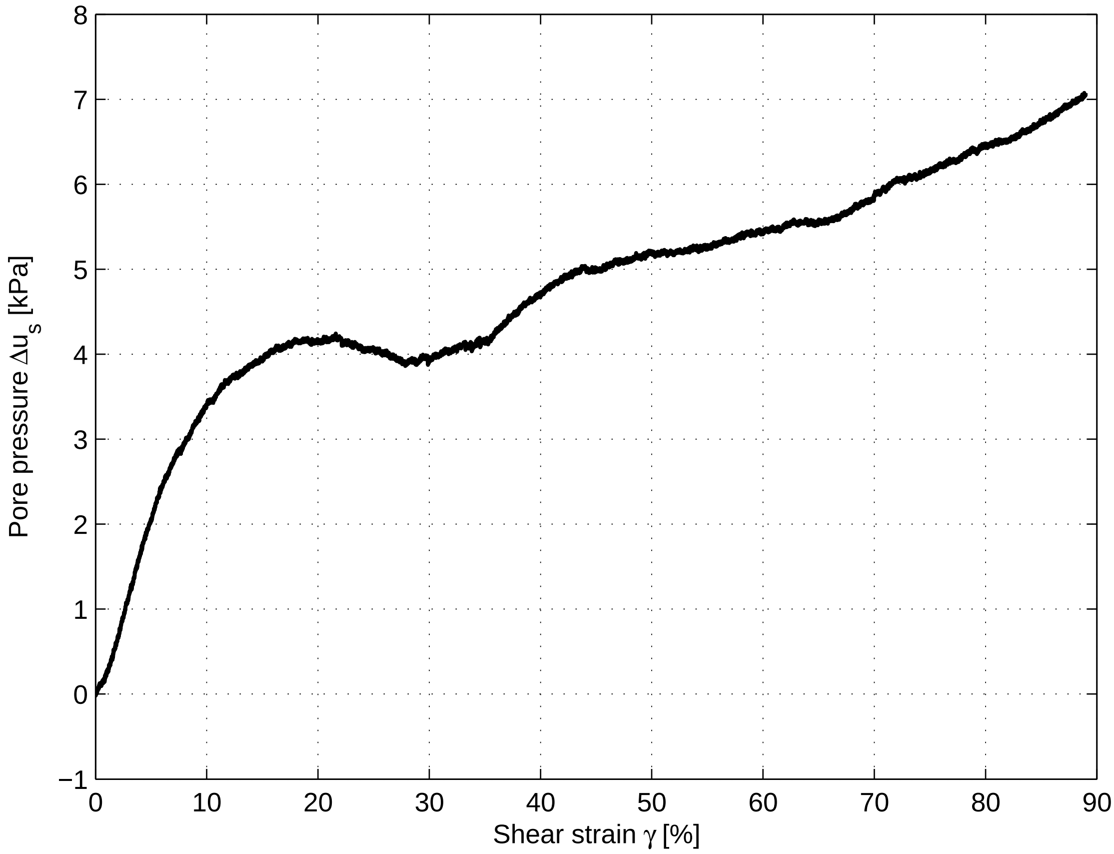
NW1A2−B1−3B	1

Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−B1−3B

Direct Simple Shear Test





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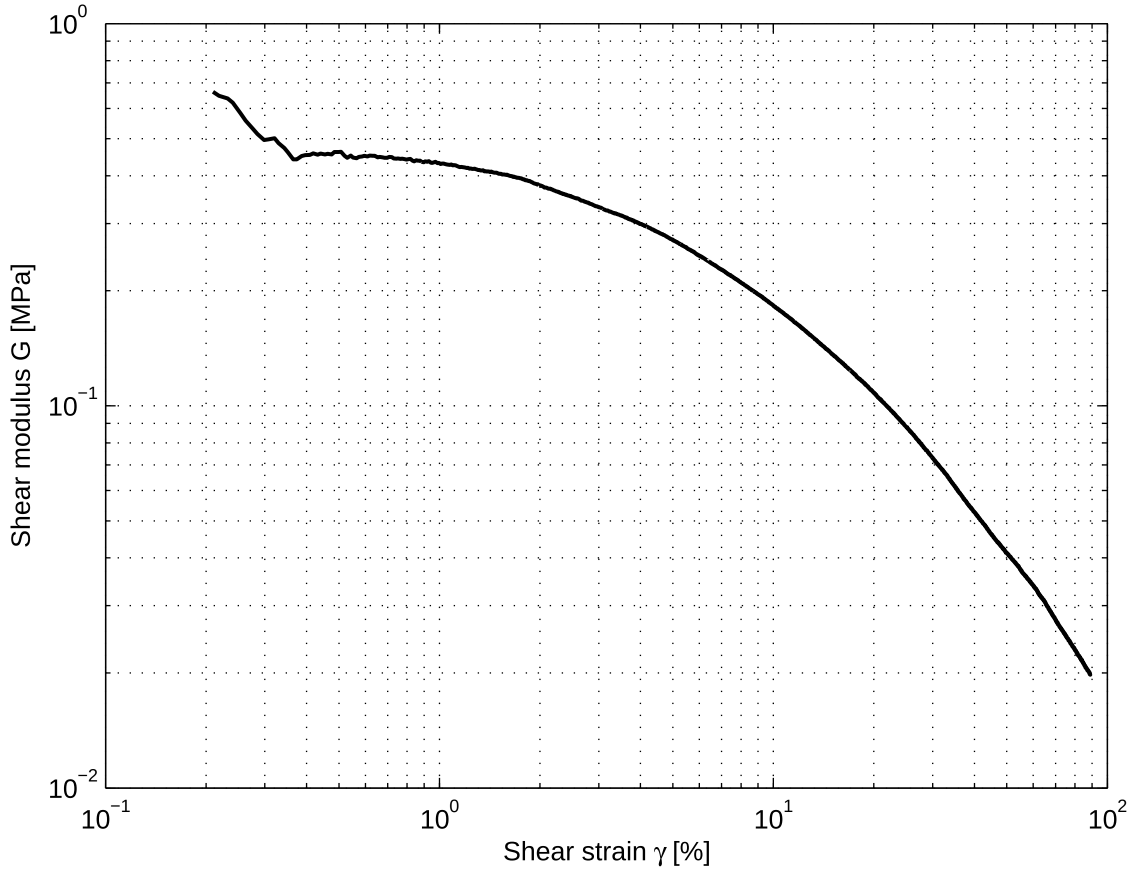
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−B1−3B	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−B1−3B	page 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	13.6	N.A	23.9	2.0	0.3
15% deformation	20.5	N.A	22.0	3.9	0.1
30% deformation	21.9	N.A	22.0	3.9	0.1
Maximum strain	17.6	N.A	18.8	7.1	0.0
Maximum τ	22.1	0.00	21.9	4.0	0.1

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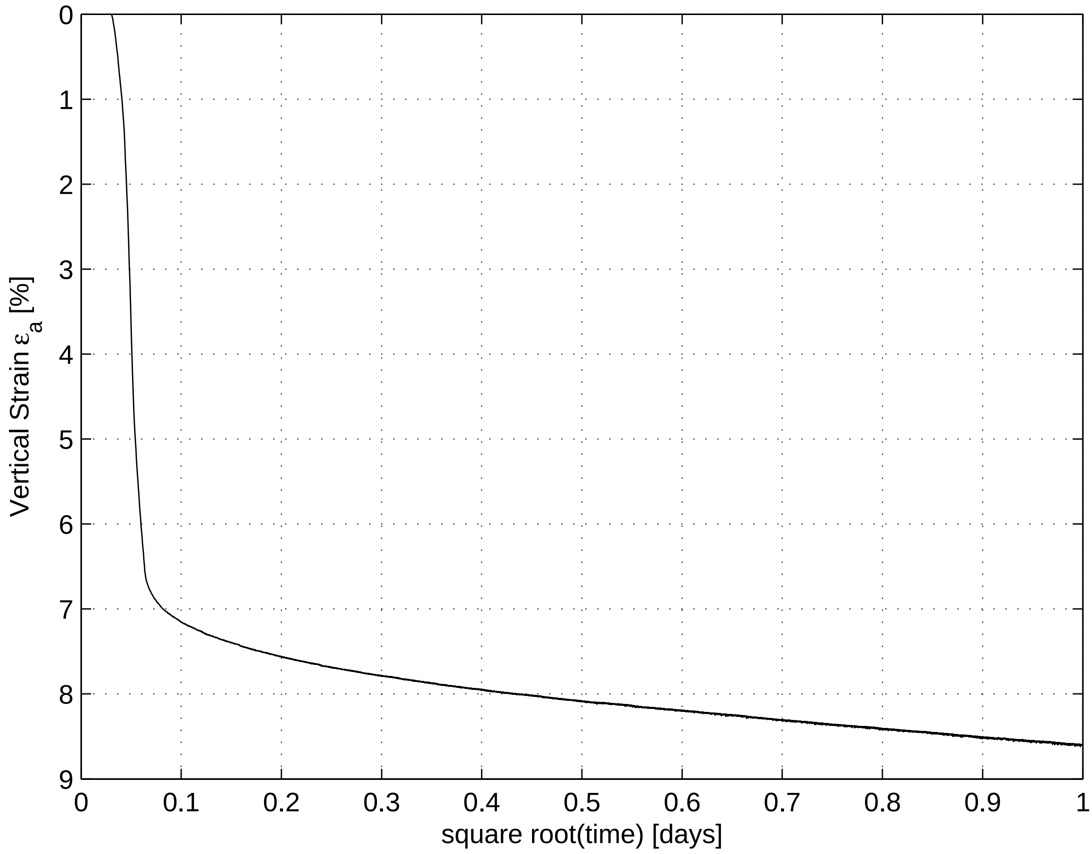
2016−04−19	konstadi
project	**version**
1209862.11	1.3
appendix	**page**
NW1A2−B1−3B	3

Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−B1−3B

Direct Simple Shear Test



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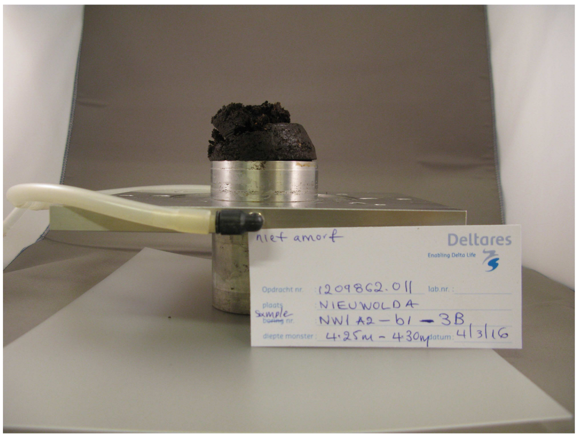
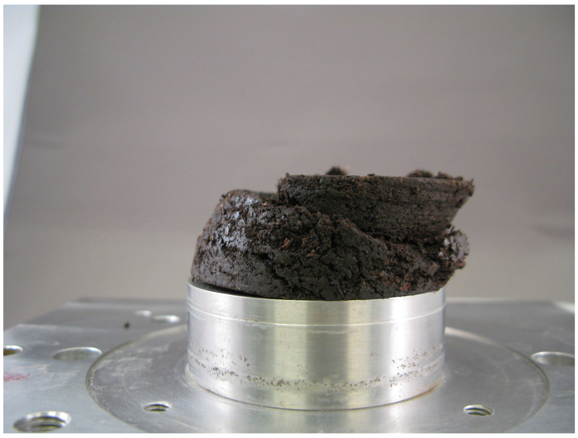
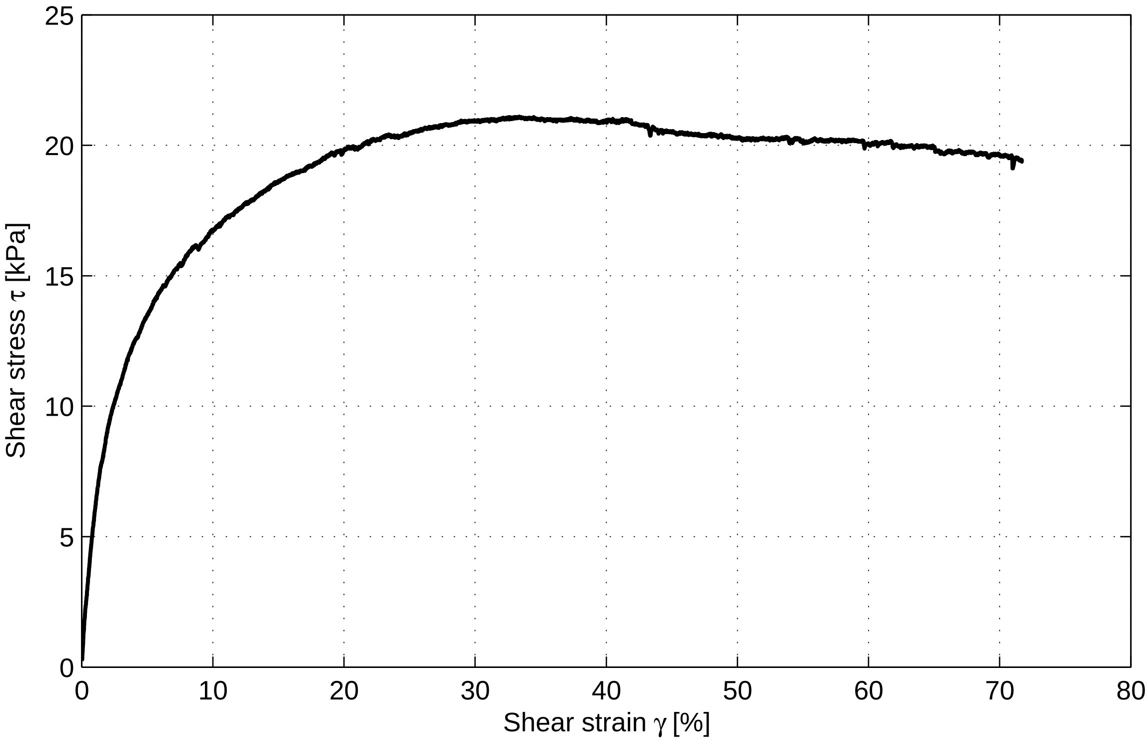
	date 2016−04−19	signed konstadi
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−B1−3B	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−B1−3B	page 4


niet amorf
Deltares
Enabling Delta Life
Opdracht nr. : 1209862.011
lab.nr. :
plaats : NIEUWOLDA
sample
boring nr. : NW1 A2 – b1 – 3B
diepte monster : 4.25m – 4.30m
datum : 4/3/16





Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.5
Test type	Constant height
Apparatus code	DSS−D
Sample name	NW1A2−B2−2B
Bore code	NW1A2−B
Depth top [m]	−6.82
Depth bottom [m]	−6.84
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.87
w_0 [%]	633.4
w_{final} [%]	593.9
Consolidation stress [kPa]	29.8
Consolidation strain [%]	12.11
Strain rate [%/h]	8.0
Max shear stress [kPa]	21.1
Vert. stress at max shear stress [kPa]	23.1
Horz. strain at max shear stress [kPa]	33.4
σ_v at γ = 40% [kPa]	22.2
τ at γ = 40% [kPa]	20.9
Sample Disturbance Index [%]	−
SDI qualification	−

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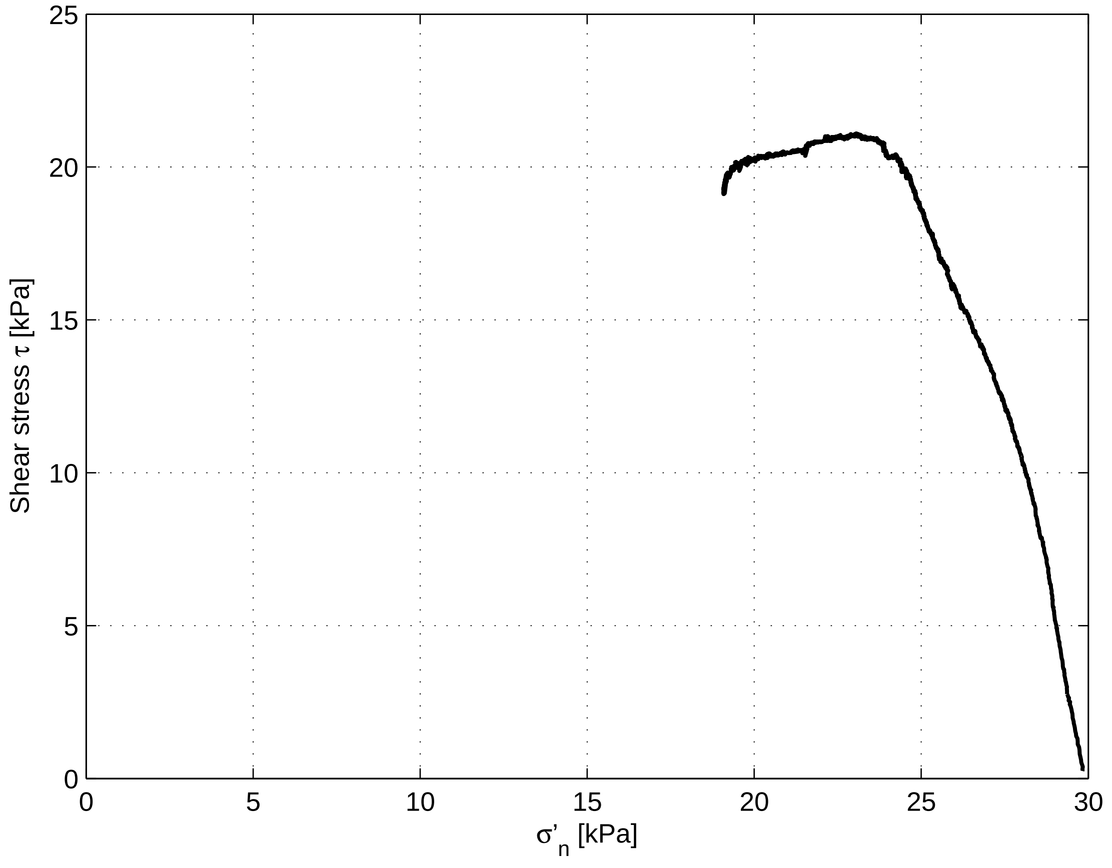
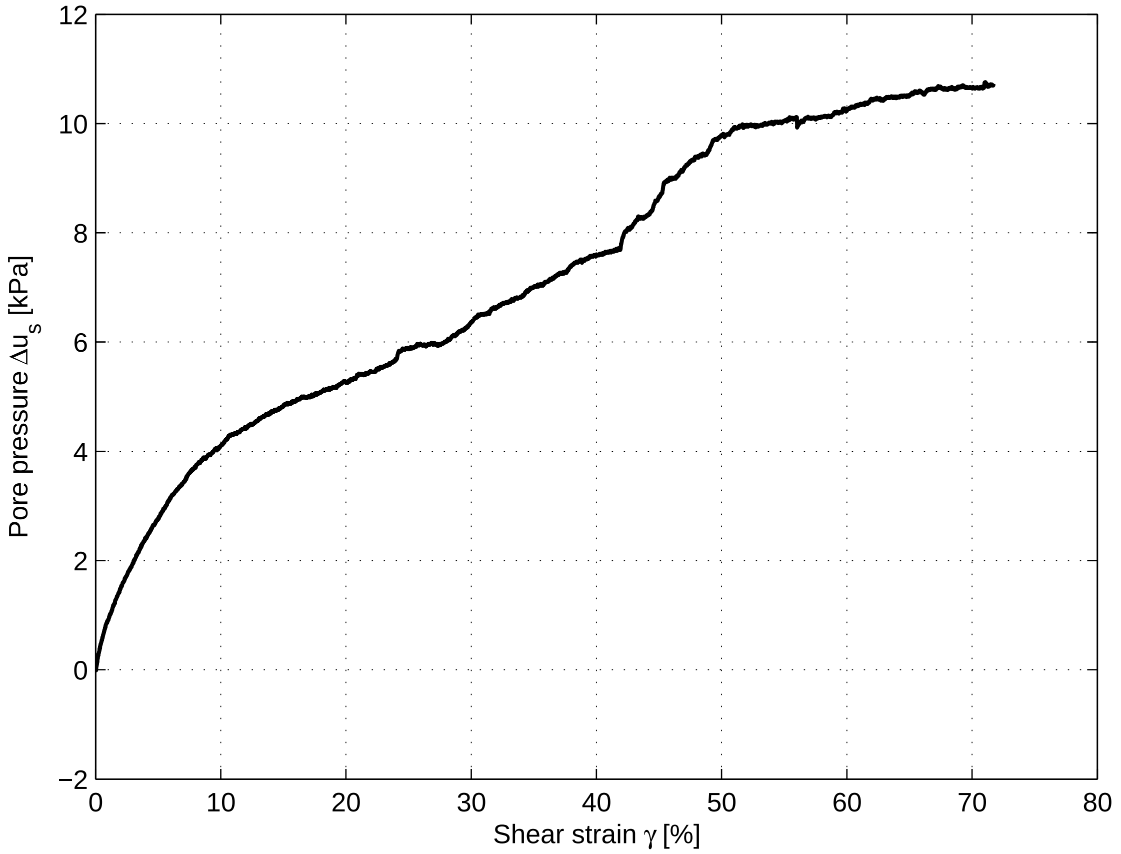
Shear degradation and damping curves for peat	date: 2016−04−15	signed: konstad
Direct Simple Shear test on sample NW1A2−B2−2B	project: 1209862.11	version: 1.3
Direct Simple Shear Test	appendix: NW1A2−B2−2B	page: 1





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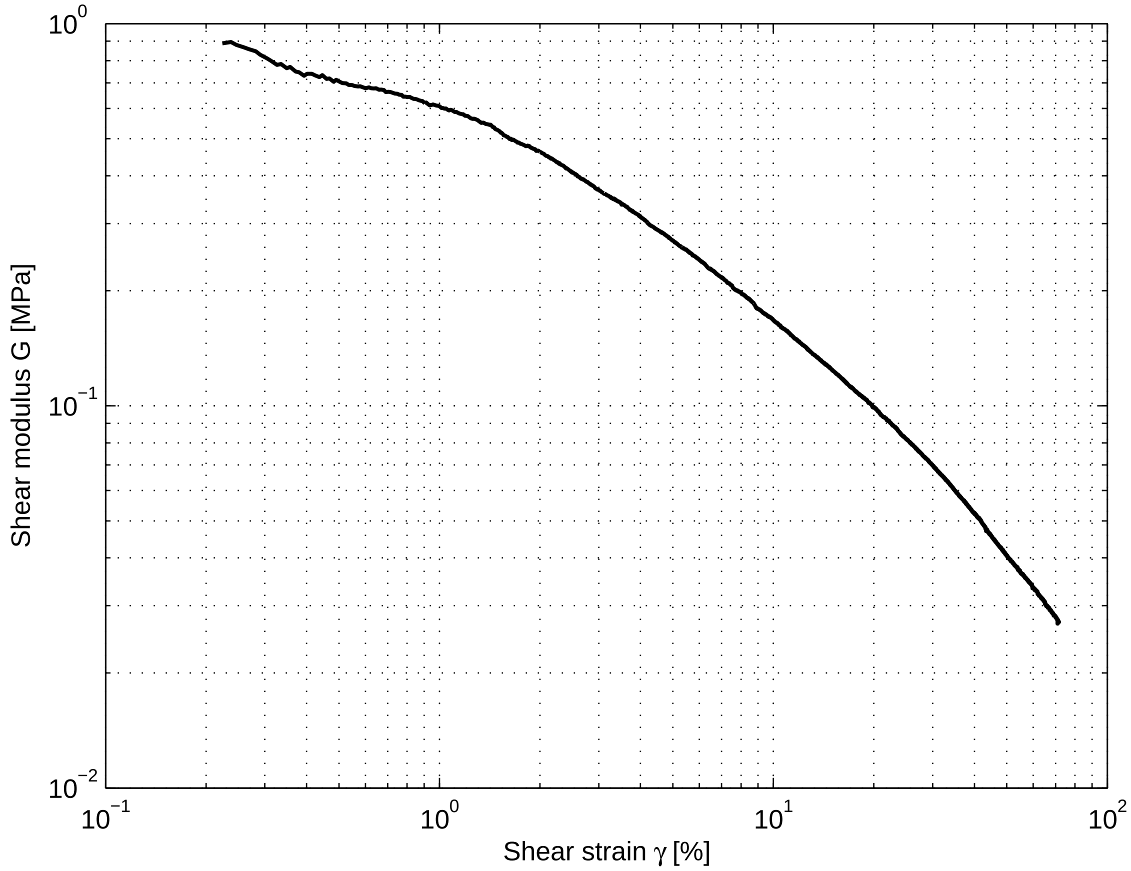
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−B2−2B				project 1209862.11	version 1.3
Direct Simple Shear Test				appendix NW1A2−B2−2B	page 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	13.5	N.A	27.1	2.8	0.3
15% deformation	18.6	N.A	25.0	4.8	0.1
30% deformation	20.9	N.A	23.5	6.4	0.1
Maximum strain	19.4	N.A	19.1	10.7	0.0
Maximum τ	21.1	0.00	23.1	6.8	0.1

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date	signed
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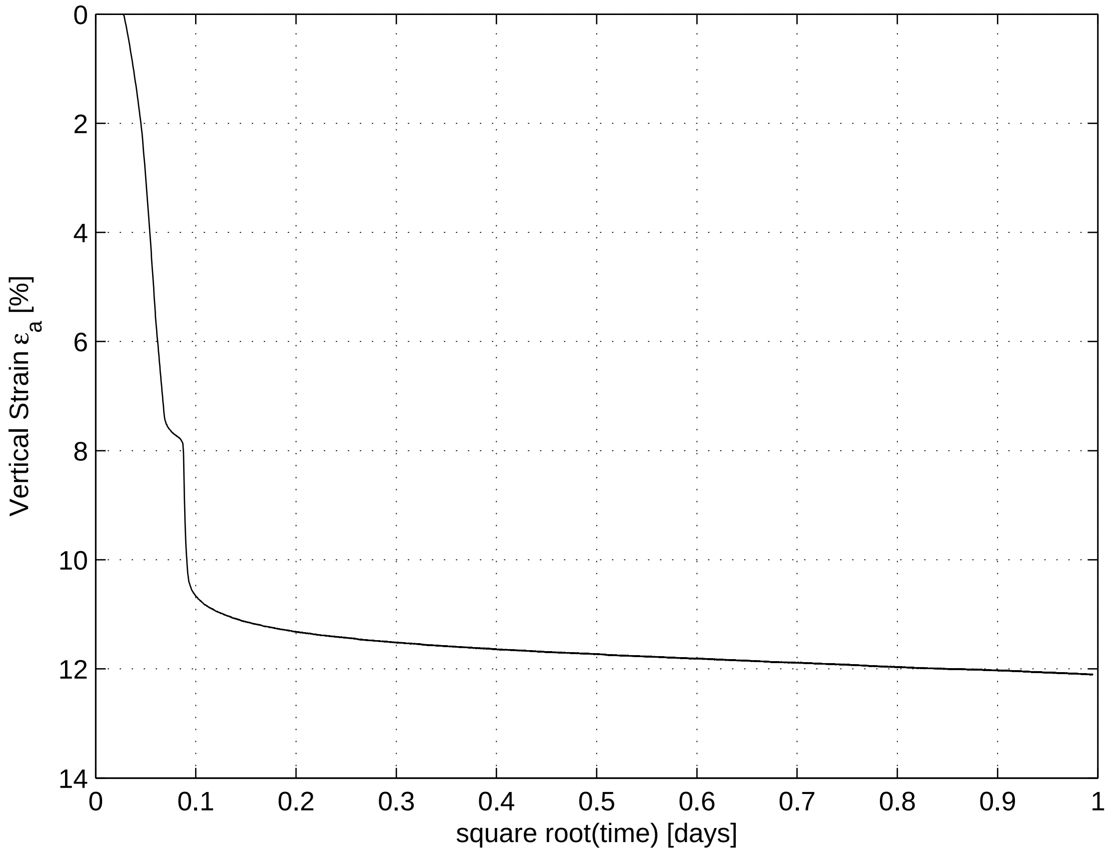
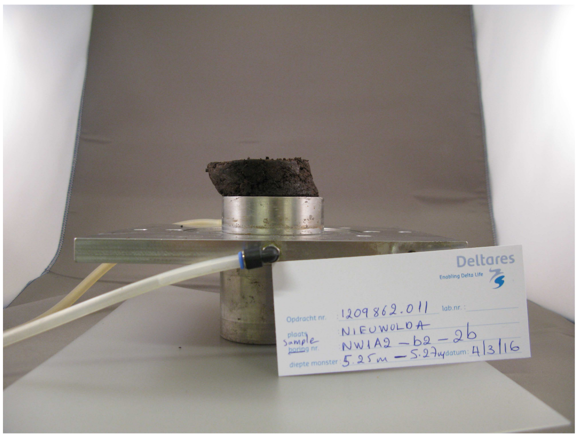
project	version
1209862.11	1.3
appendix	page
NW1A2−B2−2B	3

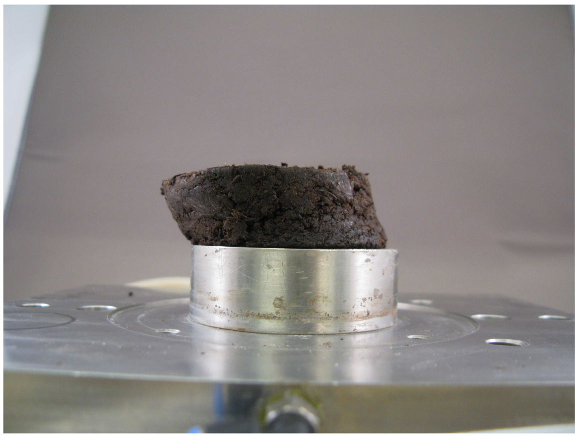
Shear degradation and damping curves for peat

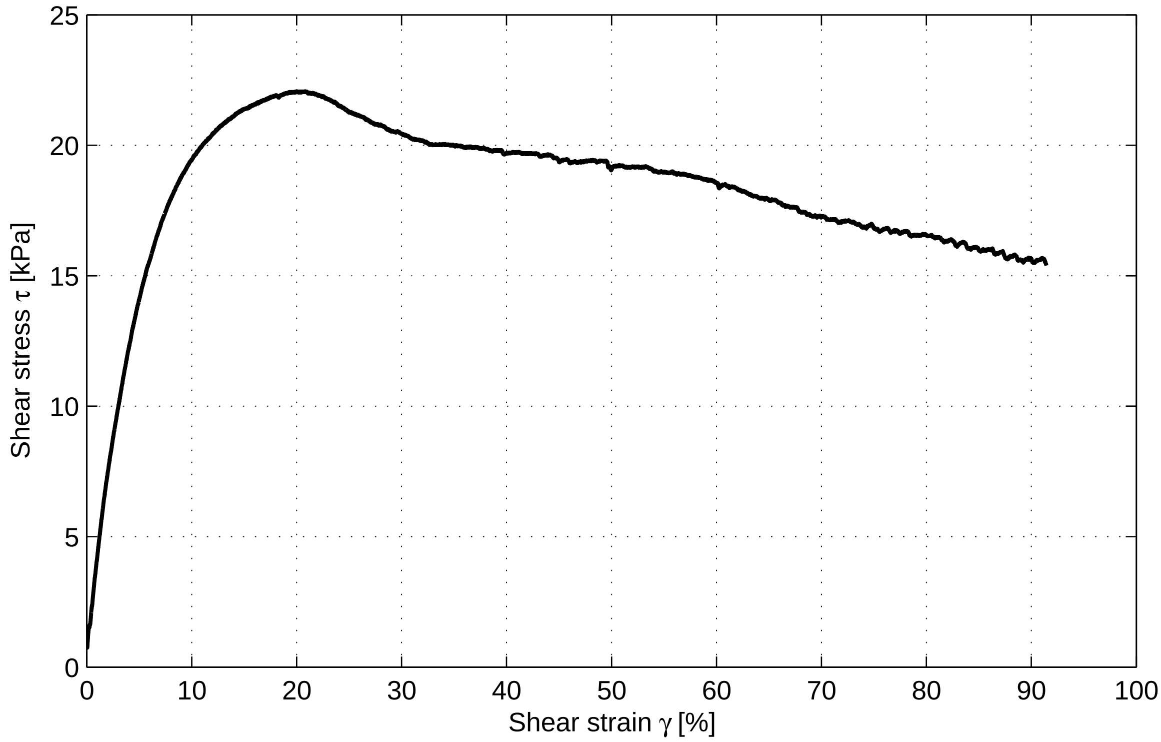
Direct Simple Shear test on sample NW1A2−B2−2B

Direct Simple Shear Test


Vertical Strain ε_a [%]
square root(time) [days]
0
2
4
6
8
10
12
14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Deltares
Enabling Delta Life
Opdracht nr. : 1209862.011
lab.nr. :
plaats sample boring nr. : NIEUWOLDA
NW1A2 - b2 - 2b
diepte monster : 5.25m - 5.27m
datum : 4/3/16





Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.7
Test type	Constant height
Apparatus code	DSS−C
Sample name	NW1A2−C1−1B
Bore code	NW1A2−C
Depth top [m]	−5.35
Depth bottom [m]	−5.37
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	1.0
S_0 [%]	−
Void ratio start shear [−]	1.00
w_0 [%]	487.5
w_{final} [%]	465.4
Consolidation stress [kPa]	27.0
Consolidation strain [%]	9.72
Strain rate [%/h]	8.0
Max shear stress [kPa]	22.1
Vert. stress at max shear stress [kPa]	25.2
Horz. strain at max shear stress [kPa]	20.8
σ_v at γ = 40% [kPa]	22.1
τ at γ = 40% [kPa]	19.7
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample's photos).

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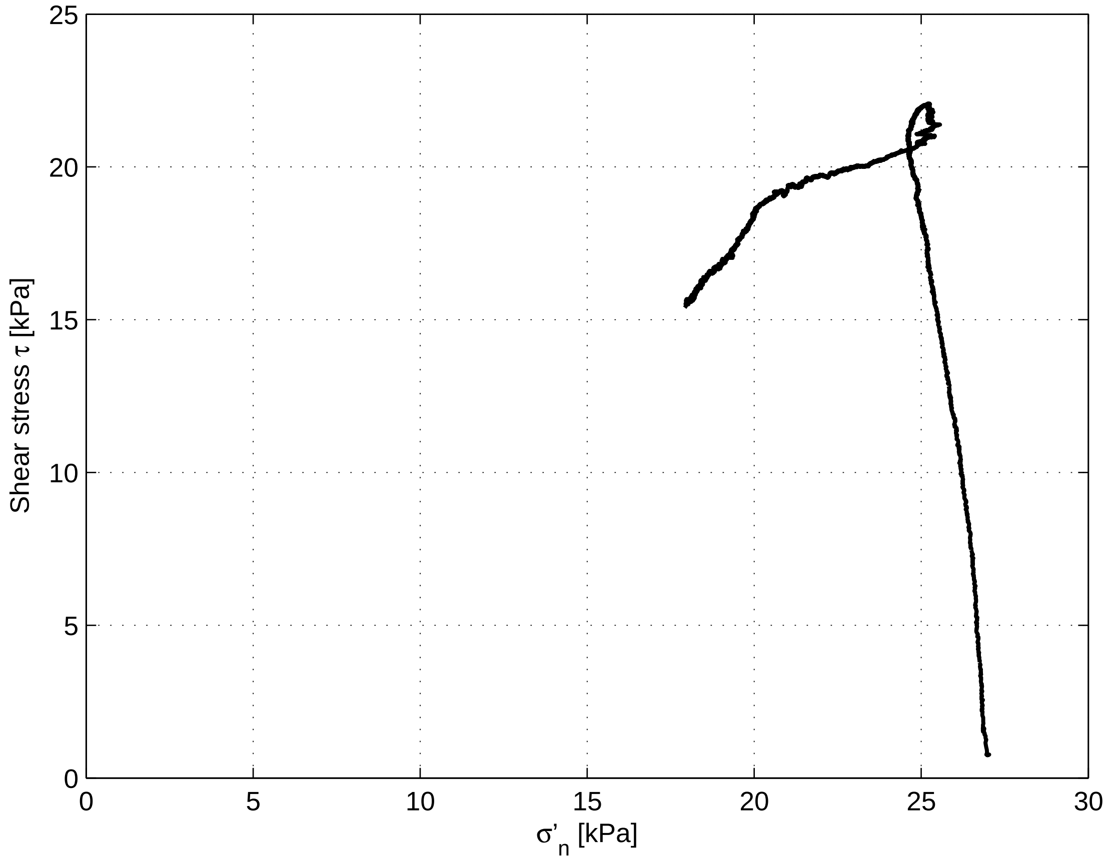
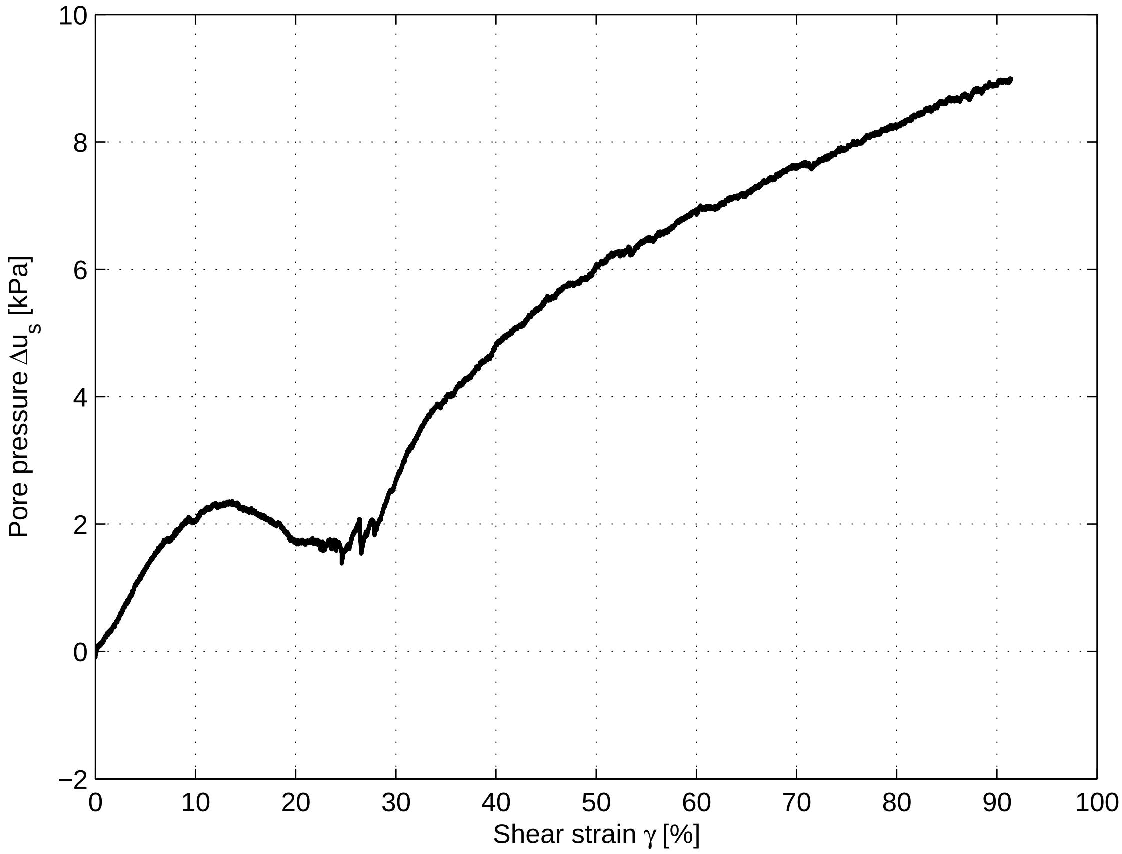
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−C1−1B	date: 2016−04−15	signed: konstad
	project: 1209862.11	version: 1.3
Direct Simple Shear Test	appendix: NW1A2−C1−1B	page: 1





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Shear degradation and damping curves for peat	project 1209862.11	version 1.3
Direct Simple Shear test on sample NW1A2−C1−1B		
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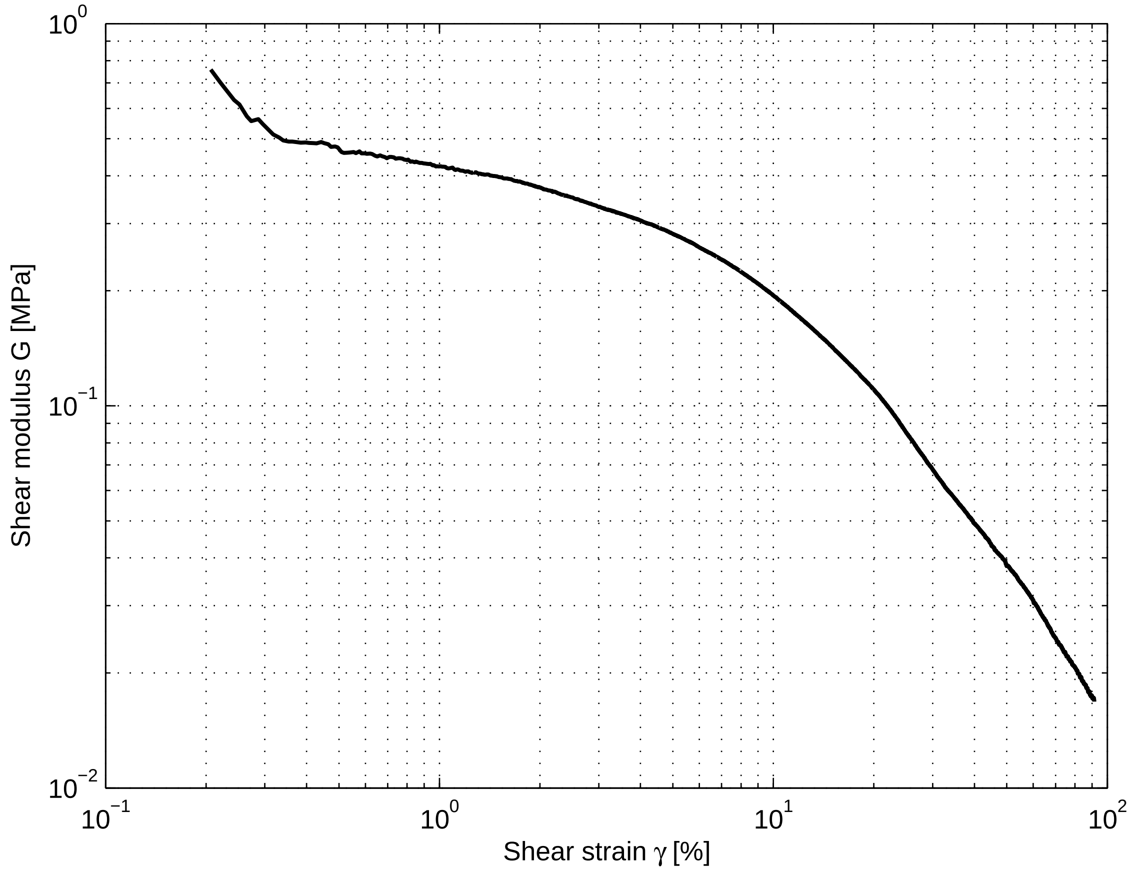

γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	14.1	N.A	25.6	1.3	0.3
15% deformation	21.4	N.A	24.7	2.2	0.1
30% deformation	20.4	N.A	24.2	2.7	0.1
Maximum strain	15.4	N.A	17.9	9.0	0.0
Maximum τ	22.1	0.00	25.2	1.7	0.1

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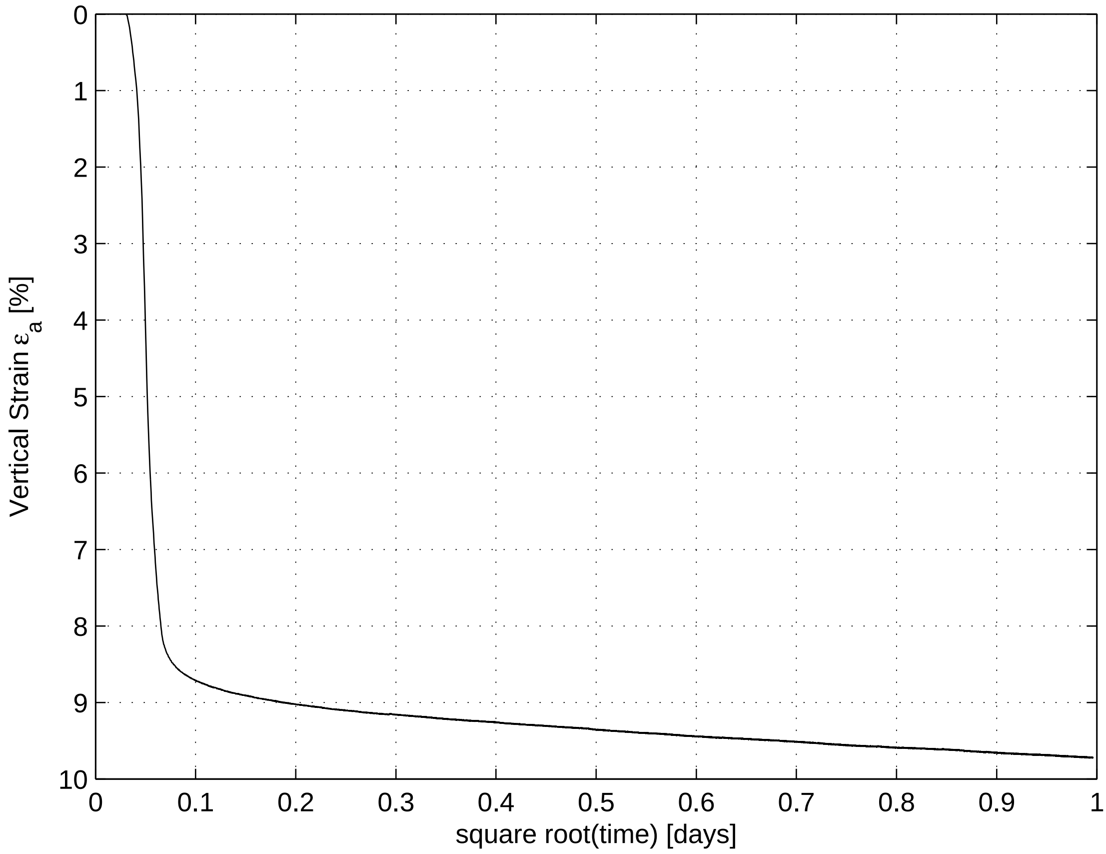
Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−C1−1B

Direct Simple Shear Test



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Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−C1−1B				project 1209862.11	version 1.3
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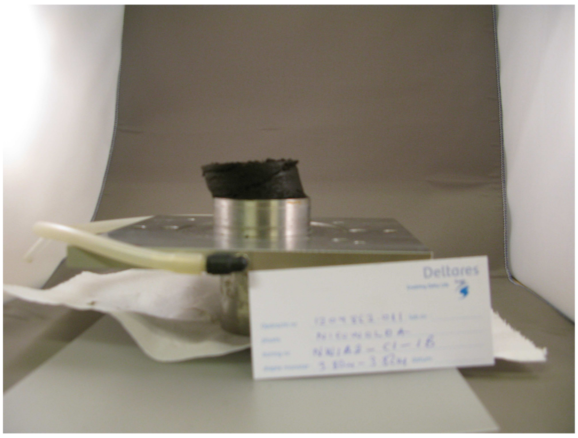

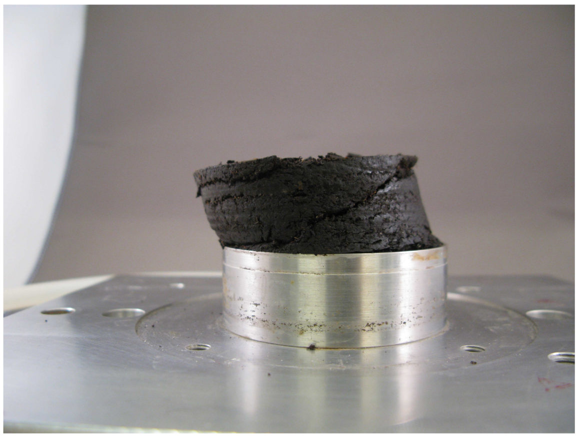

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Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−C1−1B				project 1209862.11	version 1.3
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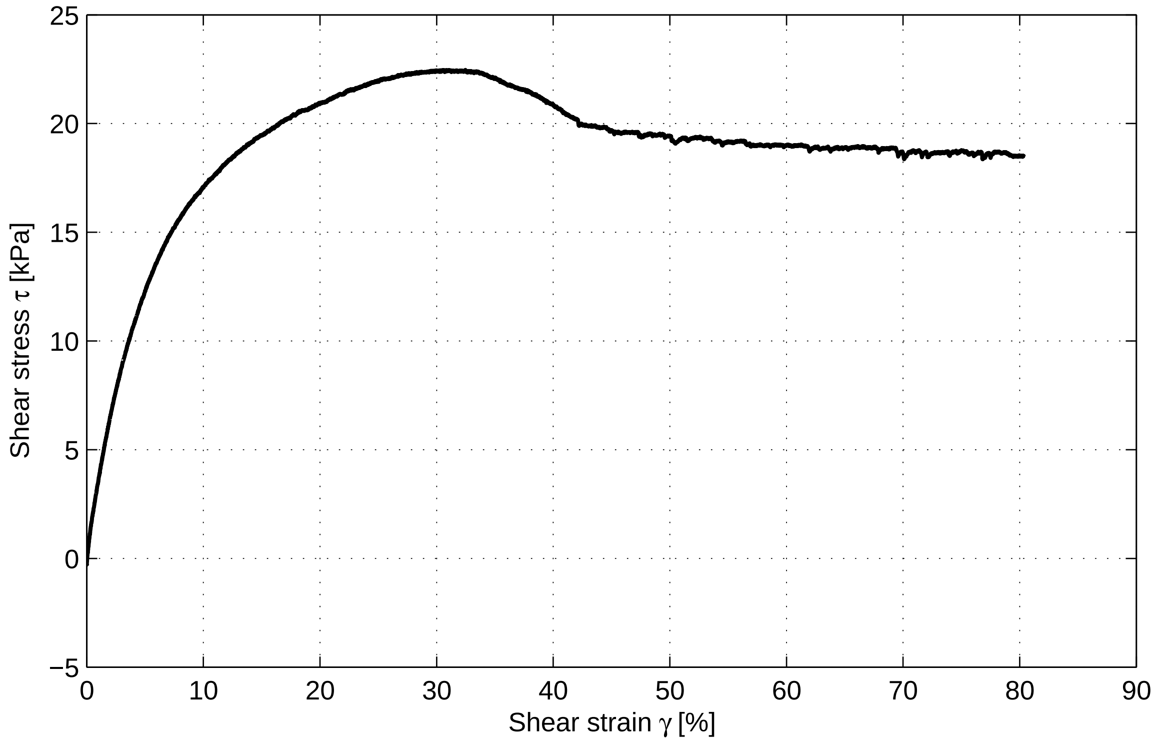
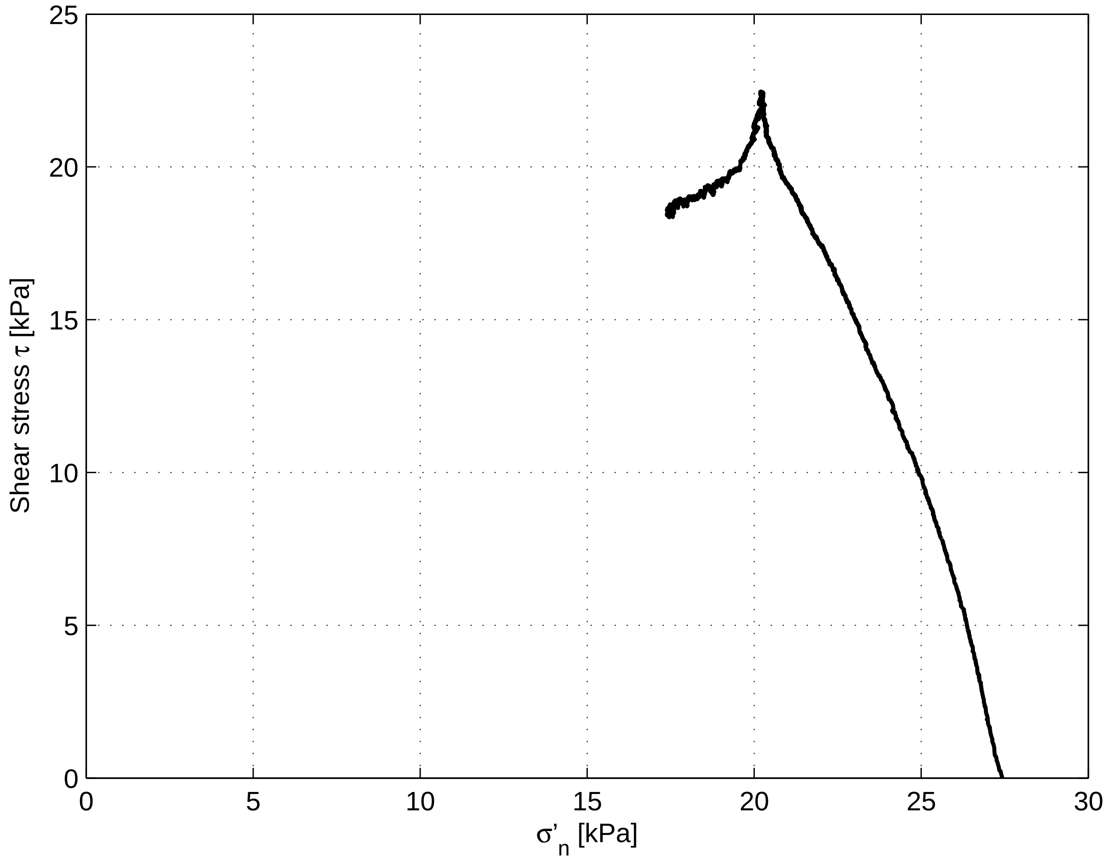
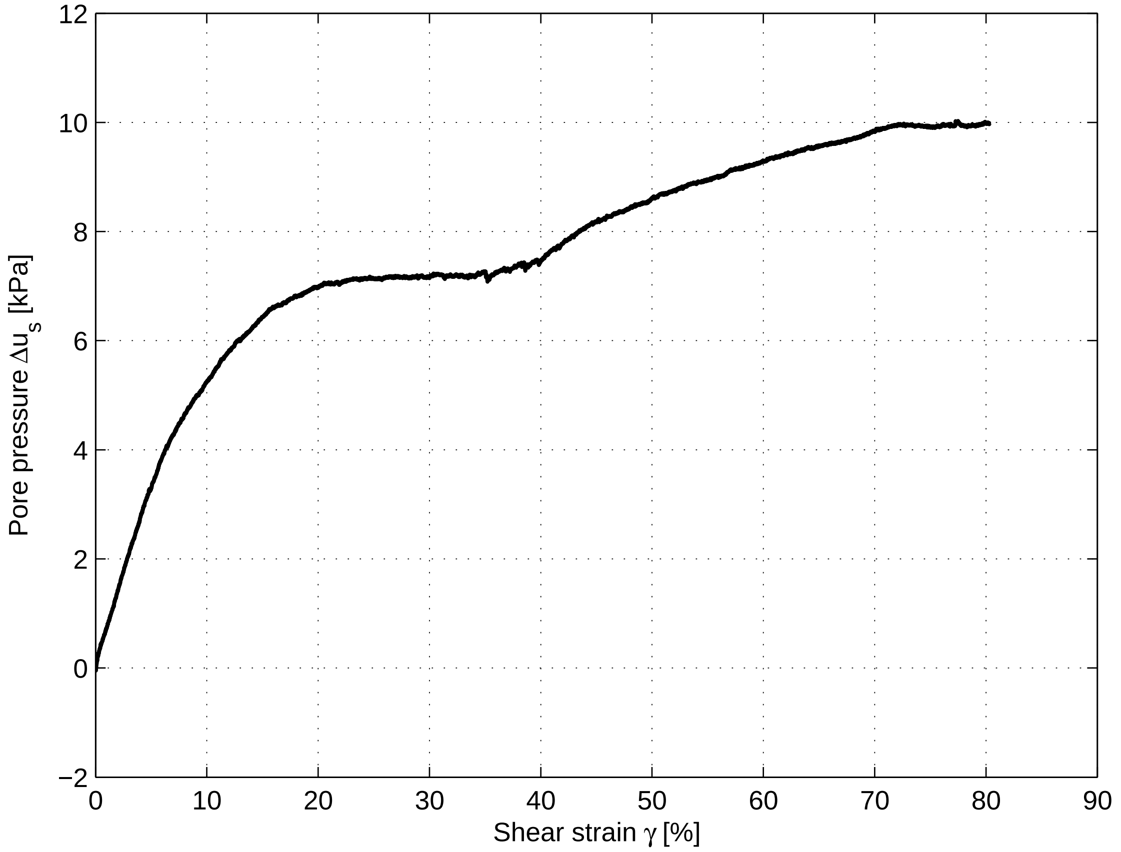


Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.7
Test type	Constant height
Apparatus code	DSS−D
Sample name	NW1A2−C1−2A
Bore code	NW1A2−C
Depth top [m]	−5.70
Depth bottom [m]	−5.72
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.94
w_0 [%]	554.1
w_{final} [%]	517.0
Consolidation stress [kPa]	27.4
Consolidation strain [%]	12.29
Strain rate [%/h]	8.0
Max shear stress [kPa]	22.5
Vert. stress at max shear stress [kPa]	20.2
Horz. strain at max shear stress [kPa]	32.5
σ_v at γ = 40% [kPa]	20.0
τ at γ = 40% [kPa]	20.9
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample's photos).





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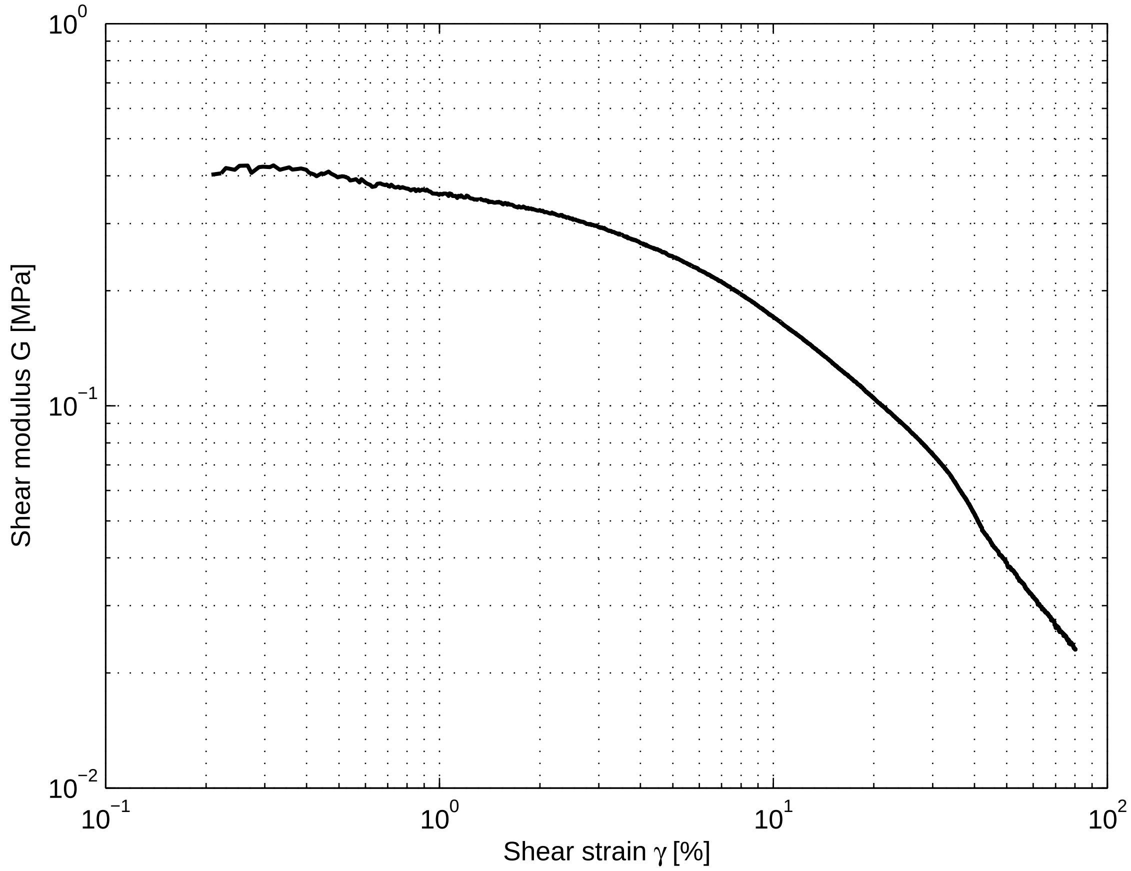
Direct Simple Shear Test		appendix NW1A2−C1−2A	page 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	12.3	N.A	24.1	3.3	0.2
15% deformation	19.5	N.A	21.0	6.4	0.1
30% deformation	22.4	N.A	20.3	7.1	0.1
Maximum strain	18.5	N.A	17.4	10.0	0.0
Maximum τ	22.4	−0.00	20.2	7.2	0.1

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Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−C1−2A

Direct Simple Shear Test

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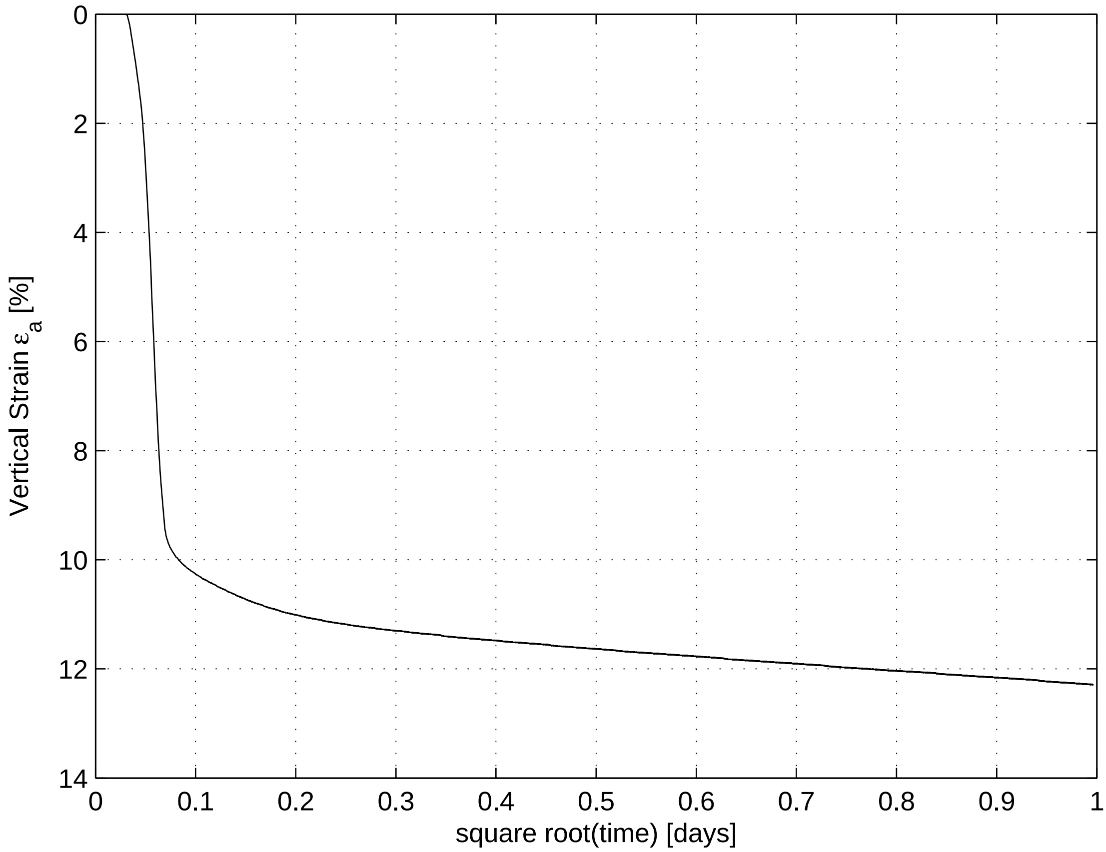
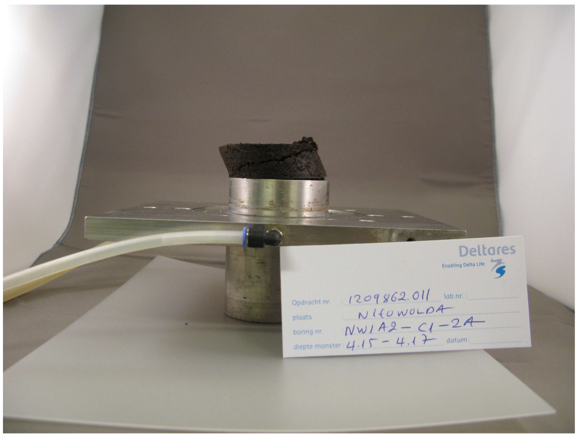
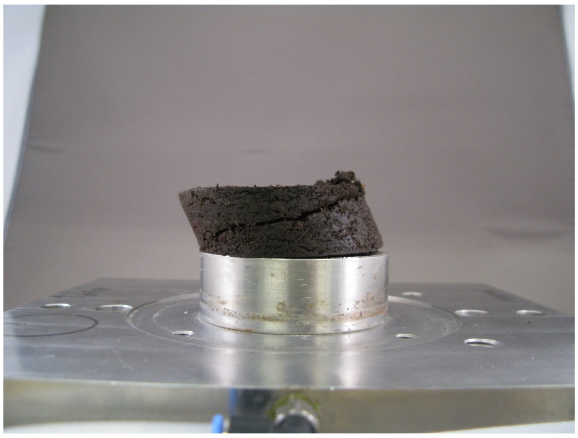


Vertical Strain ε_a [%]
0
2
4
6
8
10
12
14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
square root(time) [days]





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Direct Simple Shear test on sample NW1A2−C1−2A		2016−04−15	konstadi
Direct Simple Shear Test		project	version
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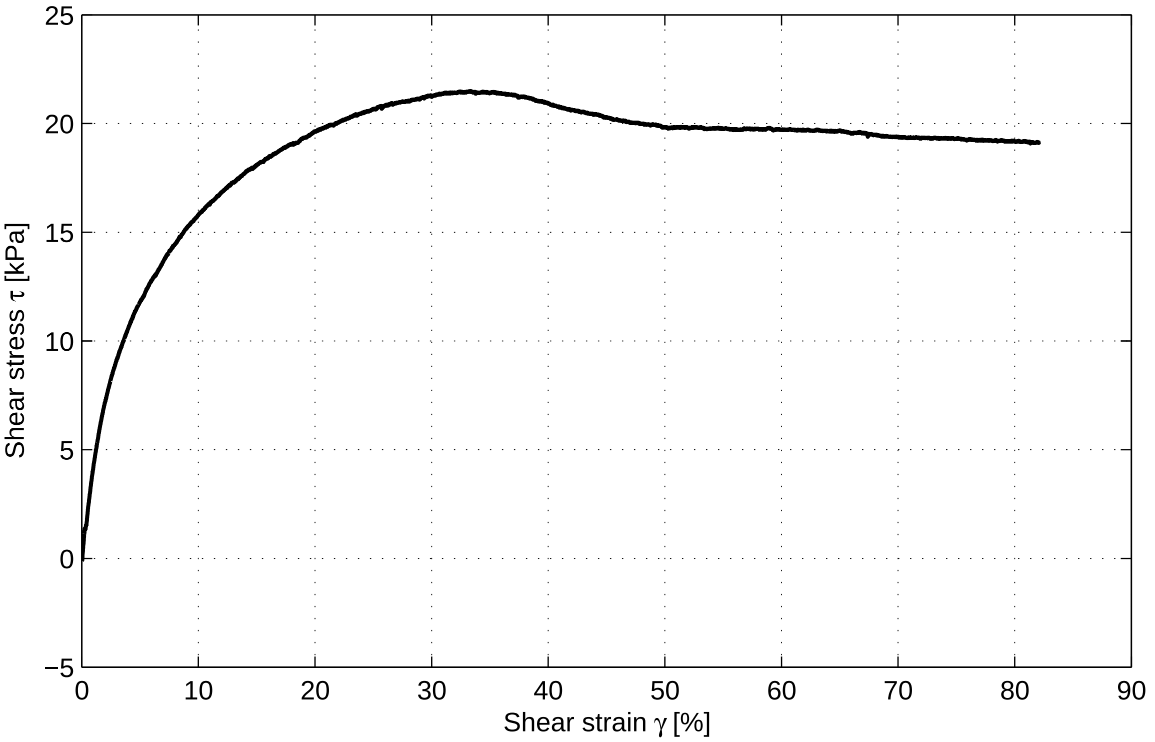
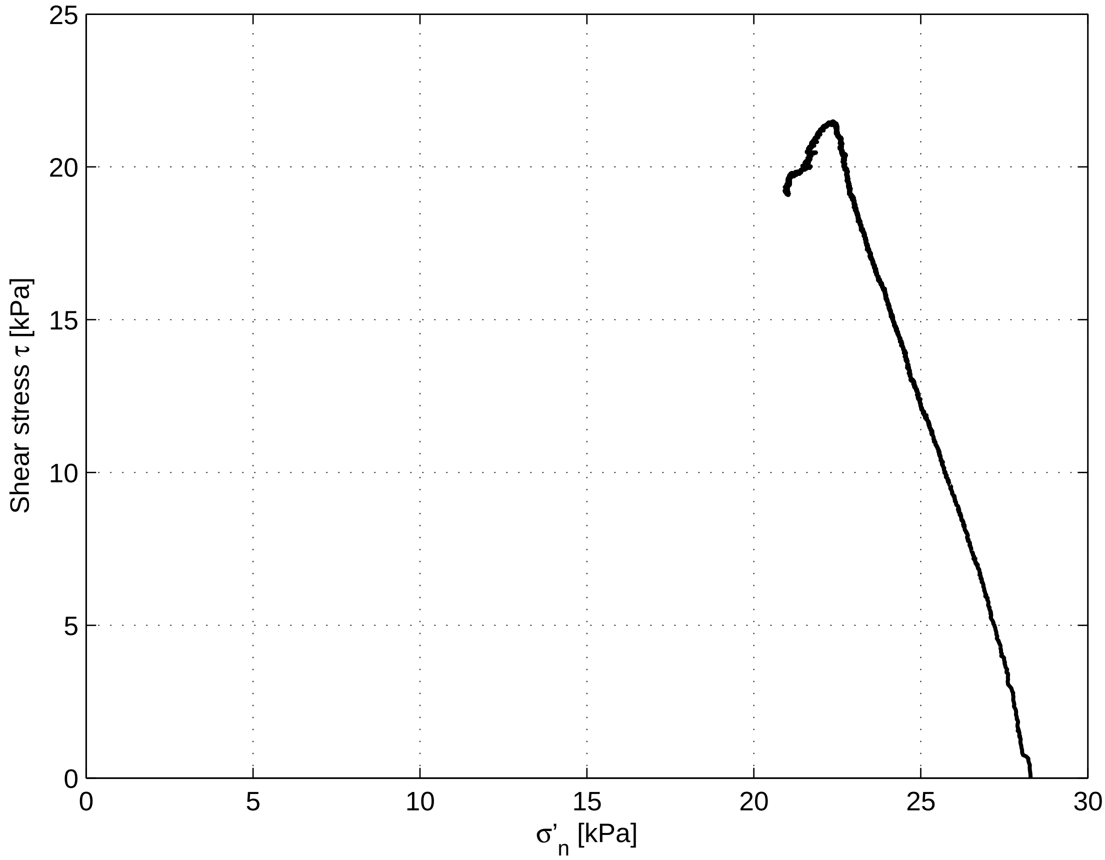
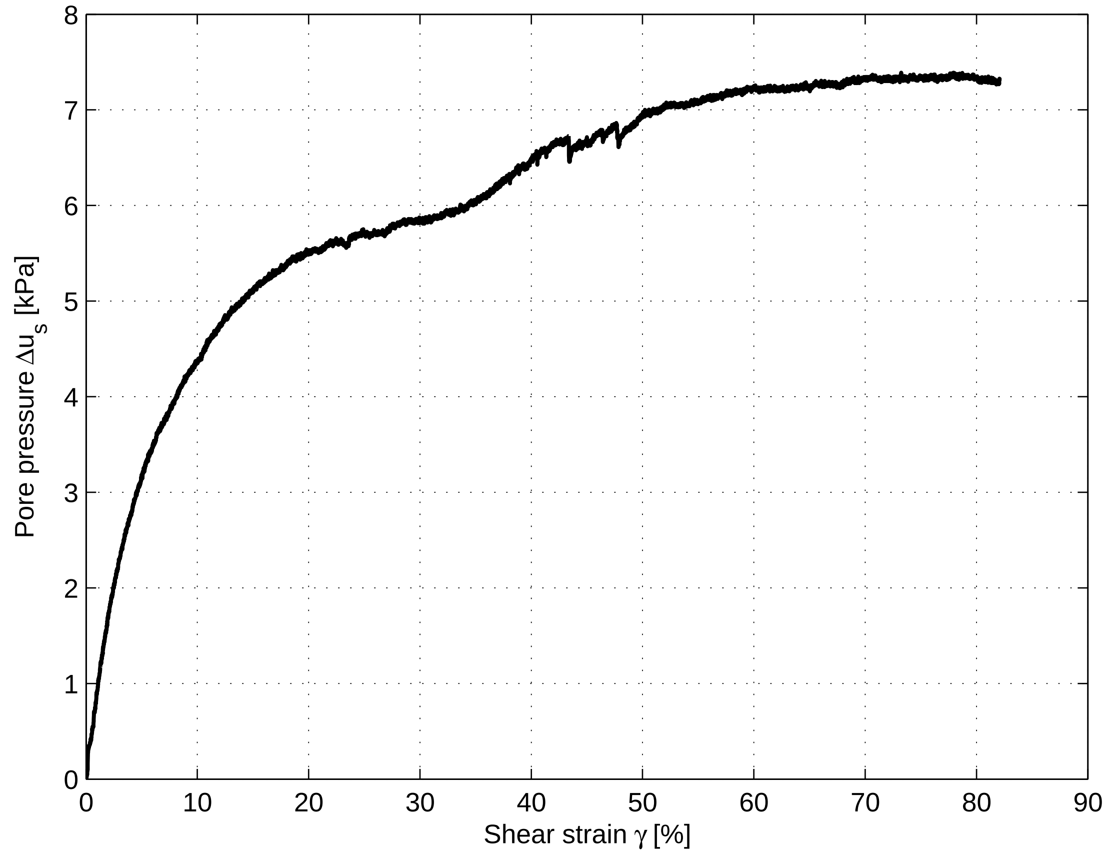
		NW1A2−C1−2A	5



Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.7
Test type	Constant height
Apparatus code	DSS−C
Sample name	NW1A2−C2−1A
Bore code	NW1A2−C
Depth top [m]	−6.40
Depth bottom [m]	−6.42
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.89
w_0 [%]	606.1
w_{final} [%]	555.6
Consolidation stress [kPa]	28.3
Consolidation strain [%]	14.85
Strain rate [%/h]	8.0
Max shear stress [kPa]	21.5
Vert. stress at max shear stress [kPa]	22.4
Horz. strain at max shear stress [kPa]	33.3
σ_v at γ = 40% [kPa]	21.8
τ at γ = 40% [kPa]	20.9
Sample Disturbance Index [%]	−
SDI qualification	−





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Shear degradation and damping curves for peat	date 2016−04−15	signed konstad
Direct Simple Shear test on sample NW1A2−C2−1A	project 1209862.11	version 1.3
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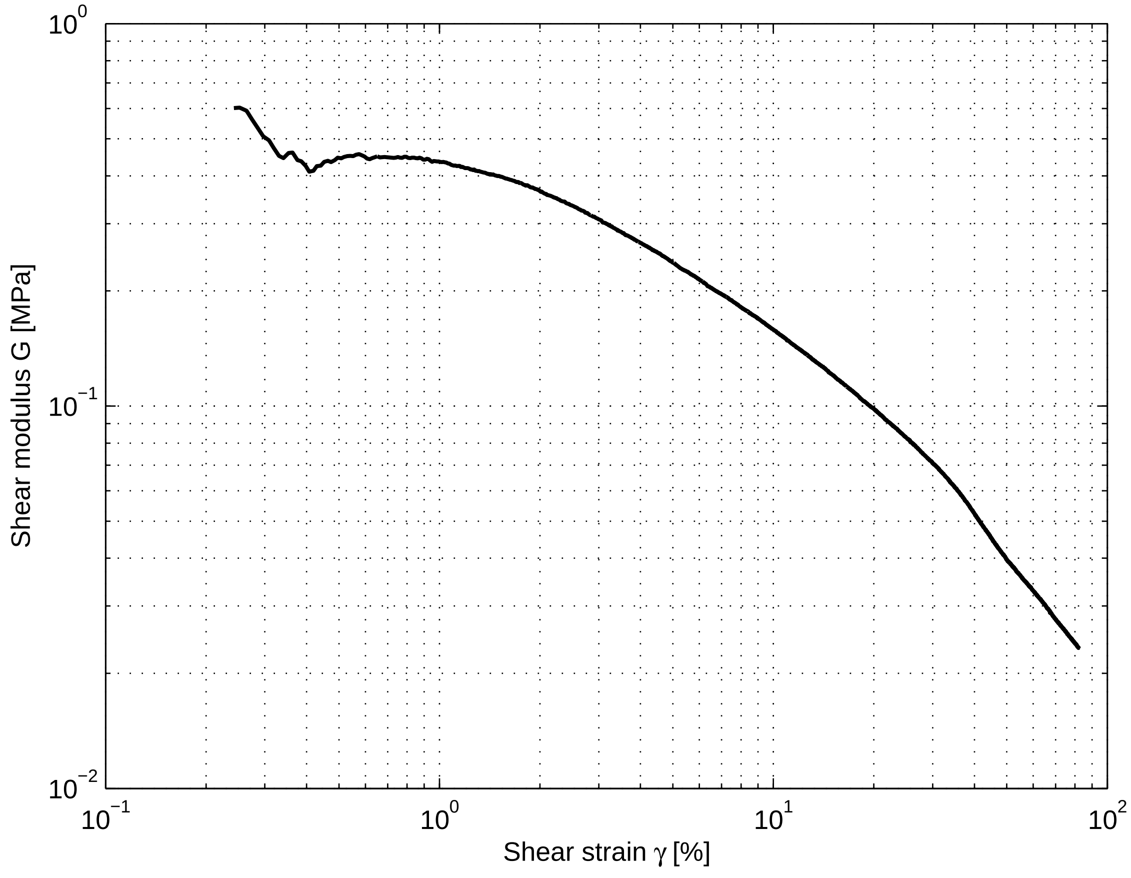

γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	11.8	N.A	25.1	3.2	0.2
15% deformation	18.1	N.A	23.2	5.1	0.1
30% deformation	21.3	N.A	22.5	5.8	0.1
Maximum strain	19.1	N.A	21.0	7.3	0.0
Maximum τ	21.5	0.00	22.4	5.9	0.1

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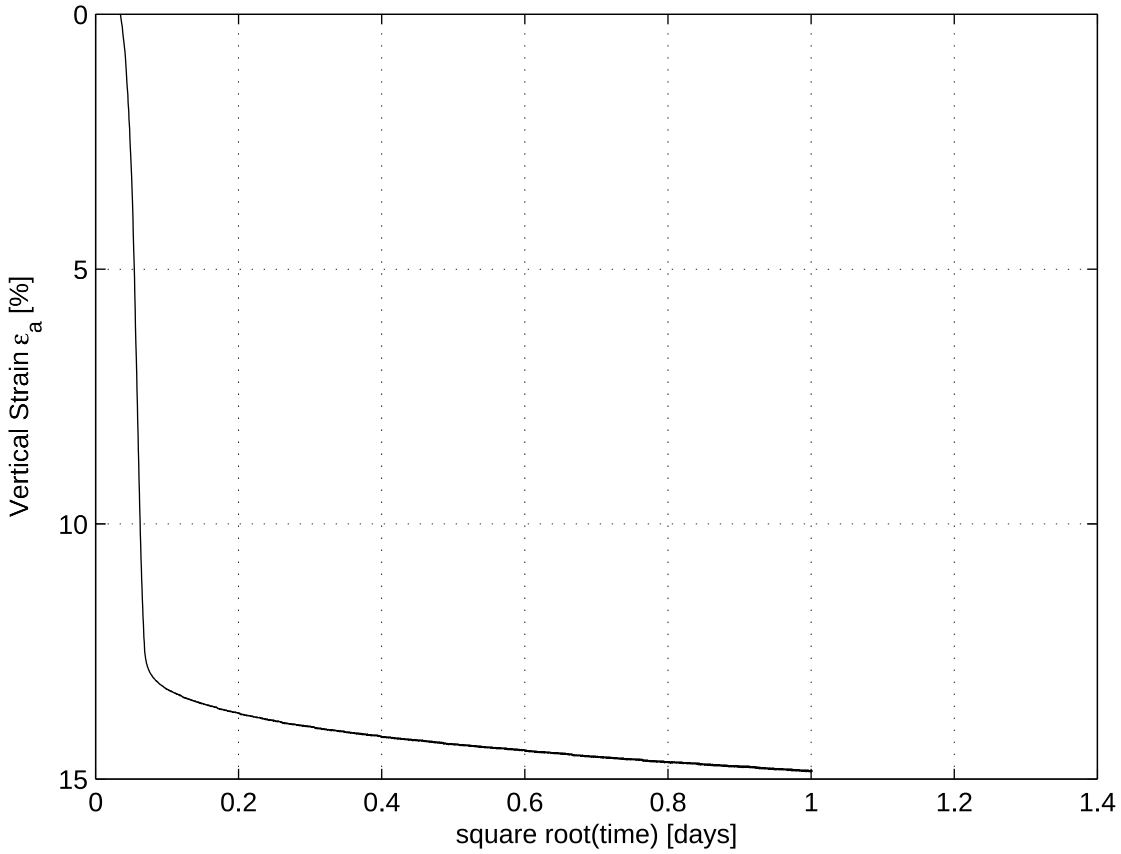
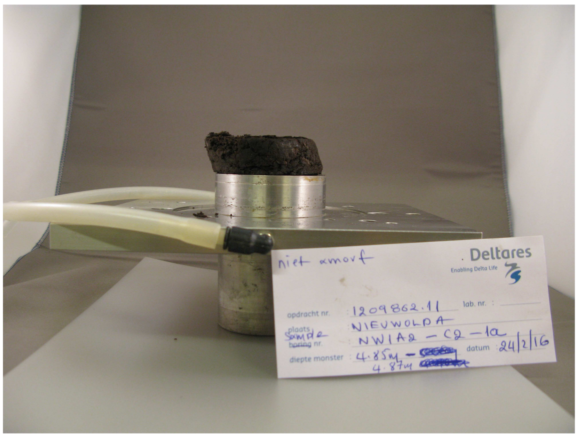
Direct Simple Shear test on sample NW1A2−C2−1A

Direct Simple Shear Test



Vertical Strain ε_a [%]
0
5
10
15
0
0.2
0.4
0.6
0.8
1
1.2
1.4
square root(time) [days]



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Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−C2−1A

Direct Simple Shear Test

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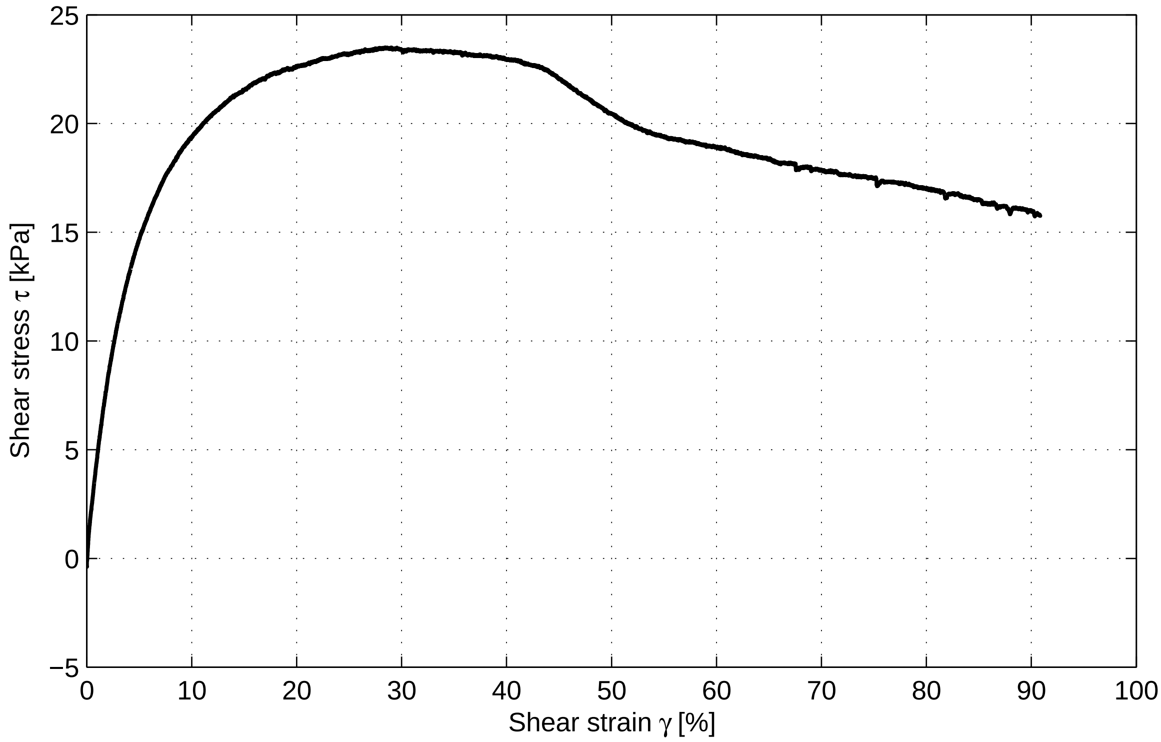
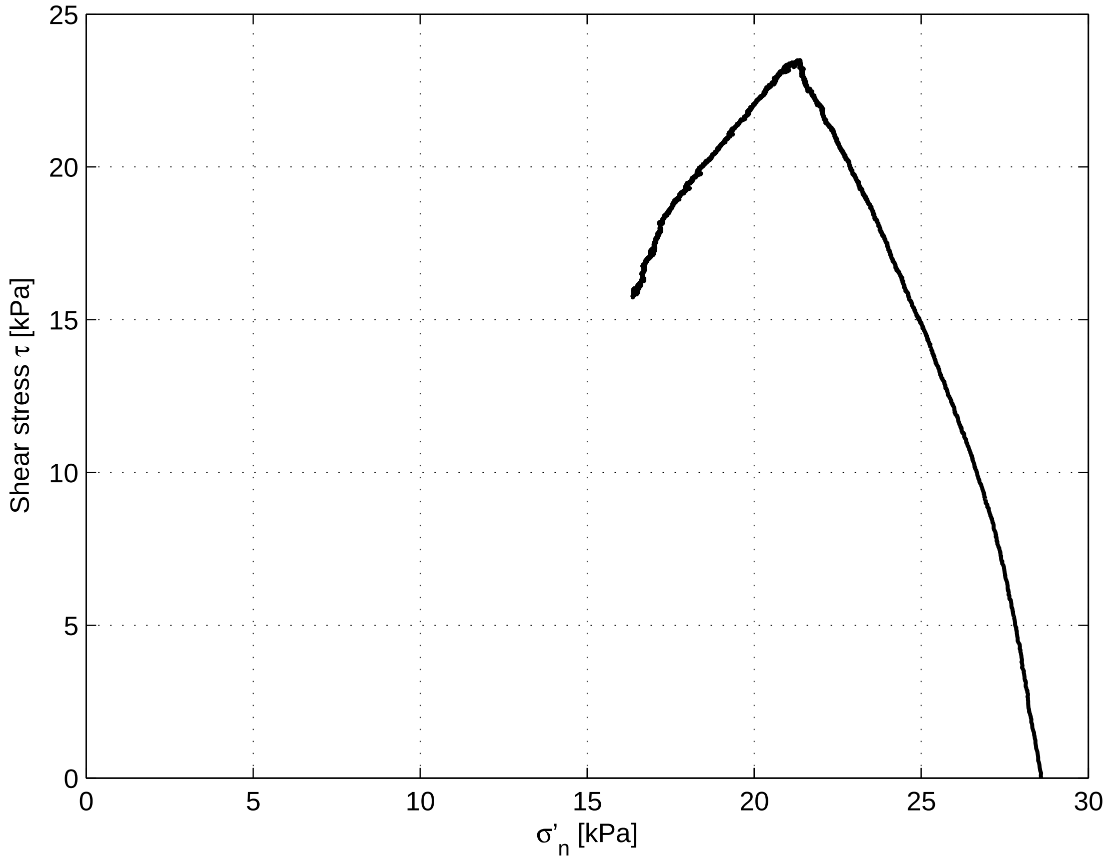
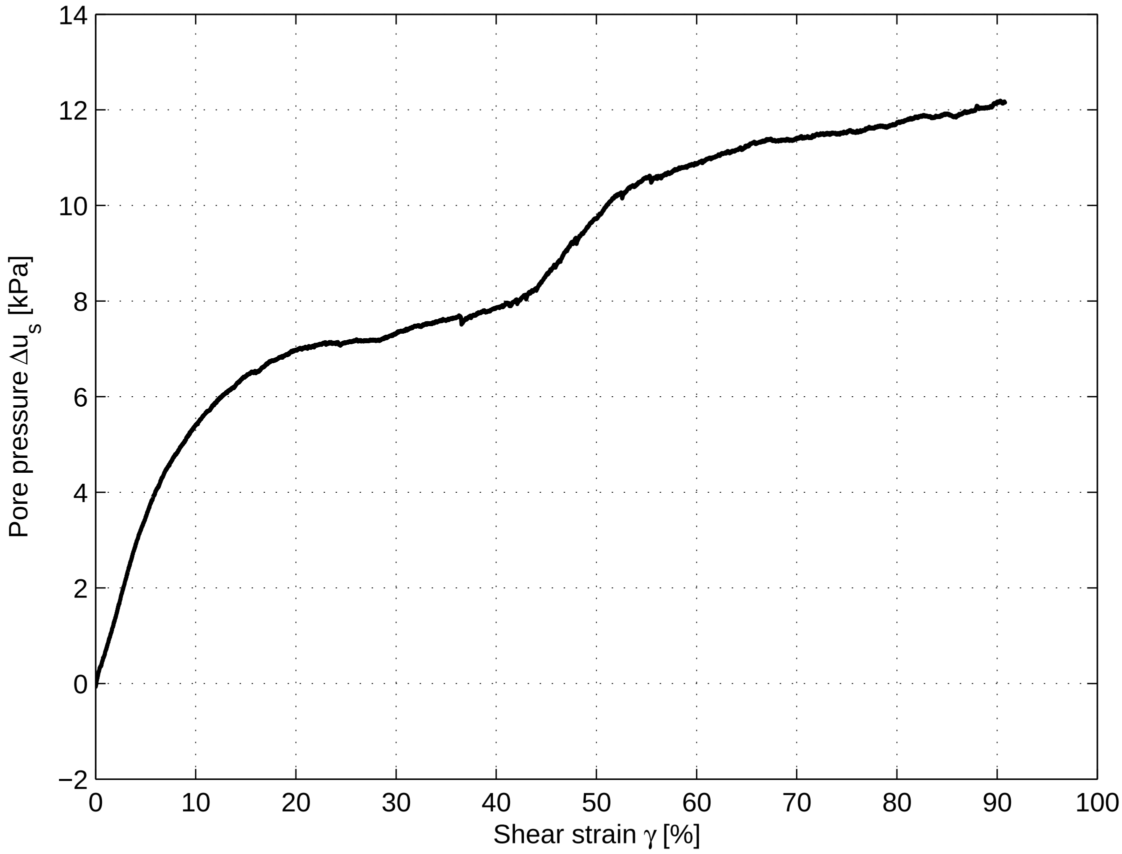


Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−D
Sample name	NW1A2−C2−2A
Bore code	NW1A2−C
Depth top [m]	−6.70
Depth bottom [m]	−6.72
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.94
w_0 [%]	581.6
w_{final} [%]	559.3
Consolidation stress [kPa]	28.6
Consolidation strain [%]	11.65
Strain rate [%/h]	8.0
Max shear stress [kPa]	23.5
Vert. stress at max shear stress [kPa]	21.4
Horz. strain at max shear stress [kPa]	28.5
σ_v at γ = 40% [kPa]	20.7
τ at γ = 40% [kPa]	22.9
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample’s photos).





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Direct Simple Shear test on sample NW1A2−C2−2A	project 1209862.11	version 1.3
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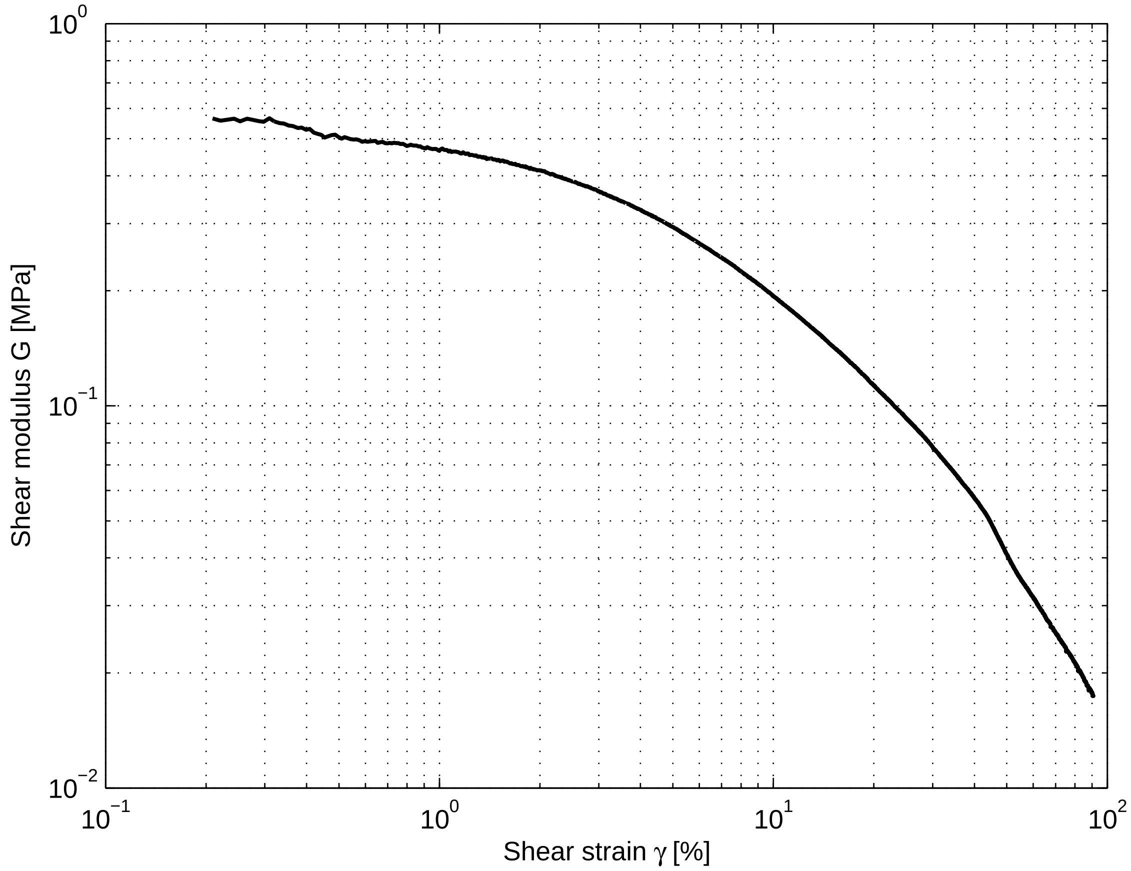

γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	14.7	N.A	25.1	3.5	0.3
15% deformation	21.5	N.A	22.1	6.4	0.1
30% deformation	23.4	N.A	21.2	7.3	0.1
Maximum strain	15.7	N.A	16.4	12.2	0.0
Maximum τ	23.5	0.00	21.4	7.2	0.1

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Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−C2−2A

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Direct Simple Shear Test

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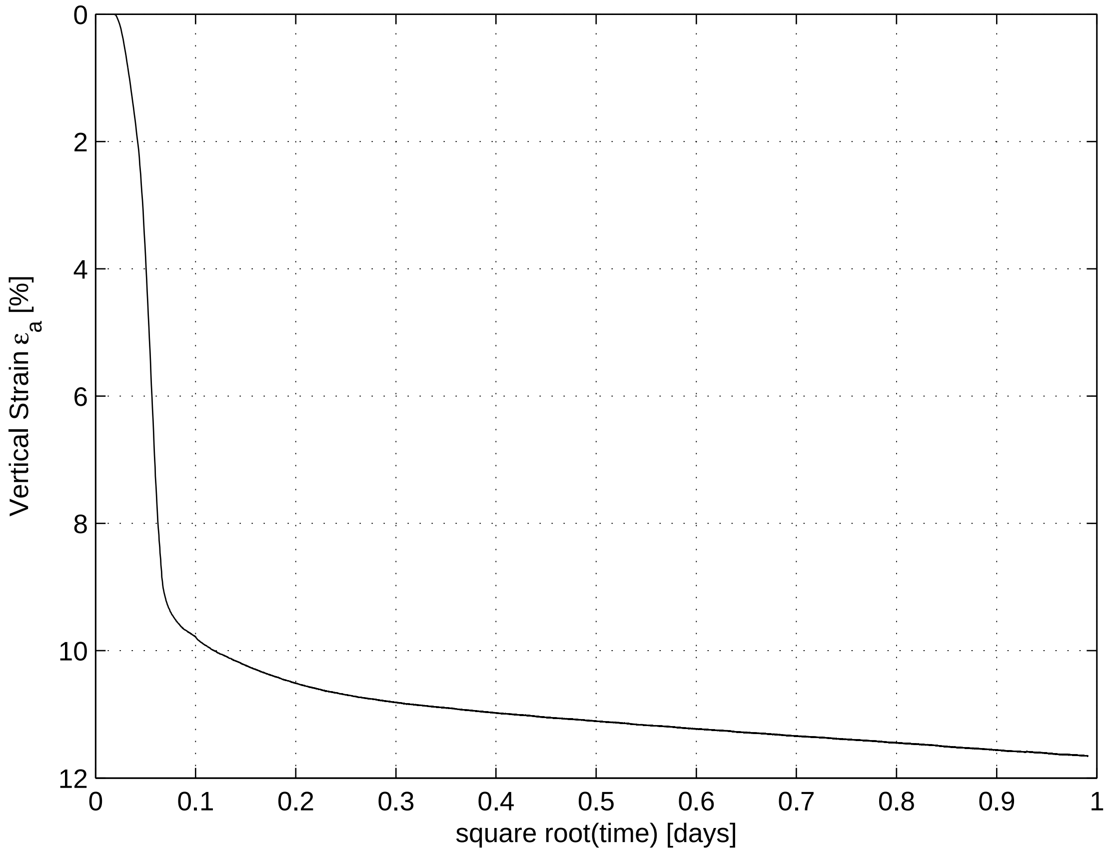
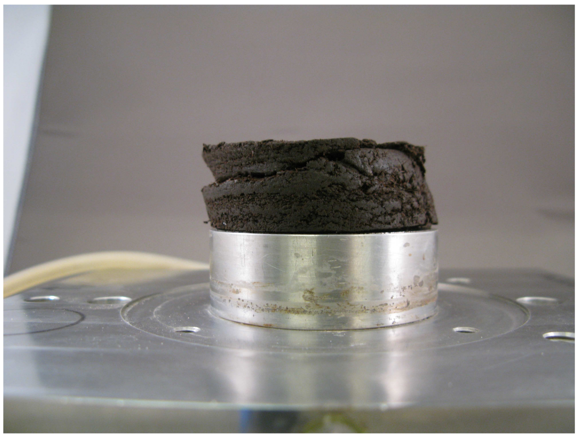


0
2
4
6
8
10
12
Vertical Strain ε_a [%]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
square root(time) [days]



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Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−C2−2A

Direct Simple Shear Test

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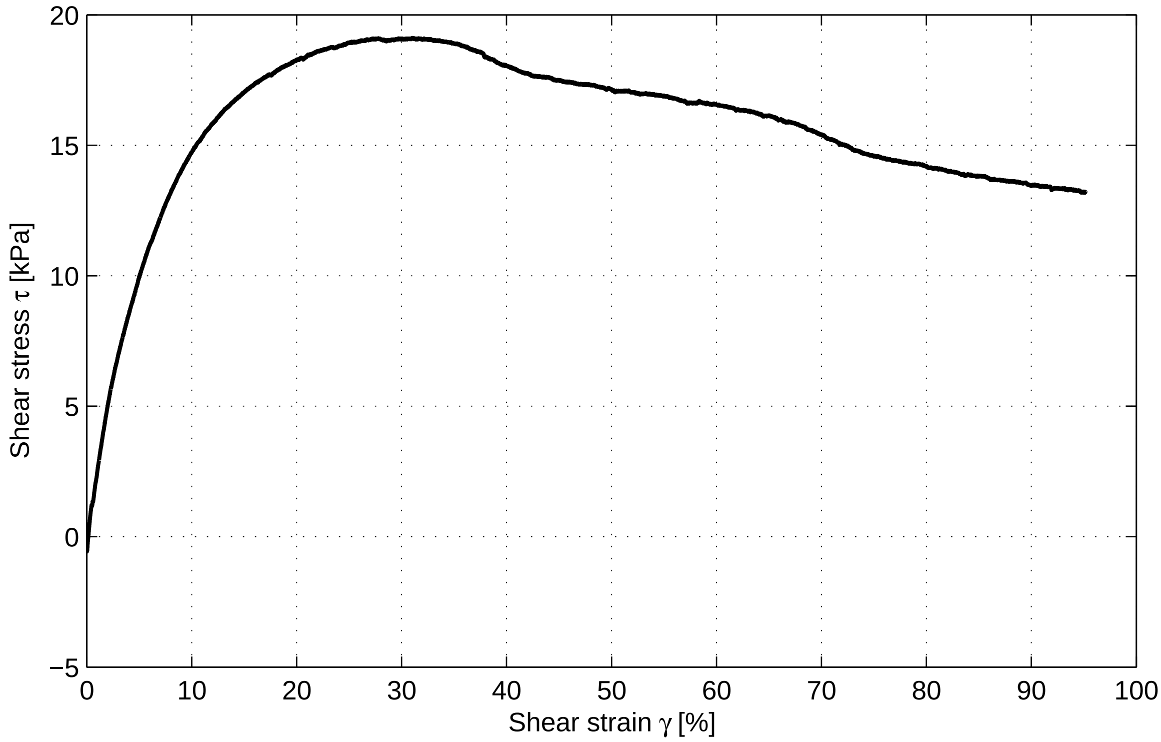

Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.7
Test type	Constant height
Apparatus code	DSS−C
Sample name	NW1A2−d1−1D
Bore code	NW1A2−D
Depth top [m]	−5.46
Depth bottom [m]	−5.48
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	1.0
S_0 [%]	−
Void ratio start shear [−]	0.99
w_0 [%]	518.5
w_{final} [%]	554.8
Consolidation stress [kPa]	26.6
Consolidation strain [%]	11.66
Strain rate [%/h]	8.0
Max shear stress [kPa]	19.1
Vert. stress at max shear stress [kPa]	20.4
Horz. strain at max shear stress [kPa]	31.0
σ_v at γ = 40% [kPa]	19.4
τ at γ = 40% [kPa]	18.0
Sample Disturbance Index [%]	−
SDI qualification	−

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Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−d1−1D	date: 2016−04−14	signed: konstad
	project: 1209862.11	version: 1.3
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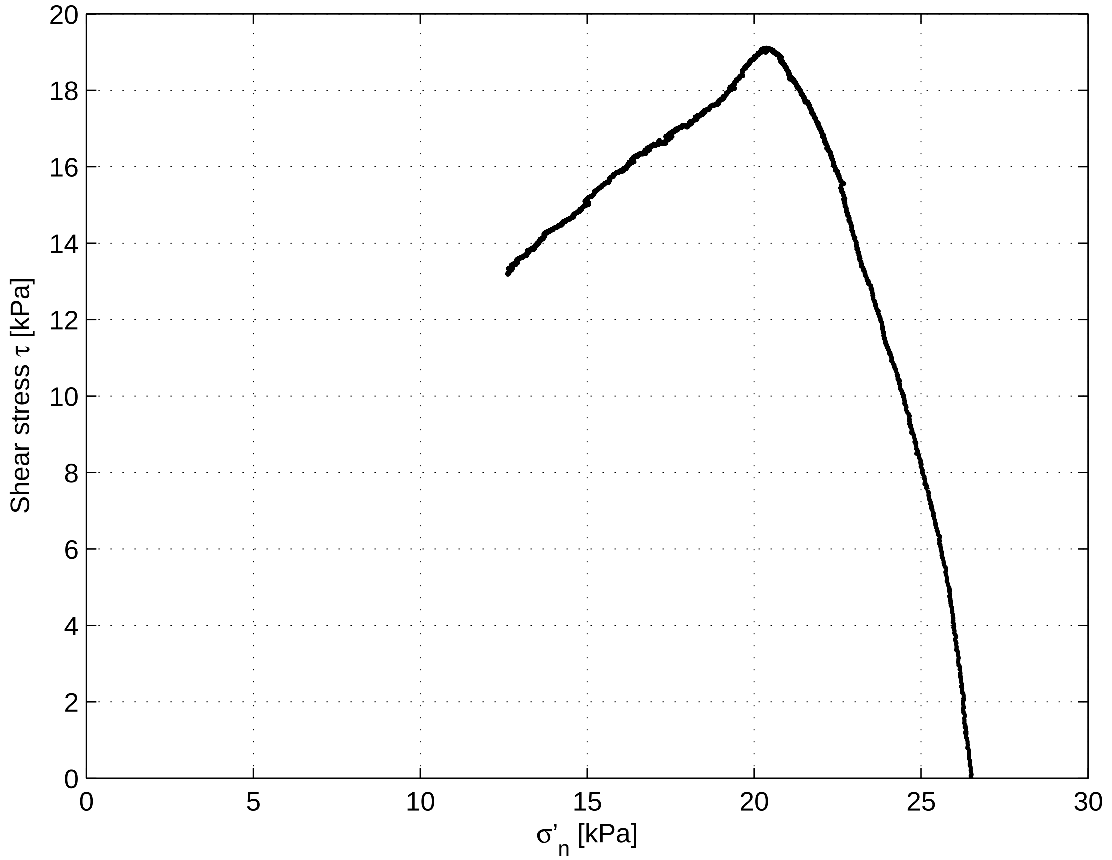

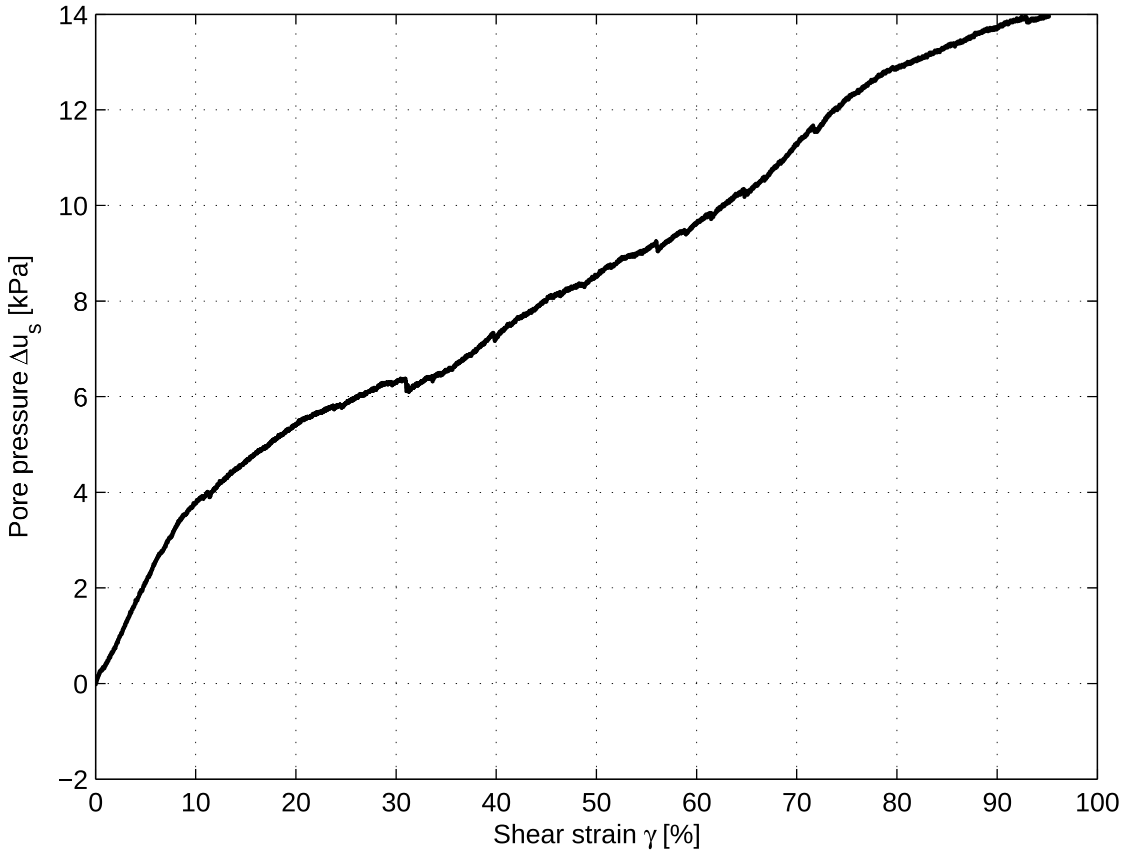

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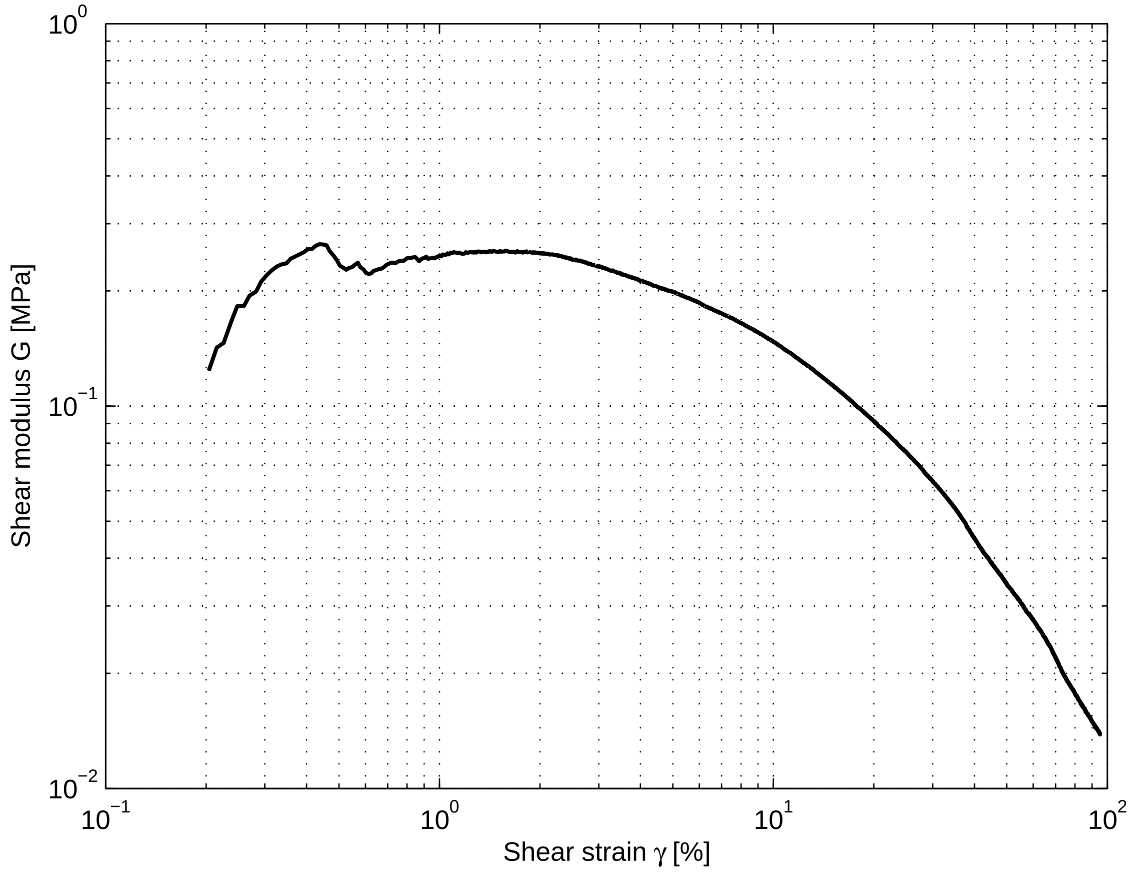
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−d1−1D		project 1209862.11	version 1.3
Direct Simple Shear Test		appendix NW1A2−d1−1D	page 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	9.9	N.A	24.5	2.1	0.2
15% deformation	17.0	N.A	21.9	4.7	0.1
30% deformation	19.1	N.A	20.3	6.3	0.1
Maximum strain	13.2	N.A	12.6	14.0	0.0
Maximum τ	19.1	−0.00	20.4	6.2	0.1

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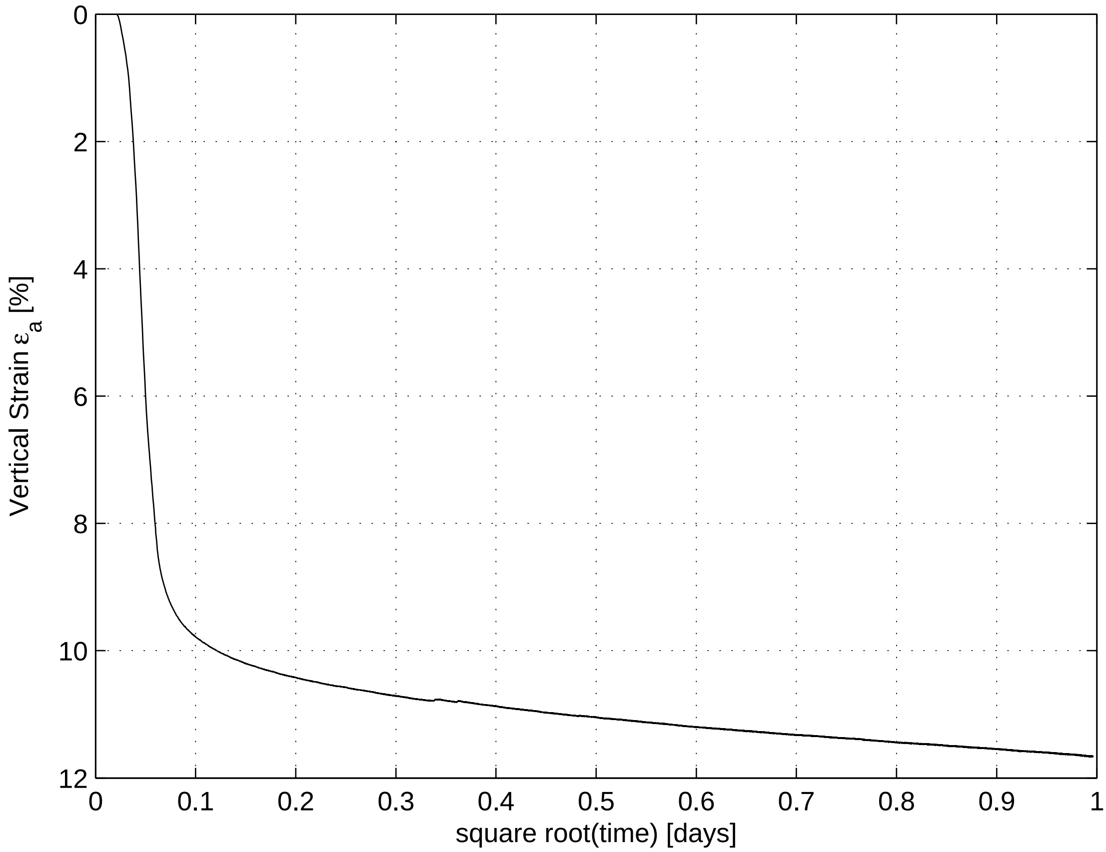
date	signed
2016−04−14	konstad
project	version
1209862.11	1.3
appendix	page
NW1A2−d1−1D	3

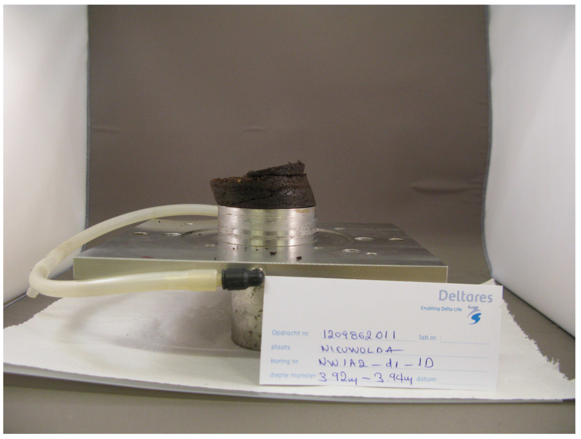
Shear degradation and damping curves for peat

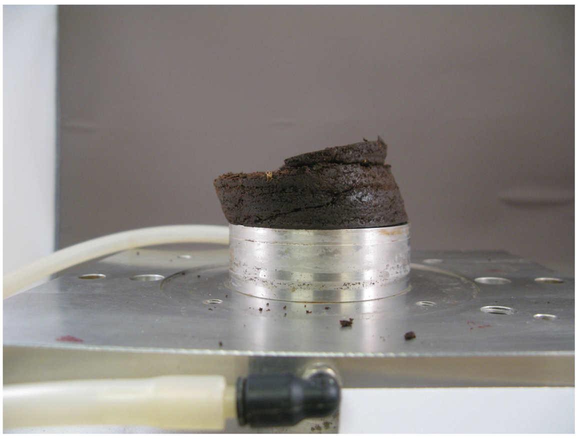
Direct Simple Shear test on sample NW1A2−d1−1D

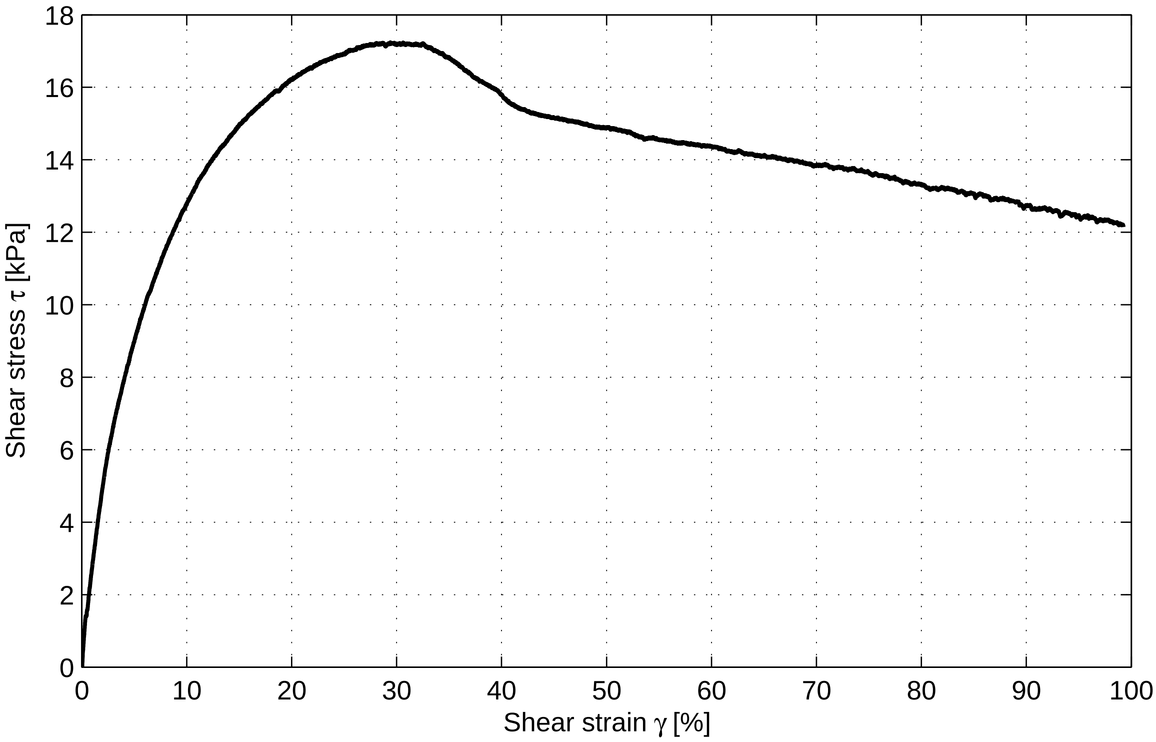
Direct Simple Shear Test



Vertical Strain ε_a [%]
0
2
4
6
8
10
12
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
square root(time) [days]


Deltares
Enabling Delta Life
Opdracht nr. 1209862011
lab.nr. :
plaats NIEUWOLDA
boring nr. NW1A2-d1-1D
diepte monster 3.92m - 3.94m
datum :

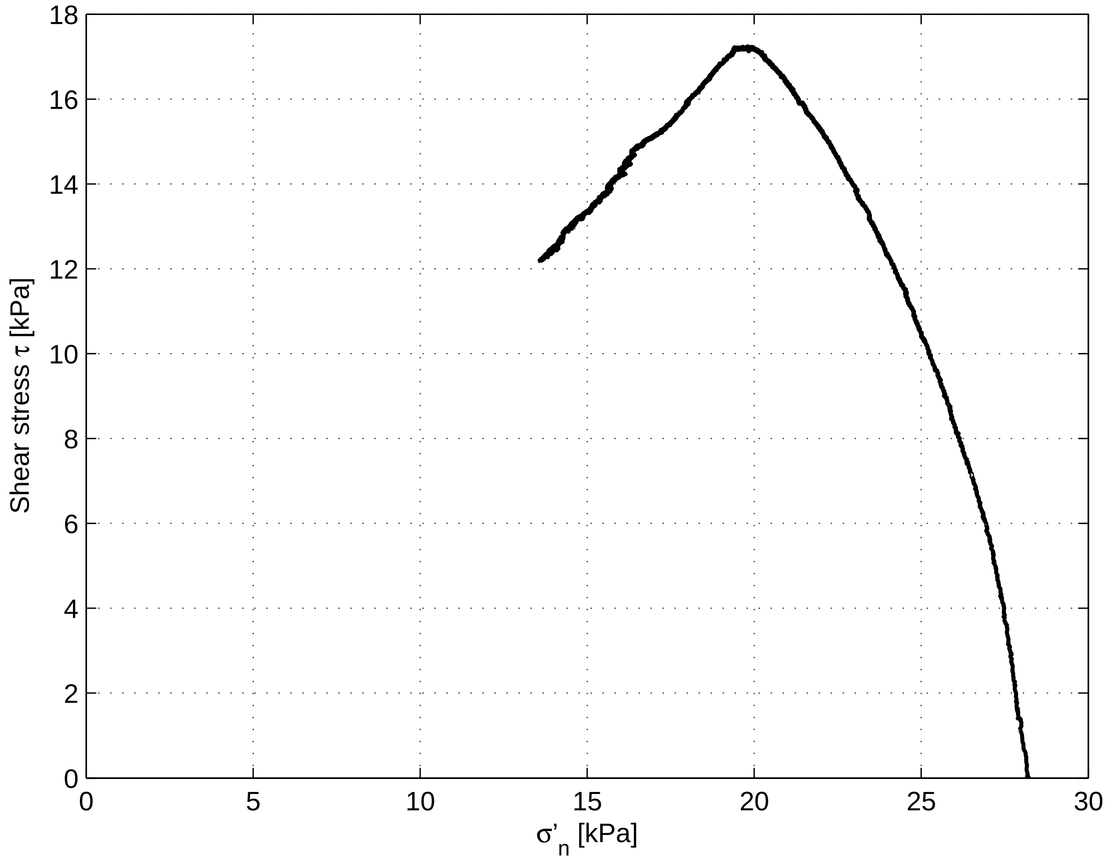


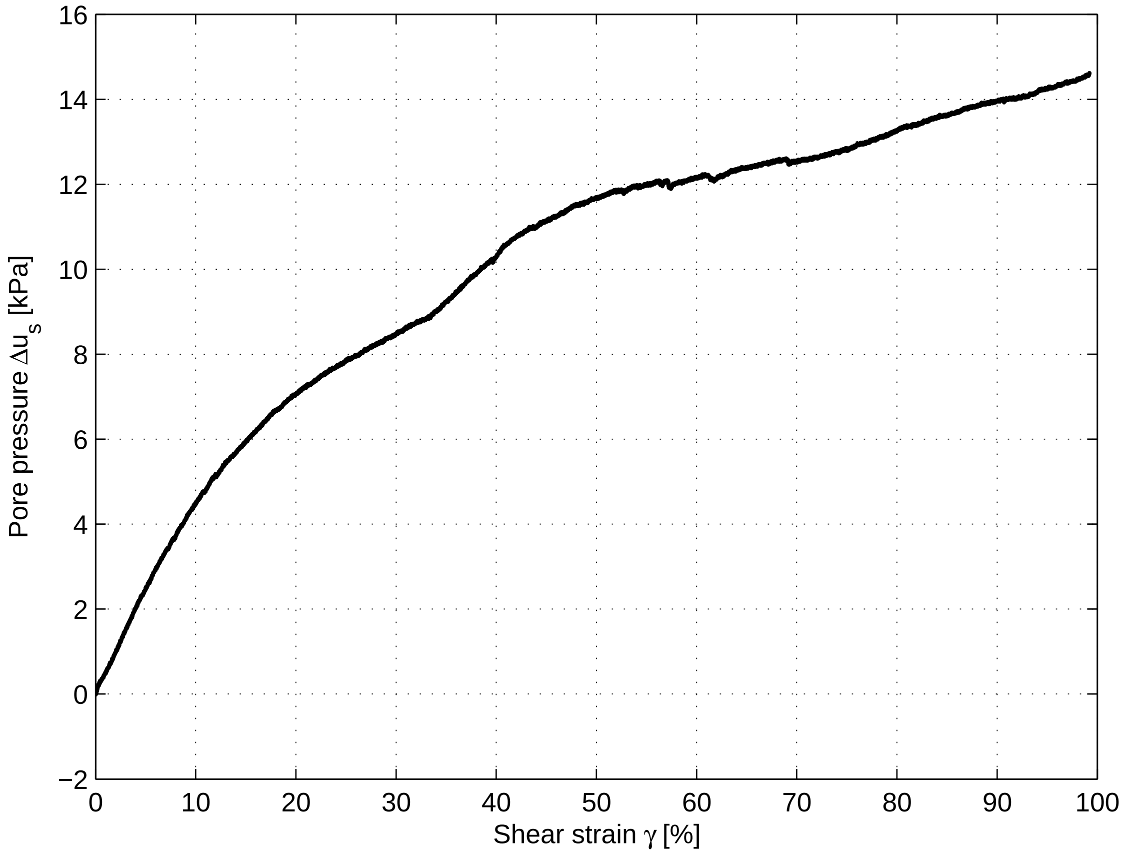


Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−C
Sample name	NW1A2−d2−1B
Bore code	NW1A2−D
Depth top [m]	−6.34
Depth bottom [m]	−6.36
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	1.0
S_0 [%]	−
Void ratio start shear [−]	0.96
w_0 [%]	659.3
w_{final} [%]	660.4
Consolidation stress [kPa]	28.1
Consolidation strain [%]	14.64
Strain rate [%/h]	7.9
Max shear stress [kPa]	17.2
Vert. stress at max shear stress [kPa]	19.8
Horz. strain at max shear stress [kPa]	29.4
σ_v at γ = 40% [kPa]	17.9
τ at γ = 40% [kPa]	15.8
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample’s photos).





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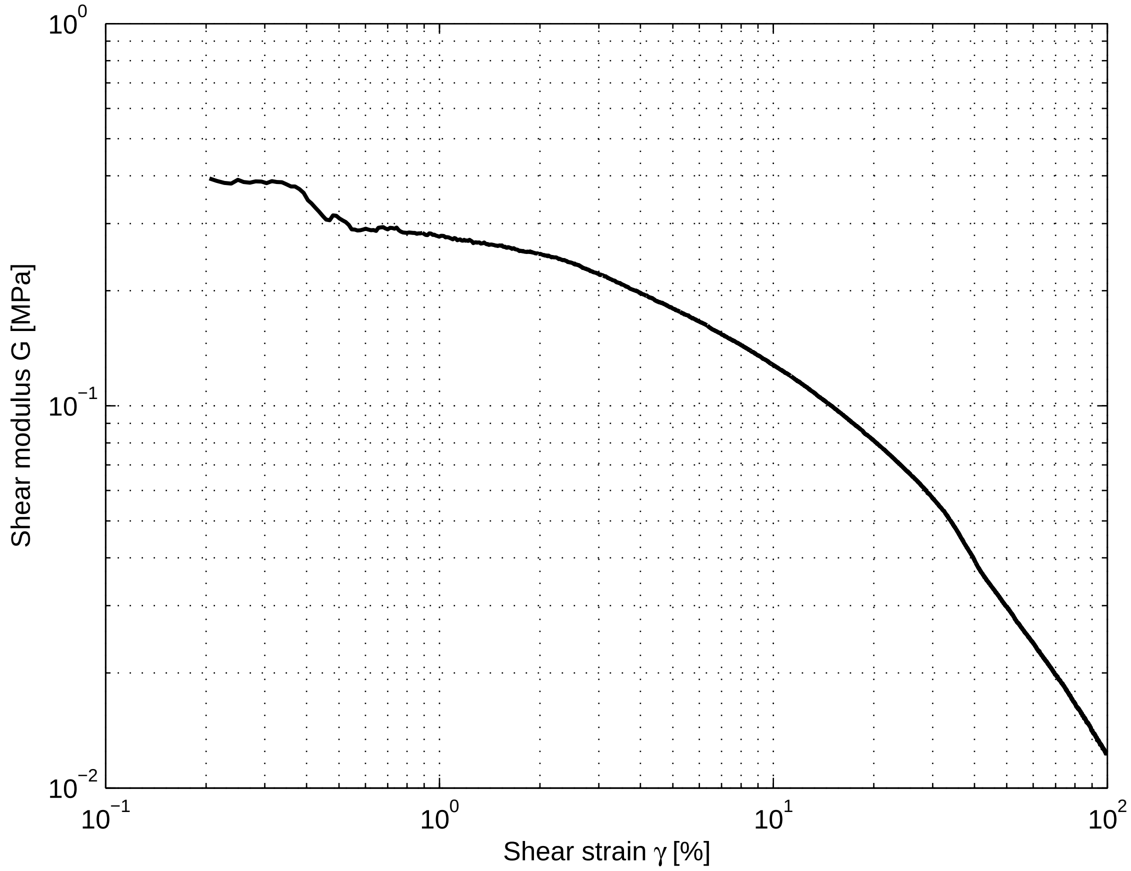
	date	signed
	2016−04−14	konstad
Shear degradation and damping curves for peat Direct Simple Shear test on sample NW1A2−d2−1B	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−d2−1B	page 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	9.0	N.A	25.7	2.5	0.2
15% deformation	15.0	N.A	22.3	5.9	0.1
30% deformation	17.2	N.A	19.7	8.5	0.1
Maximum strain	12.2	N.A	13.6	14.6	0.0
Maximum τ	17.2	0.00	19.8	8.4	0.1

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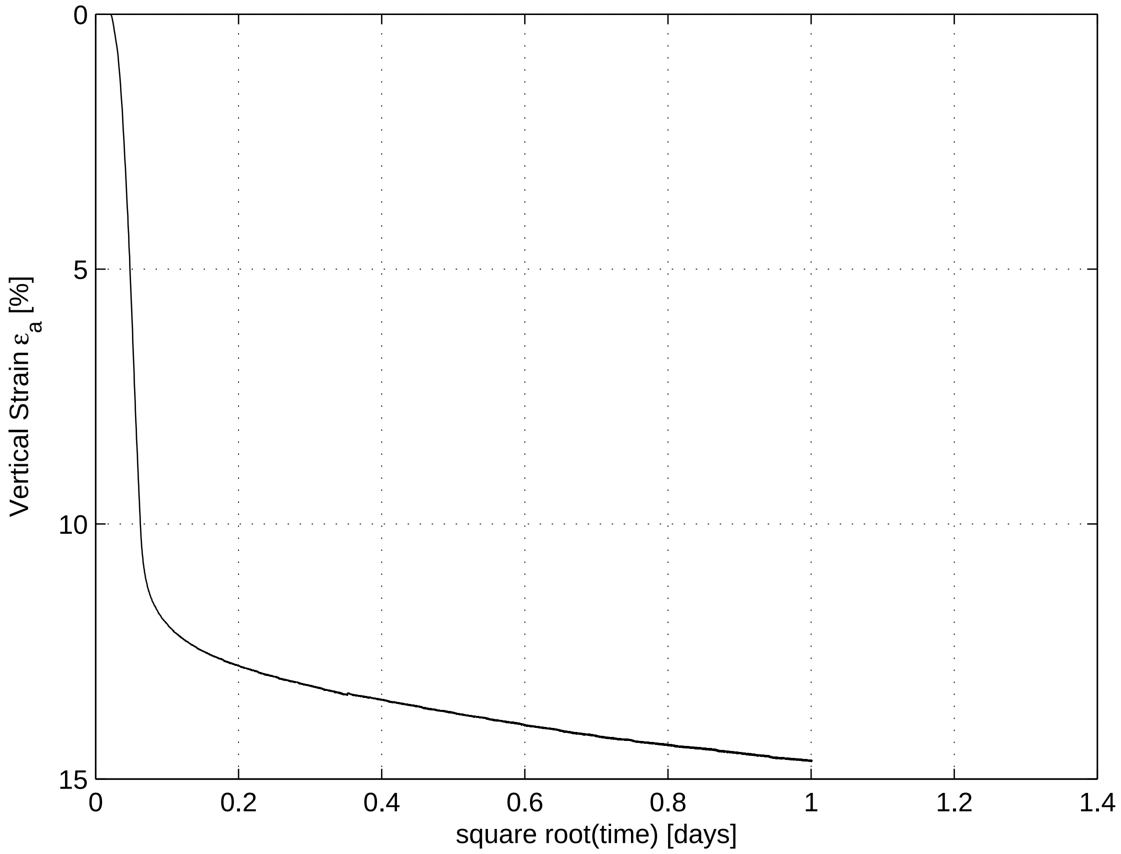
Shear degradation and damping curves for peat

Direct Simple Shear test on sample NW1A2−d2−1B

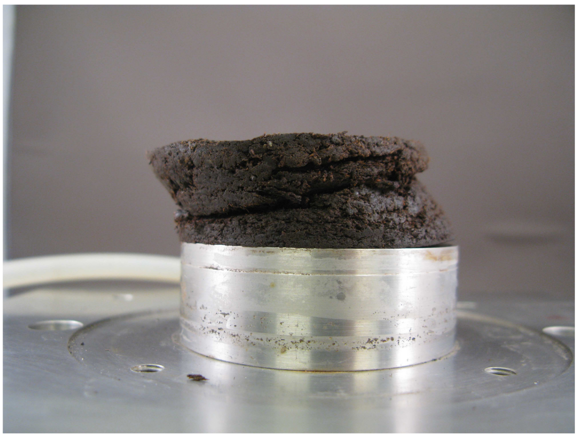
Direct Simple Shear Test

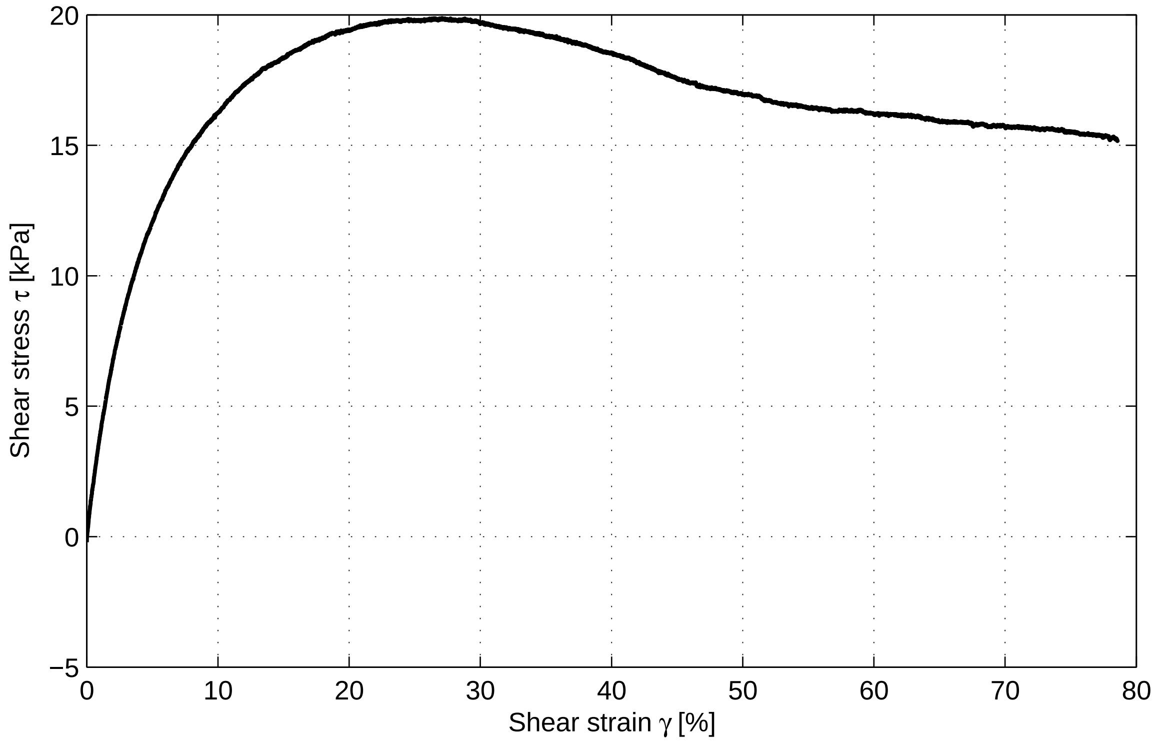
date	signed
2016−04−14	konstad
project	version
1209862.11	1.3
appendix	page
NW1A2−d2−1B	3



0
5
10
15
Vertical Strain ε_a [%]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
square root(time) [days]


Deltares
Enabling Delta Life
opdracht nr. : 1209862.011
lab. nr. :
plaats : NIEUWOLDA
boring nr. : NW1A2 – d2 – 1B
diepte monster : 4.80m – 4.85m
datum :





Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.7
Test type	Constant height
Apparatus code	DSS−D
Sample name	NW1A2−d2−2C
Bore code	NW1A2−D
Depth top [m]	−6.74
Depth bottom [m]	−6.76
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.94
w_0 [%]	612.4
w_{final} [%]	568.3
Consolidation stress [kPa]	28.7
Consolidation strain [%]	13.56
Strain rate [%/h]	8.0
Max shear stress [kPa]	19.9
Vert. stress at max shear stress [kPa]	20.3
Horz. strain at max shear stress [kPa]	26.6
σ_v at γ = 40% [kPa]	18.6
τ at γ = 40% [kPa]	18.5
Sample Disturbance Index [%]	−
SDI qualification	−

Formation of a shearing plane (refer to sample’s photos).

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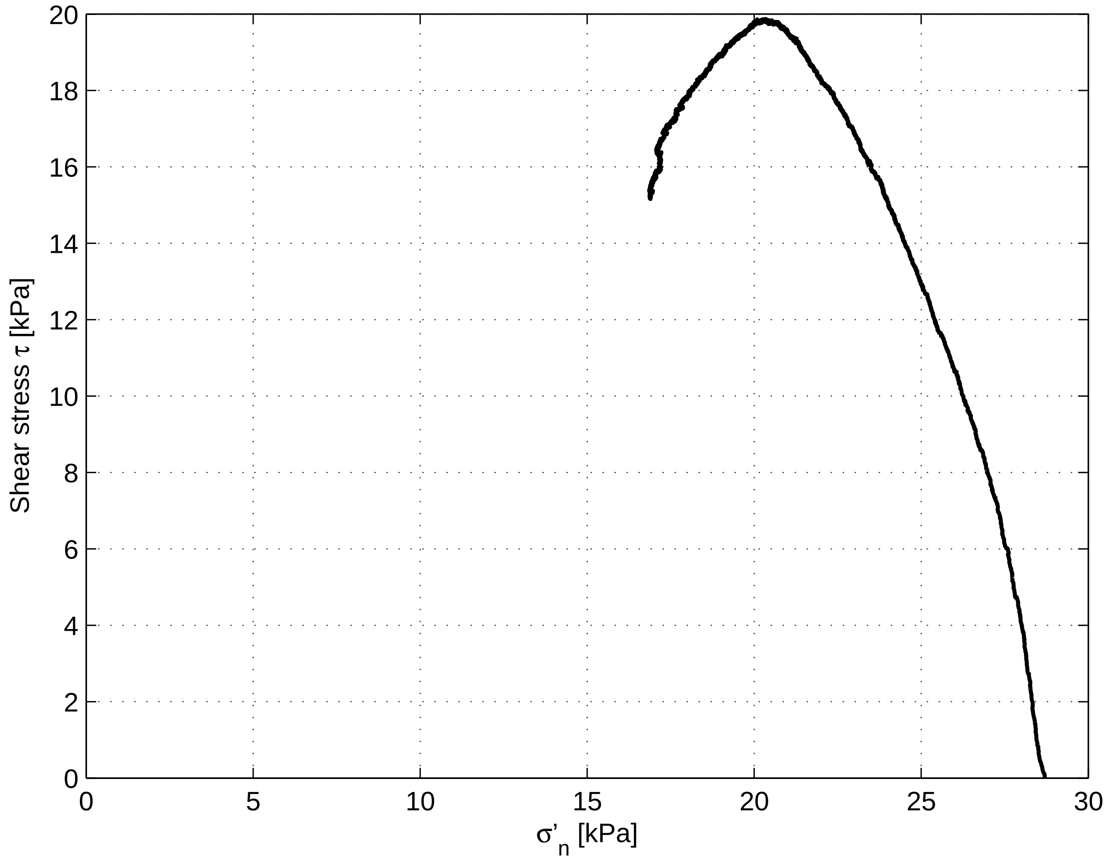
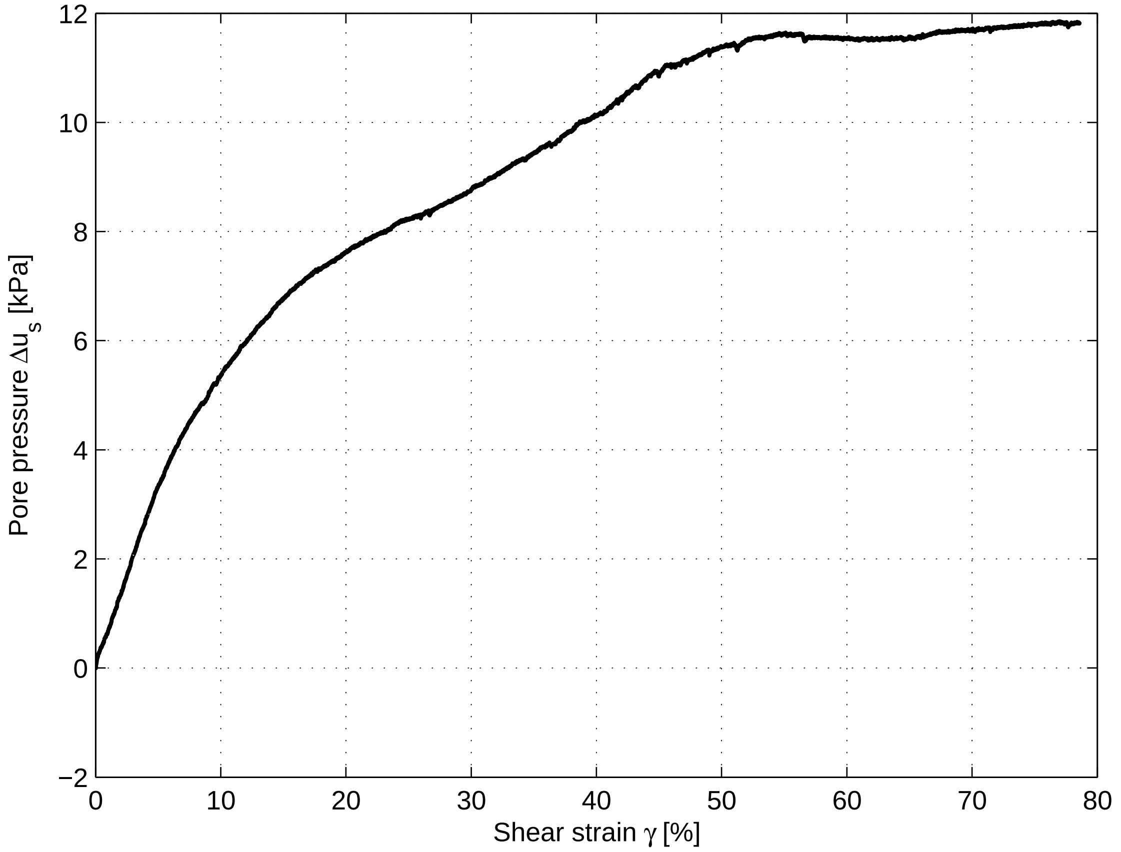
Shear degradation and damping curves for peat	date 2016−04−14	signed konstad
Direct Simple Shear test on sample NW1A2−d2−2C	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−d2−2C	page 1





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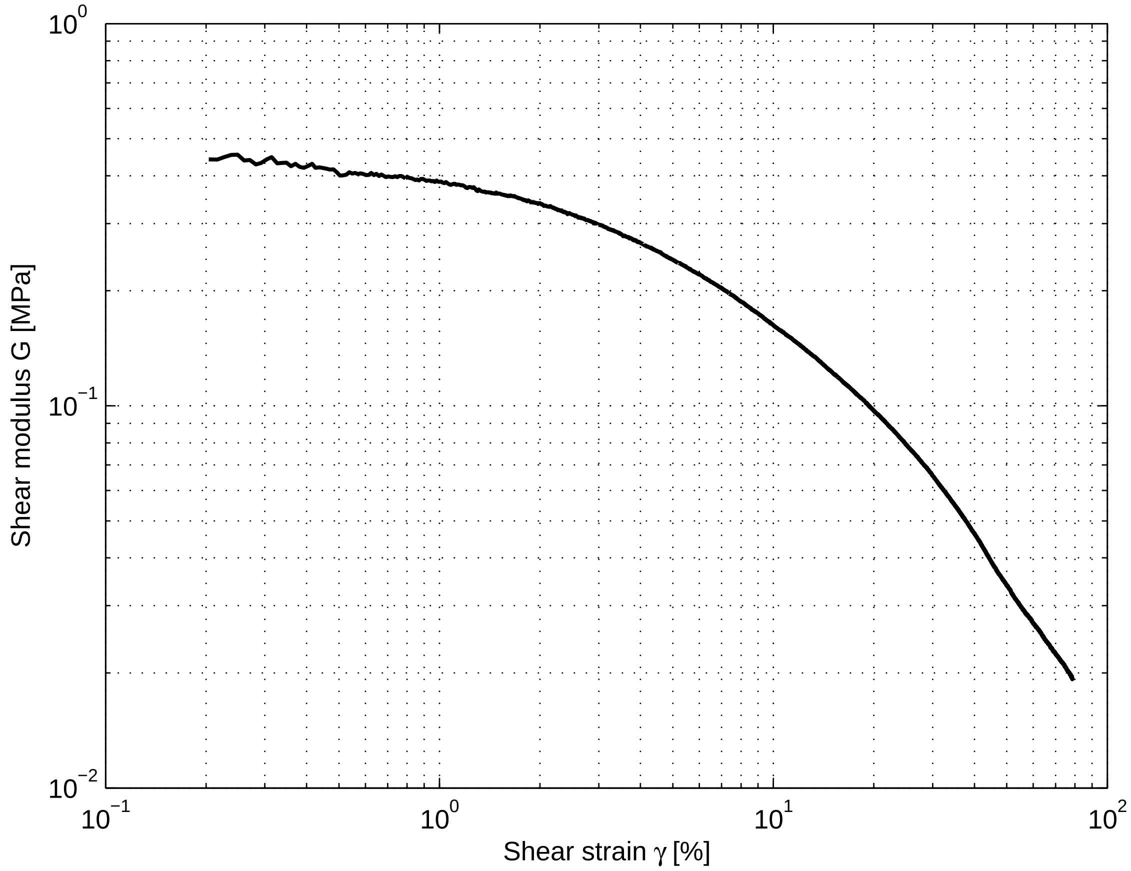
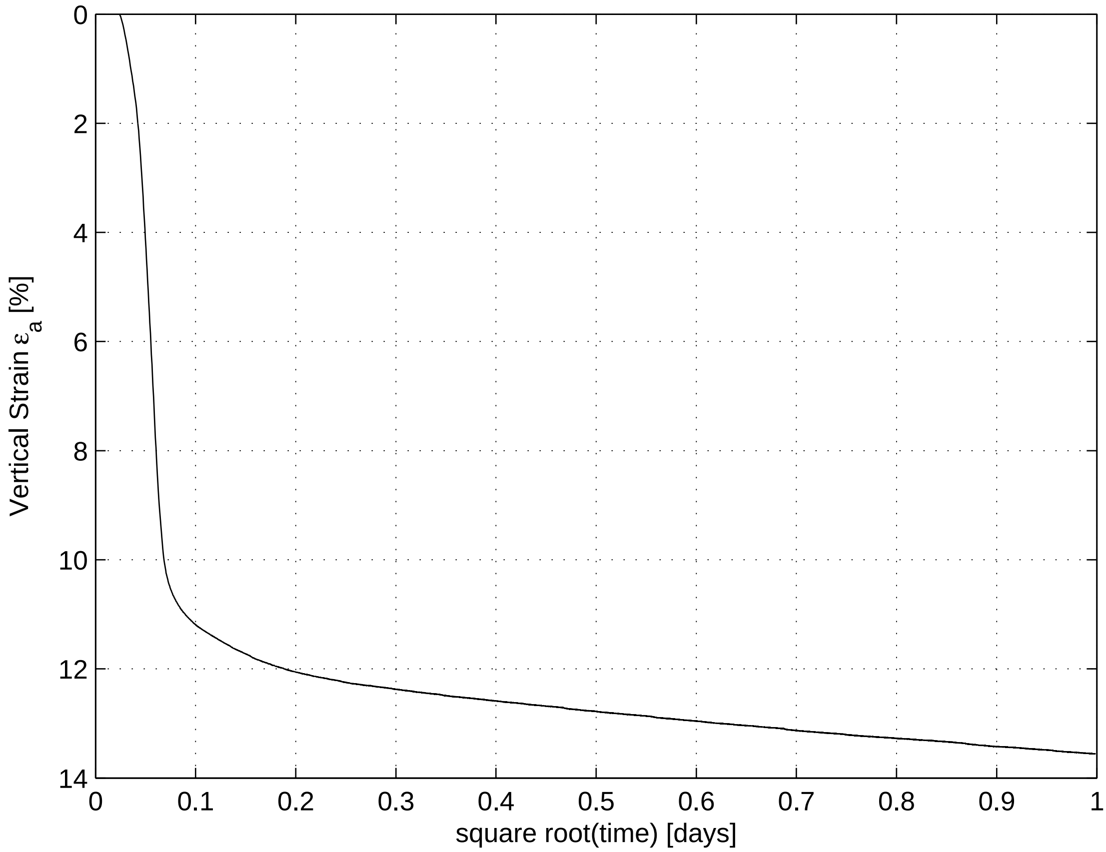
Shear degradation and damping curves for peat				project 1209862.11	version 1.3
Direct Simple Shear test on sample NW1A2−d2−2C					
Direct Simple Shear Test				appendix NW1A2−d2−2C	page 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	12.1	N.A	25.4	3.3	0.2
15% deformation	18.3	N.A	21.9	6.8	0.1
30% deformation	19.7	N.A	20.0	8.8	0.1
Maximum strain	15.1	N.A	16.9	11.8	0.0
Maximum τ	19.9	0.00	20.3	8.4	0.1



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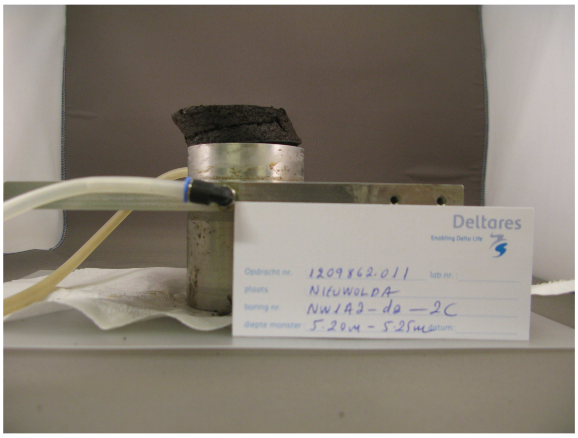
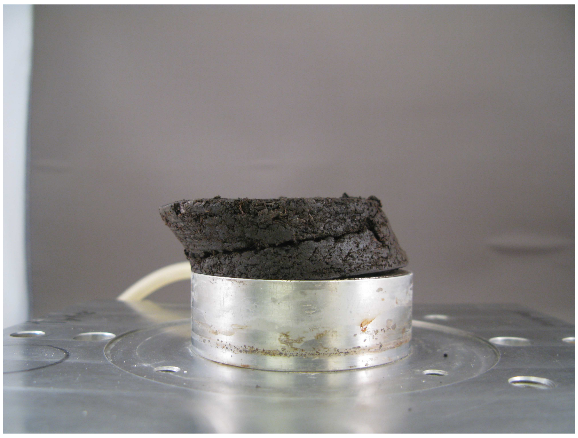
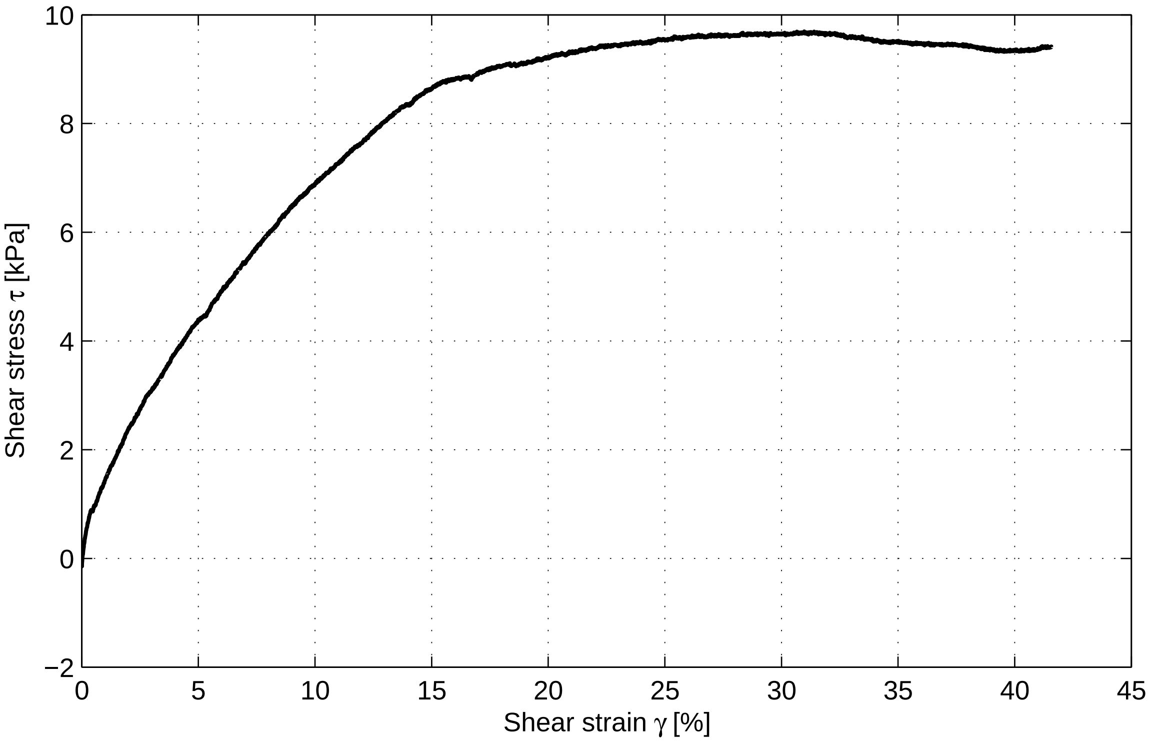
Shear degradation and damping curves for peat	date 2016−04−14	signed konstadi
Direct Simple Shear test on sample NW1A2−d2−2C	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix NW1A2−d2−2C	page 4

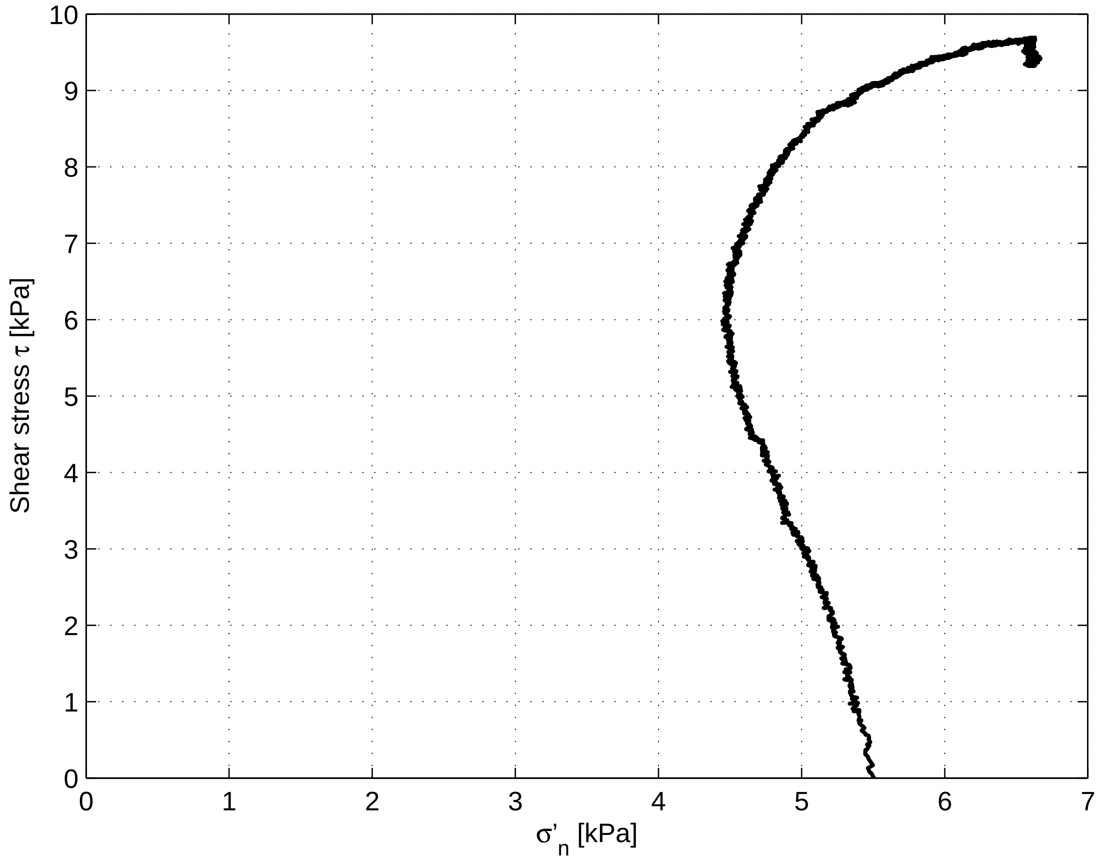

Deltares
Enabling Delta Life
Opdracht nr. 1209862.011
lab.nr.
plaats NIEUWOLDA
boring nr. NW1A2-d2 —2C
diepte monster 5.20m - 5.25m
datum

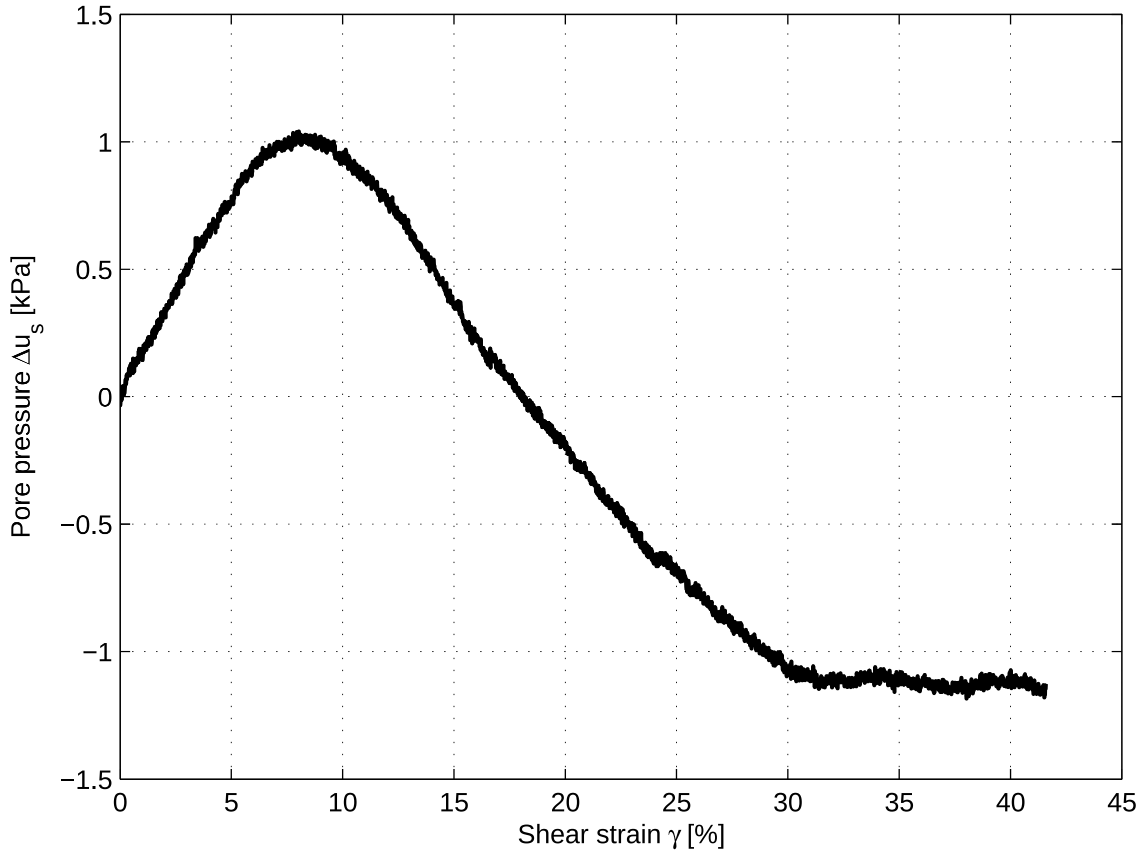




Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−C
Sample name	SB4A−A2−2C
Bore code	SB4A−A
Depth top [m]	−3.48
Depth bottom [m]	−3.50
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.93
w_0 [%]	533.4
w_{final} [%]	554.4
Consolidation stress [kPa]	5.5
Consolidation strain [%]	2.60
Strain rate [%/h]	8.0
Max shear stress [kPa]	9.7
Vert. stress at max shear stress [kPa]	6.6
Horz. strain at max shear stress [kPa]	31.0
σ_v at γ = 40% [kPa]	6.6
τ at γ = 40% [kPa]	9.4
Sample Disturbance Index [%]	−
SDI qualification	−





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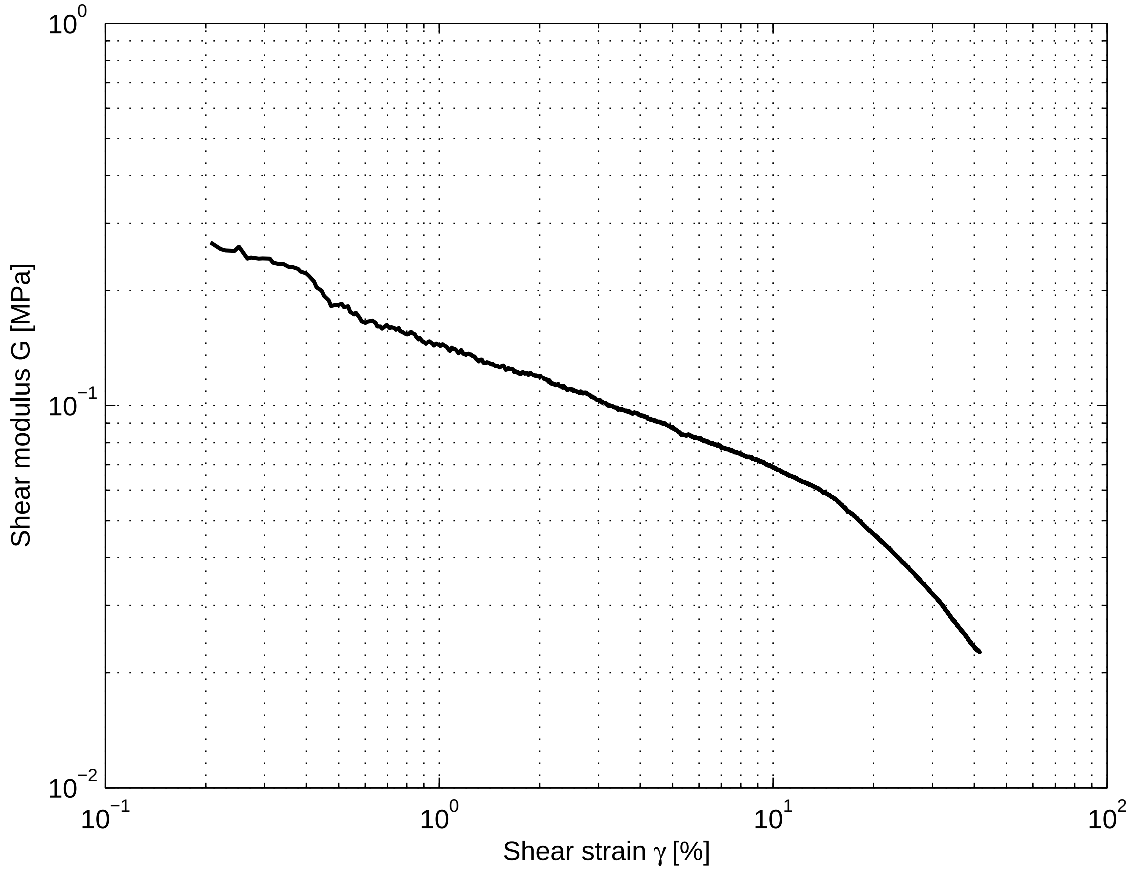
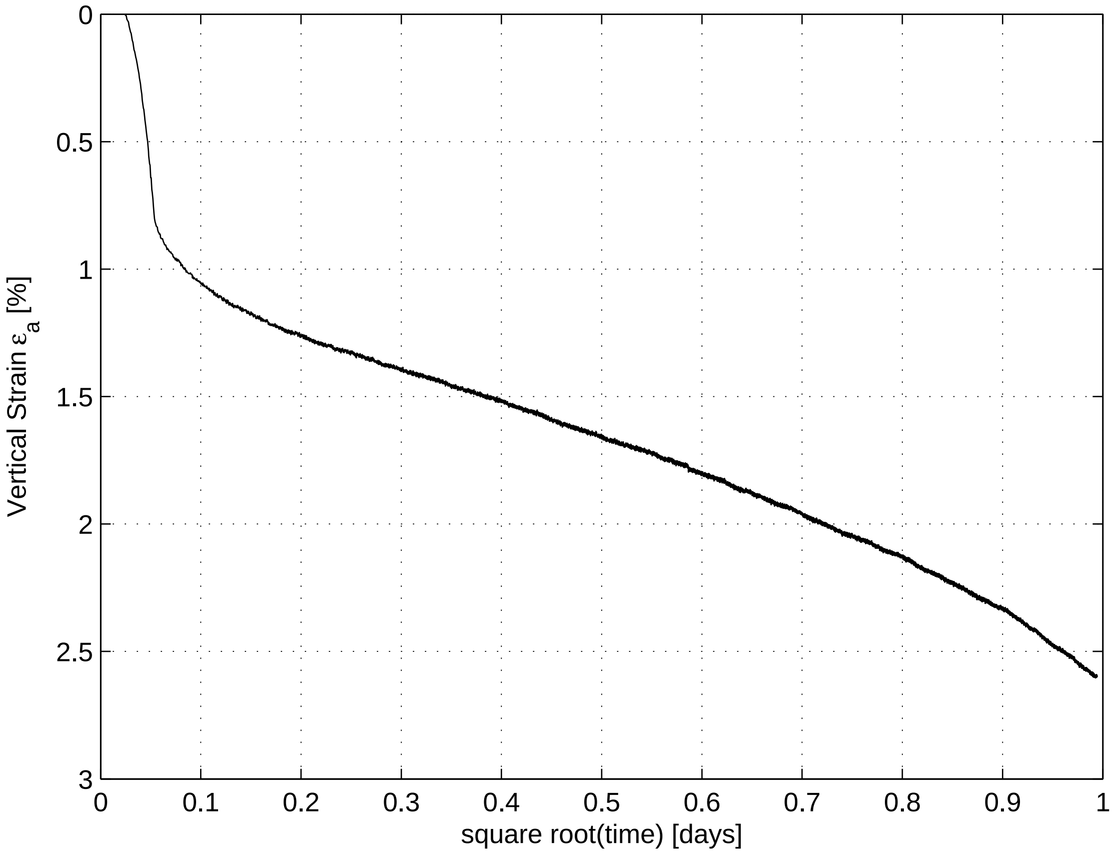
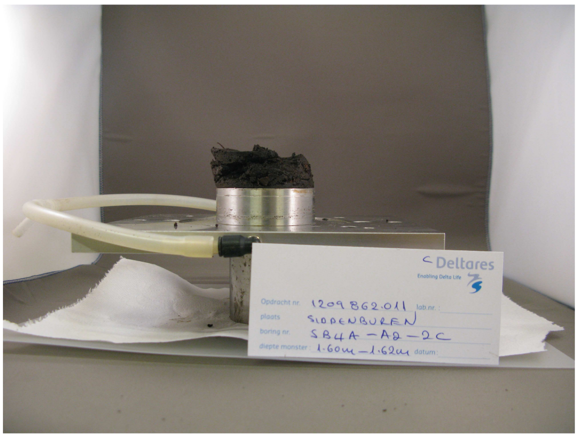
	date	signed
Shear degradation and damping curves for peat	2016−04−18	konstad
Direct Simple Shear test on sample SB4A−A2−2C	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix SB4A−A2−2C	page 2

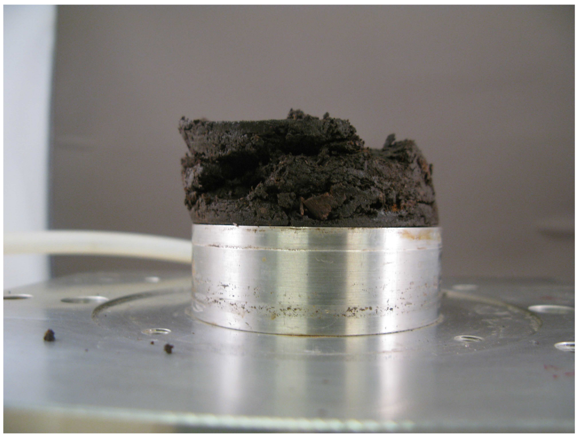


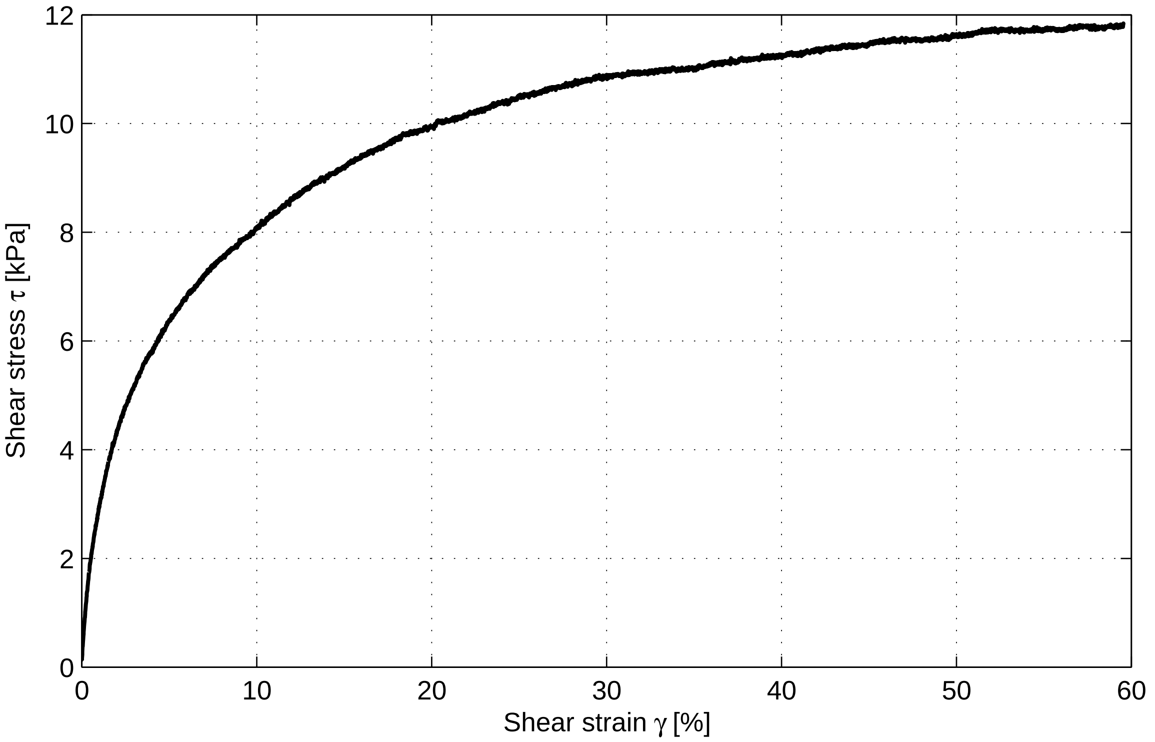
γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	4.4	N.A	4.7	0.8	0.1
15% deformation	8.6	N.A	5.1	0.4	0.1
30% deformation	9.7	N.A	6.6	−1.1	0.0
Maximum strain	9.4	N.A	6.6	−1.1	0.0
Maximum τ	9.7	0.02	6.6	−1.1	0.0



Vertical Strain ε_a [%]
0
0.5
1
1.5
2
2.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
square root(time) [days]


Deltares
Enabling Delta Life
Opdracht nr. 1209862.011 lab.nr. :
plaats SIDDENBUREN
boring nr. SB4A-A2-2C
diepte monster : 1.60m-1.62m datum:





Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−D
Sample name	SM2C−A2−1A
Bore code	SM2C−A
Depth top [m]	−3.02
Depth bottom [m]	−3.04
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	1.0
S_0 [%]	−
Void ratio start shear [−]	1.00
w_0 [%]	476.5
w_{final} [%]	451.5
Consolidation stress [kPa]	7.8
Consolidation strain [%]	4.14
Strain rate [%/h]	8.0
Max shear stress [kPa]	11.8
Vert. stress at max shear stress [kPa]	9.4
Horz. strain at max shear stress [kPa]	59.5
σ_v at γ = 40% [kPa]	8.7
τ at γ = 40% [kPa]	11.2
Sample Disturbance Index [%]	−
SDI qualification	−

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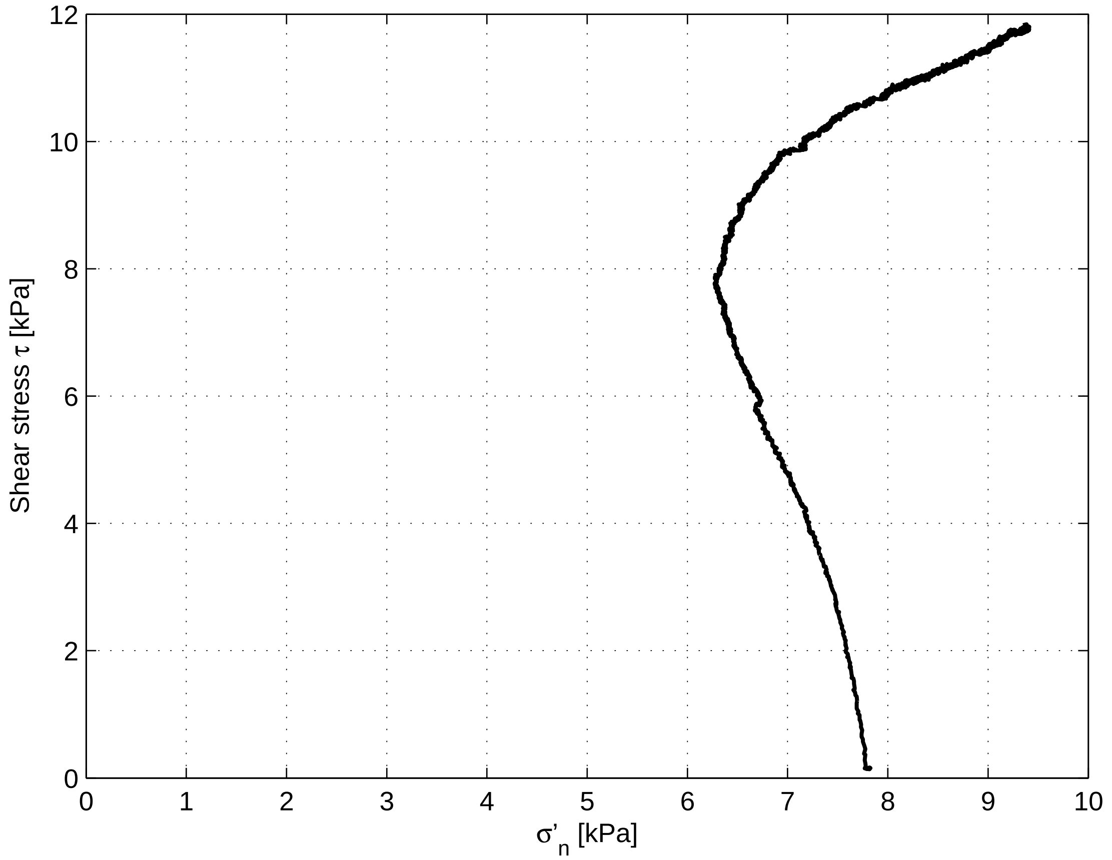
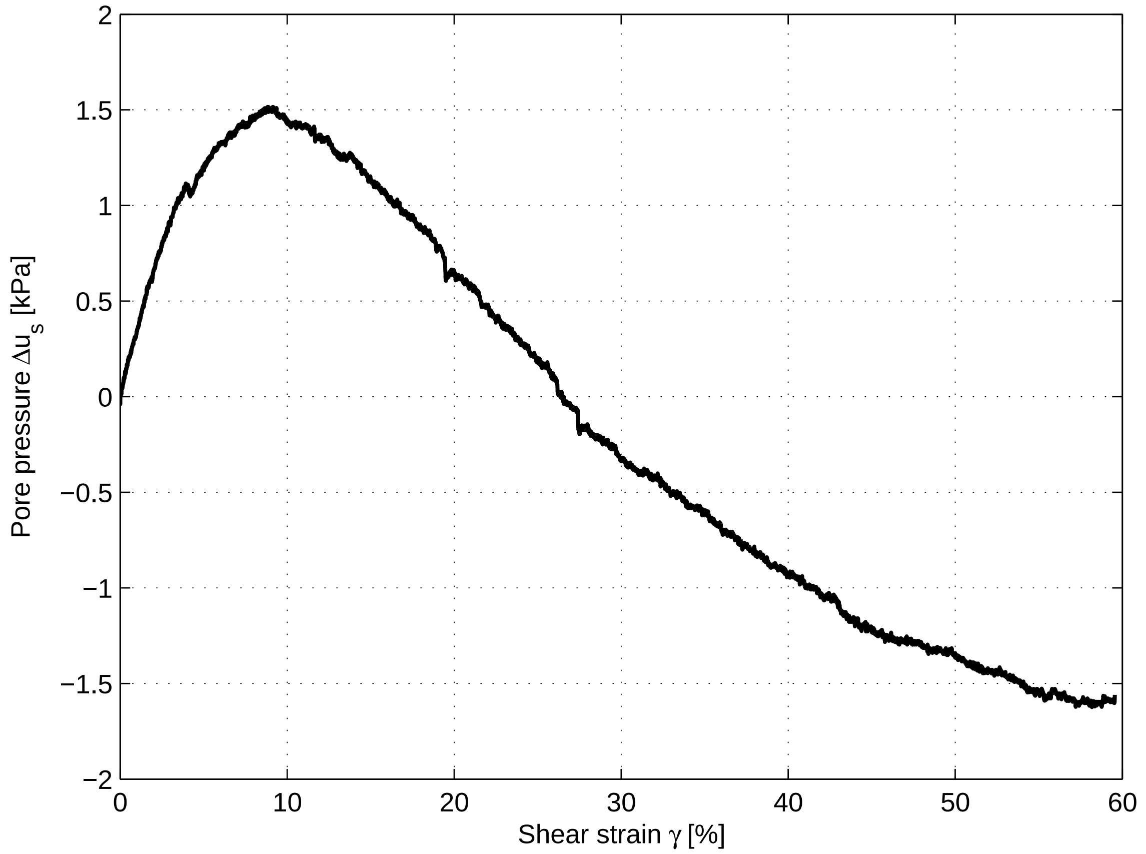
Shear degradation and damping curves for peat	date: 2016−04−15	signed: konstad
Direct Simple Shear test on sample SM2C−A2−1A	project: 1209862.11	version: 1.3
Direct Simple Shear Test	appendix: SM2C−A2−1A	page: 1





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Homepage:
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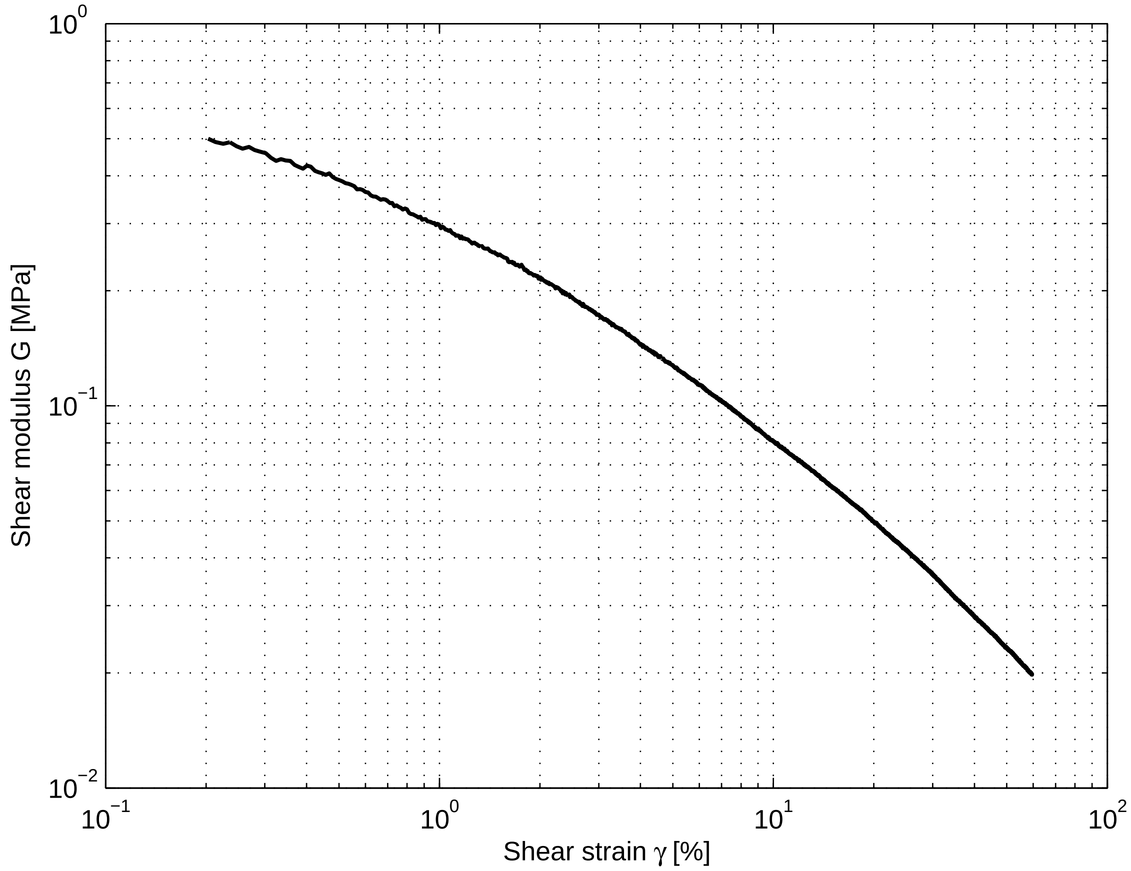
	date 2016−04−15	signed konstad
Shear degradation and damping curves for peat Direct Simple Shear test on sample SM2C−A2−1A	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix SM2C−A2−1A	page 2

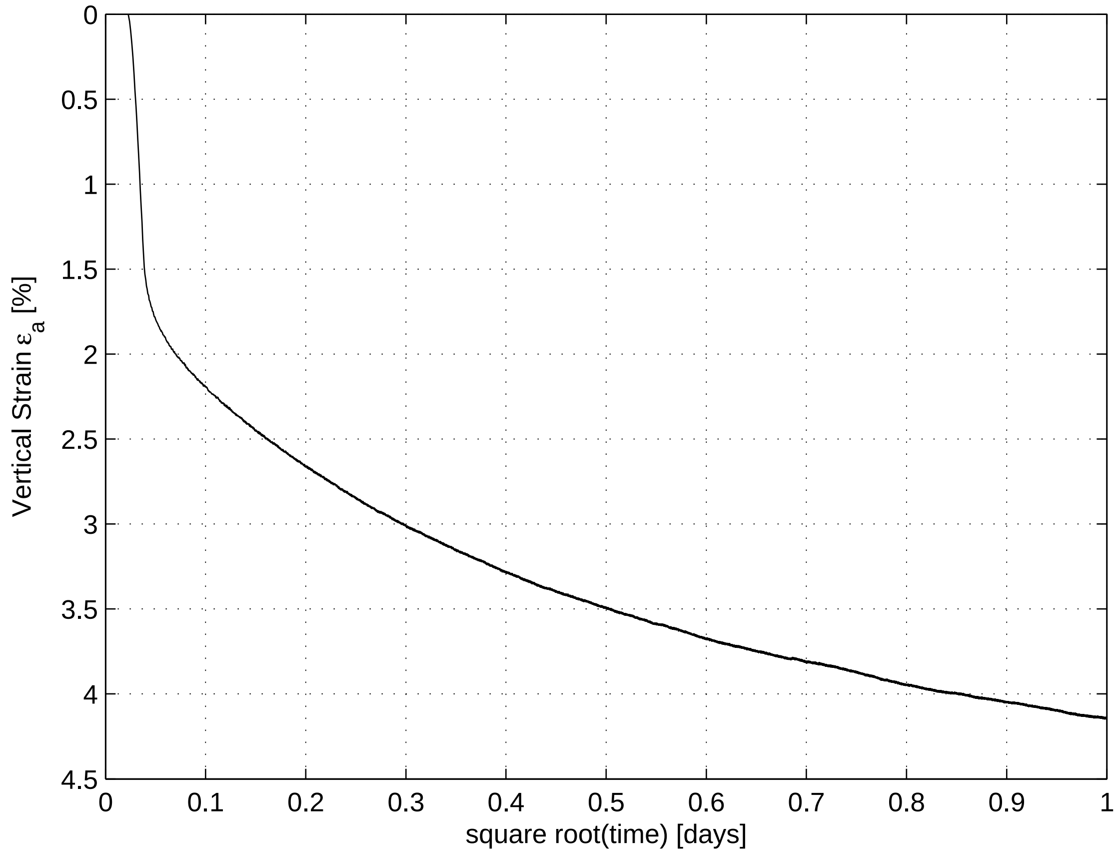


γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	6.4	N.A	6.6	1.2	0.1
15% deformation	9.2	N.A	6.7	1.1	0.1
30% deformation	10.9	N.A	8.1	−0.3	0.0
Maximum strain	11.8	N.A	9.3	−1.6	0.0
Maximum τ	11.8	0.00	9.4	−1.6	0.0

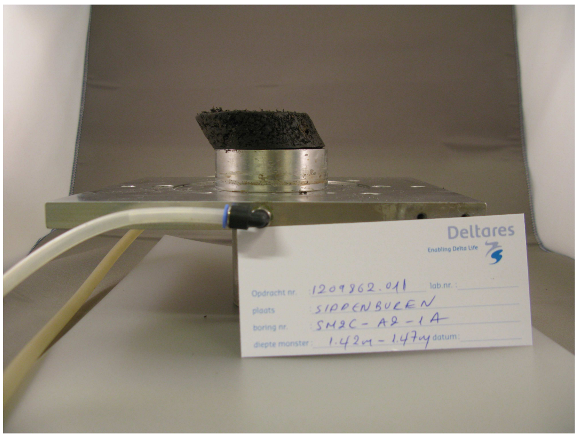
Shear degradation and damping curves for peat

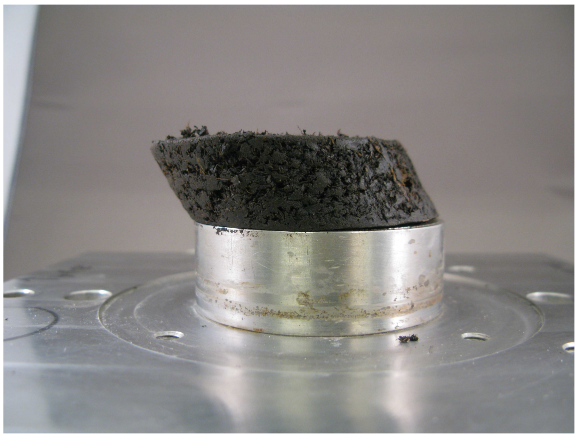
Direct Simple Shear test on sample SM2C−A2−1A

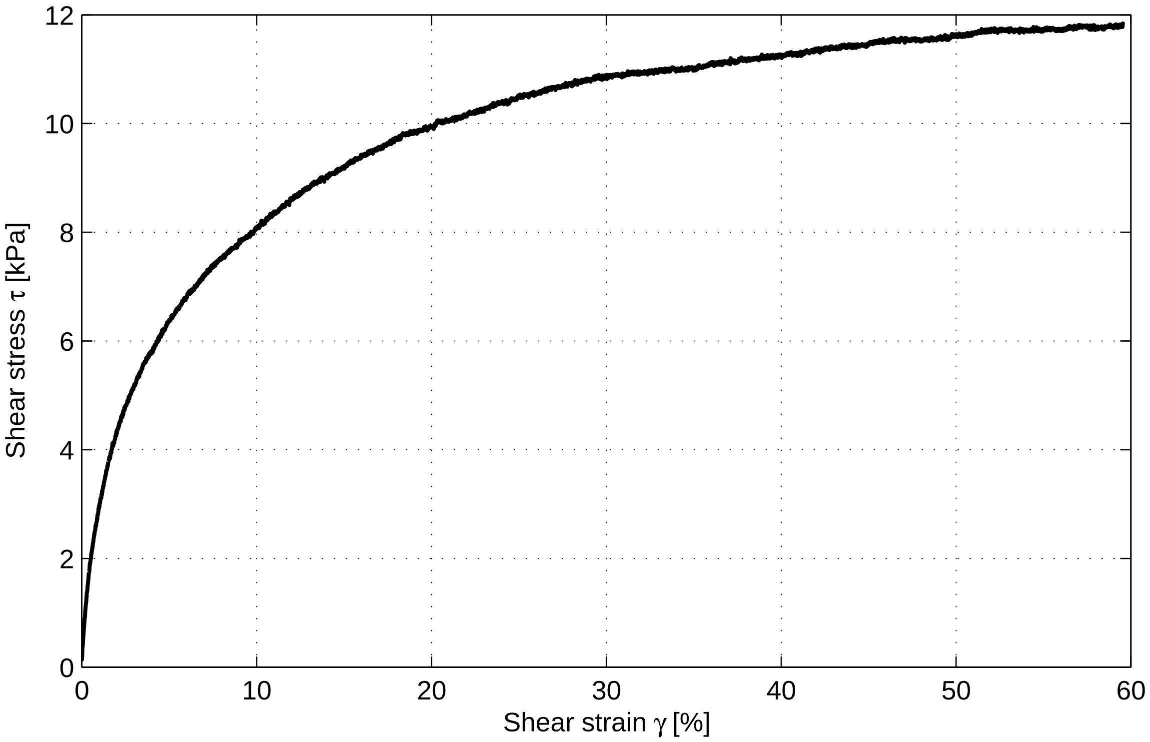
Direct Simple Shear Test



Vertical Strain ε_a [%]
square root(time) [days]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Deltares
Enabling Delta Life
Opdracht nr. : 1209862.011
lab.nr. :
plaats : SIPPENBUREN
boring nr. : SM2C - A2 - 1A
diepte monster : 1.42m - 1.47m
datum :





Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−D
Sample name	SM2C−A2−1A
Bore code	SM2C−A
Depth top [m]	−3.02
Depth bottom [m]	−3.04
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	1.0
S_0 [%]	−
Void ratio start shear [−]	1.00
w_0 [%]	476.5
w_{final} [%]	451.5
Consolidation stress [kPa]	7.8
Consolidation strain [%]	4.14
Strain rate [%/h]	8.0
Max shear stress [kPa]	11.8
Vert. stress at max shear stress [kPa]	9.4
Horz. strain at max shear stress [kPa]	59.5
σ_v at γ = 40% [kPa]	8.7
τ at γ = 40% [kPa]	11.2
Sample Disturbance Index [%]	−
SDI qualification	−

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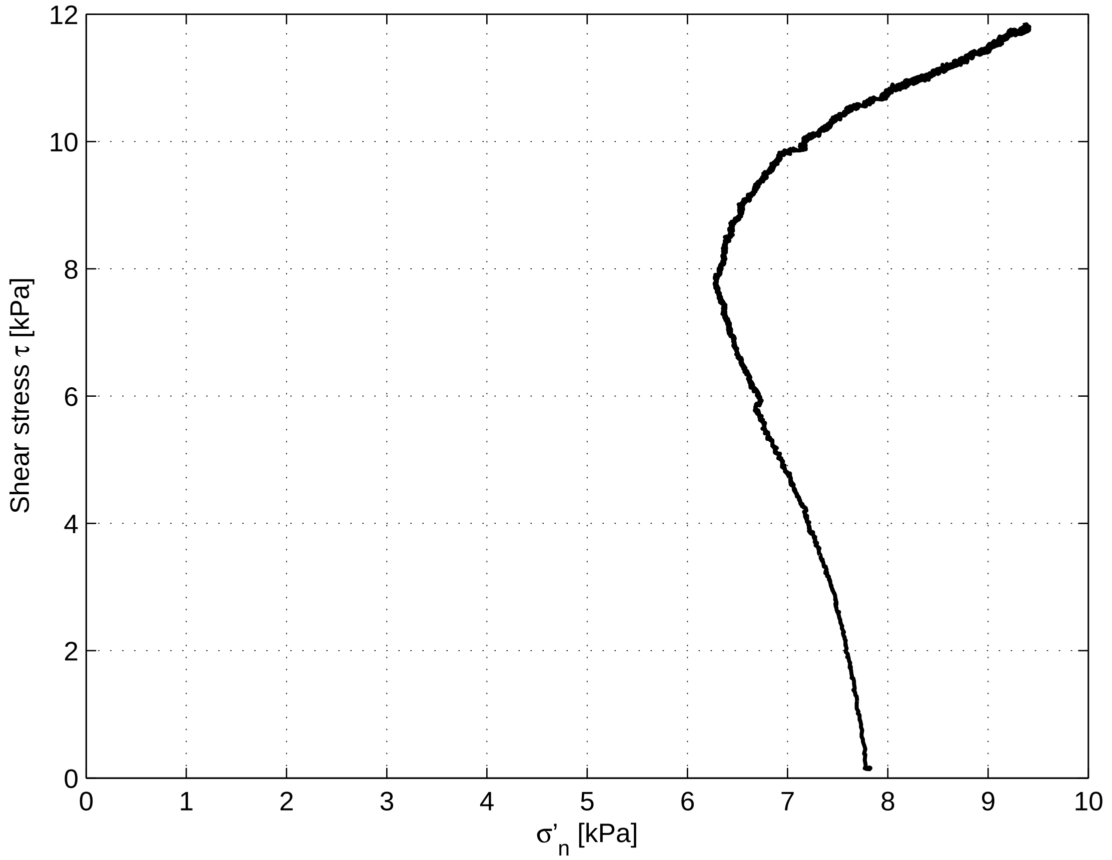
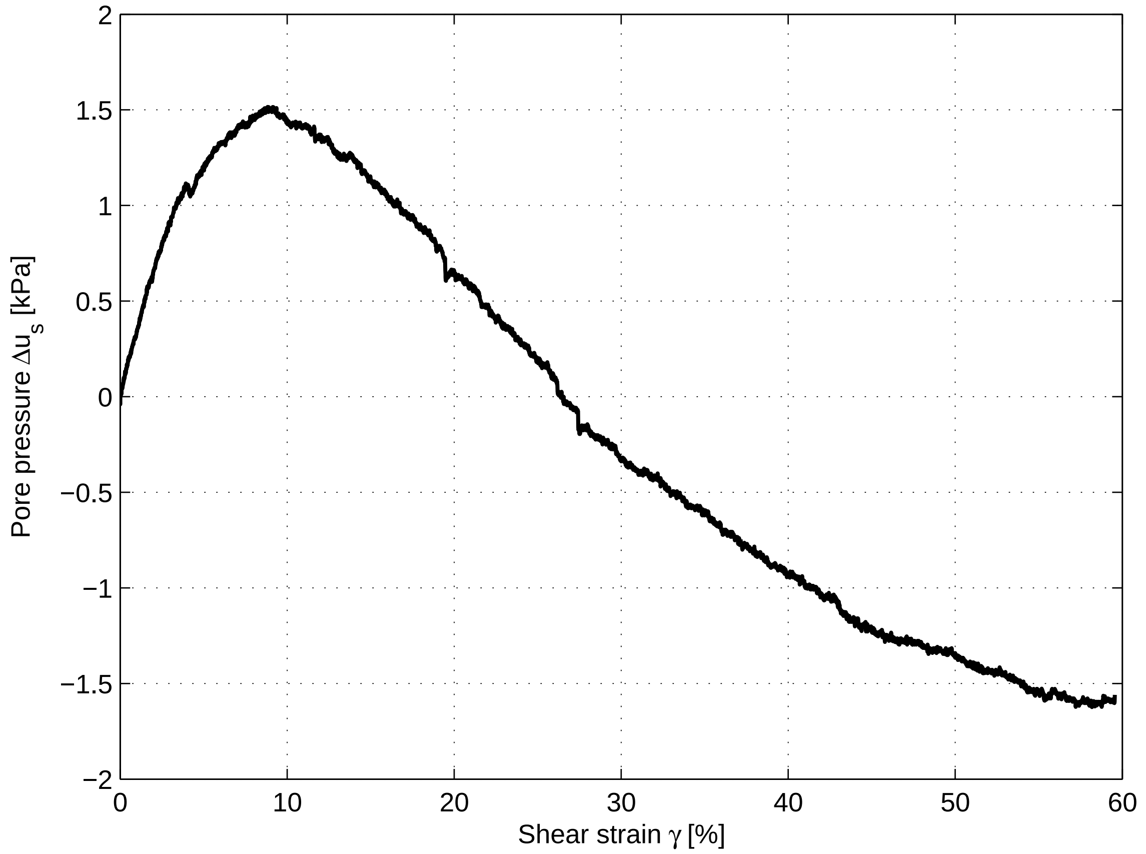
Shear degradation and damping curves for peat	date 2016−04−15	signed konstad
Direct Simple Shear test on sample SM2C−A2−1A	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix SM2C−A2−1A	page 1





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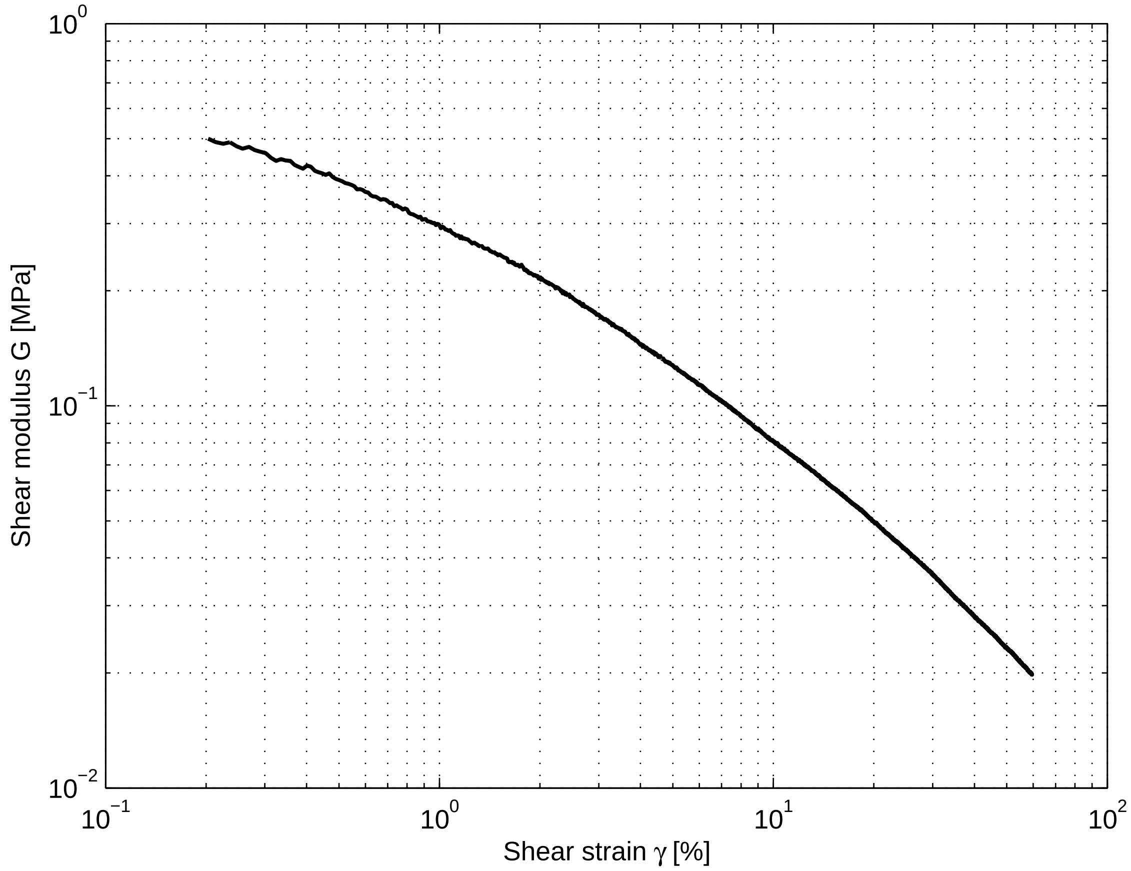
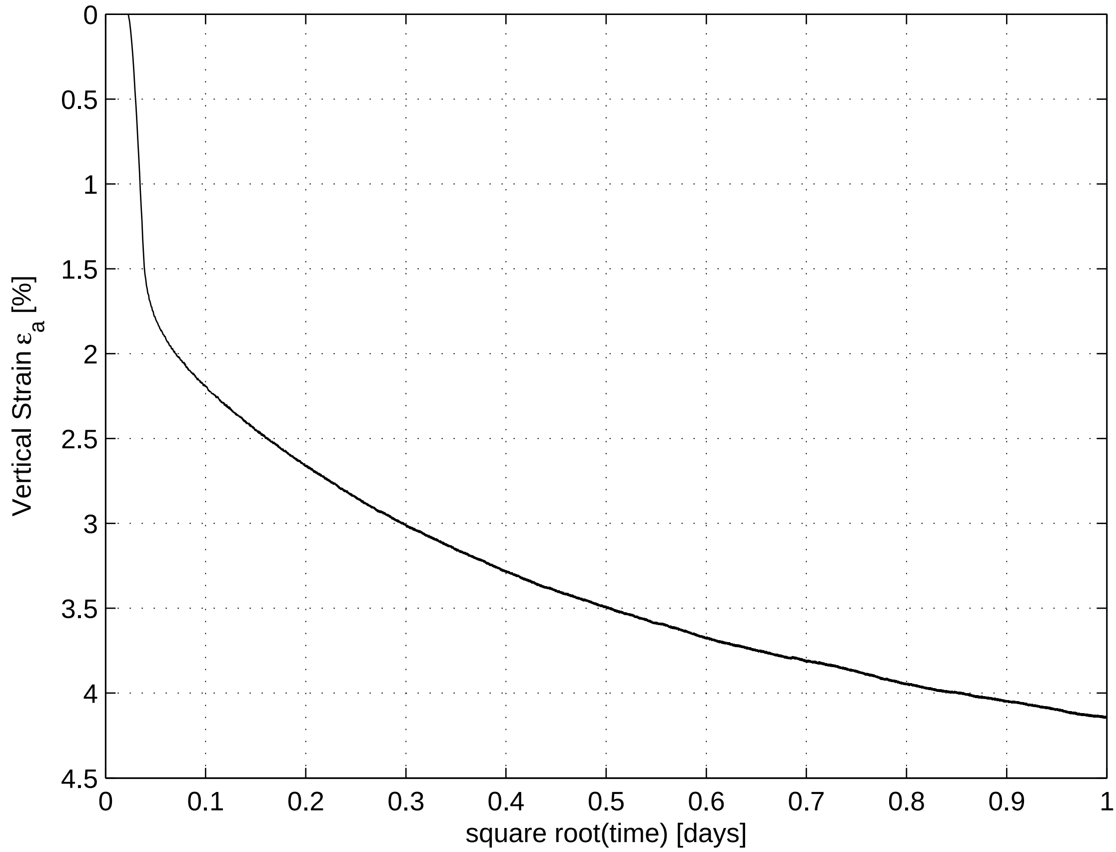
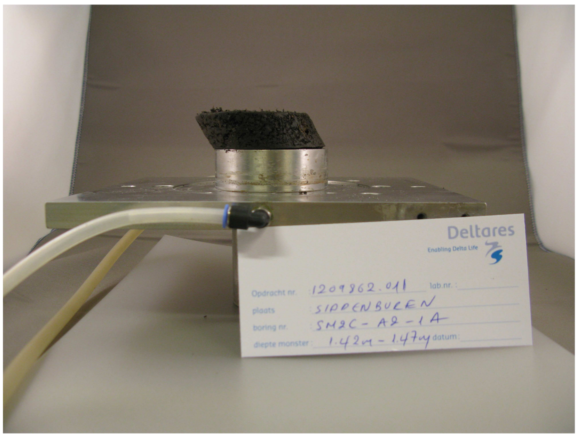
Shear degradation and damping curves for peat	date 2016−04−15	signed konstad
Direct Simple Shear test on sample SM2C−A2−1A	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix SM2C−A2−1A	page 2

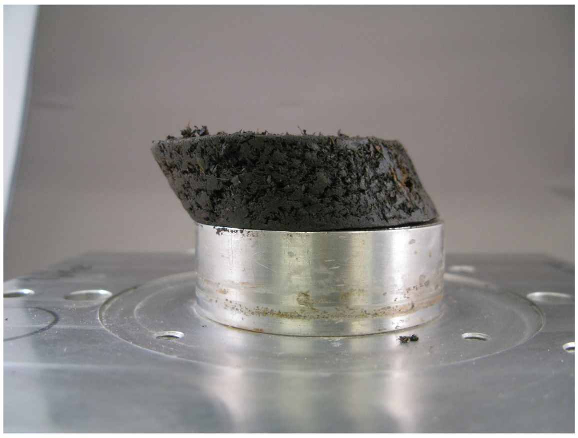


γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	6.4	N.A	6.6	1.2	0.1
15% deformation	9.2	N.A	6.7	1.1	0.1
30% deformation	10.9	N.A	8.1	−0.3	0.0
Maximum strain	11.8	N.A	9.3	−1.6	0.0
Maximum τ	11.8	0.00	9.4	−1.6	0.0



Vertical Strain εa [%]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
square root(time) [days]





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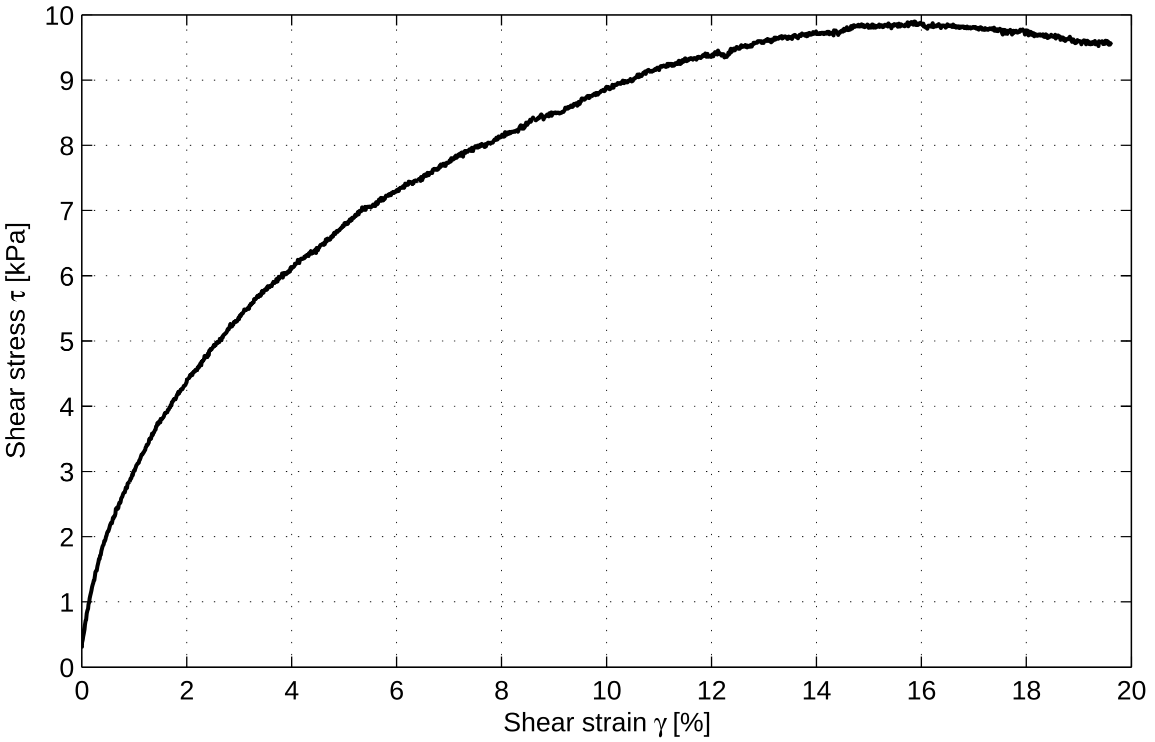
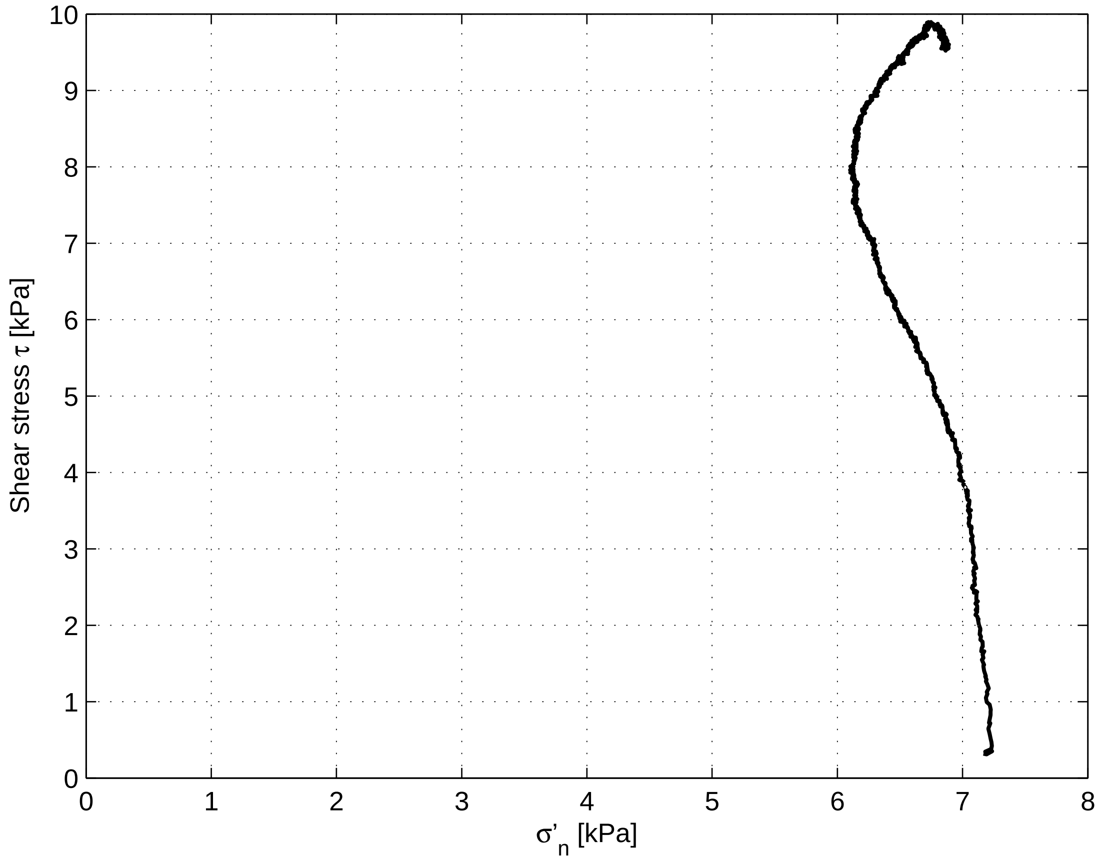
Shear degradation and damping curves for peat	date 2016−04−15	signed konstadi
Direct Simple Shear test on sample SM2C−A2−1A	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix SM2C−A2−1A	page 5

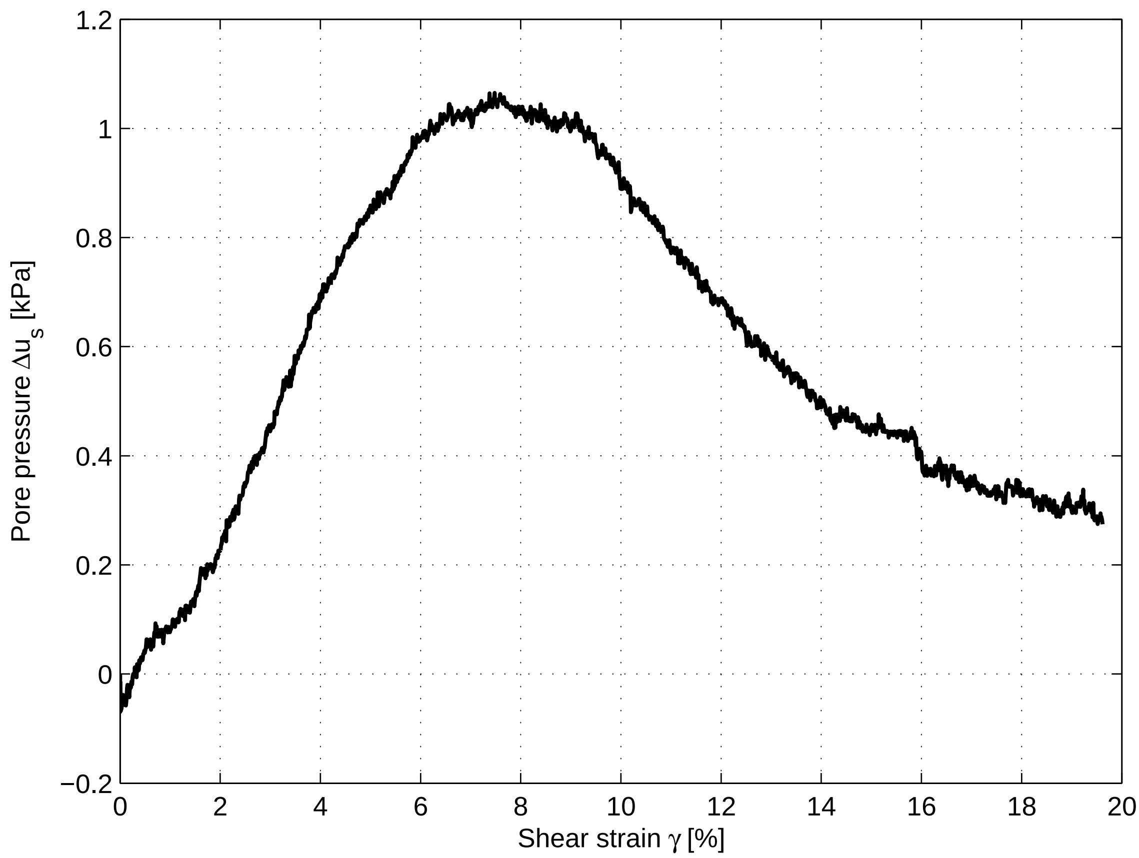


Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−D
Sample name	SM2C−A3−1B
Bore code	SM2C−A
Depth top [m]	−3.65
Depth bottom [m]	−3.67
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	1.0
S_0 [%]	−
Void ratio start shear [−]	1.01
w_0 [%]	454.7
w_{final} [%]	325.3
Consolidation stress [kPa]	7.1
Consolidation strain [%]	8.22
Strain rate [%/h]	8.0
Max shear stress [kPa]	9.9
Vert. stress at max shear stress [kPa]	6.7
Shear strain at max shear stress [kPa]	15.9
σ_v at γ = 40% [kPa]	−
τ at γ = 40% [kPa]	−
Sample Disturbance Index [%]	−
SDI qualification	−

Data above 20% shear strain are not considered representative of sample behaviour and are therefore omitted.





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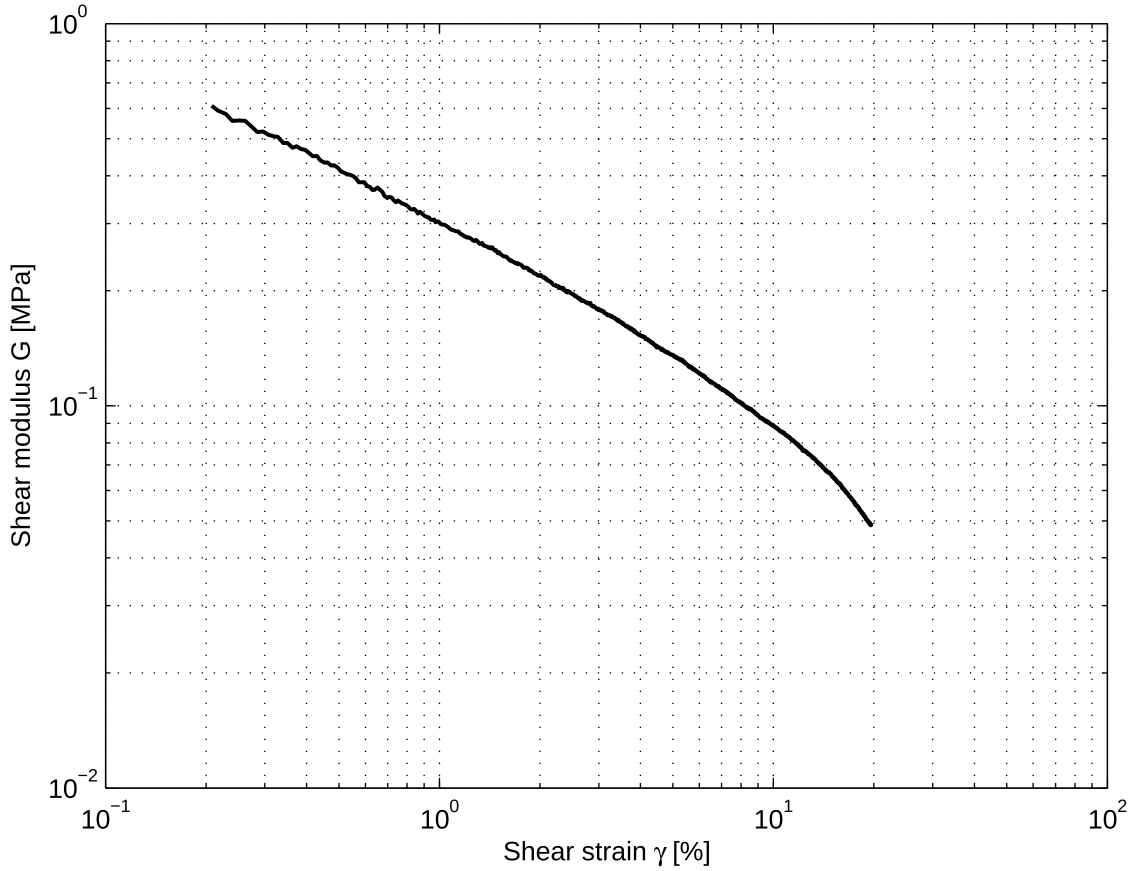
Shear degradation and damping curves for peat

Direct Simple Shear test on sample SM2C−A3−1B

Direct Simple Shear Test



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	6.8	N.A	6.3	0.9	0.1
15% deformation	9.8	N.A	6.7	0.5	0.1
30% deformation	–	N.A	–	–	–
Maximum strain	9.5	N.A	6.9	0.3	0.0
Maximum τ	9.9	0.00	6.7	0.4	0.1

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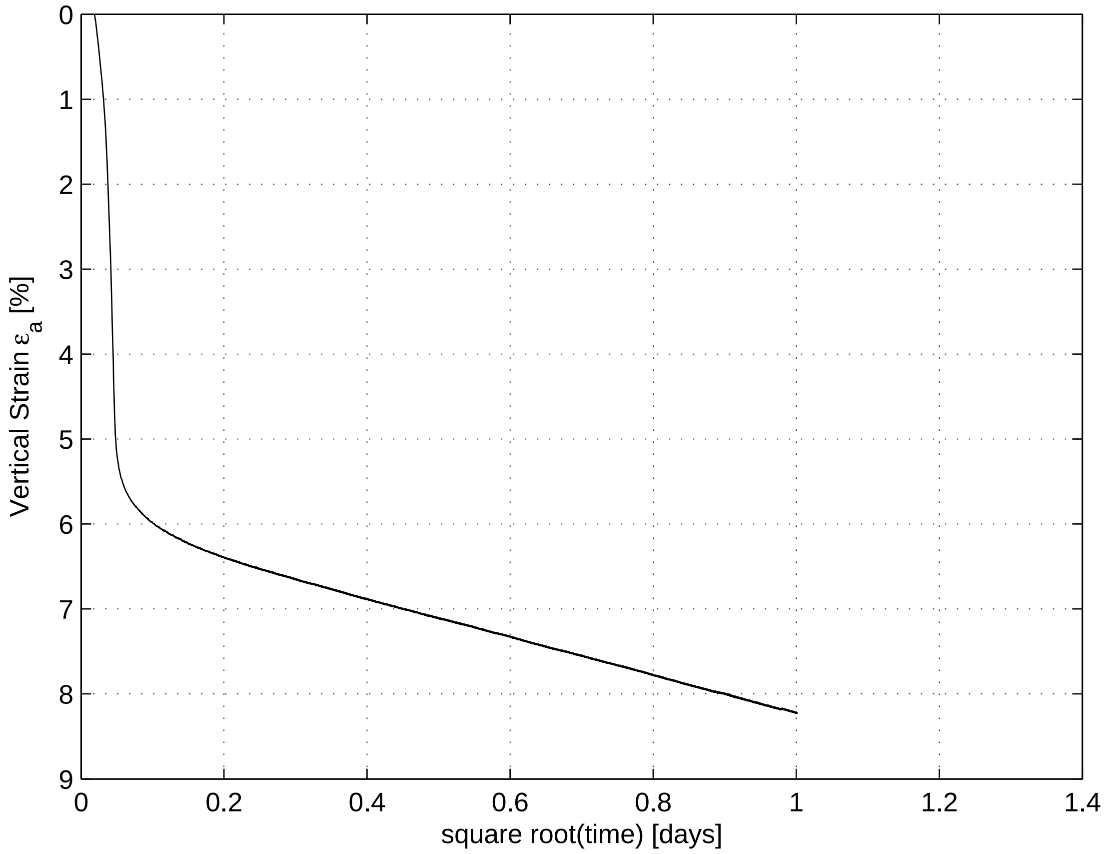
Shear degradation and damping curves for peat

Direct Simple Shear test on sample SM2C−A3−1B

Direct Simple Shear Test



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Shear degradation and damping curves for peat

Direct Simple Shear test on sample SM2C−A3−1B

Direct Simple Shear Test


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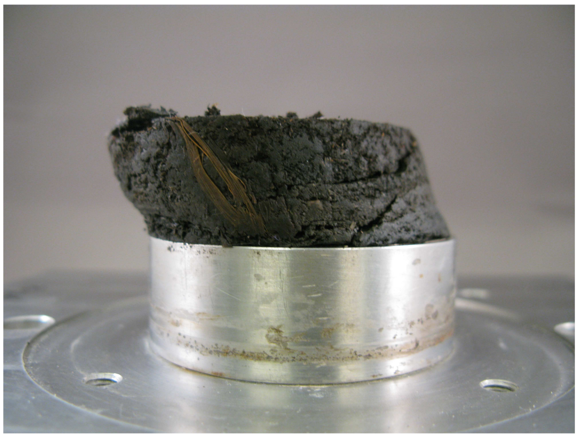
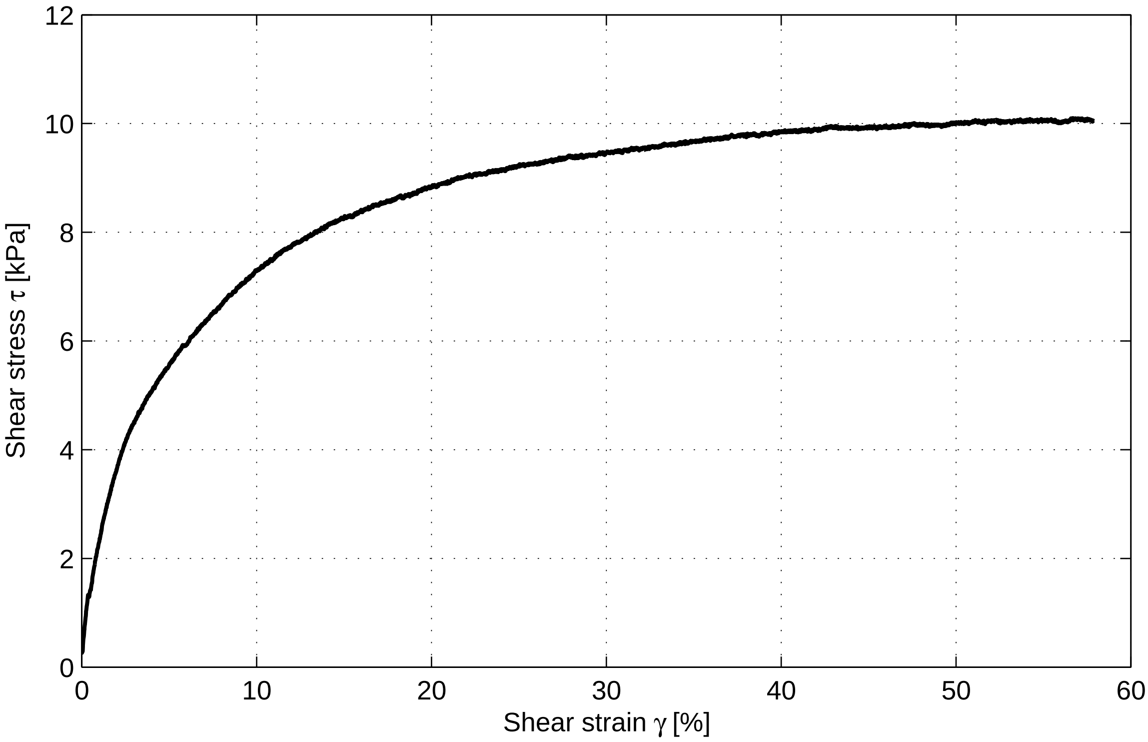
SM2C − A3 − 1B
2.05m − 2.07m





Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.6
Test type	Constant height
Apparatus code	DSS−C
Sample name	SM2C−C1−1B
Bore code	SM2C−C
Depth top [m]	−3.48
Depth bottom [m]	−3.50
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	−
Void ratio start shear [−]	0.89
w_0 [%]	680.5
w_{final} [%]	653.9
Consolidation stress [kPa]	9.1
Consolidation strain [%]	11.90
Strain rate [%/h]	8.0
Max shear stress [kPa]	10.1
Vert. stress at max shear stress [kPa]	9.1
Horz. strain at max shear stress [kPa]	56.7
σ_v at γ = 40% [kPa]	8.8
τ at γ = 40% [kPa]	9.8
Sample Disturbance Index [%]	−
SDI qualification	−

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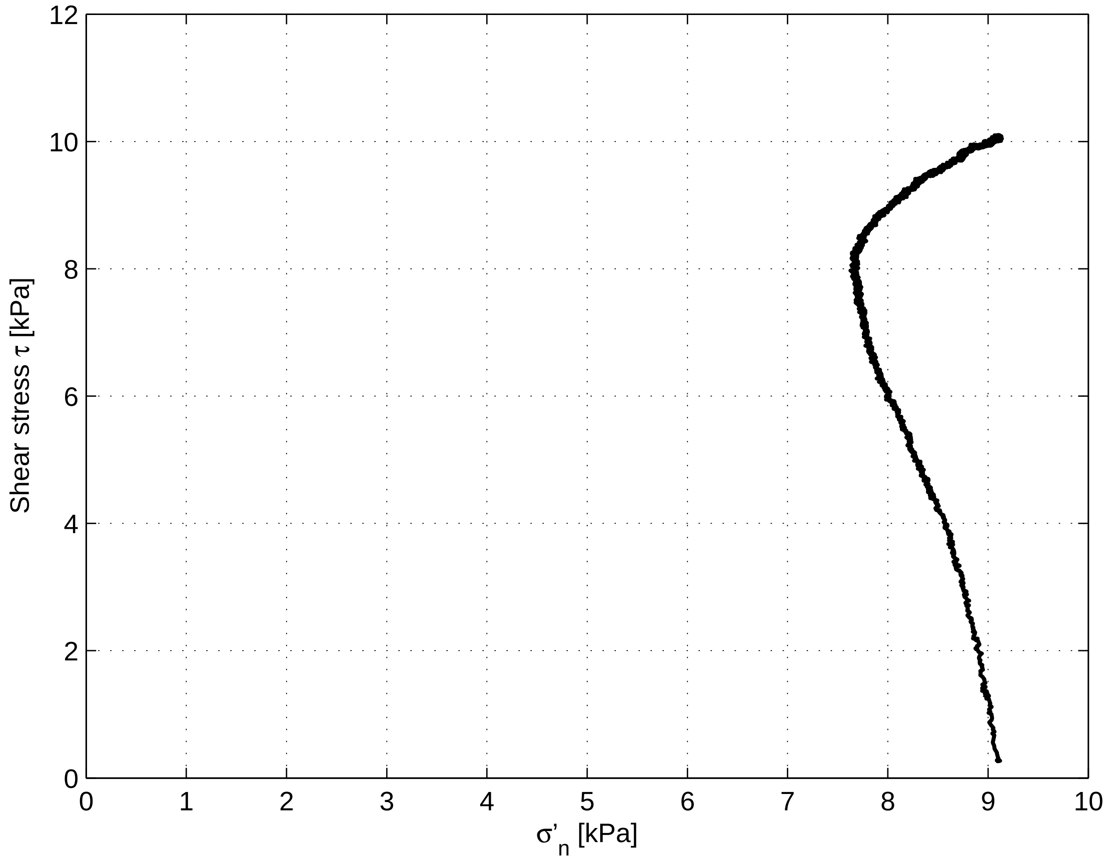
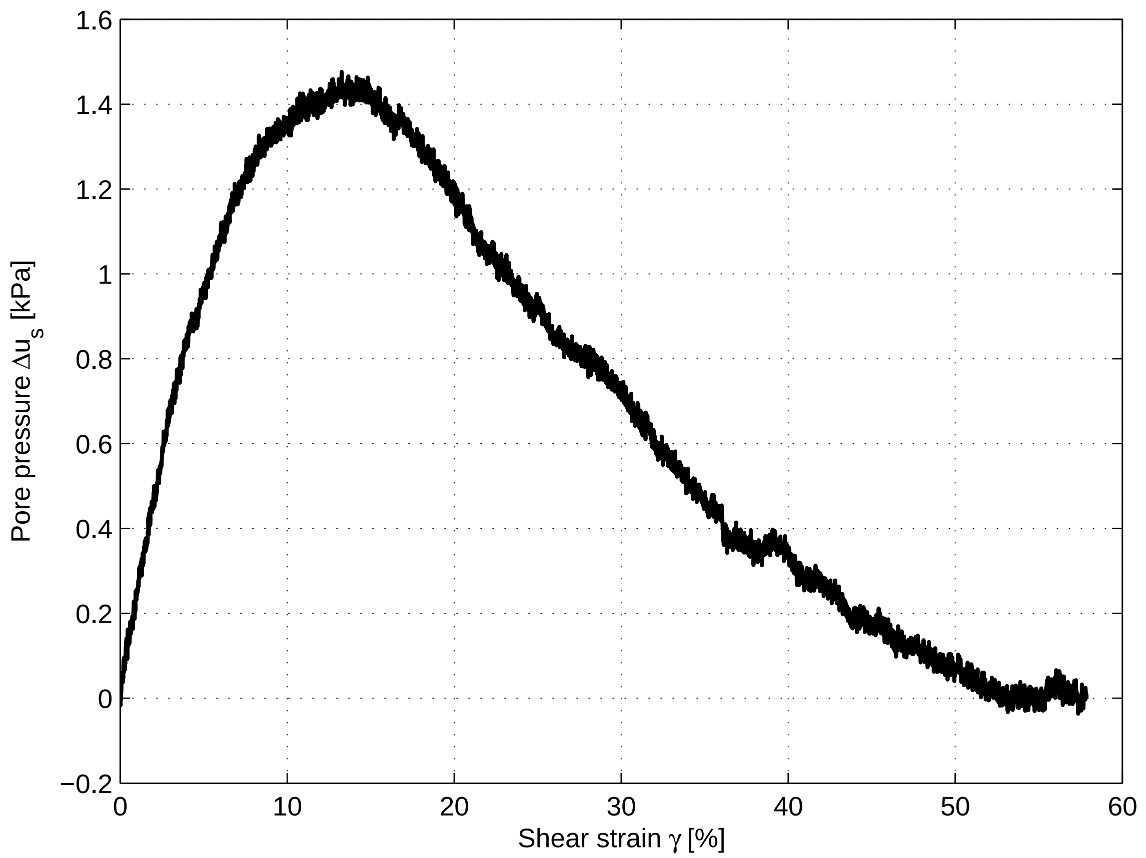
Shear degradation and damping curves for peat

Direct Simple Shear test on sample SM2C−C1−1B

Direct Simple Shear Test





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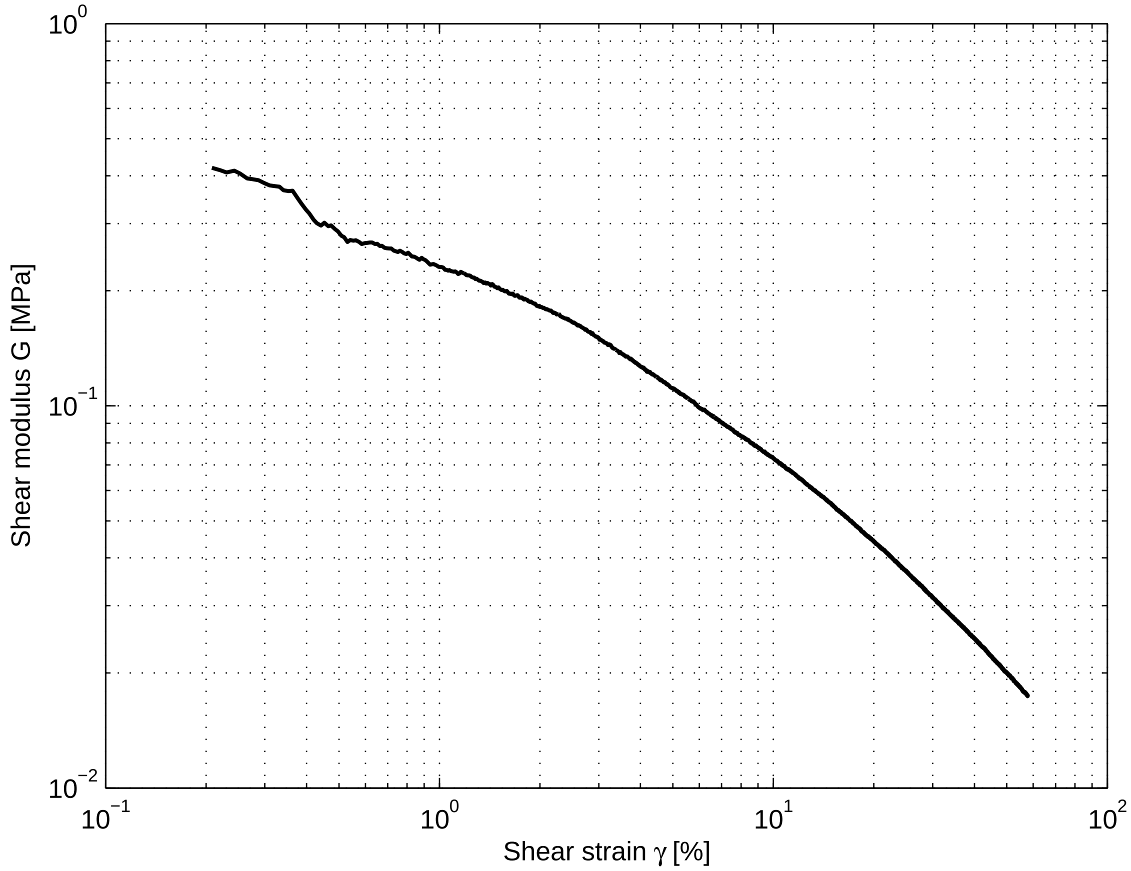
Shear degradation and damping curves for peat Direct Simple Shear test on sample SM2C−C1−1B				project 1209862.11	version 1.3
Direct Simple Shear Test				appendix SM2C−C1−1B	page 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	5.5	N.A	8.1	1.0	0.1
15% deformation	8.3	N.A	7.7	1.4	0.1
30% deformation	9.5	N.A	8.4	0.7	0.0
Maximum strain	10.1	N.A	9.1	−0.0	0.0
Maximum τ	10.1	0.00	9.1	0.0	0.0

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Shear degradation and damping curves for peat

Direct Simple Shear test on sample SM2C−C1−1B

Direct Simple Shear Test

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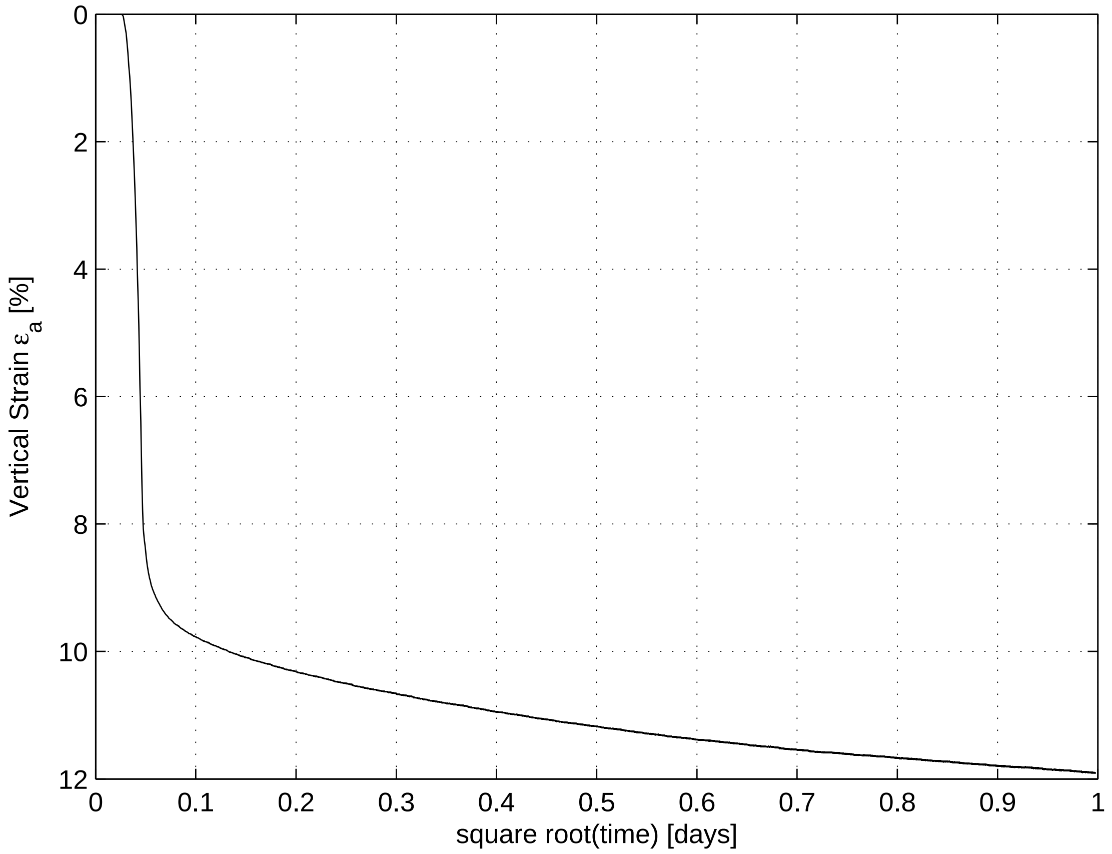

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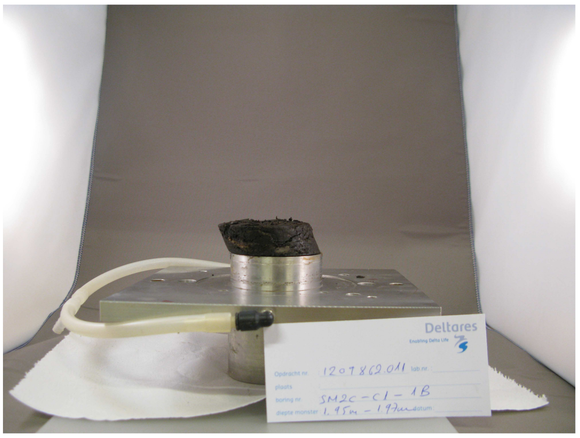
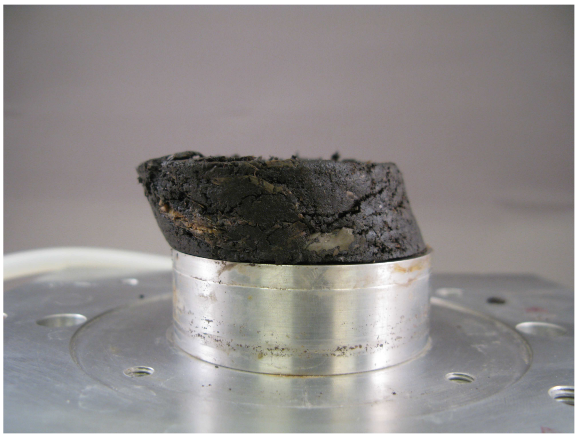
Shear degradation and damping curves for peat

Direct Simple Shear test on sample SM2C−C1−1B

Direct Simple Shear Test





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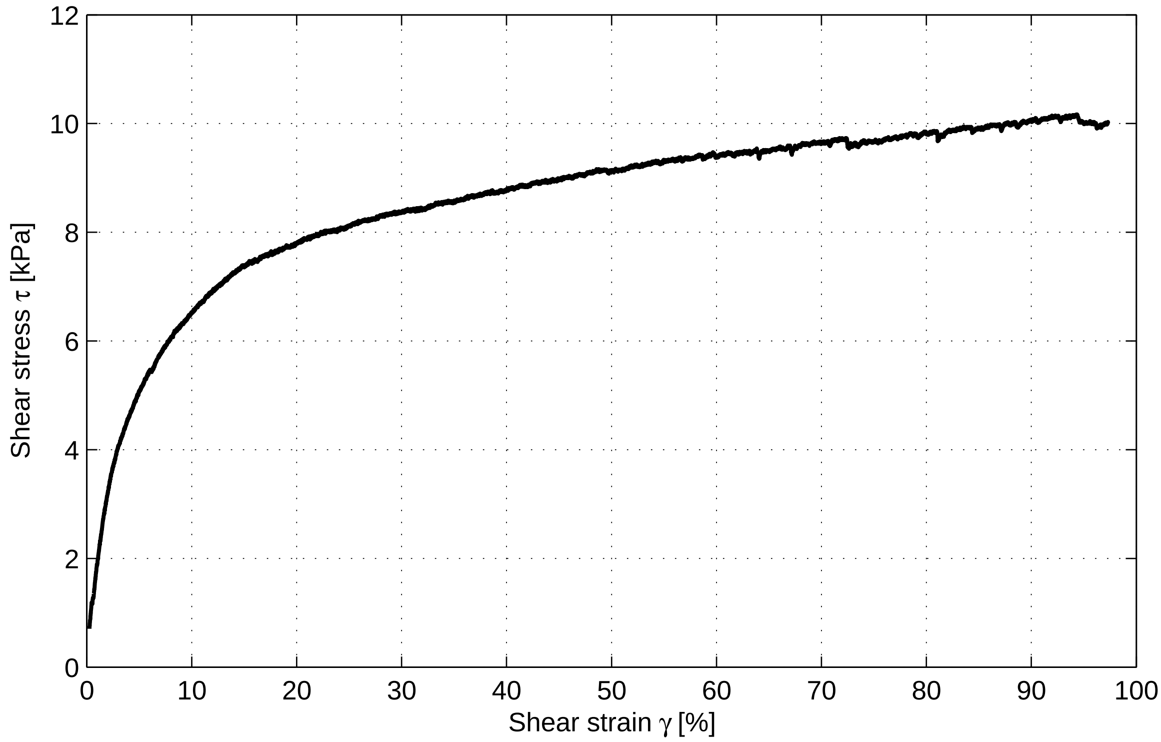
Shear degradation and damping curves for peat Direct Simple Shear test on sample SM2C−C1−1B				project 1209862.11	version 1.3
Direct Simple Shear Test				appendix SM2C−C1−1B	page 5



Description of soil sample:

Soil classification	Peat, low−mineral content
Pressure area [cm^2]	31.17
Mean temperature during shear [°C]	21.8
Test type	Constant height
Apparatus code	DSS−C
Sample name	SM2C−B1−1C
Bore code	SM2C−B
Depth top [m]	−3.52
Depth bottom [m]	−3.54
Specimen condition	Intact
Trimming procedure	With cutting ring
ρ_i [g/cm^3]	0.9
S_0 [%]	–
Void ratio start shear [−]	0.91
w_0 [%]	538.6
w_{final} [%]	550.2
Consolidation stress [kPa]	9.3
Consolidation strain [%]	12.30
Strain rate [%/h]	8.2
Max shear stress [kPa]	10.2
Vert. stress at max shear stress [kPa]	6.7
Horz. strain at max shear stress [kPa]	94.3
σ_v at γ = 40% [kPa]	7.6
τ at γ = 40% [kPa]	8.8
Sample Disturbance Index [%]	–
SDI qualification	–

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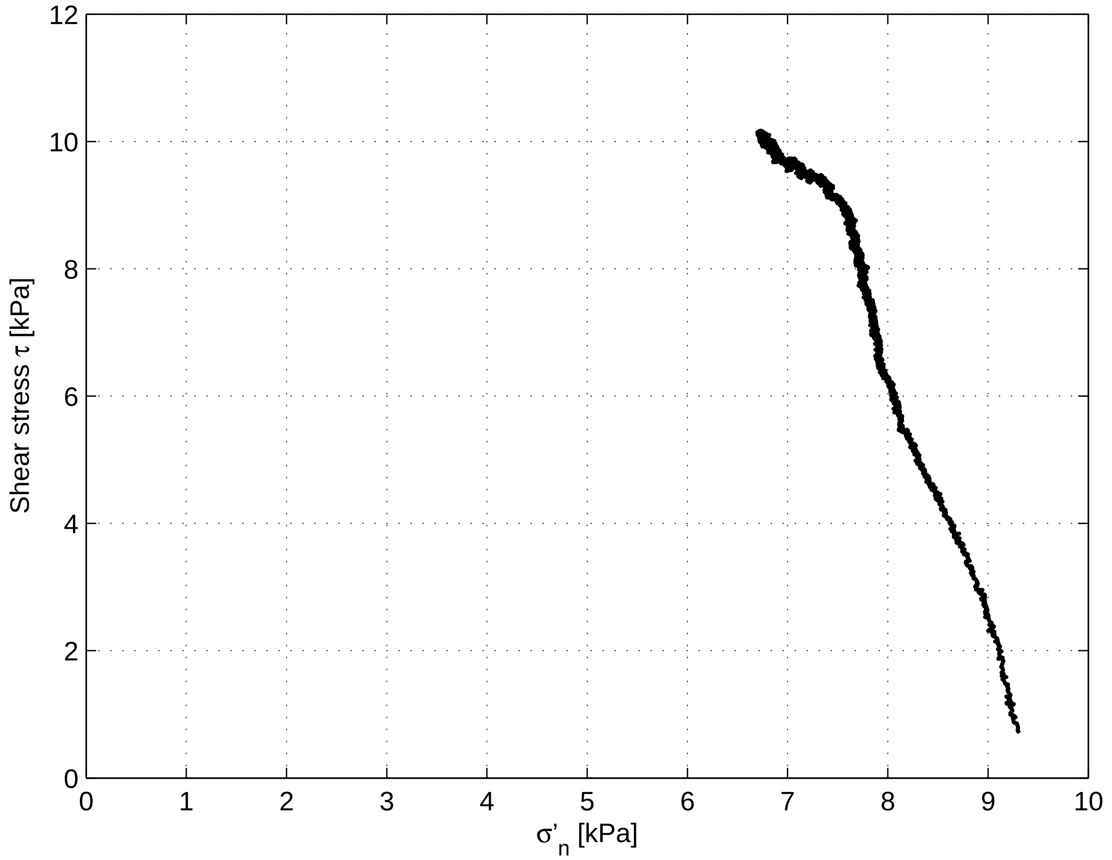
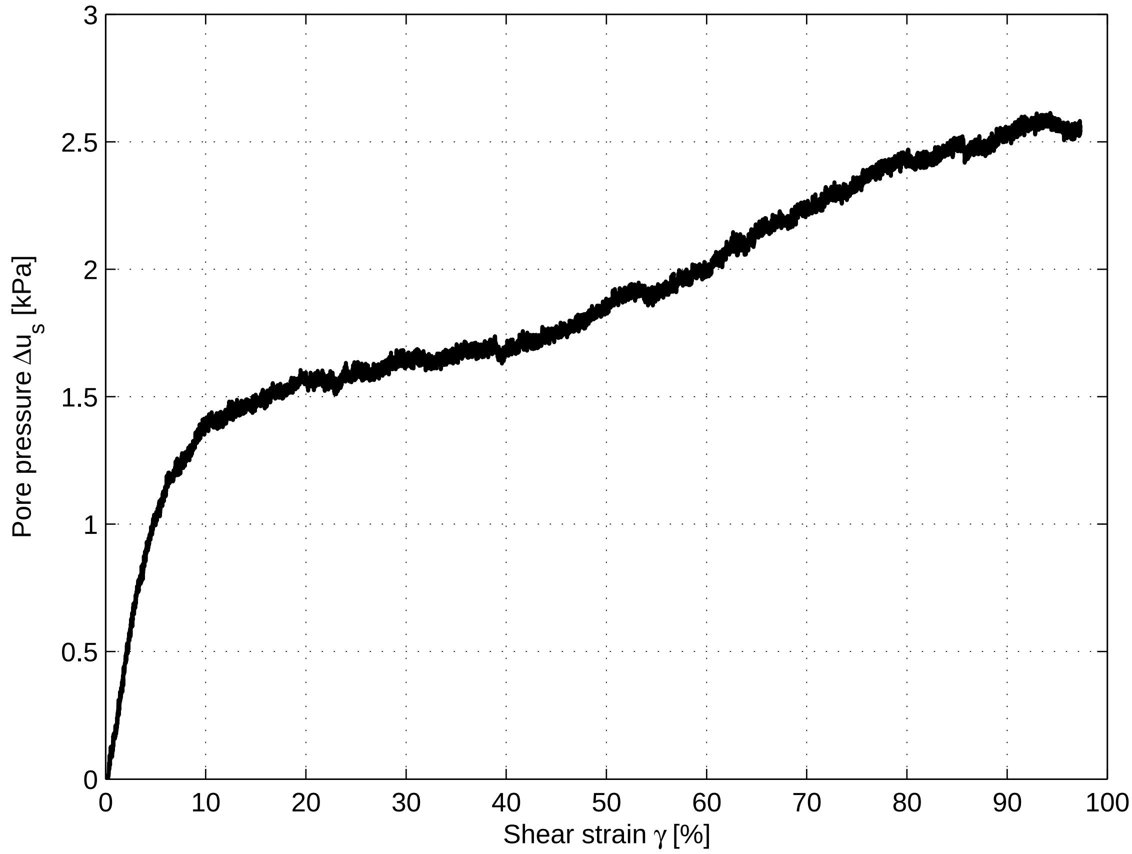
Shear degradation and damping curves for peat	date 2016−04−15	signed konstad
Direct Simple Shear test on sample SM2C−B1−1C	project 1209862.11	version 1.3
Direct Simple Shear Test	appendix SM2C−B1−1C	page 1





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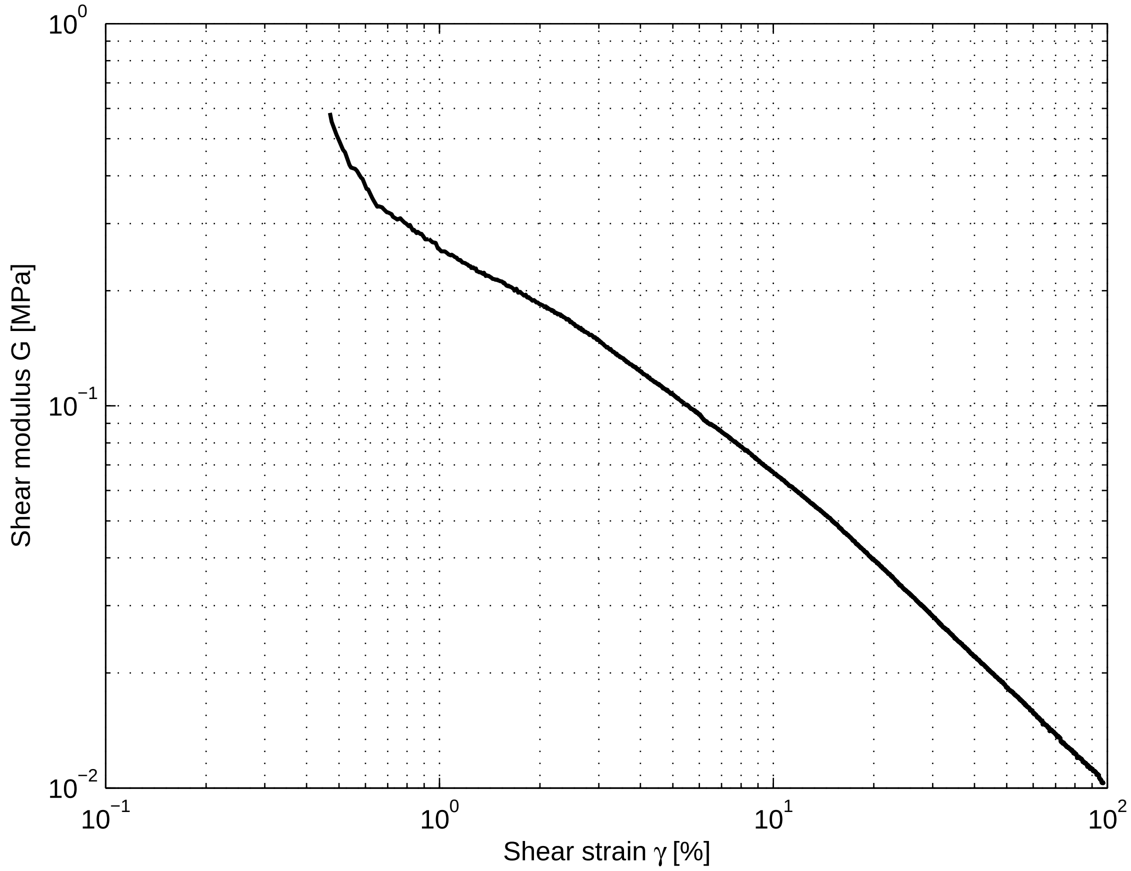
Direct Simple Shear test on sample SM2C−B1−1C	project: 1209862.11	version: 1.3
Direct Simple Shear Test	appendix: SM2C−B1−1C	page: 2



γ [%]	τ [kPa]	ε_a [%]	σ'_n [kPa]	Δu_s [kPa]	G [MPa]
5% deformation	5.1	N.A	8.3	1.0	0.1
15% deformation	7.4	N.A	7.8	1.5	0.0
30% deformation	8.4	N.A	7.7	1.6	0.0
Maximum strain	10.0	N.A	6.7	2.6	0.0
Maximum τ	10.1	0.00	6.7	2.6	0.0

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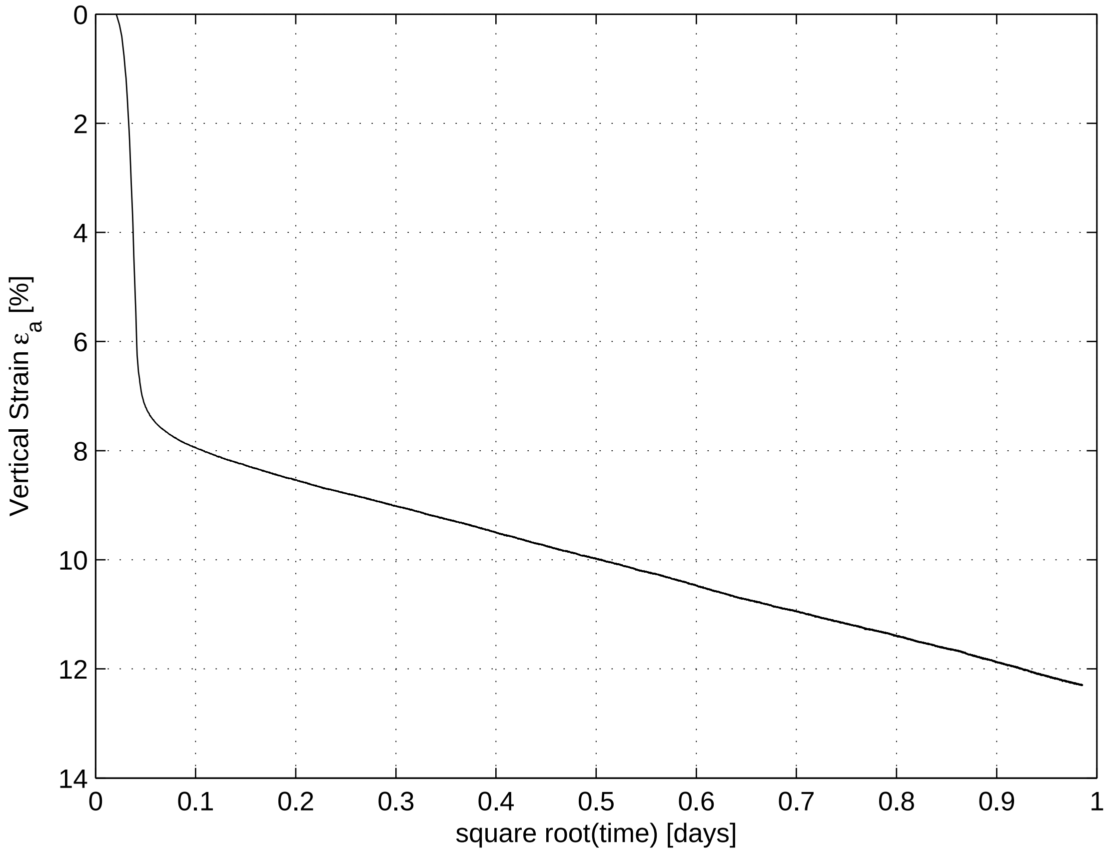
Shear degradation and damping curves for peat

Direct Simple Shear test on sample SM2C−B1−1C

Direct Simple Shear Test



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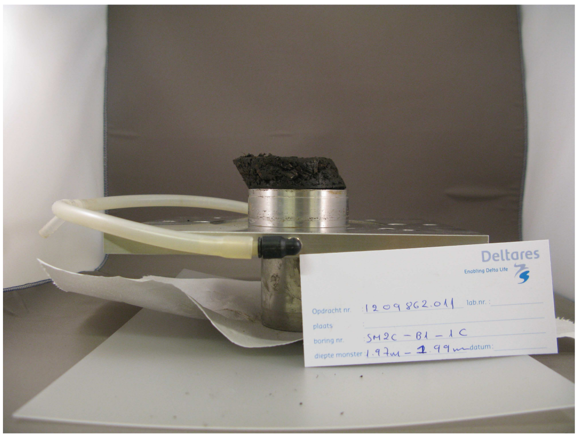
Shear degradation and damping curves for peat		date 2016−04−15	signed konstad
Direct Simple Shear test on sample SM2C−B1−1C		project 1209862.11	version 1.3
Direct Simple Shear Test		appendix SM2C−B1−1C	page 4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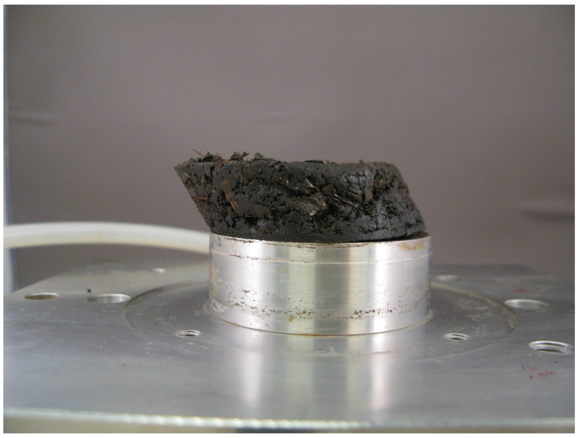
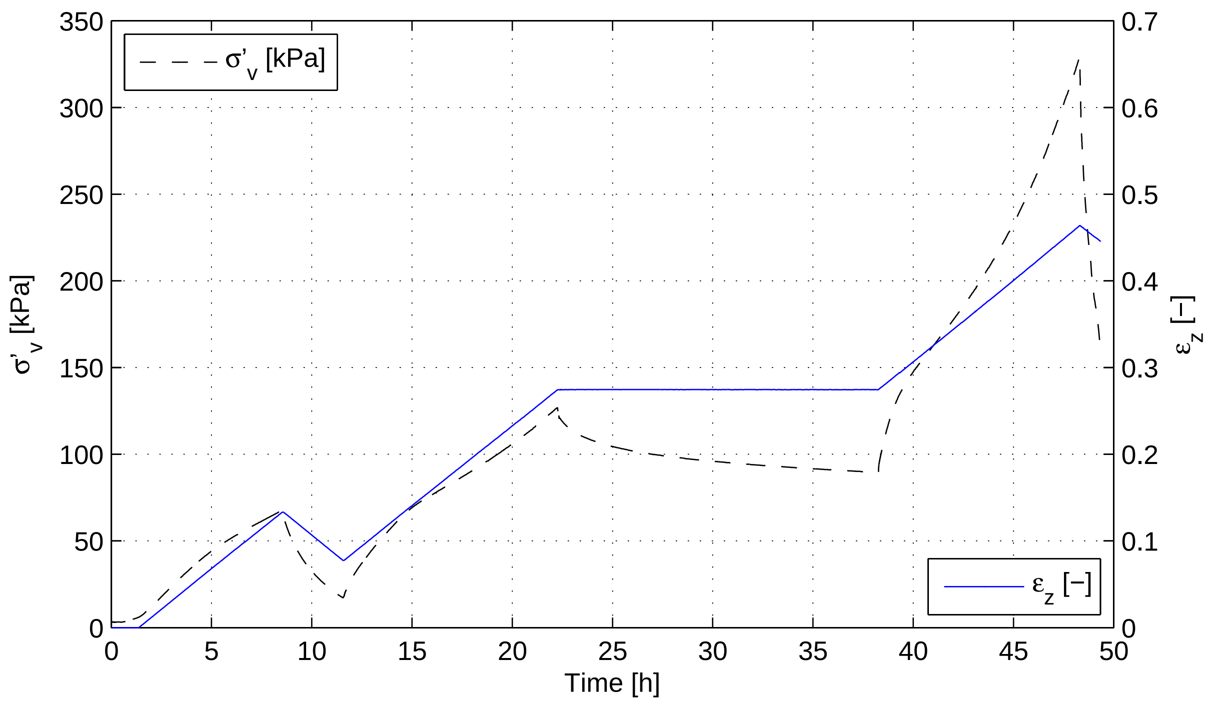
Enabling Delta Life
Opdracht nr. : 1209862.011
lab.nr. :
plaats :
boring nr. : SM2C - B1 - 1C
diepte monster : 1.97m - 1.99m
datum :



H Ko-CRS tests



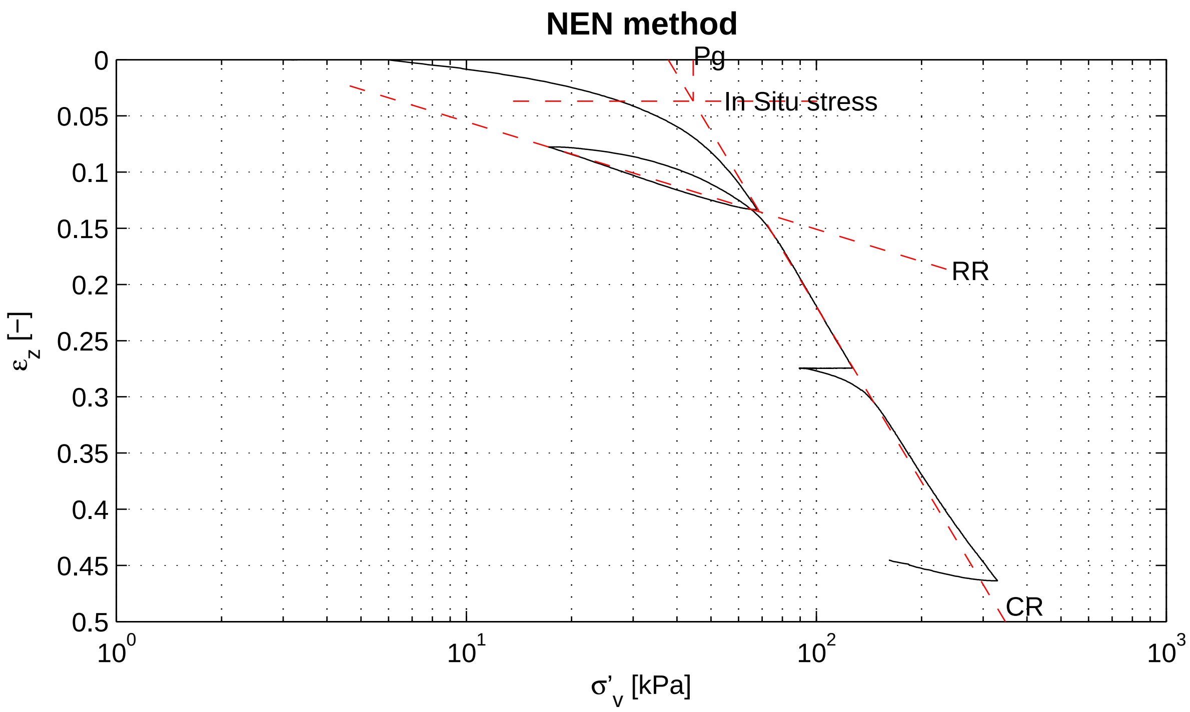
Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, rietr..
Unit weight saturated soil [kN/m^3]	9.6
Unit weight dry soil [kN/m^3]	1.6
Water content [%]	501.0
Water content final [%]	285.6
Void ratio − initial [−]	4.37 (e)
Sample disturbance index [%]	4.5, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	139
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

NEN method

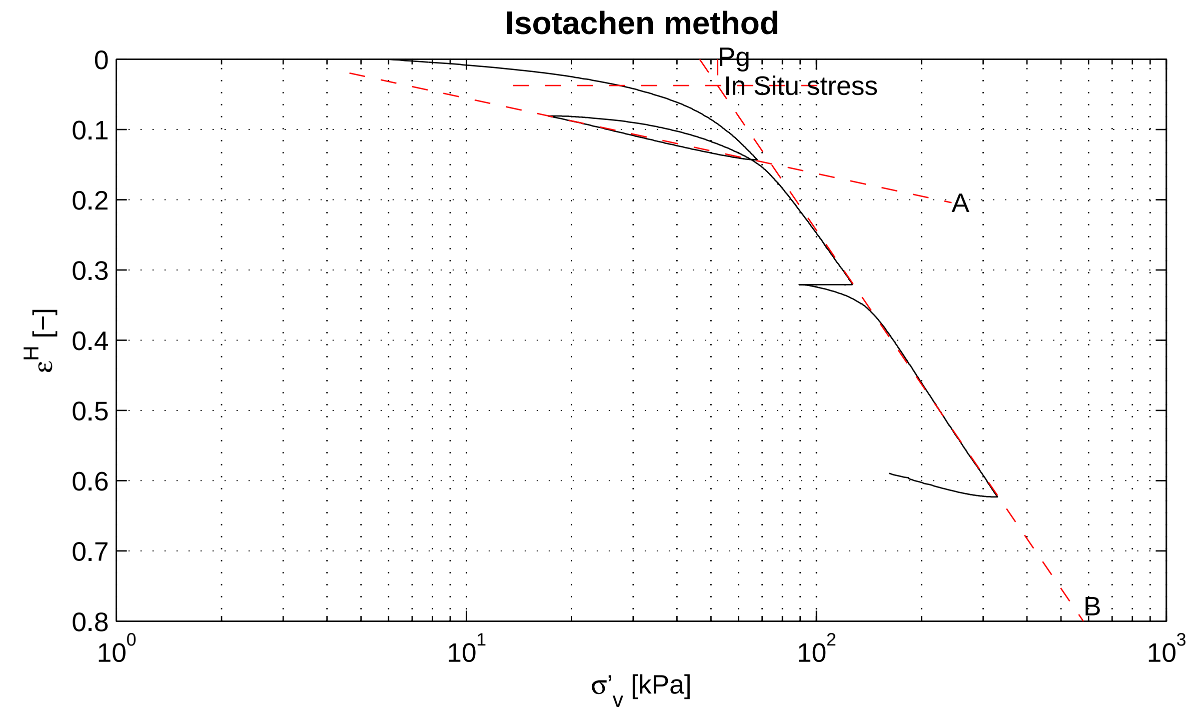


RR = 9.6e−02
CR = 5.2e−01

C_α = 4.3e−02

Pg = 44.5 kPa

Isotachen method



A = 4.7e−02
B = 3.2e−01

C = 2.6e−02

Pg = 52.3 kPa

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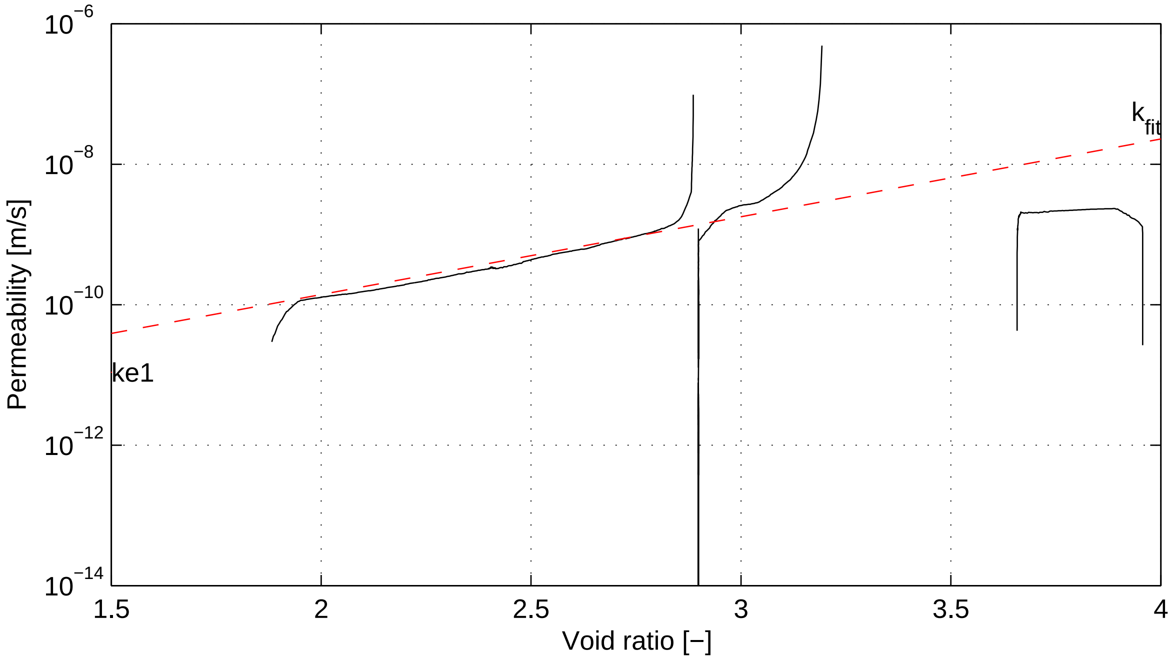
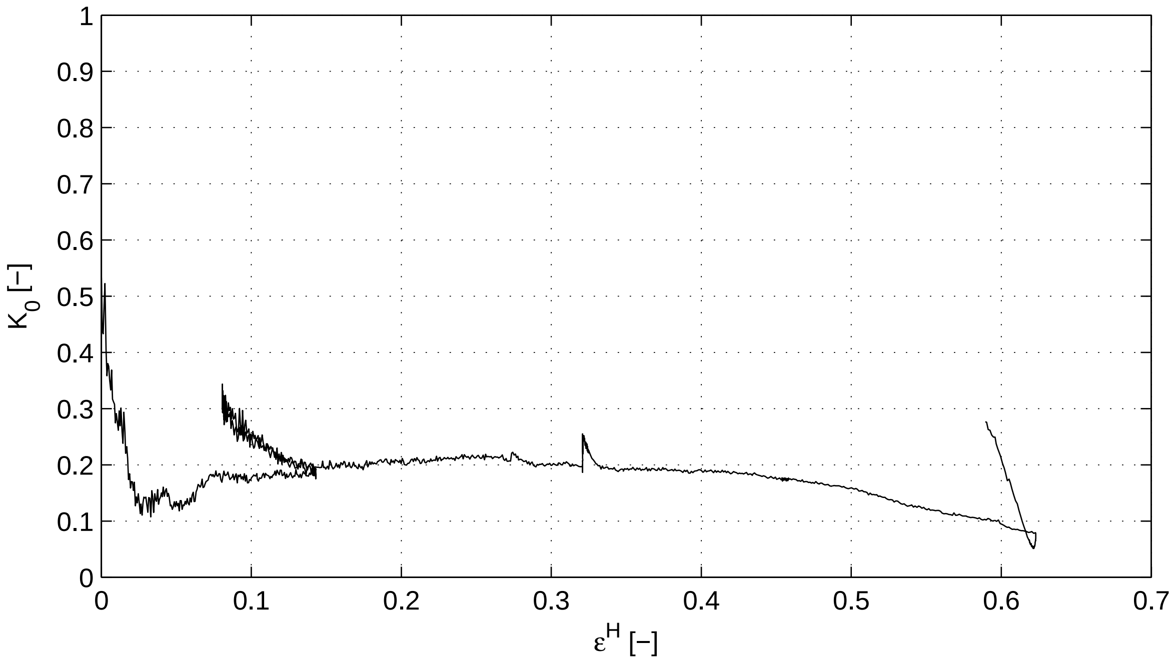
	date 2016−06−21	signed luije_sa
Contribution study program EQ Groningen field Boring NW1A2−A, sample NW1A2−A5−1B, depth: −5.38 m to −5.41 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−A5−1B	page 2



k_{e1} = 1.1e−11 m/s k_{e0} = 5.9e−08 m/s slope = 1.11e+00



ν = 0.12 K_{0c} = 0.21 K_{0e} = 0.09

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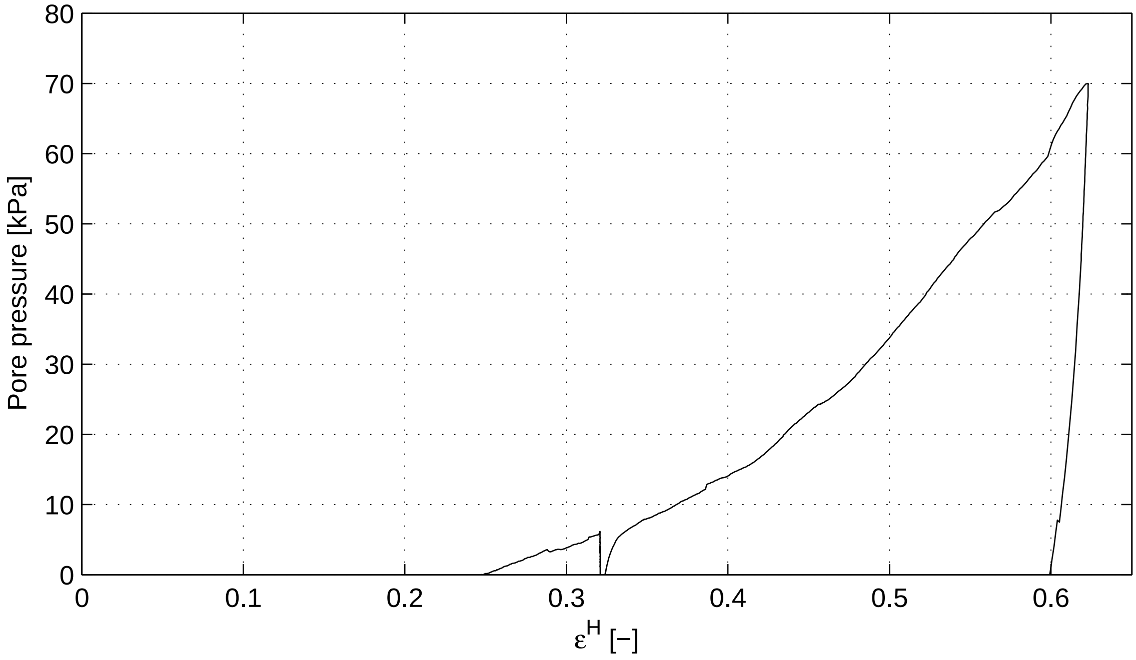
Contribution study program EQ Groningen field Boring NW1A2−A, sample NW1A2−A5−1B, depth: −5.38 m to −5.41 m NAP				project 1209862.11	version 1.1
K0−CRS measurement				appendix CRSNW1A2−A5−1B	page 3



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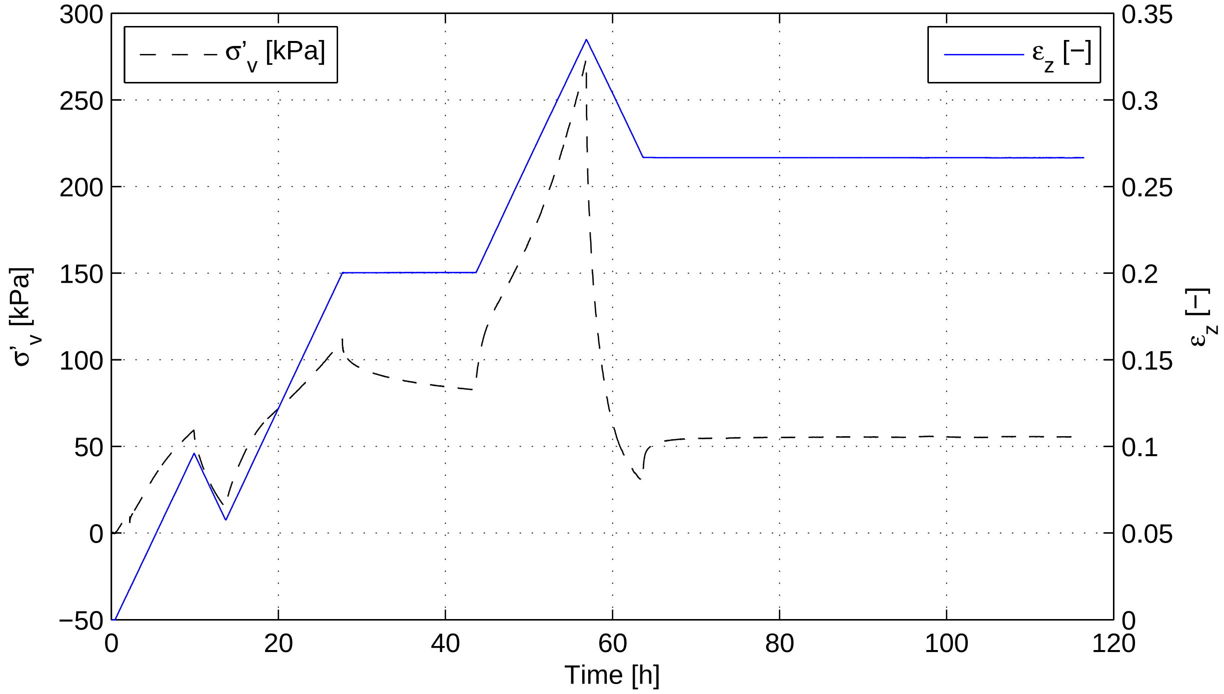
Contribution study program EQ Groningen field Boring NW1A2−A, sample NW1A2−A5−1B, depth: −5.38 m to −5.41 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−A5−1B	page 4



Description of soil sample:

Soil description (NEN 5104)	Veen, zwak kleiig
Unit weight saturated soil [kN/m^3]	7.6
Unit weight dry soil [kN/m^3]	1.3
Water content [%]	493.9
Water content final [%]	336.7
Void ratio − initial [−]	1.83 (e)
Sample disturbance index [%]	6.3, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	139
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

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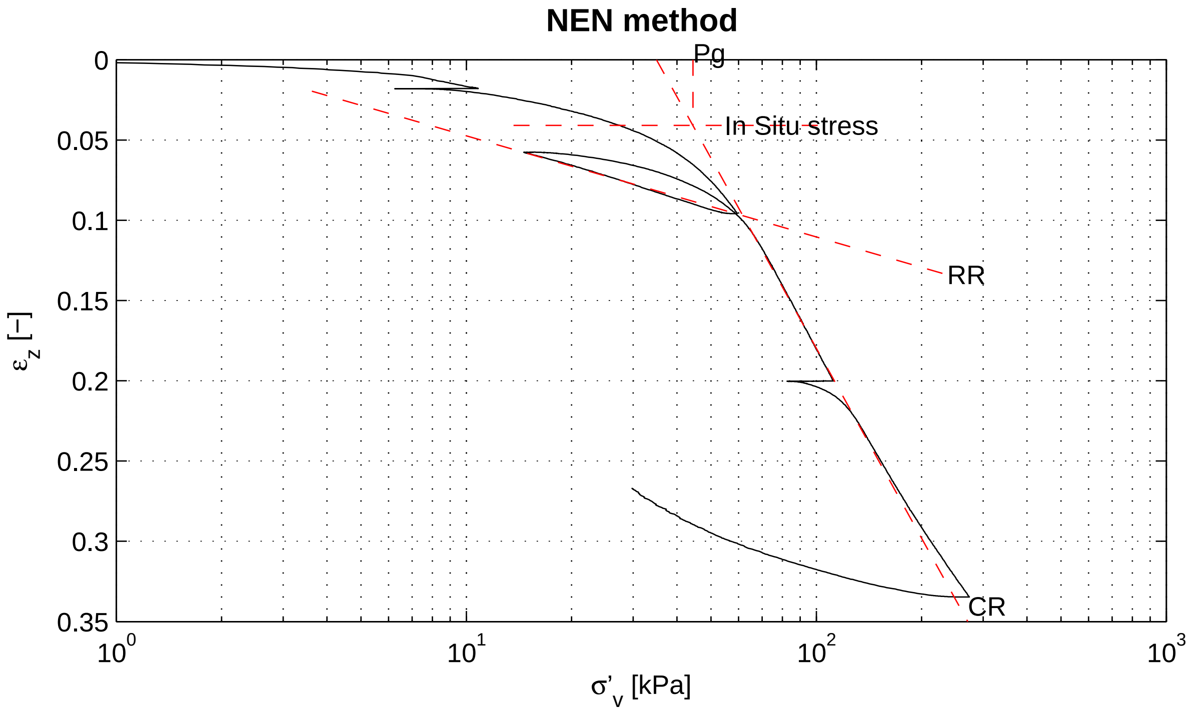
Contribution study program EQ Groningen field	date 2016−06−09	signed luije_sa
Boring NW1A2−A, sample NW1A2−A5−1C, depth: −5.43 m to −5.46 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−A5−1C	page 1

NEN method

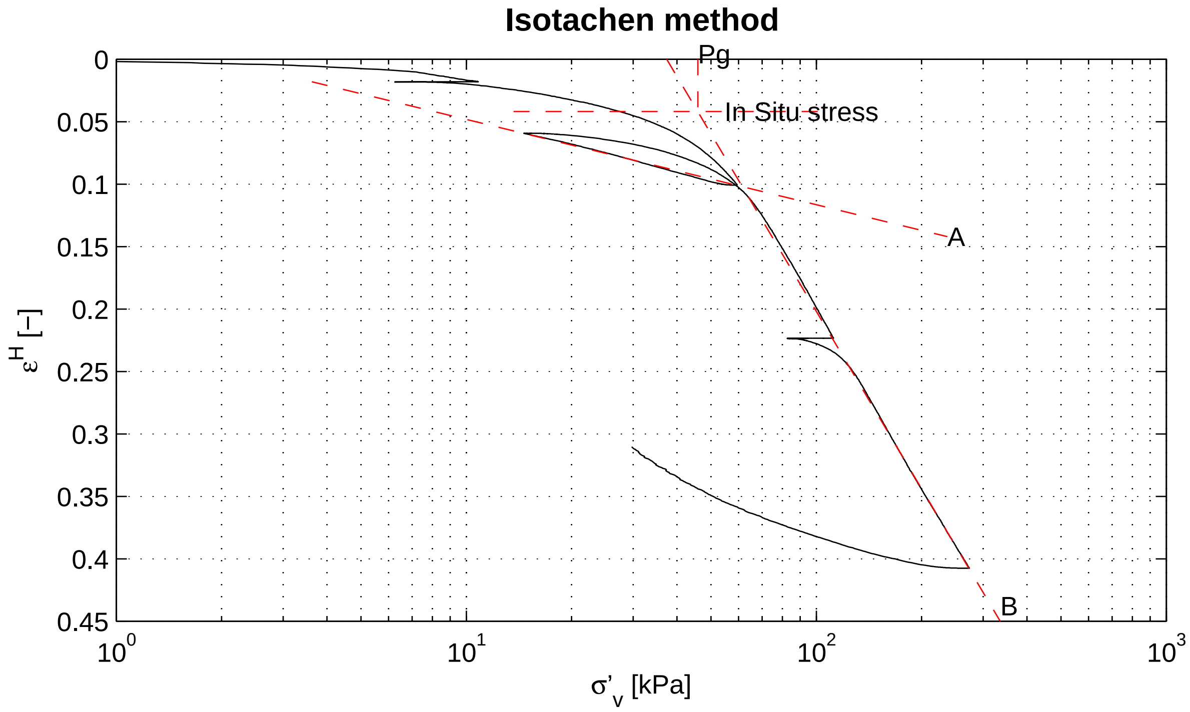


RR = 6.3e−02
CR = 3.9e−01

C_α = 2.4e−02

Pg = 44.4 kPa

Isotachen method



A = 3.0e−02
B = 2.1e−01

C = 1.3e−02

Pg = 45.9 kPa

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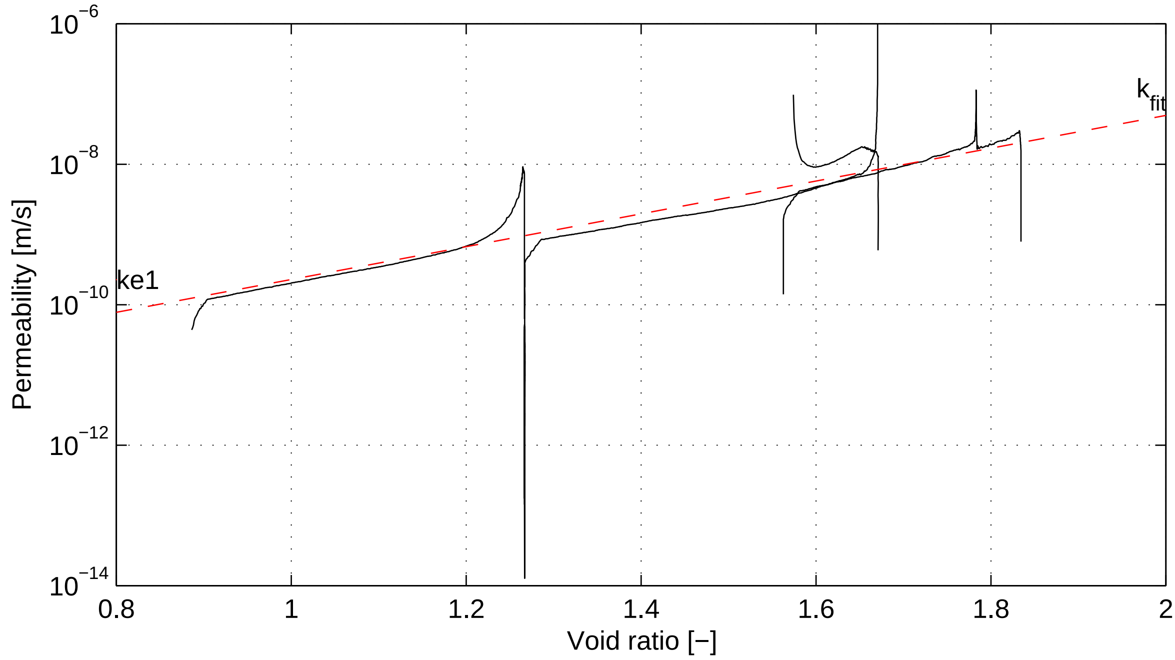
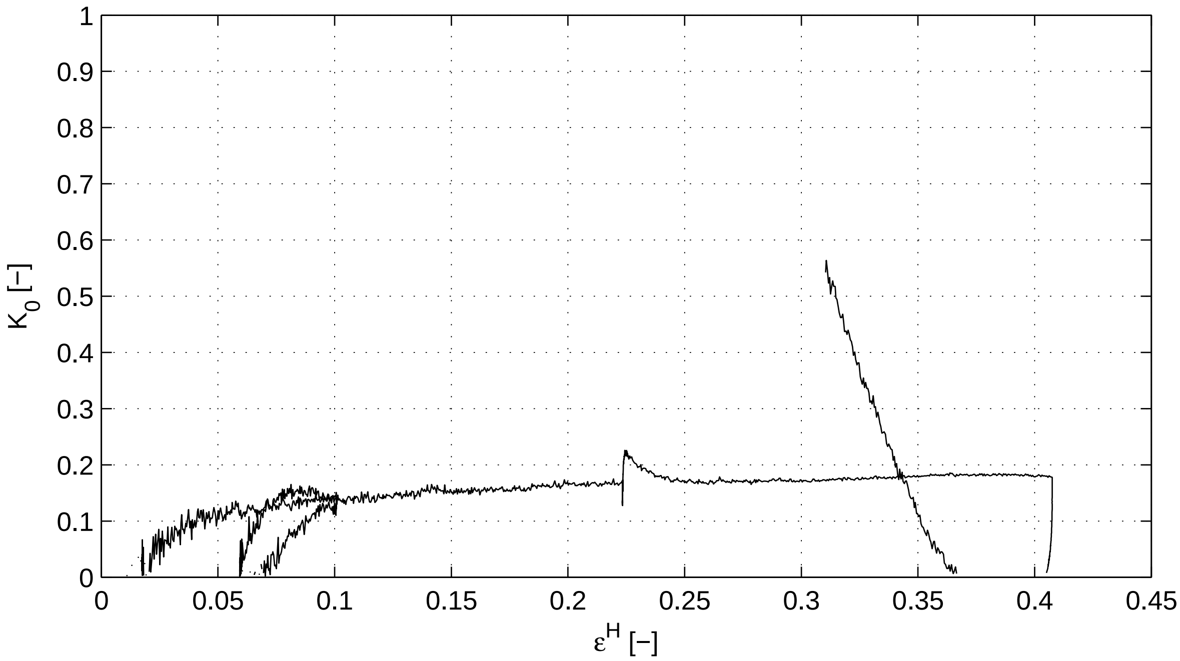
Contribution study program EQ Groningen field	date 2016−06−09	signed luije_sa
Boring NW1A2−A, sample NW1A2−A5−1C, depth: −5.43 m to −5.46 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−A5−1C	page 2



k_{e1} = 2.3e−10 m/s k_{e0} = 2.0e−08 m/s slope = 2.34e+00



ν = 0.16 K_{0m} = 0.16 K_{0e} = 0.18

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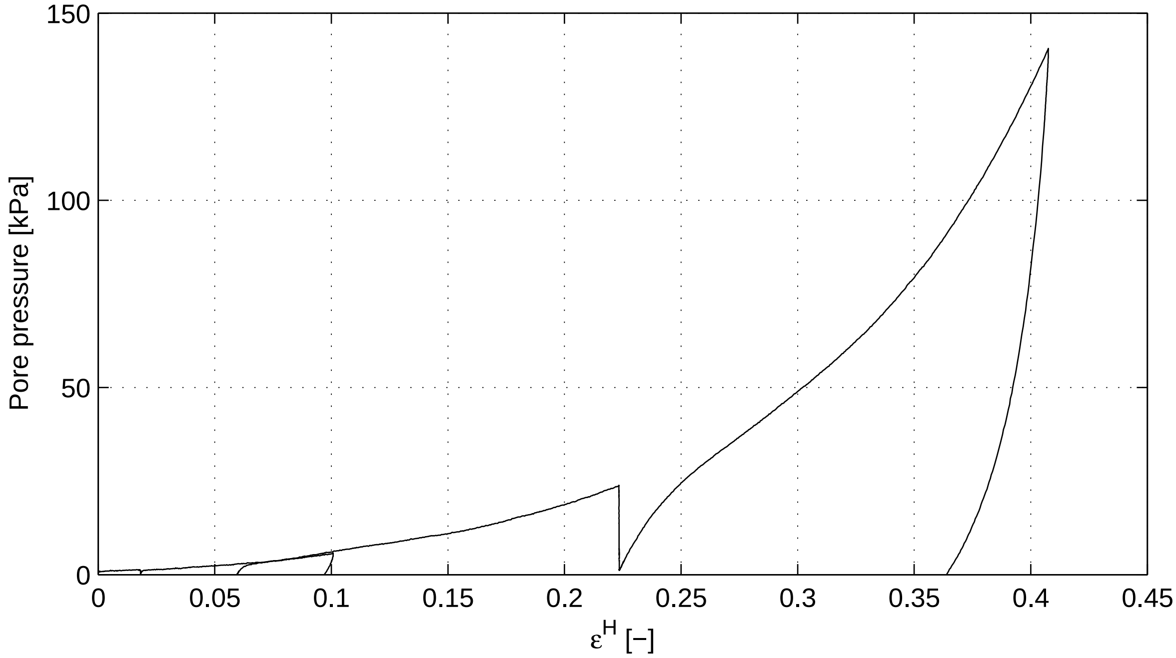
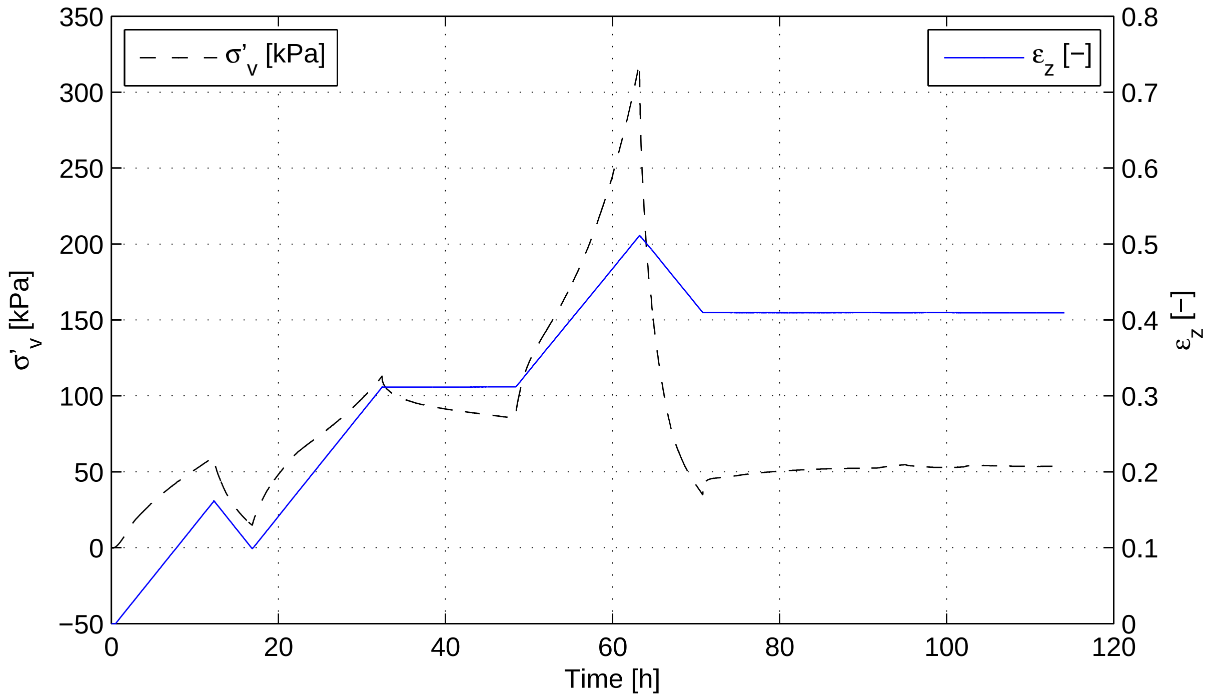
Contribution study program EQ Groningen field	date 2016−06−09	signed luije_sa
Boring NW1A2−A, sample NW1A2−A5−1C, depth: −5.43 m to −5.46 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−A5−1C	page 3



Pore pressure [kPa]
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
ε^H [−]



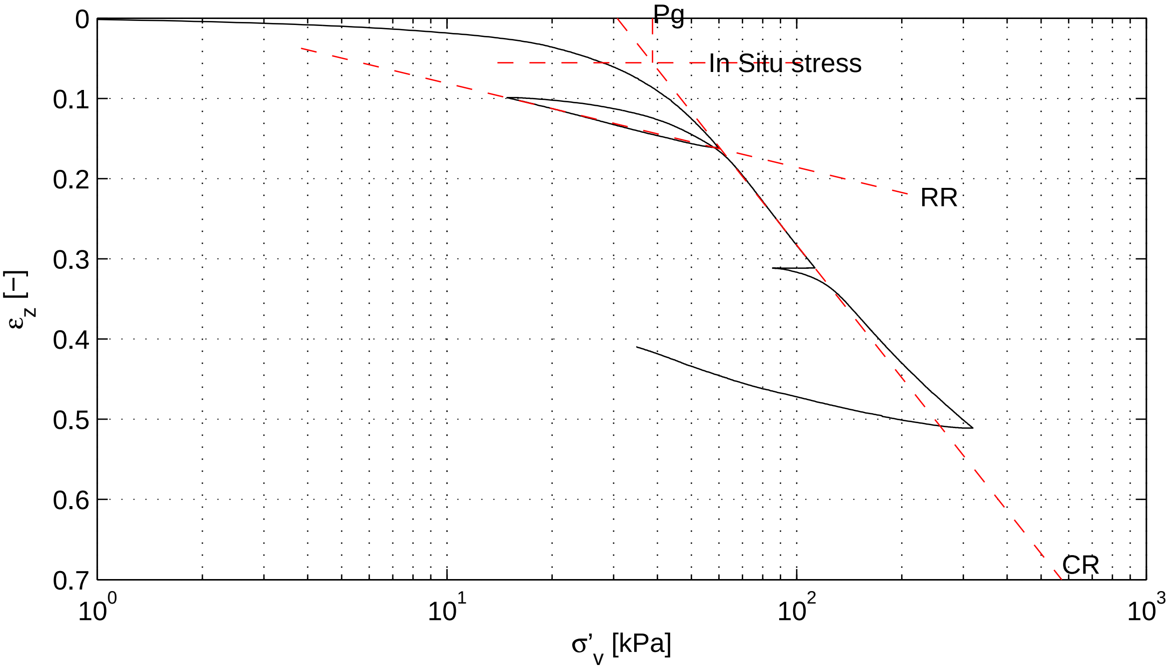
Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm
Unit weight saturated soil [kN/m^3]	10.0
Unit weight dry soil [kN/m^3]	1.4
Water content [%]	620.2
Water content final [%]	288.9
Void ratio − initial [−]	7.07 (e)
Sample disturbance index [%]	6.3, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	139
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

NEN method

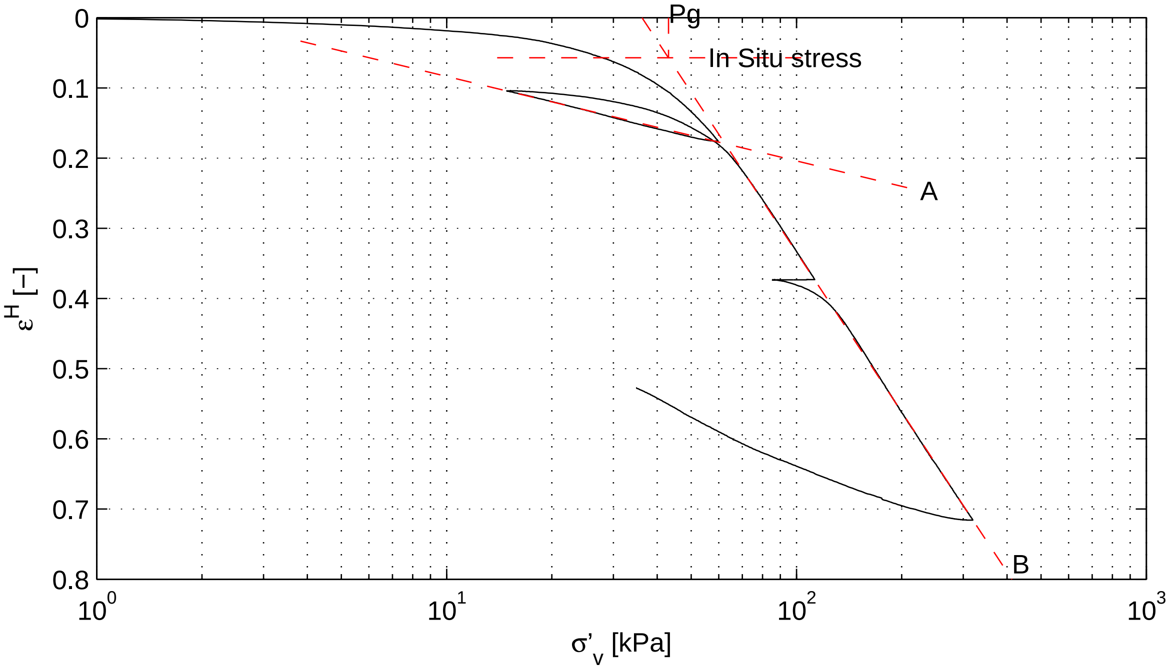


RR = 1.0e−01
CR = 5.5e−01

C_α = 3.9e−02

Pg = 38.7 kPa

Isotachen method



A = 5.2e−02
B = 3.3e−01

C = 2.3e−02

Pg = 43.1 kPa

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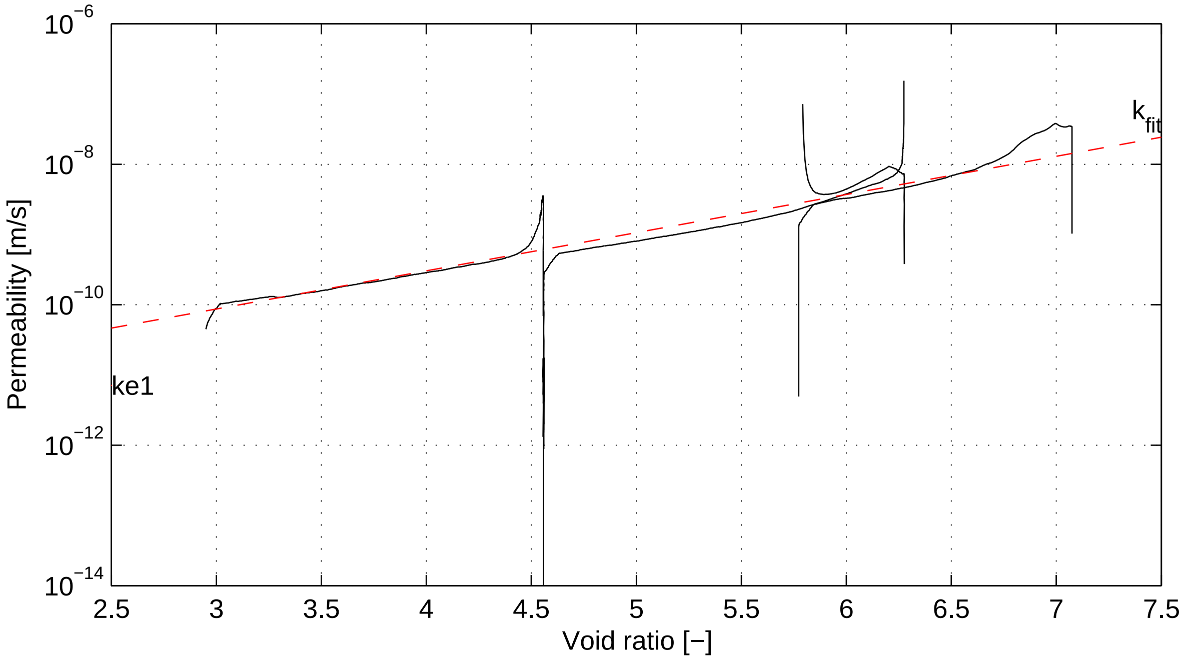
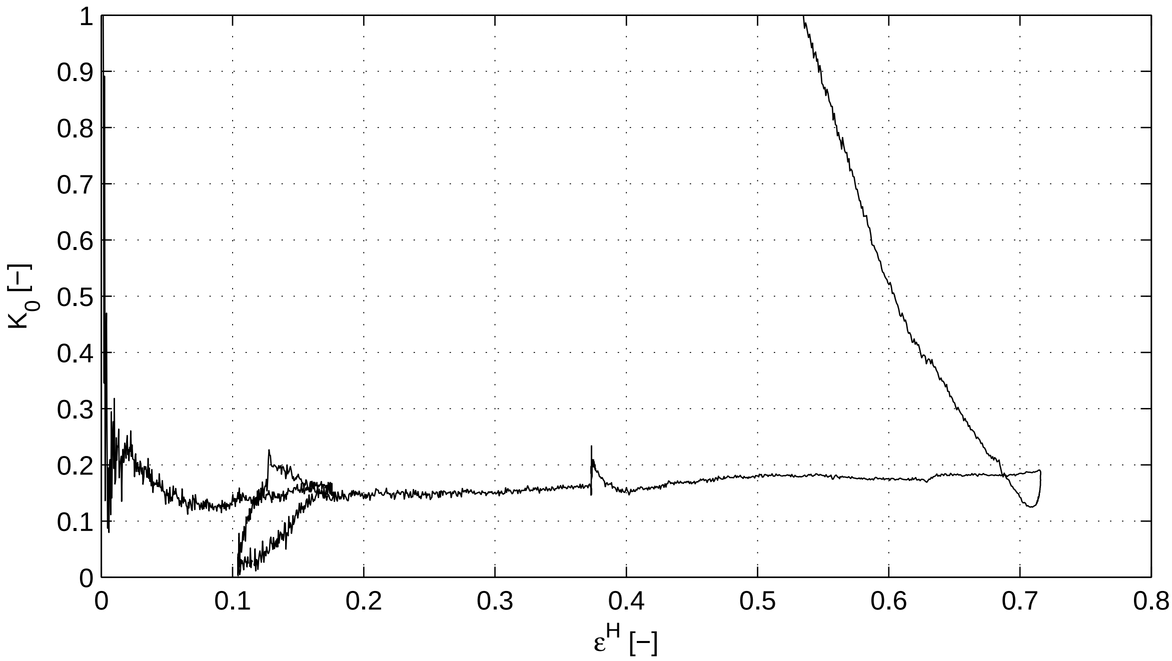
Contribution study program EQ Groningen field	date: 2016−06−09	signed: luije_sa
Boring NW1A2−A, sample NW1A2−A6−1B, depth: −5.98 m to −6.01 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSNW1A2−A6−1B	page: 2



k_{e1} = 7.1e−12 m/s k_{e0} = 1.4e−08 m/s   slope = 5.43e−01



ν = 0.16 K_{0m} = 0.18 K_{0e} = 0.18

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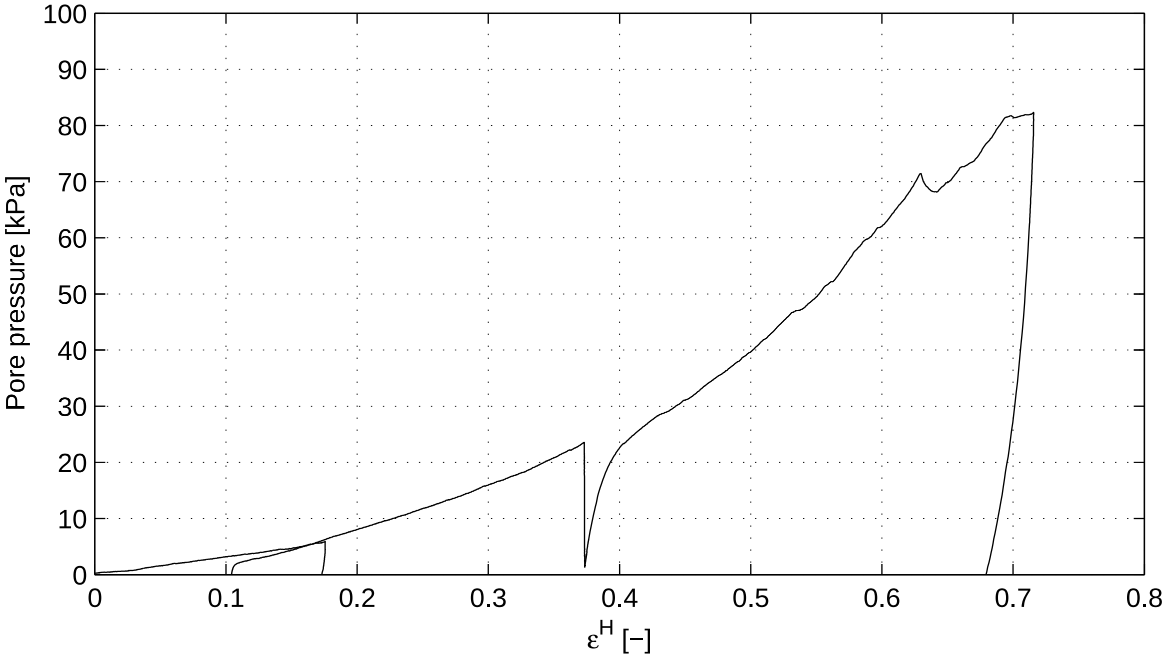
date	signed
2016−06−09	luije_sa
project	version
1209862.11	1.1
appendix	page
CRSNW1A2−A6−1B	3

Contribution study program EQ Groningen field

Boring NW1A2−A, sample NW1A2−A6−1B, depth: −5.98 m to −6.01 m NAP

K0−CRS measurement



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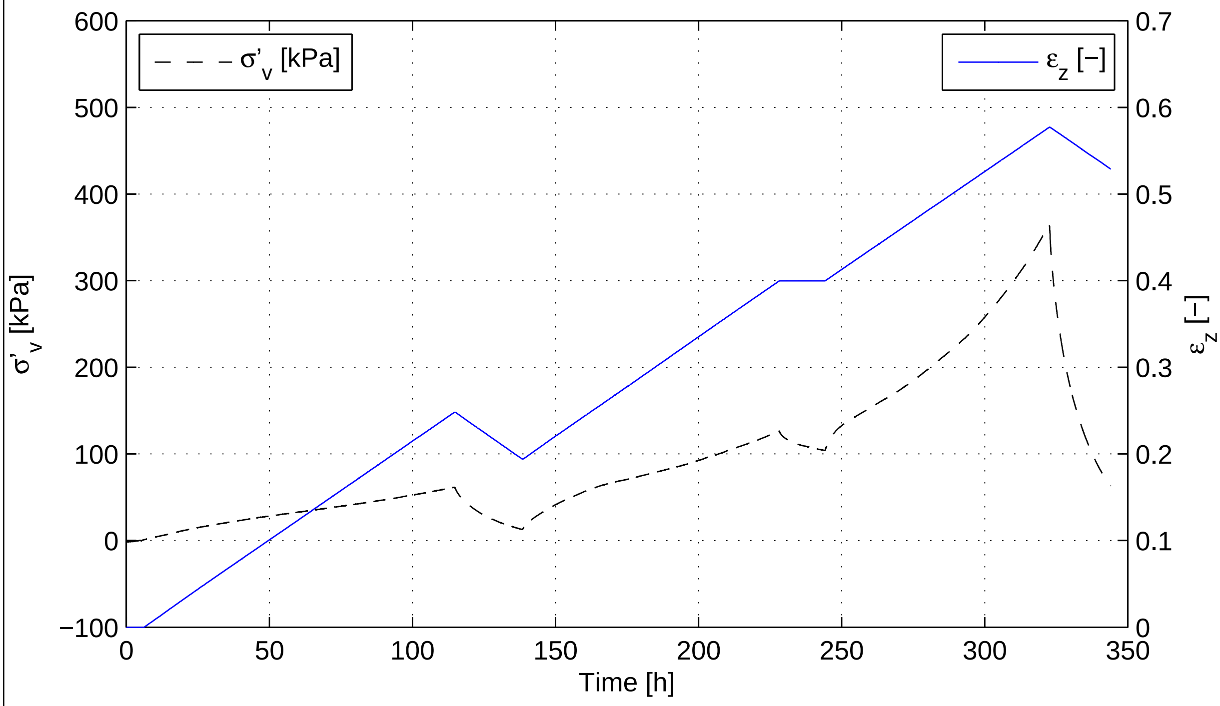
date	signed
2016−06−09	luije_sa

Contribution study program EQ Groningen field

Boring NW1A2−A, sample NW1A2−A6−1B, depth: −5.98 m to −6.01 m NAP

K0−CRS measurement

project	version
1209862.11	1.1



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, tak..
Unit weight saturated soil [kN/m^3]	9.6
Unit weight dry soil [kN/m^3]	1.3
Water content [%]	620.2
Water content final [%]	288.9
Void ratio − initial [−]	5.40 (e)
Sample disturbance index [%]	12.0, bad quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	140
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

Meting eerder beeindigd omwille van tijd

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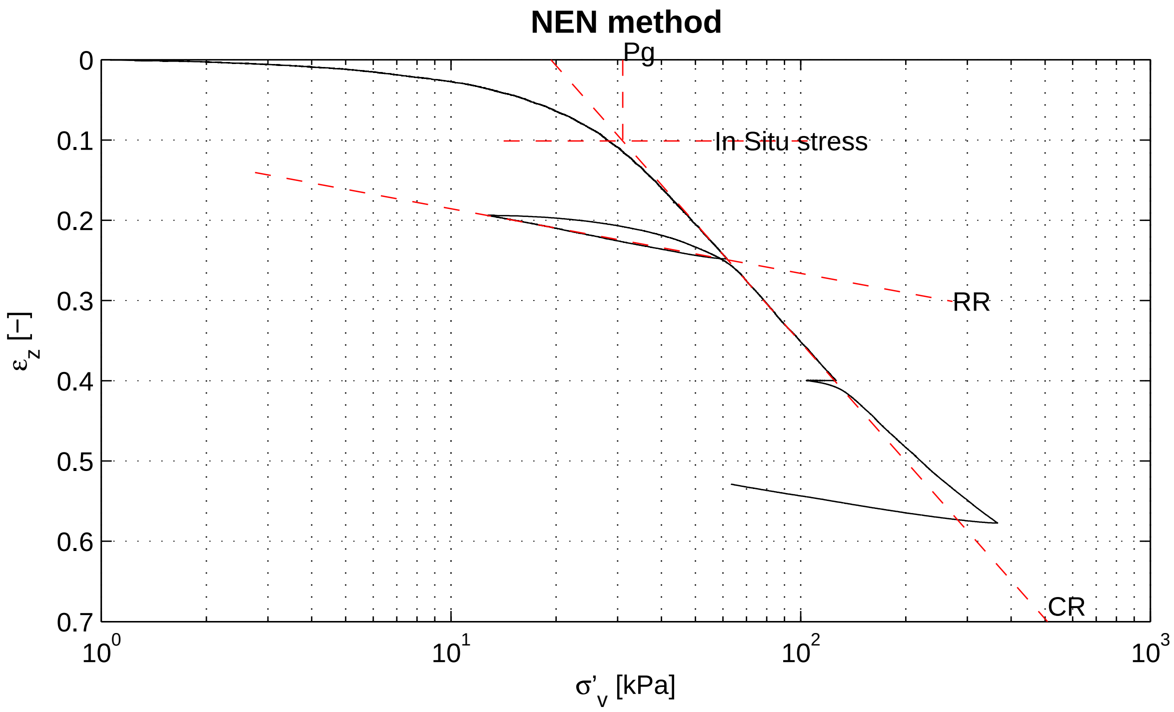
Contribution study program EQ Groningen field	date 2016−05−30	signed venema
Boring NW1A2−A, sample NW1A2−A6−2B, depth: −6.48 m to −6.51 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix NW1A2−A6−2B	page 1

NEN method

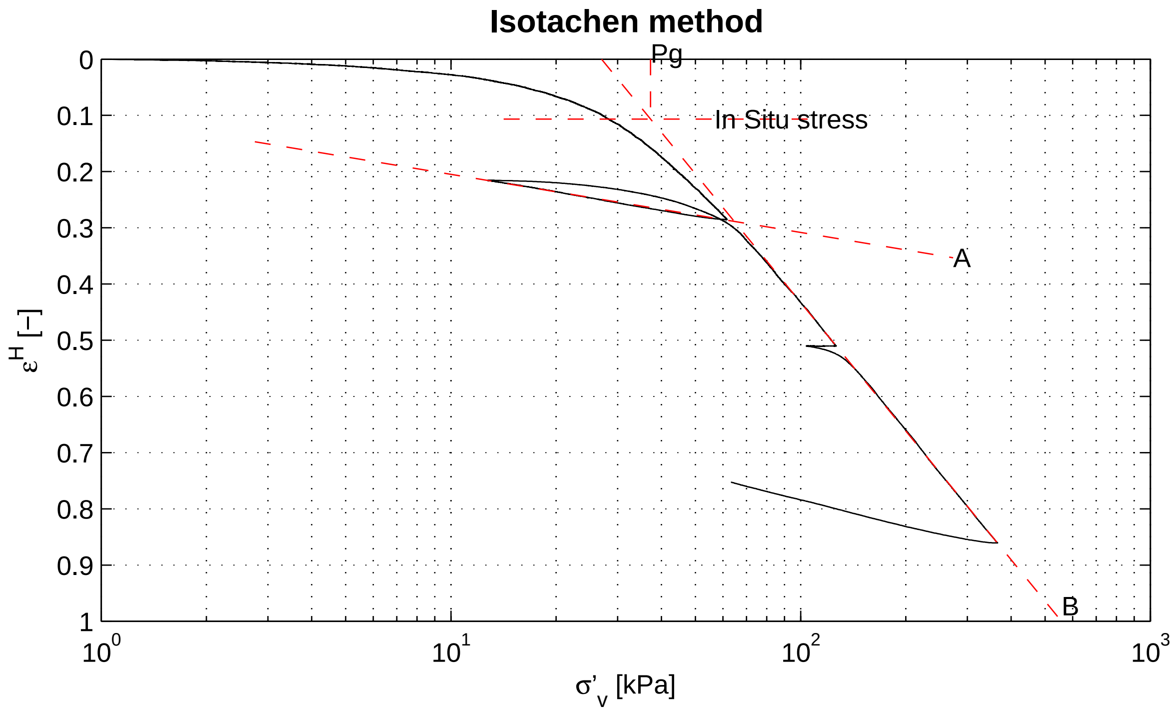


RR = 8.0e−02
CR = 4.9e−01

C_α = 3.9e−02

Pg = 31.0 kPa

Isotachen method



A = 4.5e−02
B = 3.3e−01

C = 2.6e−02

Pg = 37.2 kPa

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date	signed
2016−05−30	venema
project	version
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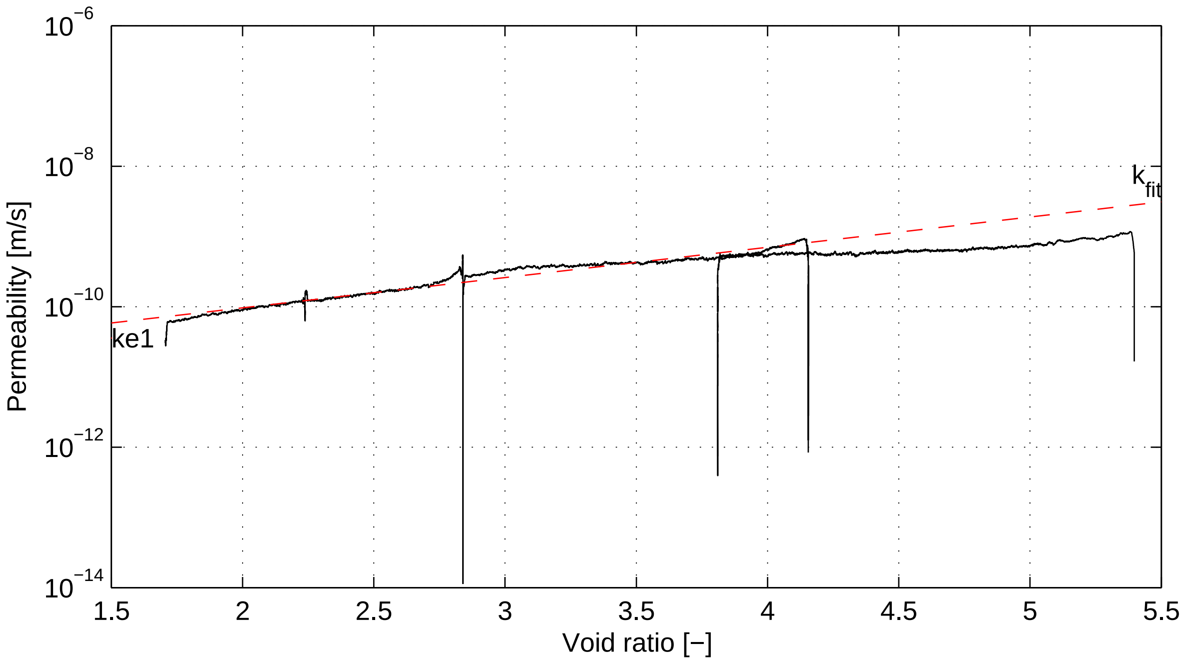
appendix	page
NW1A2−A6−2B	2

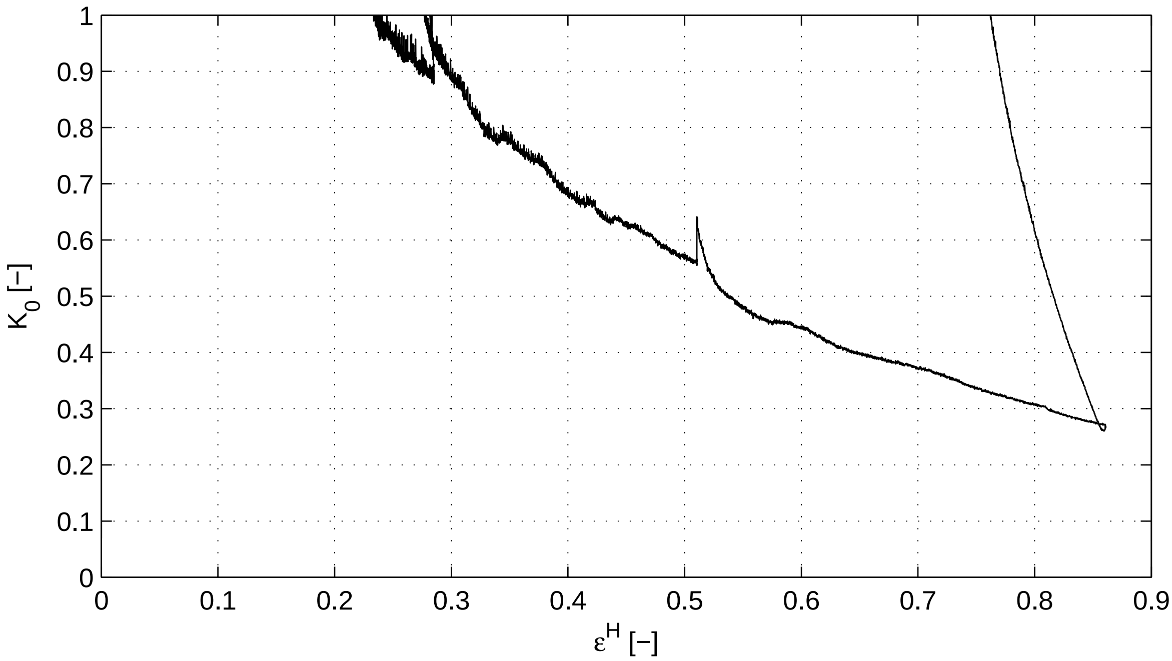
Contribution study program EQ Groningen field

Boring NW1A2−A, sample NW1A2−A6−2B, depth: −6.48 m to −6.51 m NAP

K0−CRS measurement



k_{e1} = 3.6e−11 m/s k_{e0} = 2.8e−09 m/s slope = 4.31e−01



ν = 0.13 K_{0m} = 0.27 K_{0e} = 0.27

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date	signed
2016−05−30	venema
project	version
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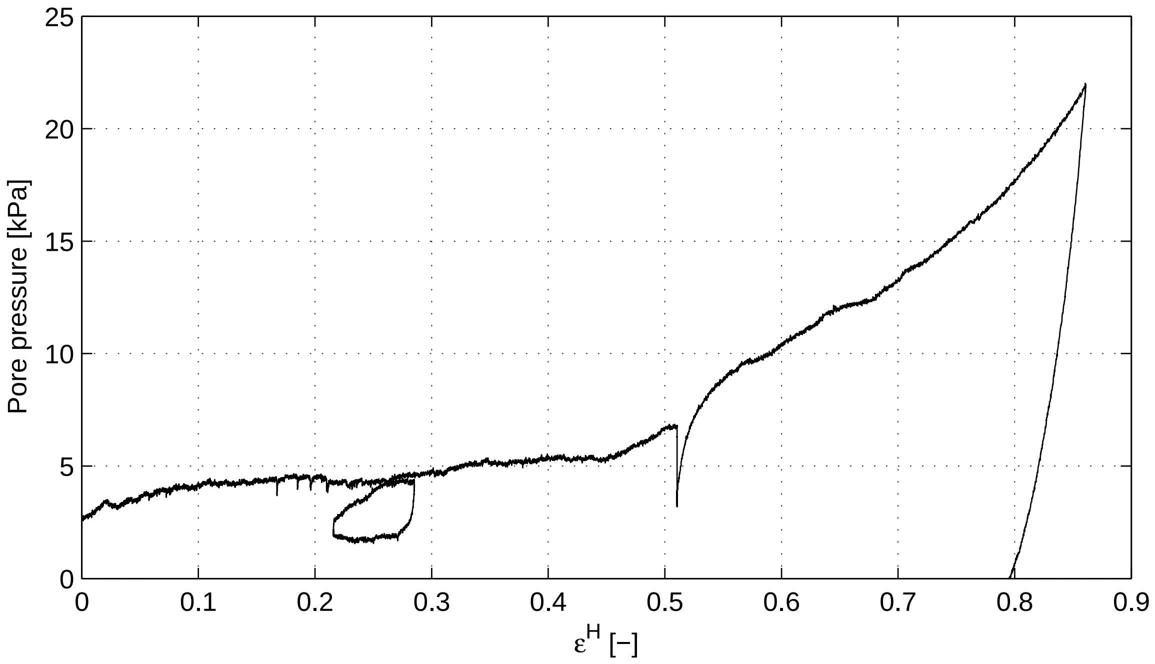
appendix	page
NW1A2−A6−2B	3

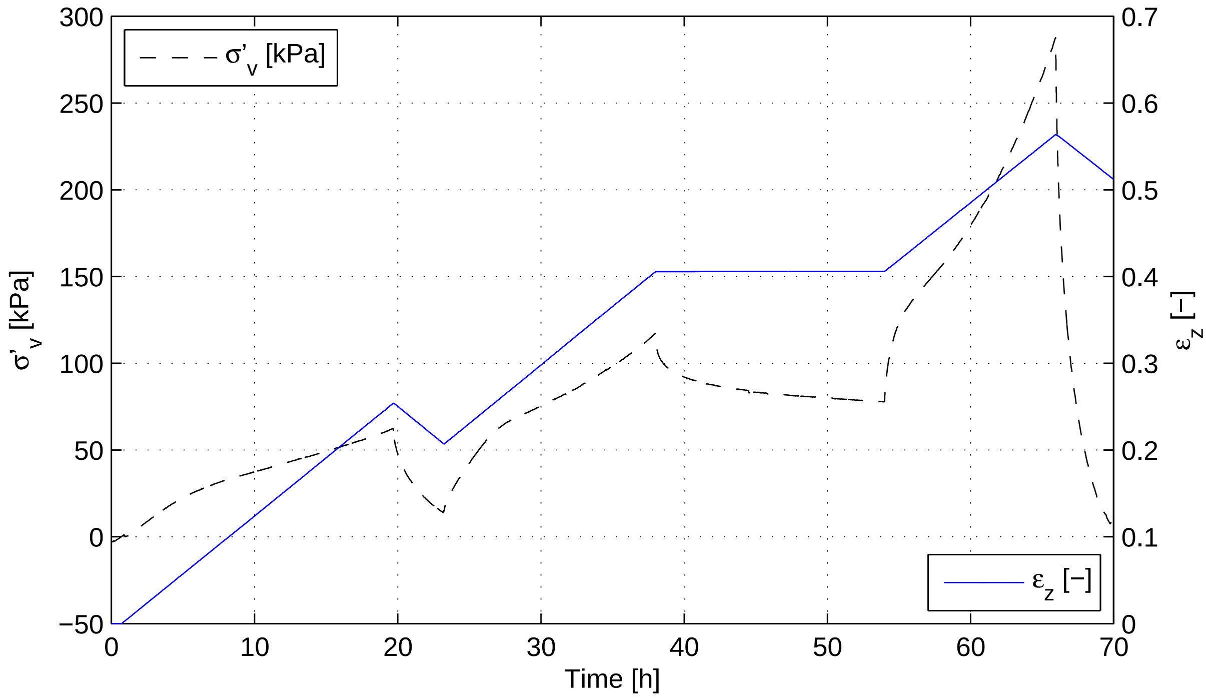
Contribution study program EQ Groningen field

Boring NW1A2−A, sample NW1A2−A6−2B, depth: −6.48 m to −6.51 m NAP

K0−CRS measurement



Pore pressure [kPa]
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
ε^H [−]



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm
Unit weight saturated soil [kN/m^3]	9.6
Unit weight dry soil [kN/m^3]	1.3
Water content [%]	627.0
Water content final [%]	310.1
Void ratio − initial [−]	5.57 (e)
Sample disturbance index [%]	9.4, bad quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	75
Stress unloading phase [kPa]	15
Stress reloading phase [kPa]	149
Stress relaxation phase [kPa]	150
Maximum stress [kPa]	400

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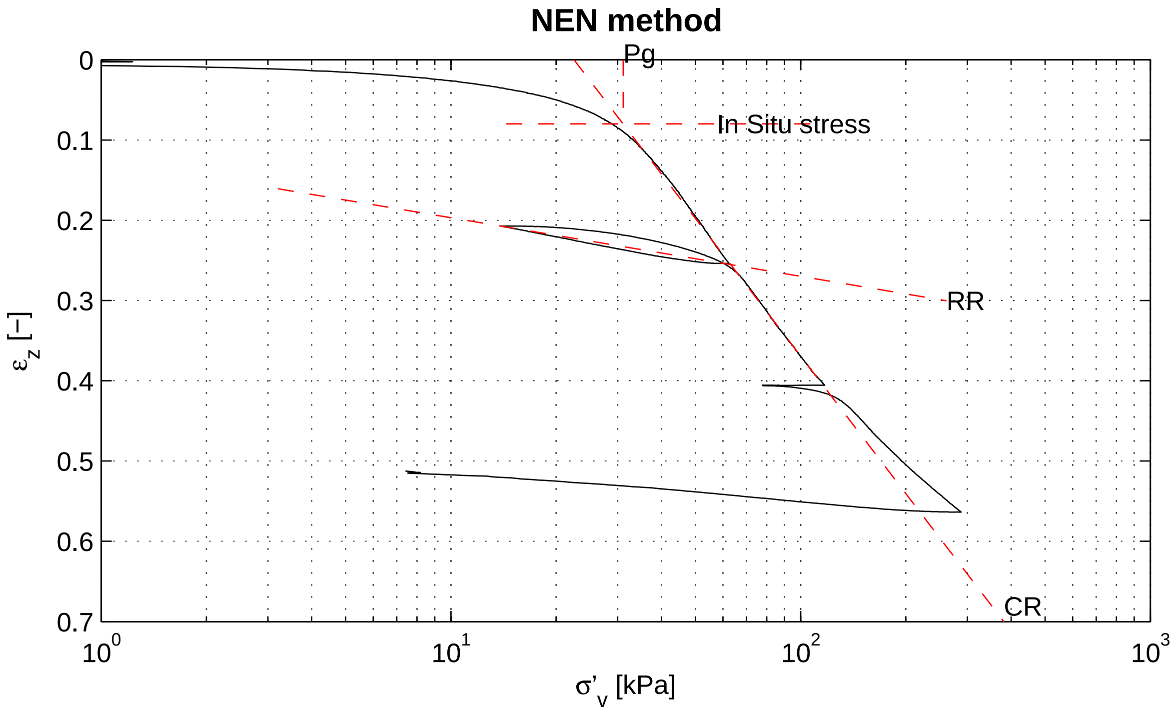
appendix	page
NW1A2−A7−1B	1

Contribution study program EQ Groningen field

Boring NW1A2−A, sample NW1A2−A7−1B, depth: −6.93 m to −6.96 m NAP

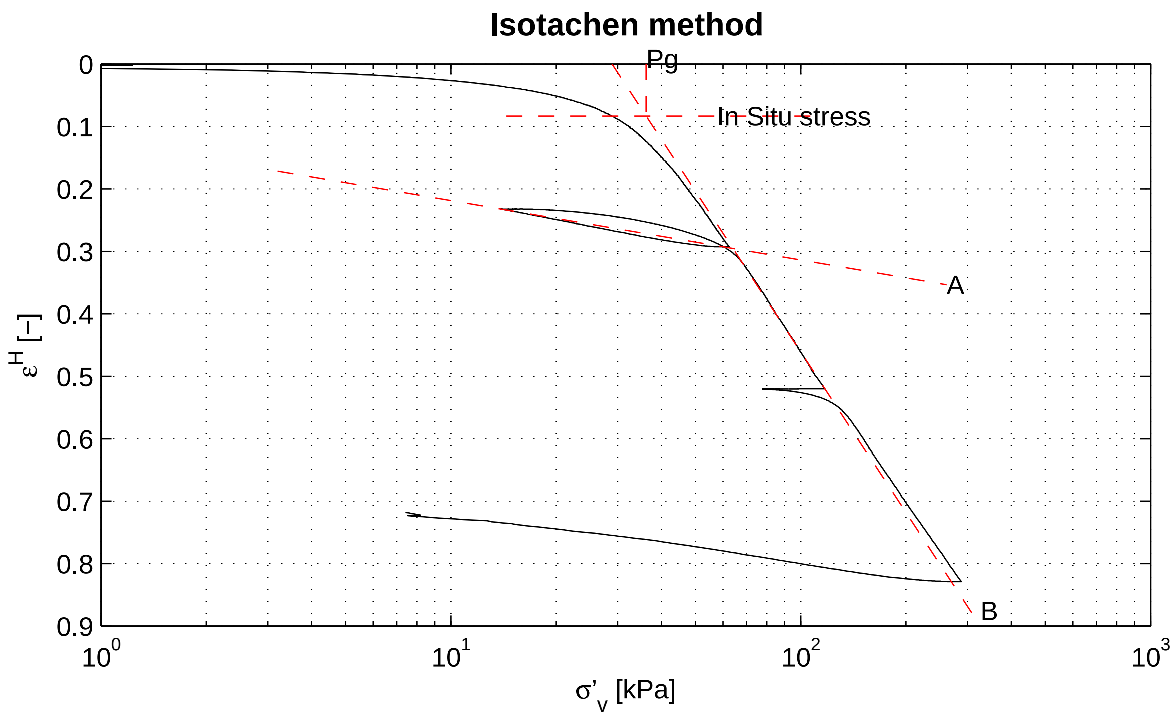
K0−CRS measurement



RR = 7.3e−02
CR = 5.7e−01

C_α = 4.4e−02

Pg = 31.1 kPa



A = 4.1e−02
B = 3.7e−01

C = 2.9e−02

Pg = 36.2 kPa

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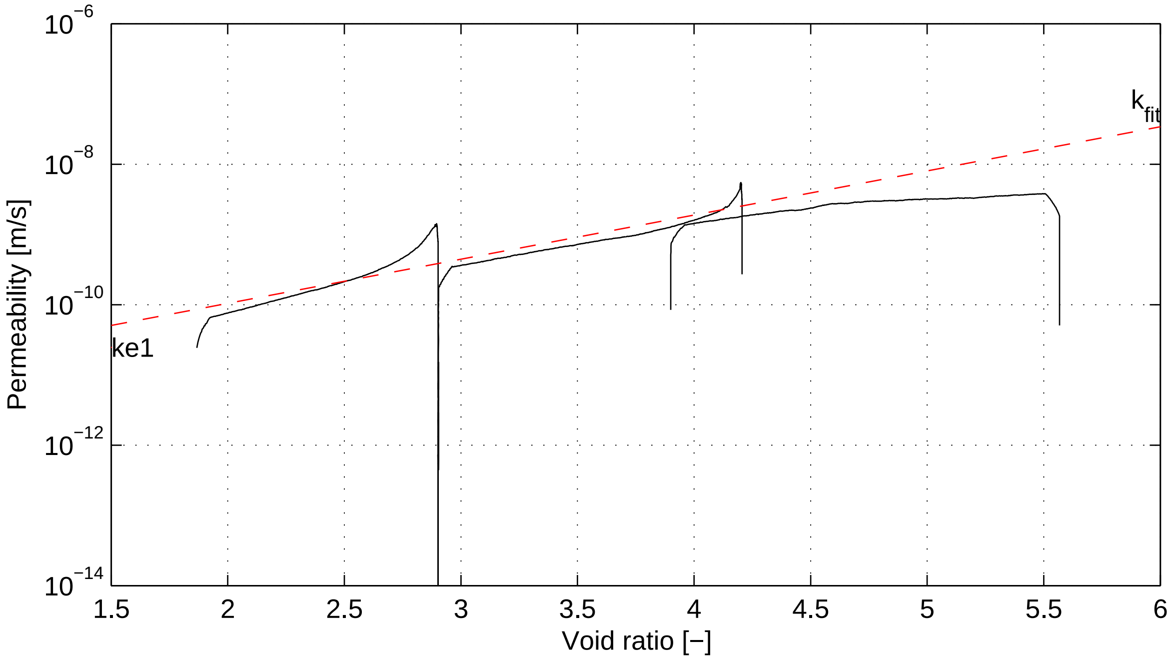
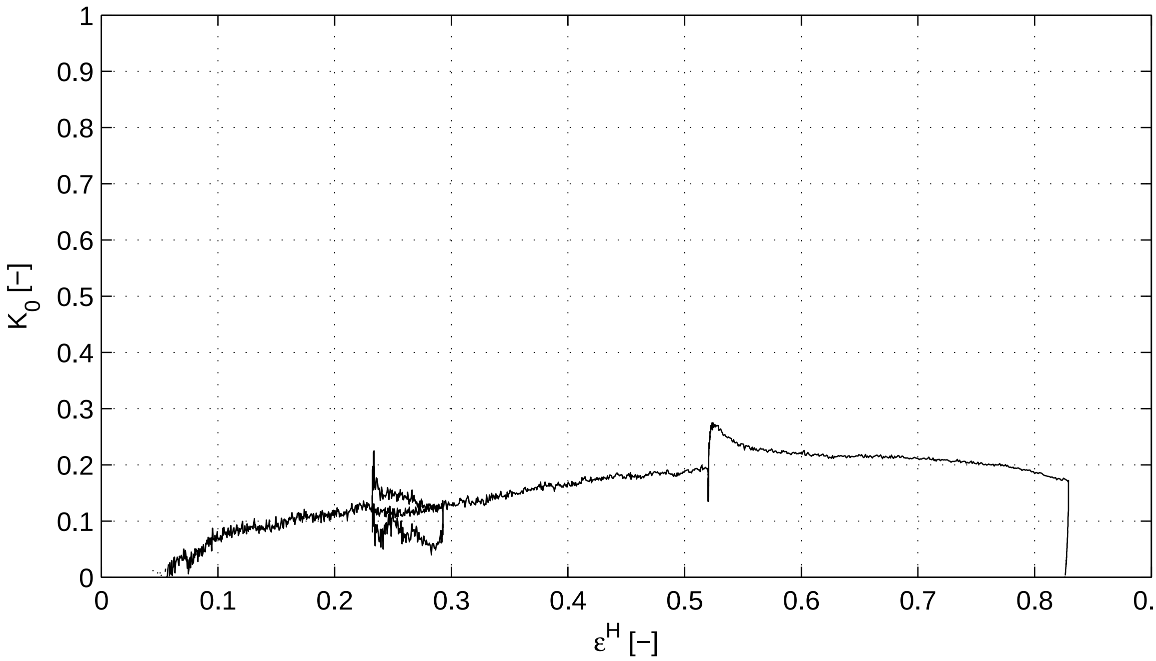
Contribution study program EQ Groningen field		date	signed
		2016−06−02	venema
Boring NW1A2−A, sample NW1A2−A7−1B, depth: −6.93 m to −6.96 m NAP		project	version
		1209862.11	1.1
K0−CRS measurement		appendix	page
		NW1A2−A7−1B	2



k_{e1} = 2.5e−11 m/s k_{e0} = 1.8e−08 m/s slope = 6.29e−01



ν = 0.11 K_{0m} = 0.16 K_{0e} = 0.18

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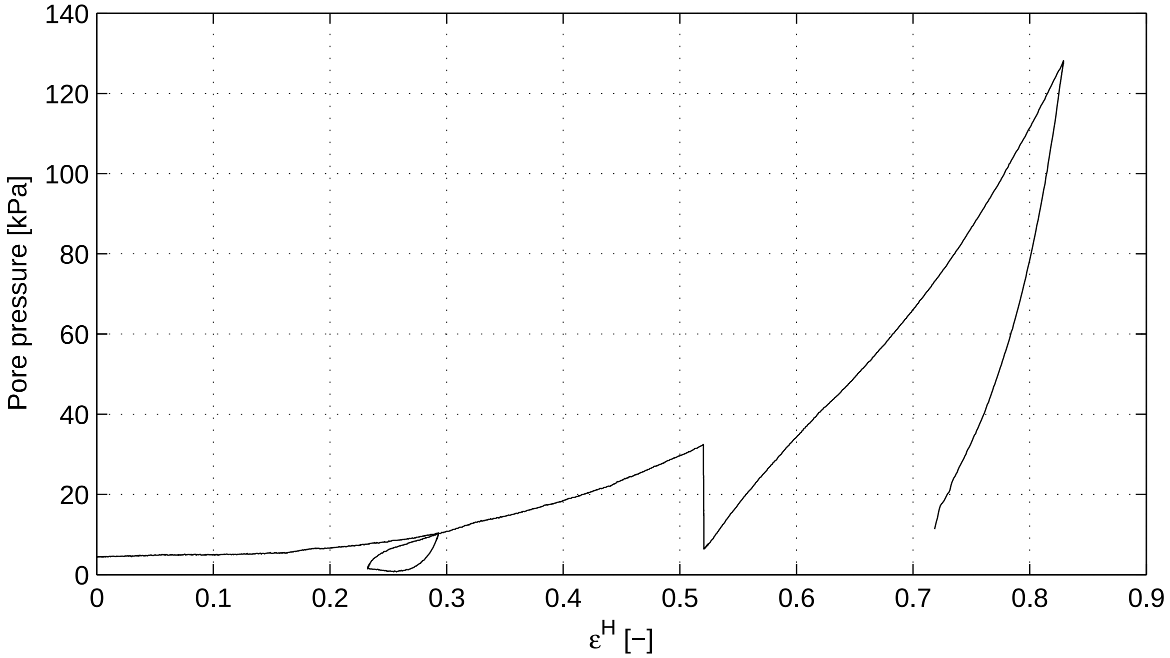
Contribution study program EQ Groningen field Boring NW1A2−A, sample NW1A2−A7−1B, depth: −6.93 m to −6.96 m NAP K0−CRS measurement				project 1209862.11 appendix NW1A2−A7−1B	version 1.1 page 3



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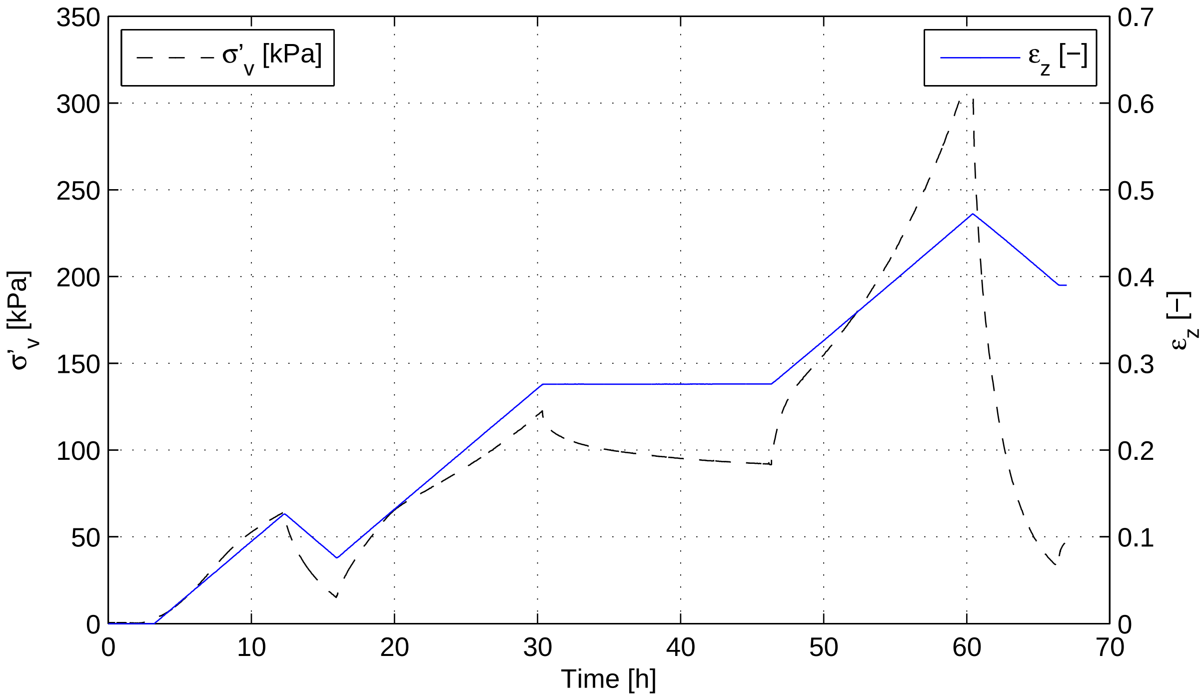
	date 2016−06−02	signed venema
Contribution study program EQ Groningen field Boring NW1A2−A, sample NW1A2−A7−1B, depth: −6.93 m to −6.96 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix NW1A2−A7−1B	page 4



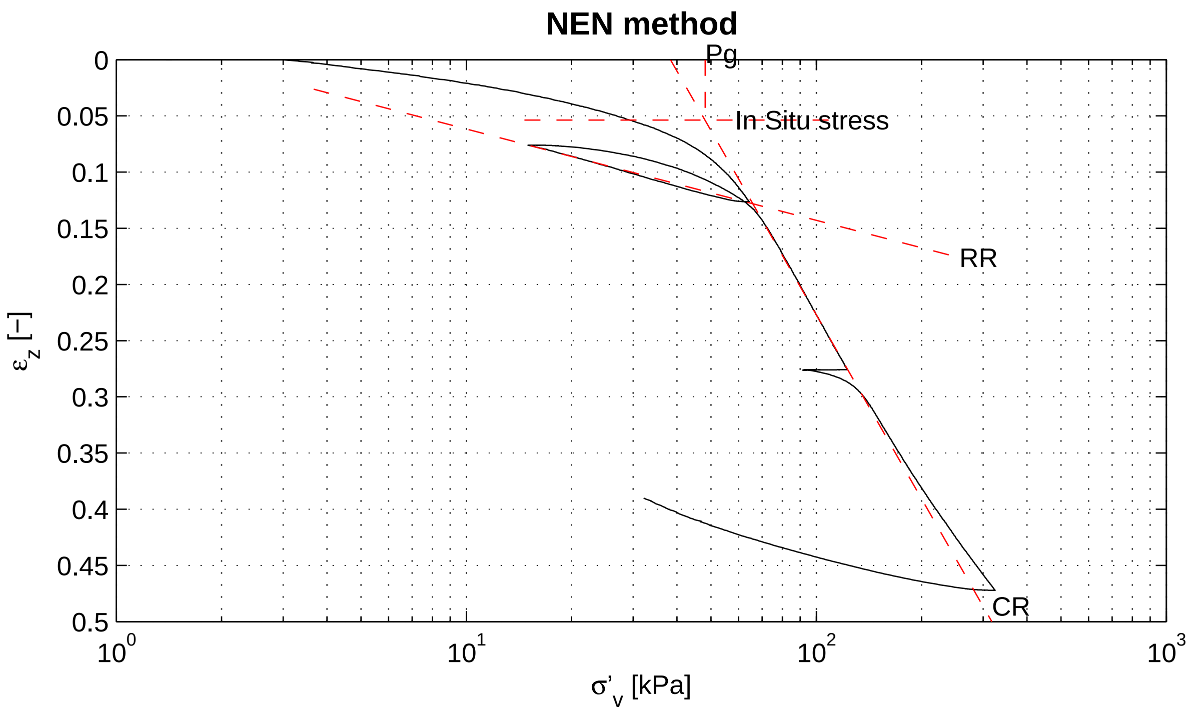
Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, zwar..
Unit weight saturated soil [kN/m^3]	10.3
Unit weight dry soil [kN/m^3]	1.9
Water content [%]	442.2
Water content final [%]	256.4
Void ratio − initial [−]	5.95 (e)
Sample disturbance index [%]	6.3, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

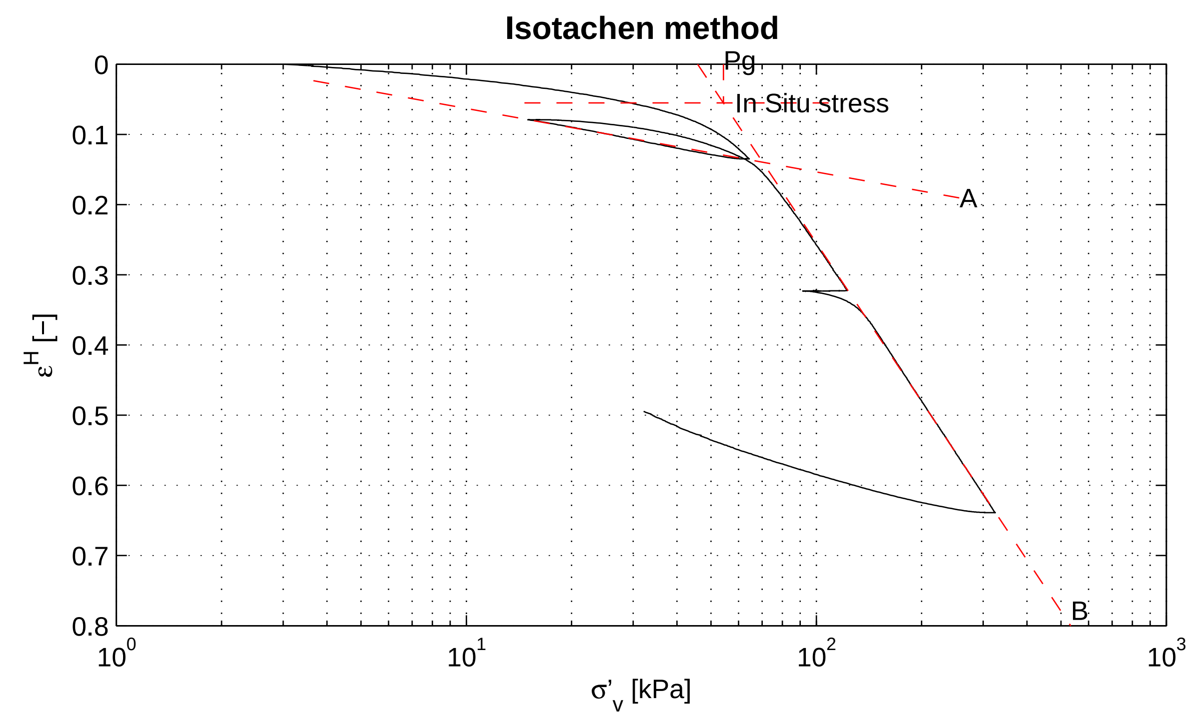
Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	139
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

NEN method



RR = 8.1e−02 C_α = 3.4e−02 Pg = 48.1 kPa
CR = 5.4e−01

Isotachen method



A = 3.9e−02 C = 2.0e−02 Pg = 54.3 kPa
B = 3.3e−01

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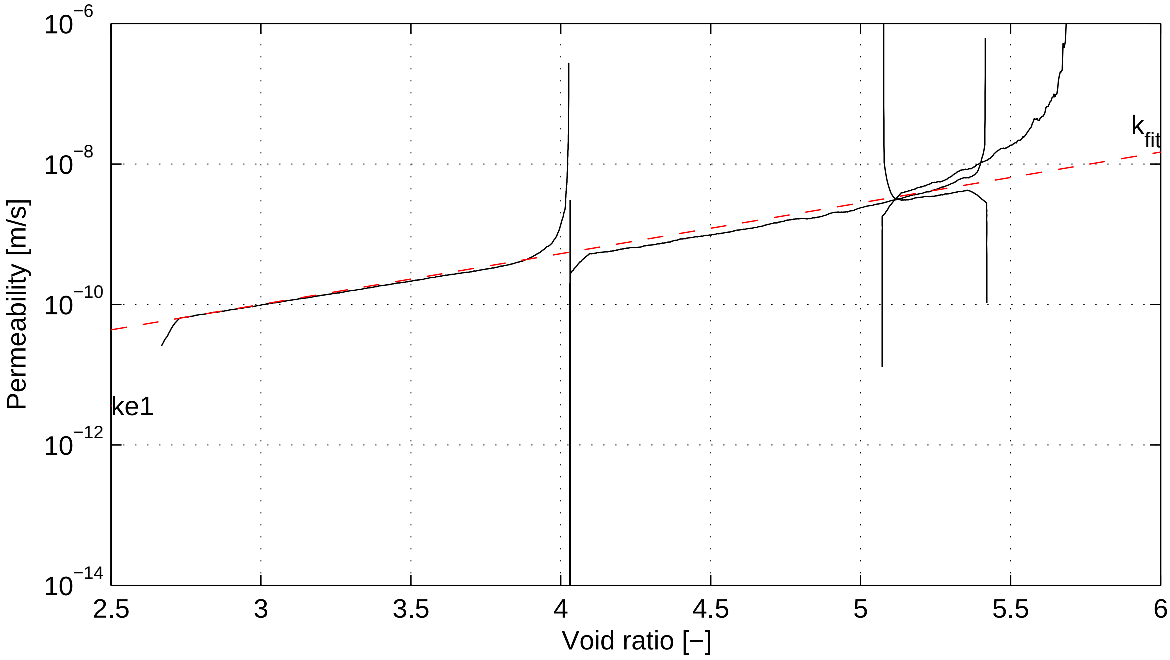
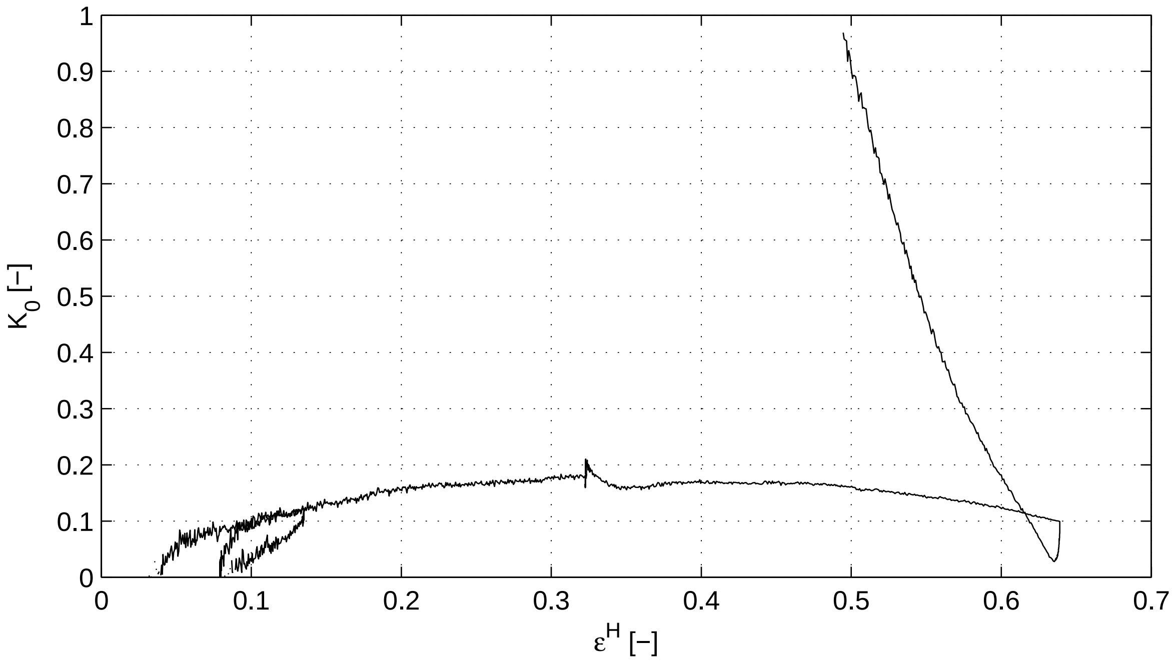
Contribution study program EQ Groningen field	date 2016−06−21	signed luije_sa
Boring NW1A2−A, sample NW1A2−A7−2B, depth: −7.13 m to −7.15 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−A7−2B	page 2



k_{e1} = 3.6e−12 m/s k_{e0} = 1.4e−08 m/s   slope = 7.23e−01



ν = 0.14 K_{0c} = 0.17 K_{0e} = 0.11

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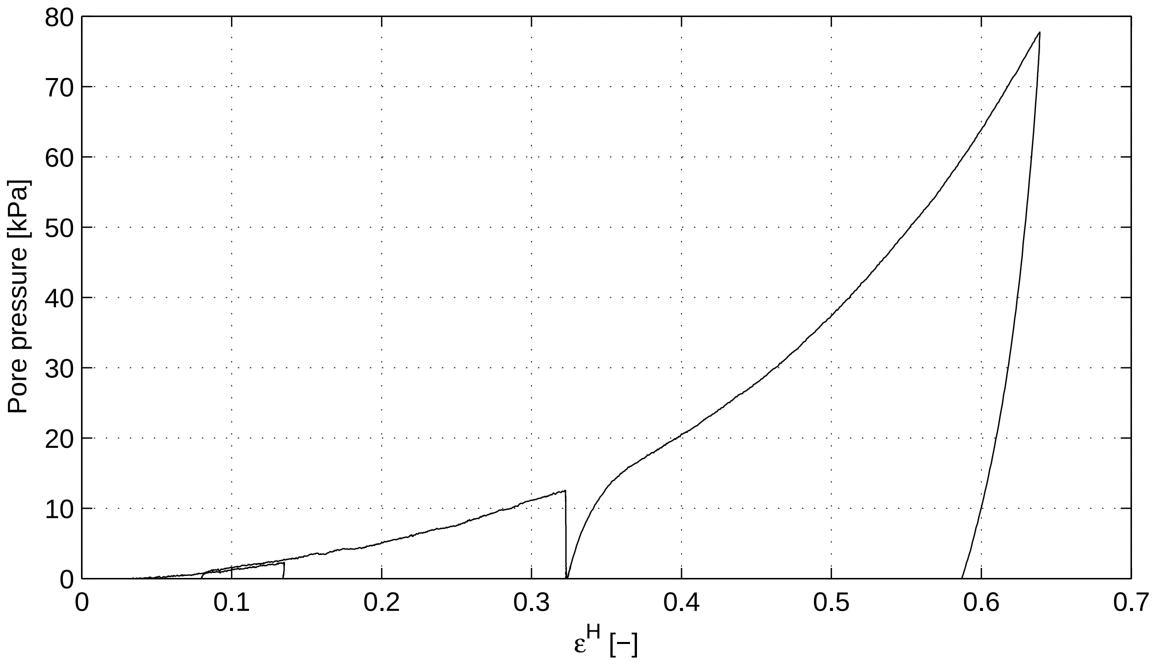
	date 2016−06−21	signed luije_sa
Contribution study program EQ Groningen field Boring NW1A2−A, sample NW1A2−A7−2B, depth: −7.13 m to −7.15 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−A7−2B	page 3



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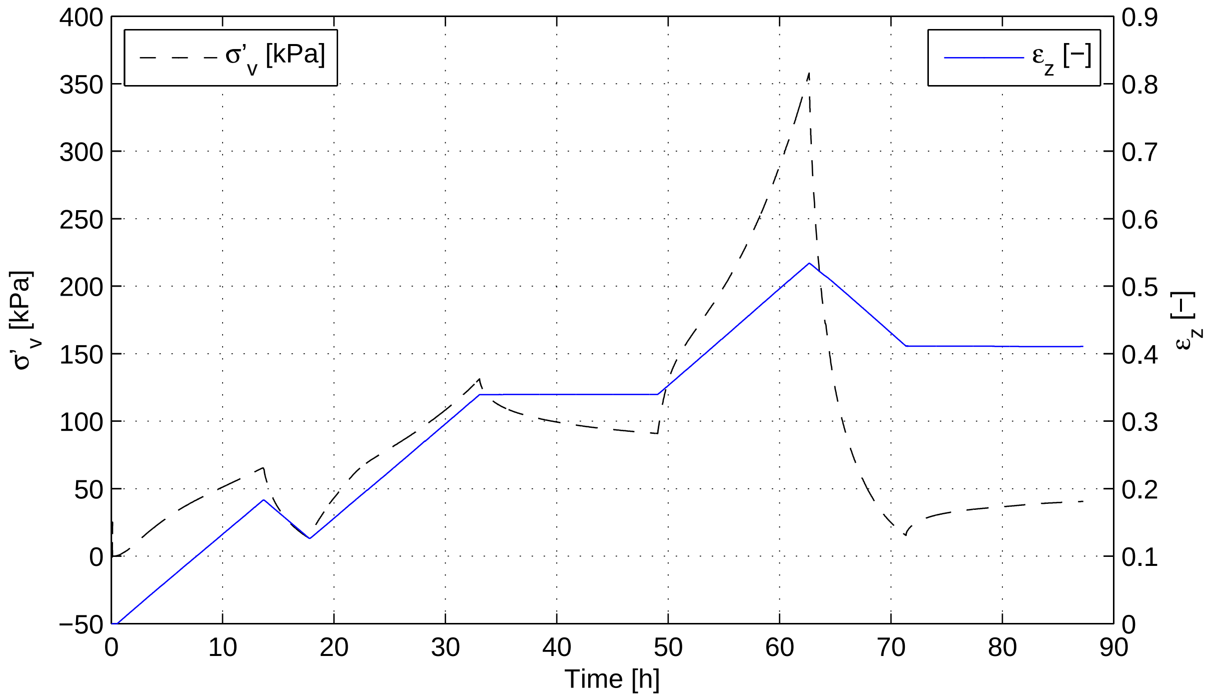
Contribution study program EQ Groningen field	date: 2016−06−21	signed: luije_sa
Boring NW1A2−A, sample NW1A2−A7−2B, depth: −7.13 m to −7.15 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSNW1A2−A7−2B	page: 4

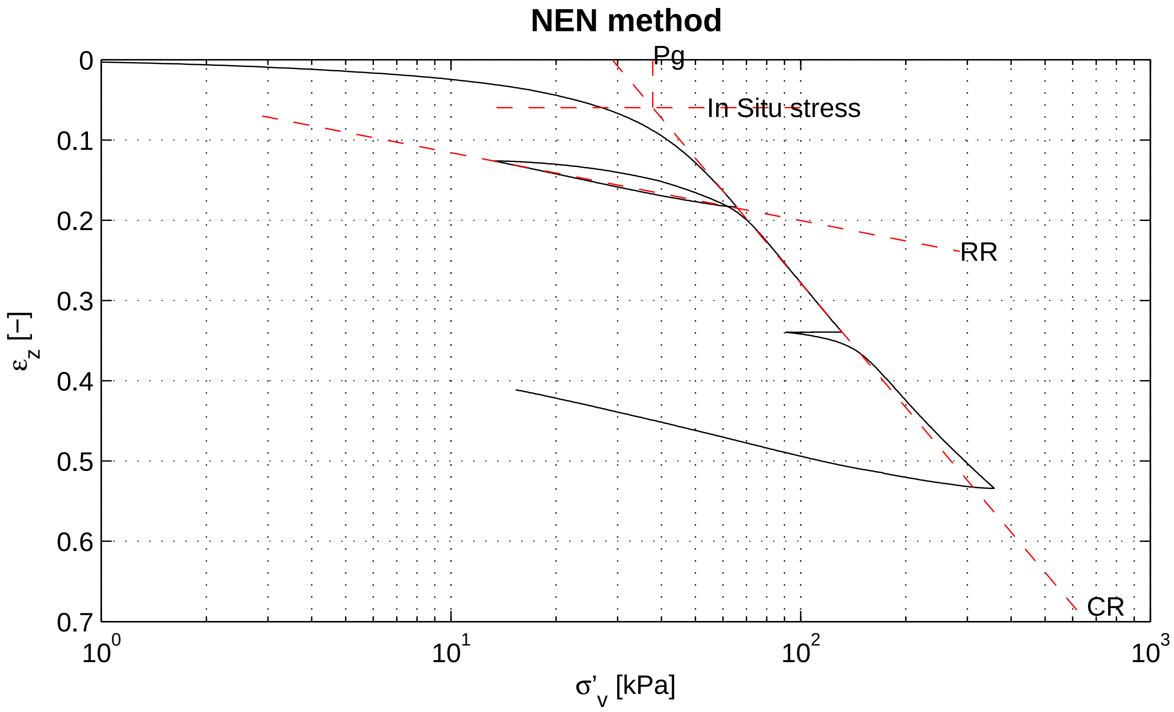


Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, plan..
Unit weight saturated soil [kN/m^3]	9.6
Unit weight dry soil [kN/m^3]	1.6
Water content [%]	494.9
Water content final [%]	318.5
Void ratio − initial [−]	4.32 (e)
Sample disturbance index [%]	7.4, bad quality
e calculated with assumed complete saturation	

Test overview (test plan):

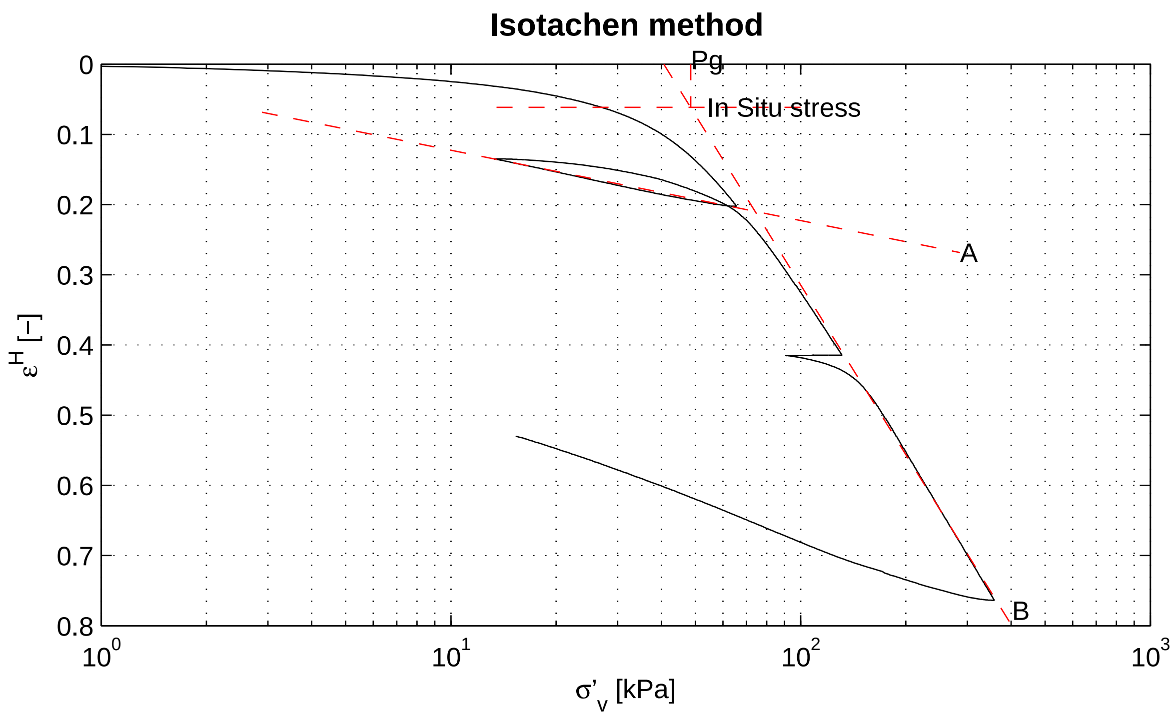
Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	140
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400



RR = 8.5e−02
CR = 5.2e−01

C_α = 5.3e−02

Pg = 37.8 kPa



A = 4.3e−02
B = 3.5e−01

C = 3.6e−02

Pg = 48.5 kPa

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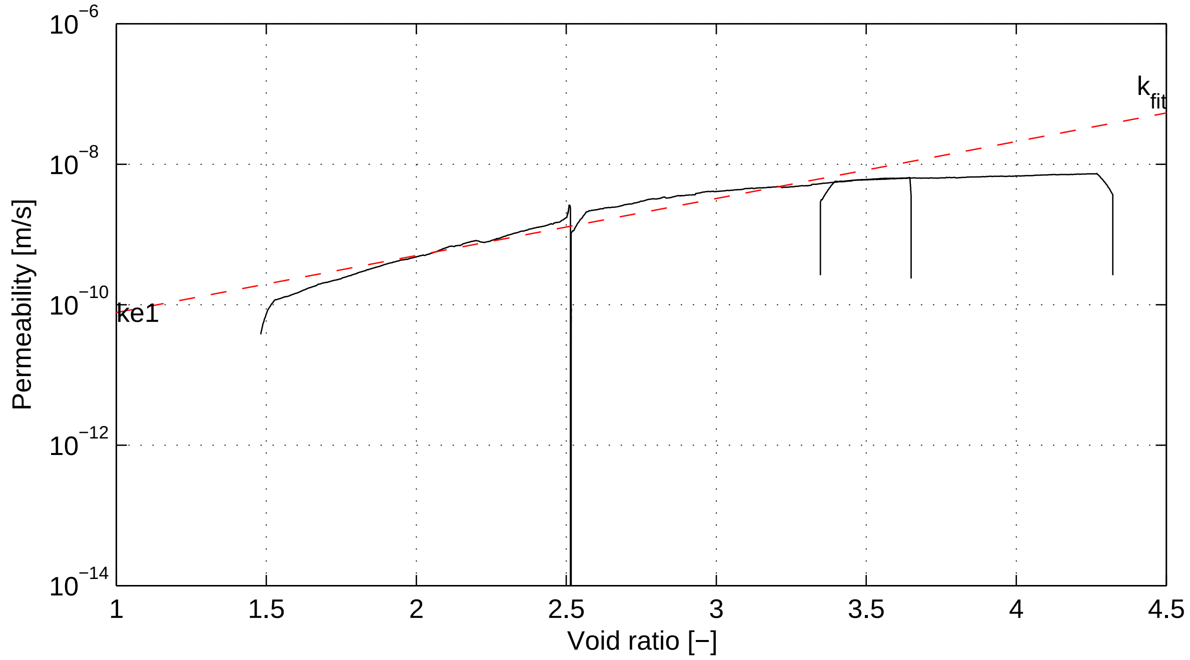
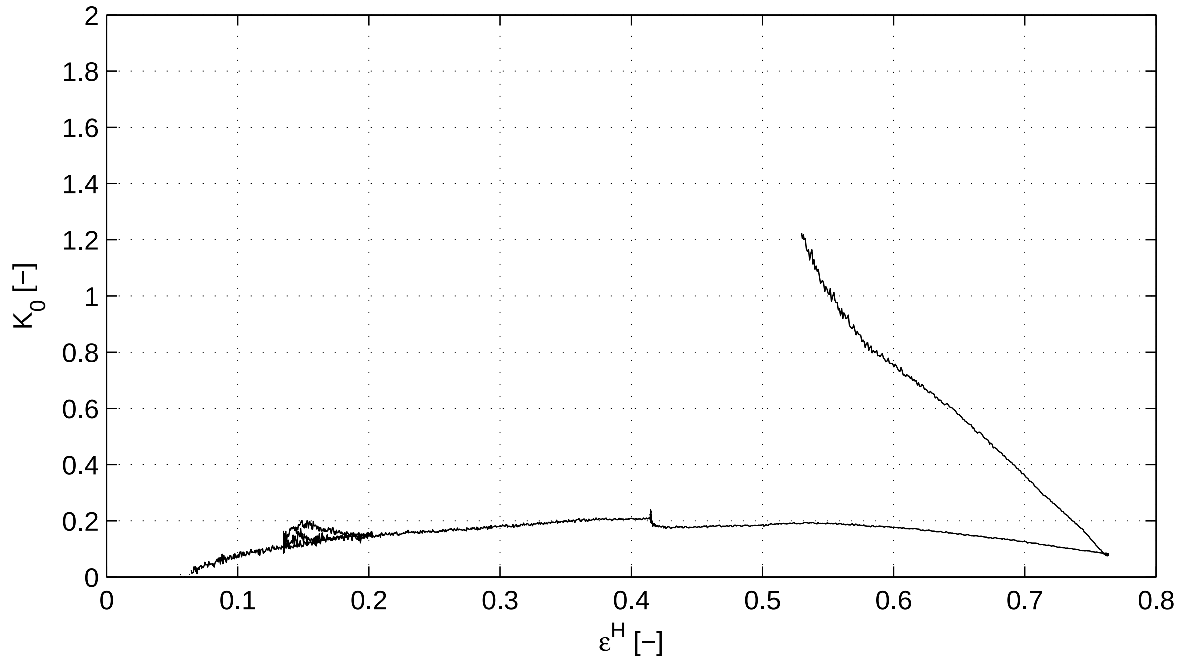
Contribution study program EQ Groningen field	date: 2016−07−12	signed: luije_sa
Boring NW1A2−B, sample NW1A2−B1−1A, depth: −5.15 m to −5.17 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSNW1A2−B1−1A	page: 2



k_{e1} = 7.7e−11 m/s k_{e0} = 3.8e−08 m/s   slope = 8.11e−01



ν = 0.14 K_{0c} = 0.20 K_{0e} = 0.09

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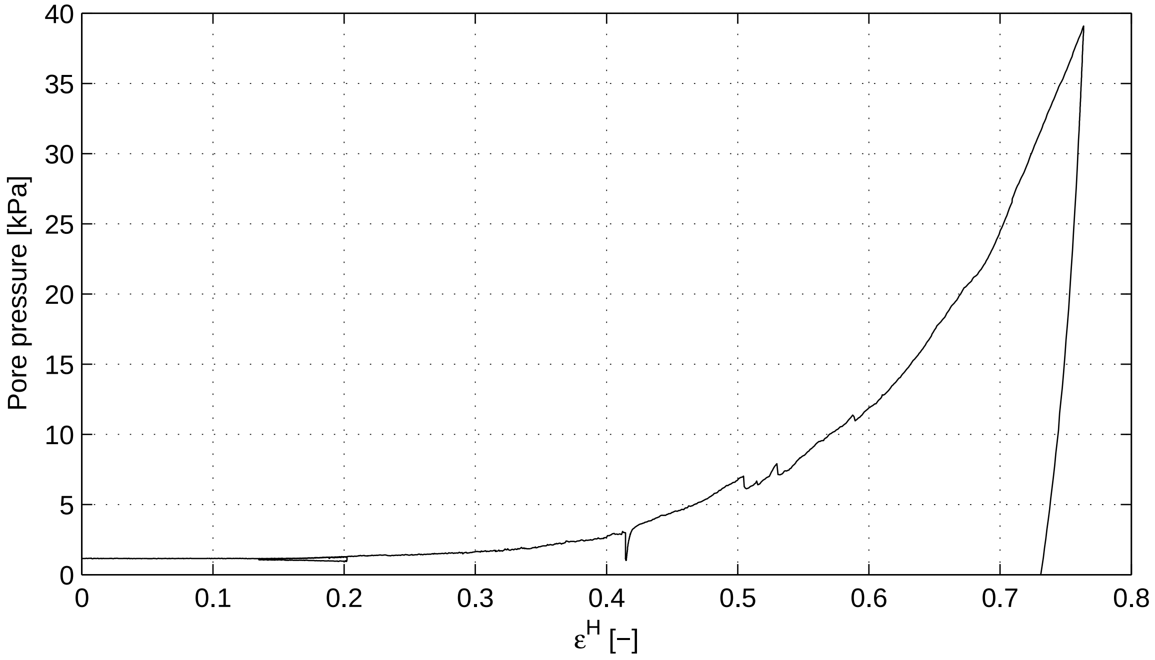
Contribution study program EQ Groningen field Boring NW1A2−B, sample NW1A2−B1−1A, depth: −5.15 m to −5.17 m NAP				project 1209862.11	version 1.1
K0−CRS measurement				appendix CRSNW1A2−B1−1A	page 3



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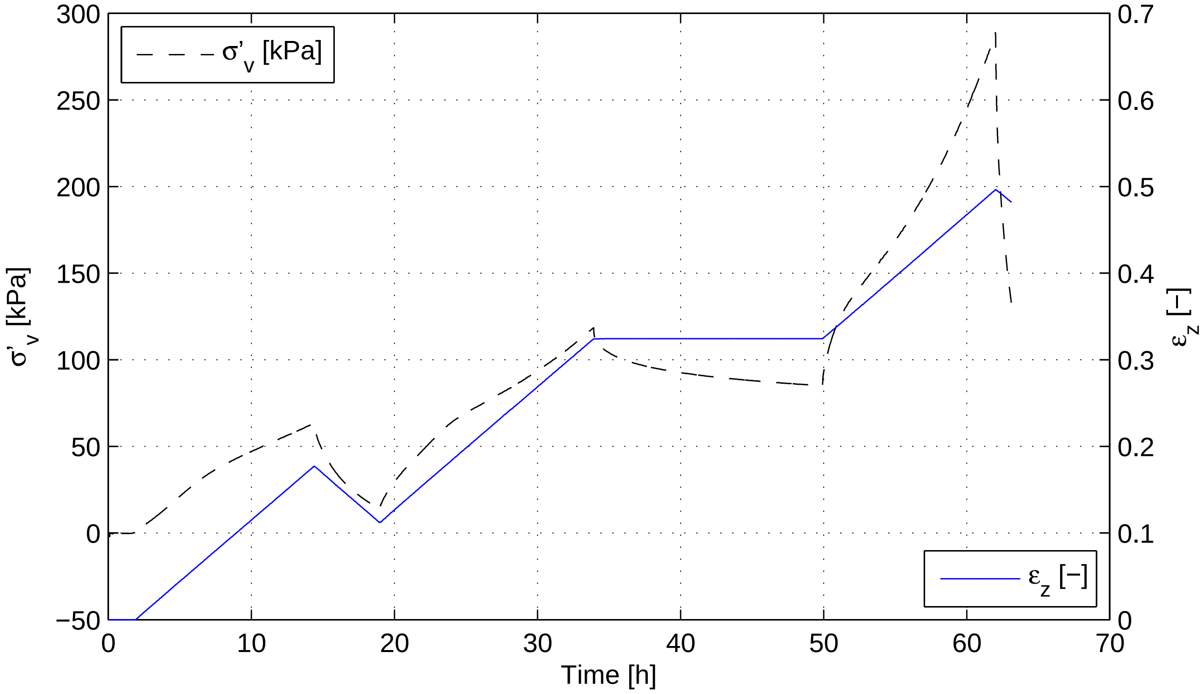
Contribution study program EQ Groningen field	date 2016−07−12	signed luije_sa
Boring NW1A2−B, sample NW1A2−B1−1A, depth: −5.15 m to −5.17 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−B1−1A	page 4



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm
Unit weight saturated soil [kN/m^3]	10.3
Unit weight dry soil [kN/m^3]	1.6
Water content [%]	521.9
Water content final [%]	319.3
Void ratio − initial [−]	7.17 (e)
Sample disturbance index [%]	6.4, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	140
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

K0 niet betrouwbaar gemeten, geen K0−parameters bepaald

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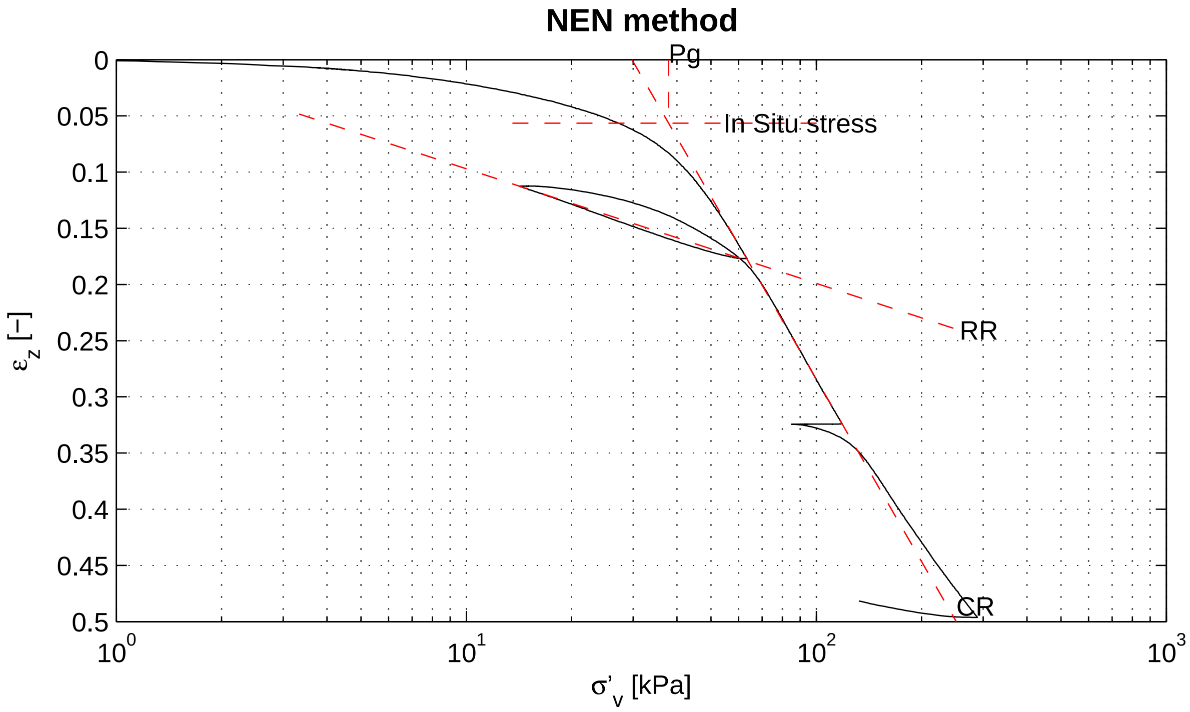
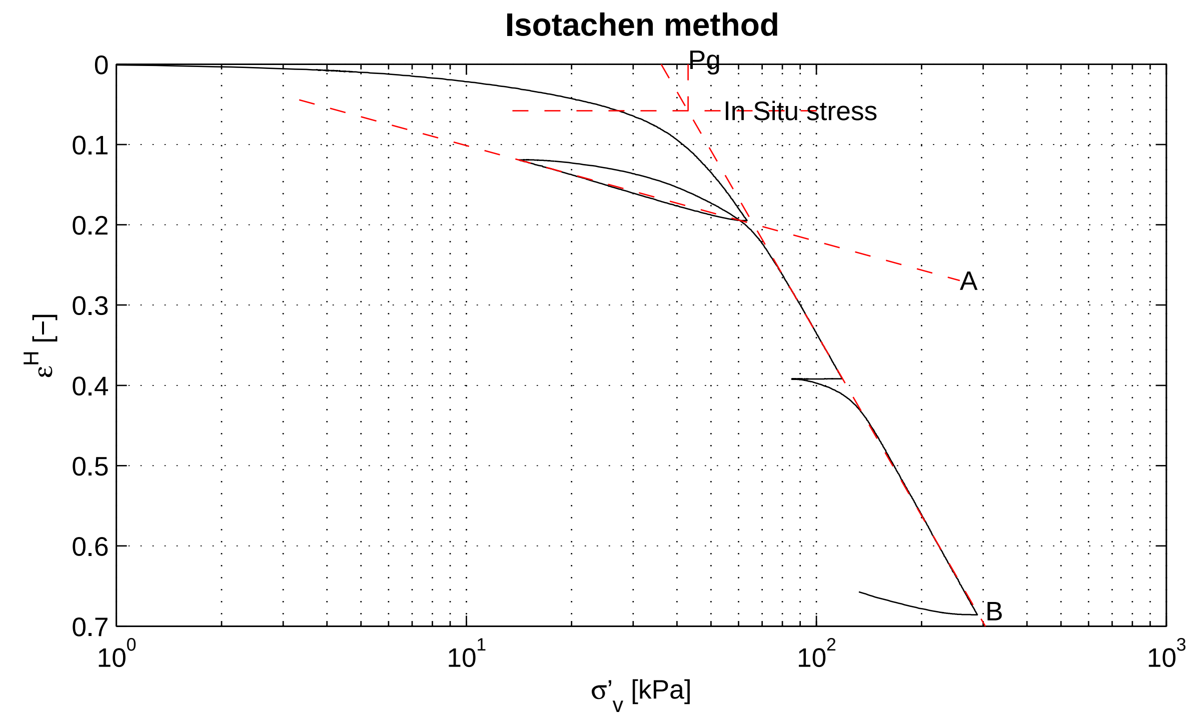
Shear degradation and damping curves for peat Boring NW1A2−B, sample NW1A2−B1−1B, depth: −5.17 m to −5.19 m NAP	date 2016−07−12	signed ess
	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−B1−1B	page 1



RR = 1.0e−01
CR = 5.4e−01

C_α = 4.0e−02

Pg = 37.8 kPa



A = 5.2e−02
B = 3.3e−01

C = 2.4e−02

Pg = 43.0 kPa

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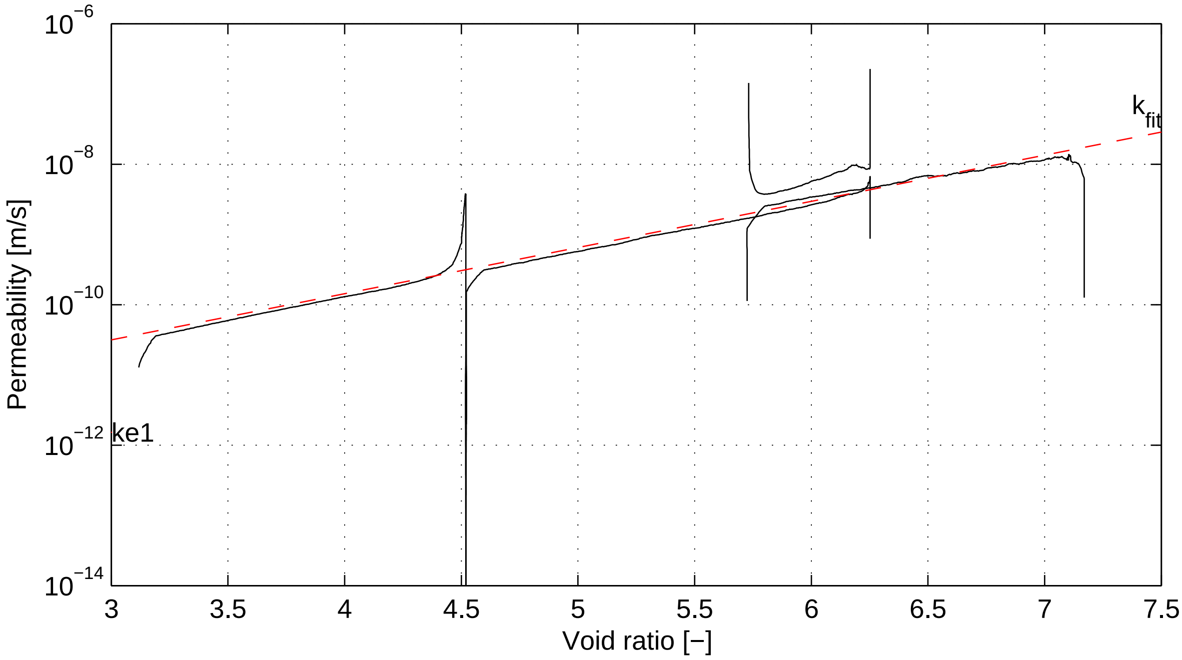
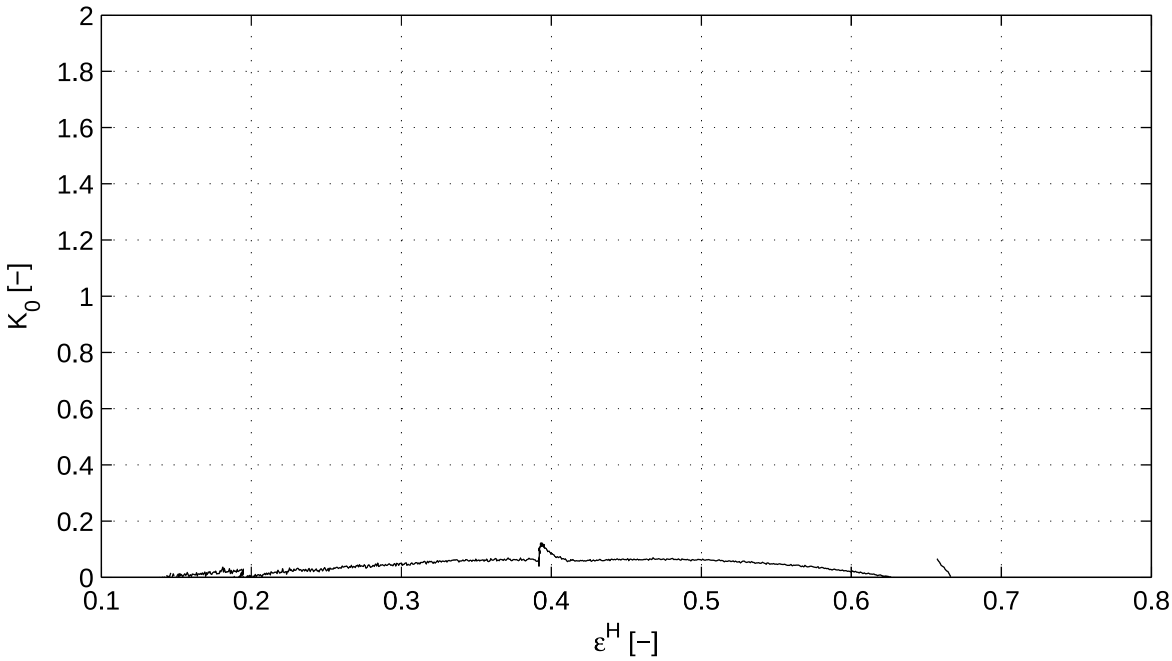
Shear degradation and damping curves for peat Boring NW1A2−B, sample NW1A2−B1−1B, depth: −5.17 m to −5.19 m NAP K0−CRS measurement				project 1209862.11 appendix CRSNW1A2−B1−1B	version 1.1 page 2



k_{e1} = 1.5e−12 m/s k_{e0} = 1.7e−08 m/s   slope = 6.58e−01



ν = NaN K_{0c} = NaN K_{0e} = NaN

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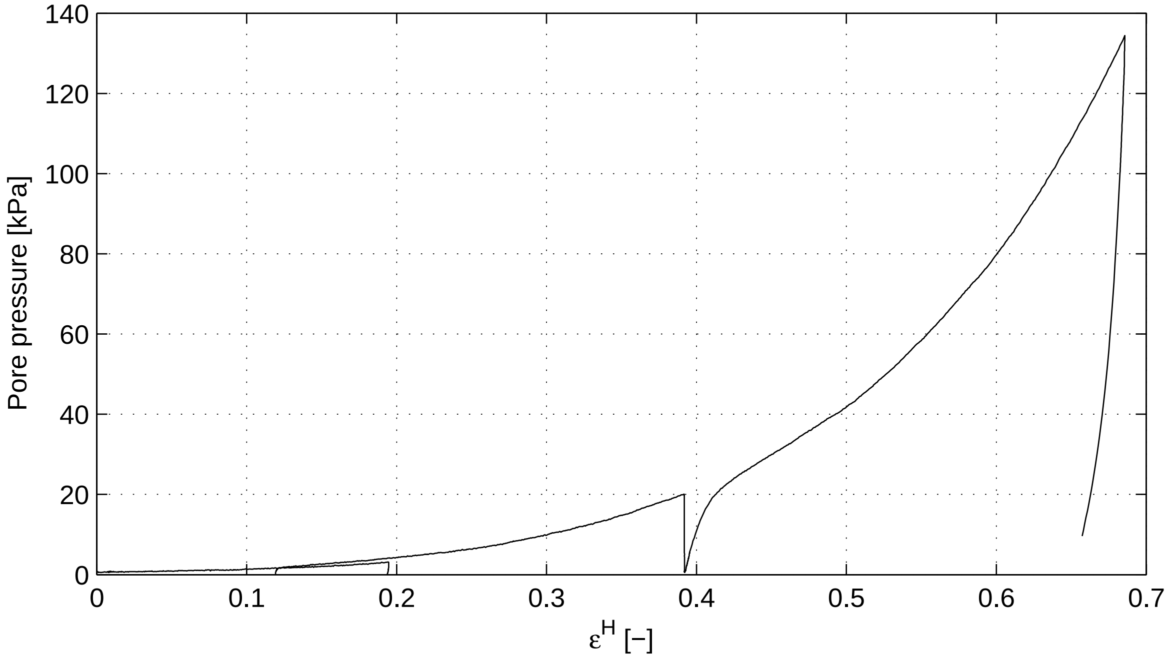
Shear degradation and damping curves for peat	date: 2016−07−12	signed: ess
Boring NW1A2−B, sample NW1A2−B1−1B, depth: −5.17 m to −5.19 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSNW1A2−B1−1B	page: 3



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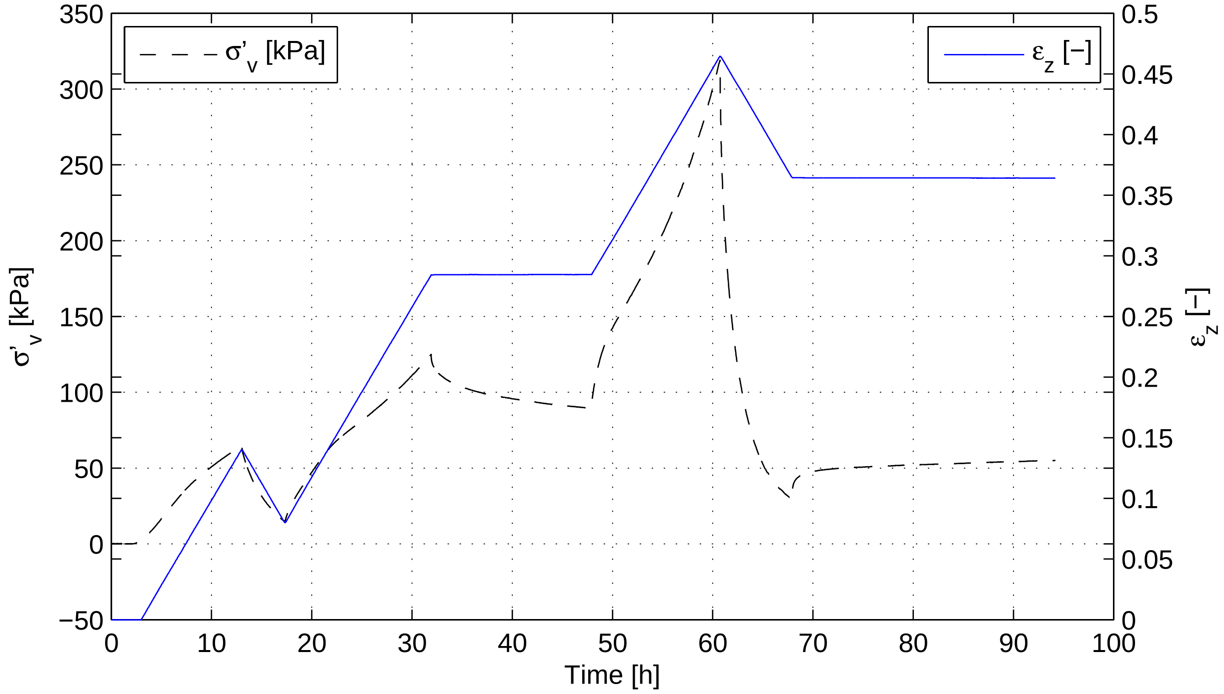
	date	signed
	2016−07−12	ess
Shear degradation and damping curves for peat Boring NW1A2−B, sample NW1A2−B1−1B, depth: −5.17 m to −5.19 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−B1−1B	page 4



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, zwart
Unit weight saturated soil [kN/m^3]	10.1
Unit weight dry soil [kN/m^3]	1.7
Water content [%]	490.4
Water content final [%]	314.0
Void ratio − initial [−]	6.06 (e)
Sample disturbance index [%]	5.5, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	140
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

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2016−06−21	luije_sa
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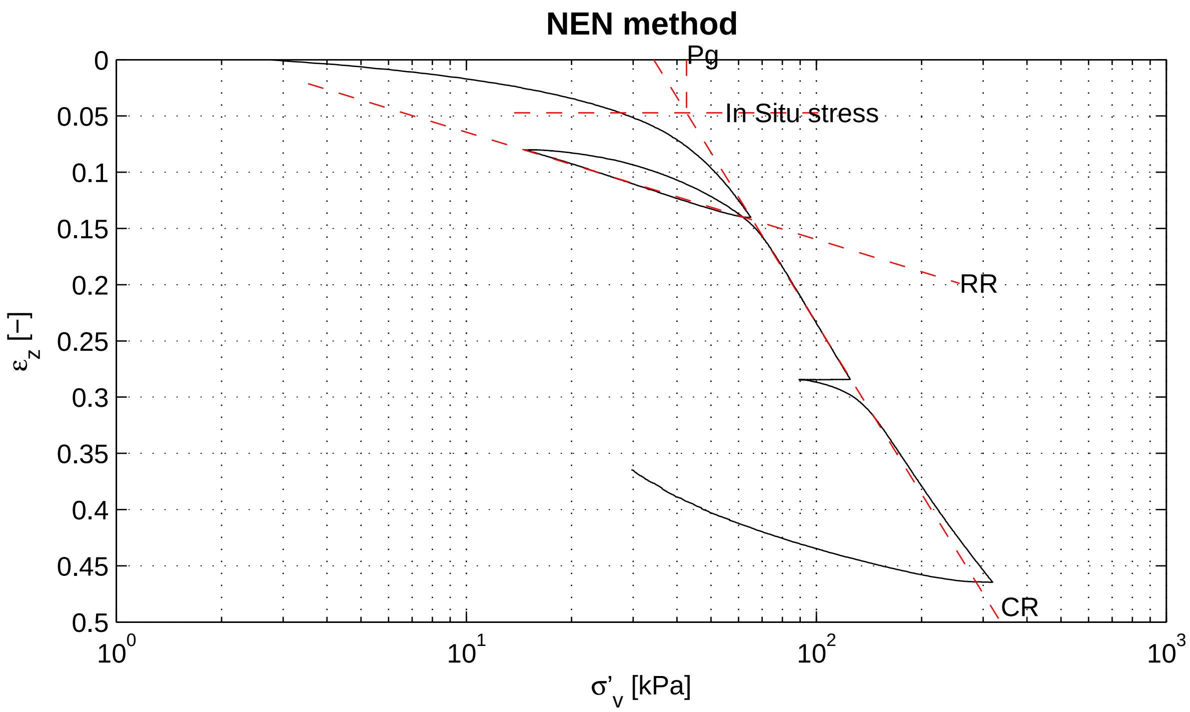
1209862.11	1.1
appendix	page
CRSNW1A2−C1−1C	1

Contribution study program EQ Groningen field

Boring NW1A2−C, sample NW1A2−C1−1C, depth: −5.40 m to −5.42 m NAP

K0−CRS measurement

NEN method

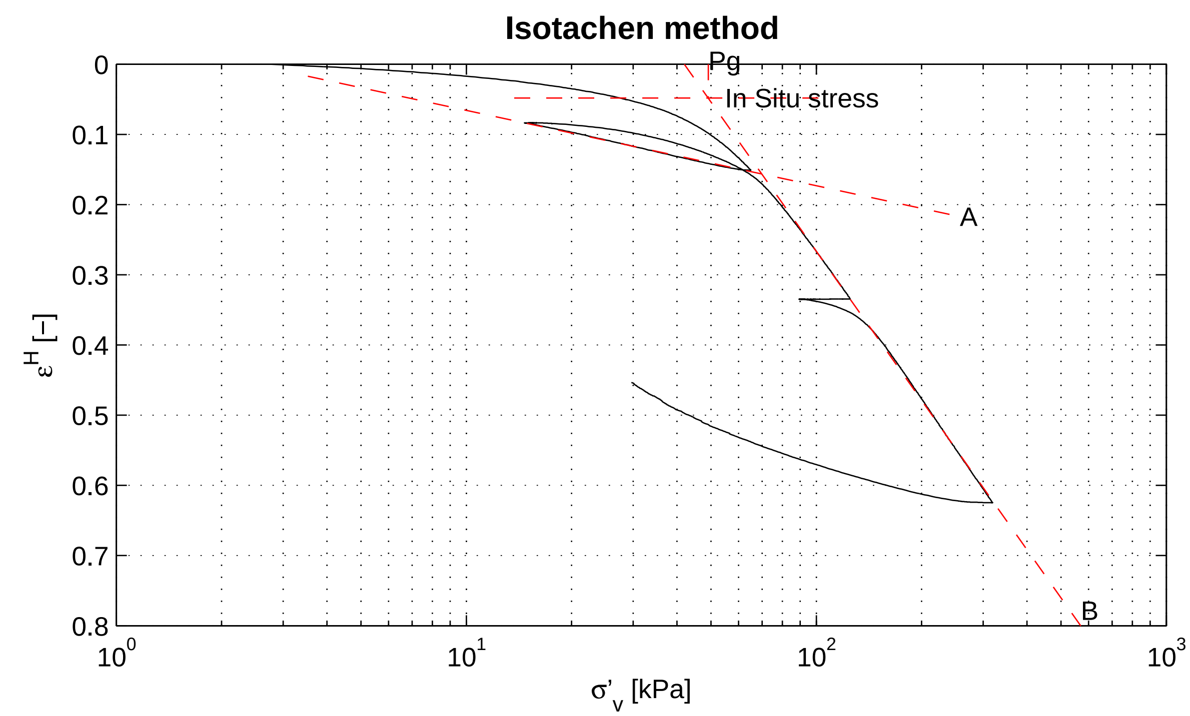


RR = 9.5e−02
CR = 5.0e−01

C_α = 4.1e−02

Pg = 42.6 kPa

Isotachen method



A = 4.7e−02
B = 3.1e−01

C = 2.5e−02

Pg = 49.1 kPa

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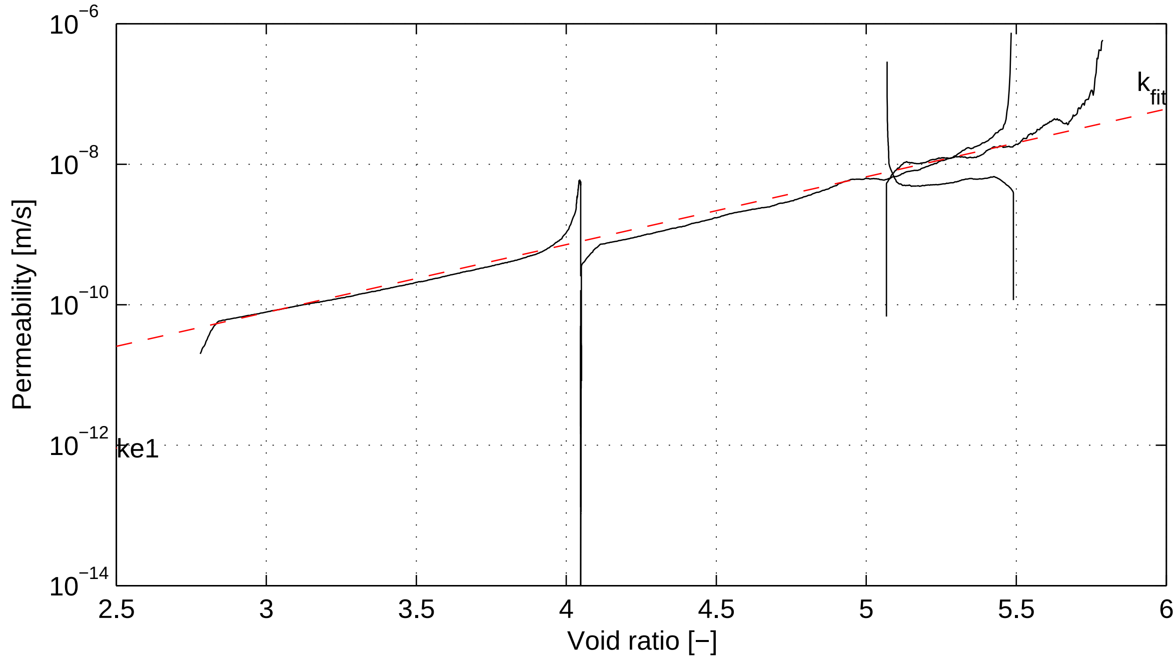
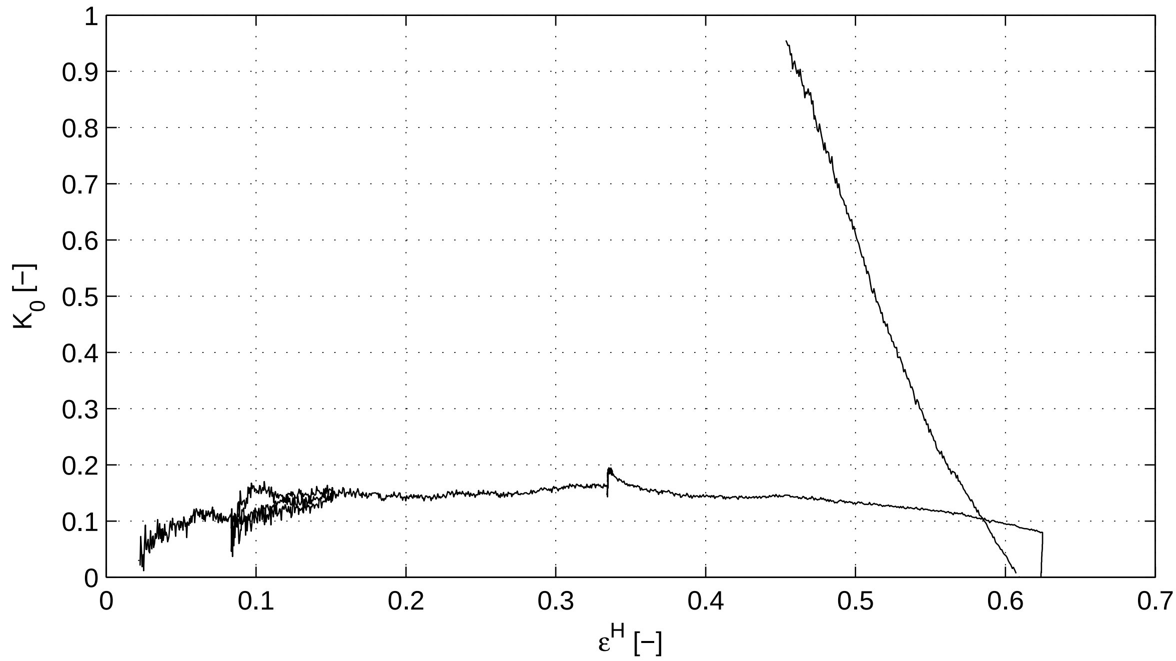
Contribution study program EQ Groningen field	date 2016−06−21	signed luije_sa
Boring NW1A2−C, sample NW1A2−C1−1C, depth: −5.40 m to −5.42 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−C1−1C	page 2



k_{e1} = 9.0e−13 m/s

k_{e0} = 6.9e−08 m/s

slope = 9.66e−01



ν = 0.15

K_{0c} = 0.15

K_{0e} = 0.09

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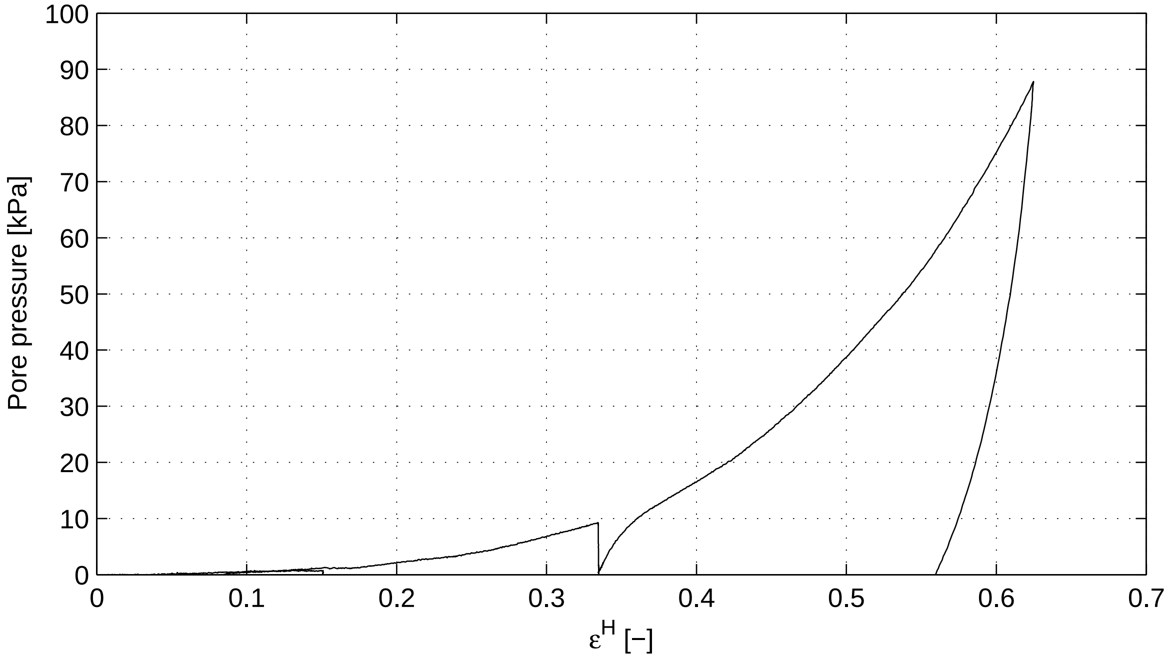
Contribution study program EQ Groningen field	date 2016−06−21	signed luije_sa
Boring NW1A2−C, sample NW1A2−C1−1C, depth: −5.40 m to −5.42 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−C1−1C	page 3



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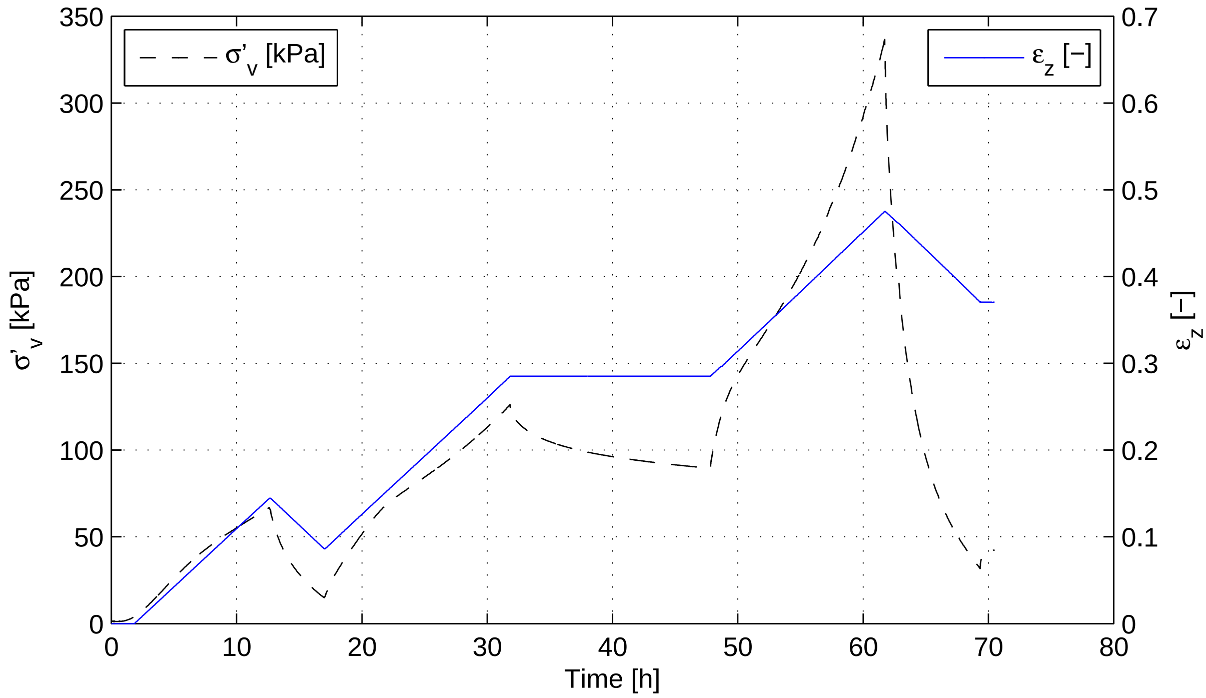
Contribution study program EQ Groningen field	date: 2016−06−21	signed: luije_sa
Boring NW1A2−C, sample NW1A2−C1−1C, depth: −5.40 m to −5.42 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSNW1A2−C1−1C	page: 4



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm
Unit weight saturated soil [kN/m^3]	9.8
Unit weight dry soil [kN/m^3]	1.7
Water content [%]	490.4
Water content final [%]	305.1
Void ratio − initial [−]	4.81 (e)
Sample disturbance index [%]	5.4, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	139
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

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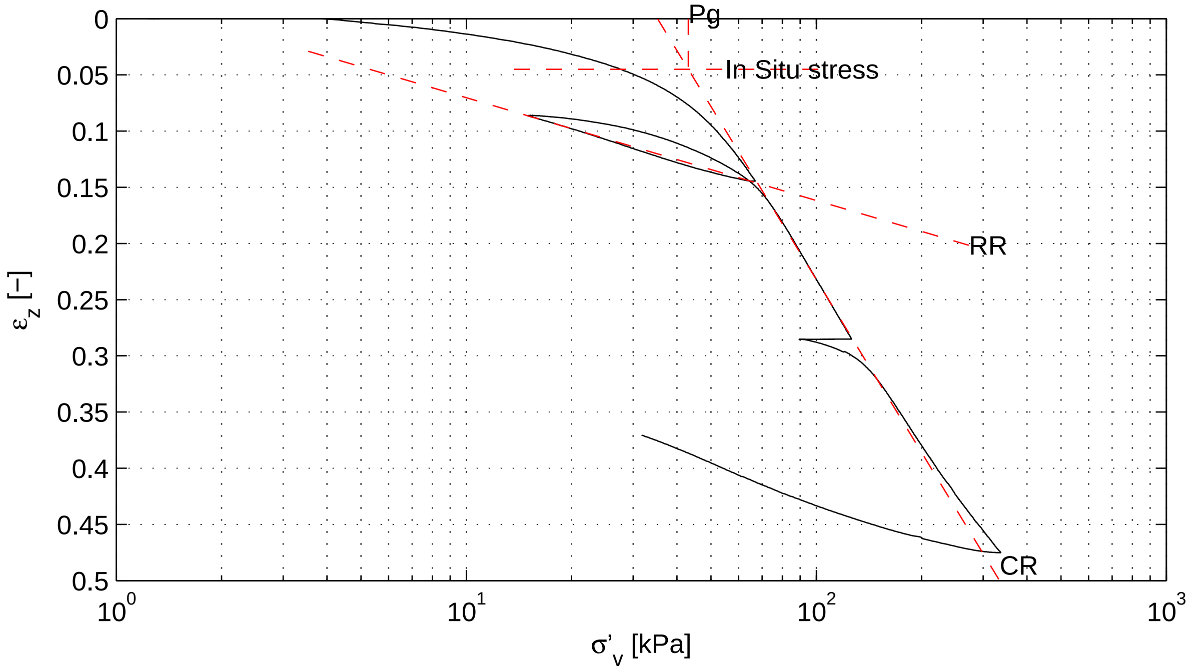
Contribution study program EQ Groningen field	date: 2016−07−04	signed: luije_sa
Boring NW1A2−C, sample NW1A2−C1−1D, depth: −5.45 m to −5.47 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSNW1A2−C1−1D	page: 1

NEN method

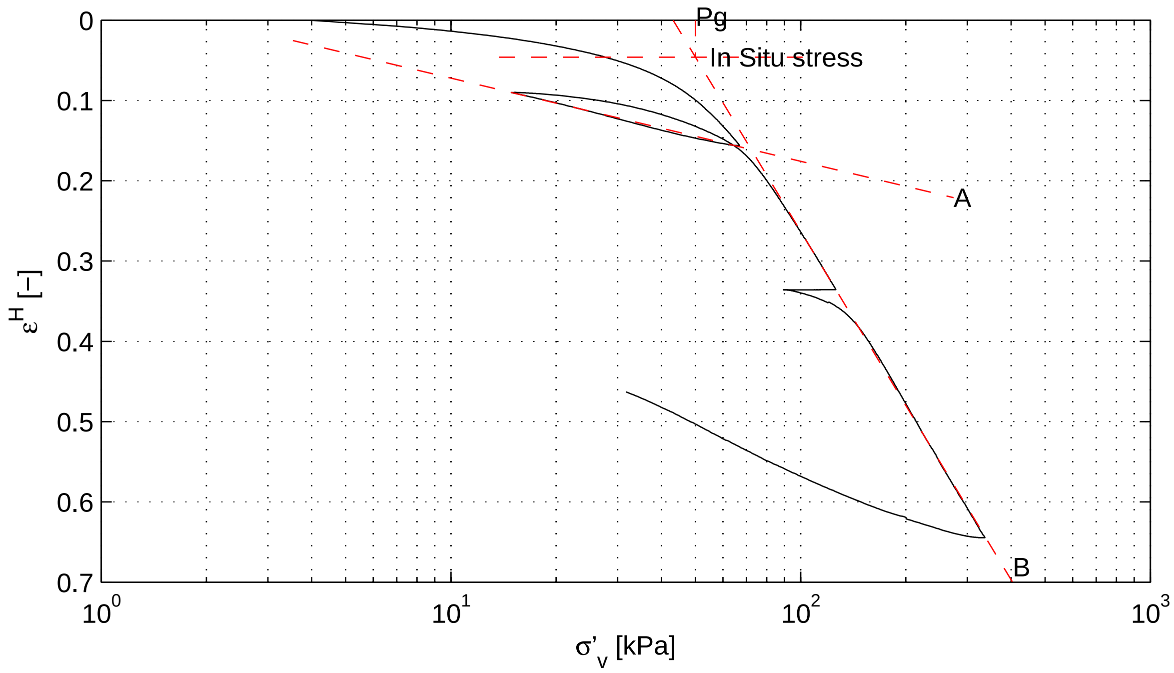


RR = 9.1e−02
CR = 5.1e−01

C_α = 5.1e−02

Pg = 43.1 kPa

Isotachen method



A = 4.5e−02
B = 3.1e−01

C = 3.1e−02

Pg = 50.0 kPa

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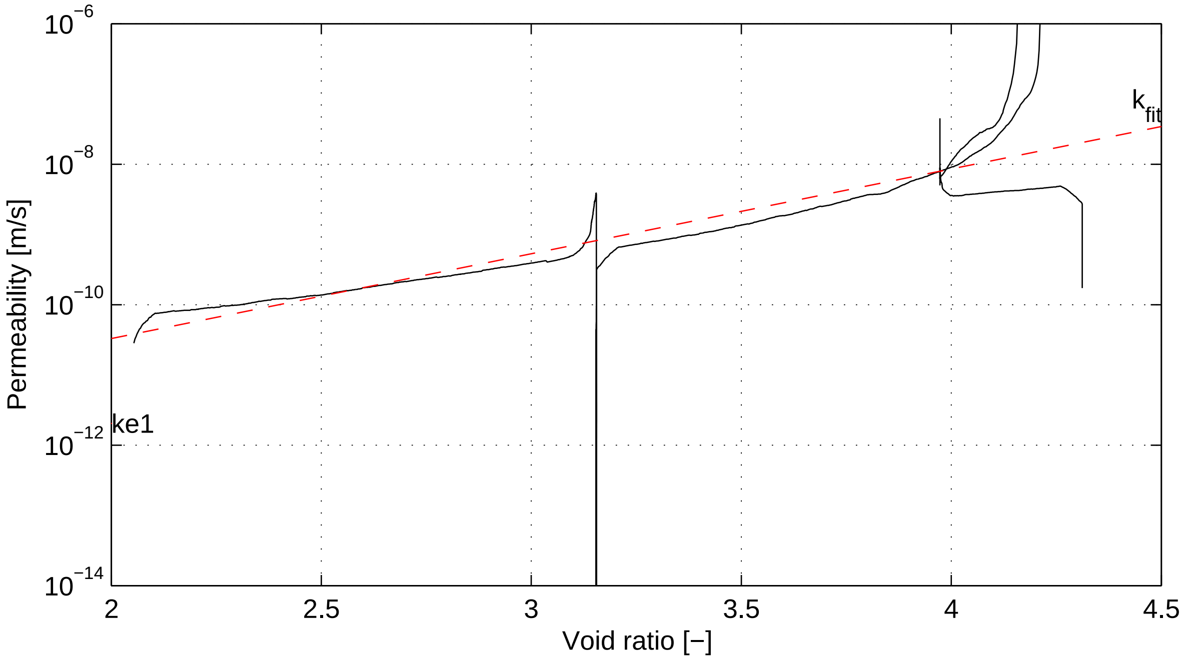
date	signed
2016−07−04	luije_sa
project	version
1209862.11	1.1
appendix	page
CRSNW1A2−C1−1D	2

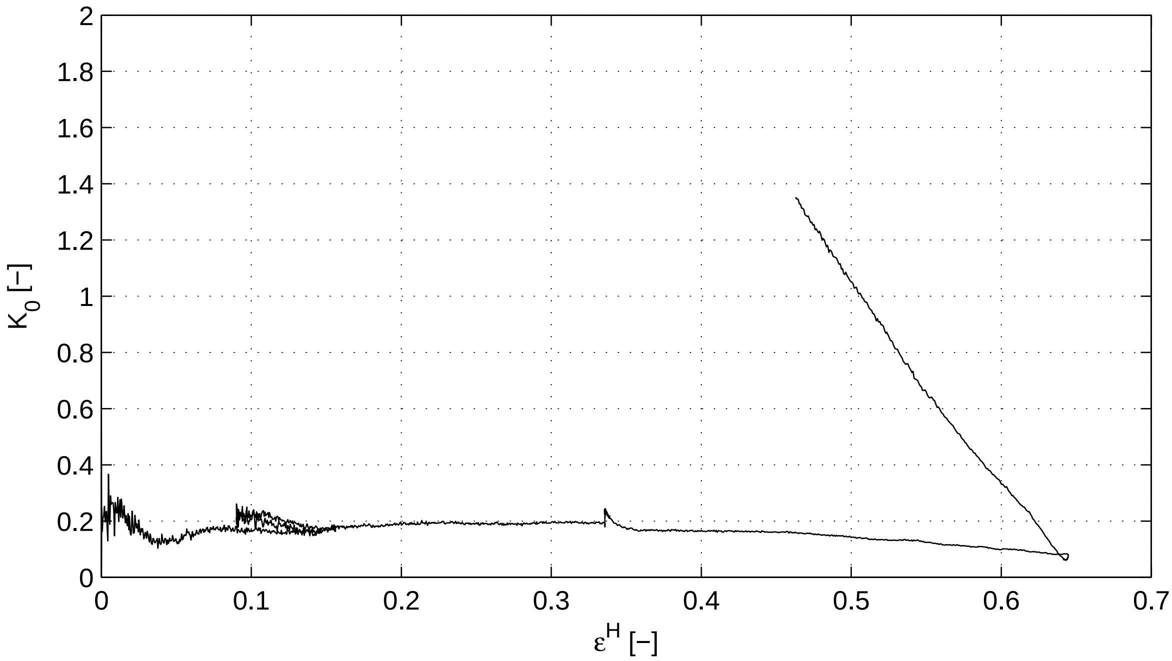
Contribution study program EQ Groningen field

Boring NW1A2−C, sample NW1A2−C1−1D, depth: −5.45 m to −5.47 m NAP

K0−CRS measurement



k_{e1} = 2.0e−12 m/s k_{e0} = 8.2e−08 m/s slope = 1.21e+00



ν = 0.14 K_{0c} = 0.19 K_{0e} = 0.09

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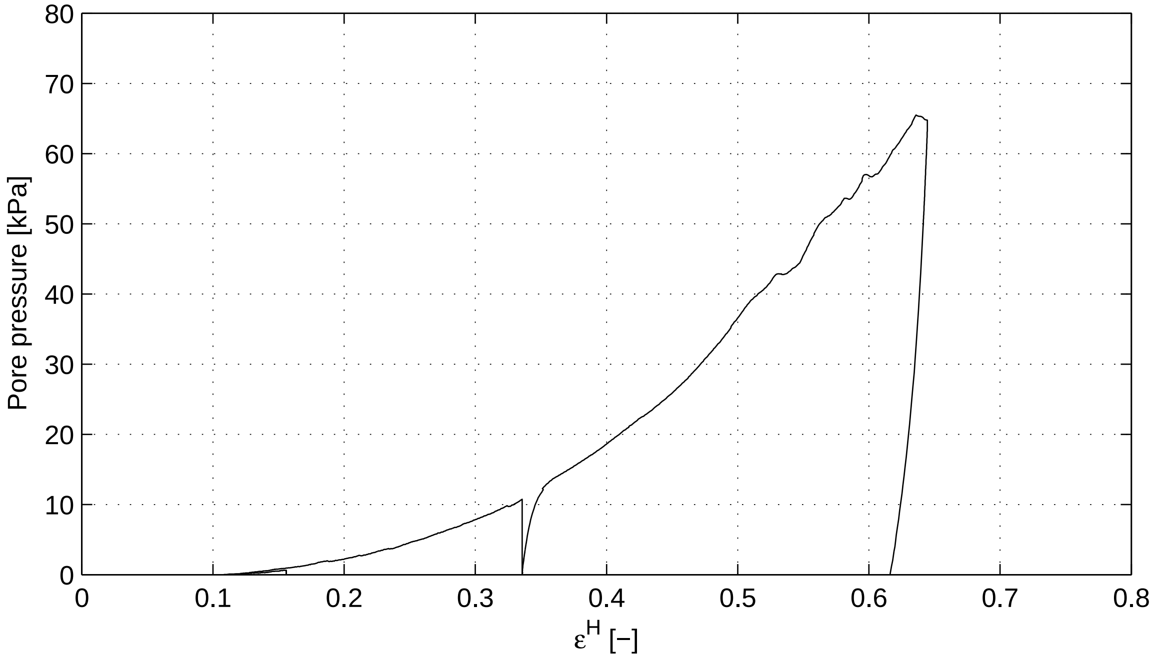
Contribution study program EQ Groningen field	date 2016−07−04	signed luije_sa
Boring NW1A2−C, sample NW1A2−C1−1D, depth: −5.45 m to −5.47 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−C1−1D	page 3



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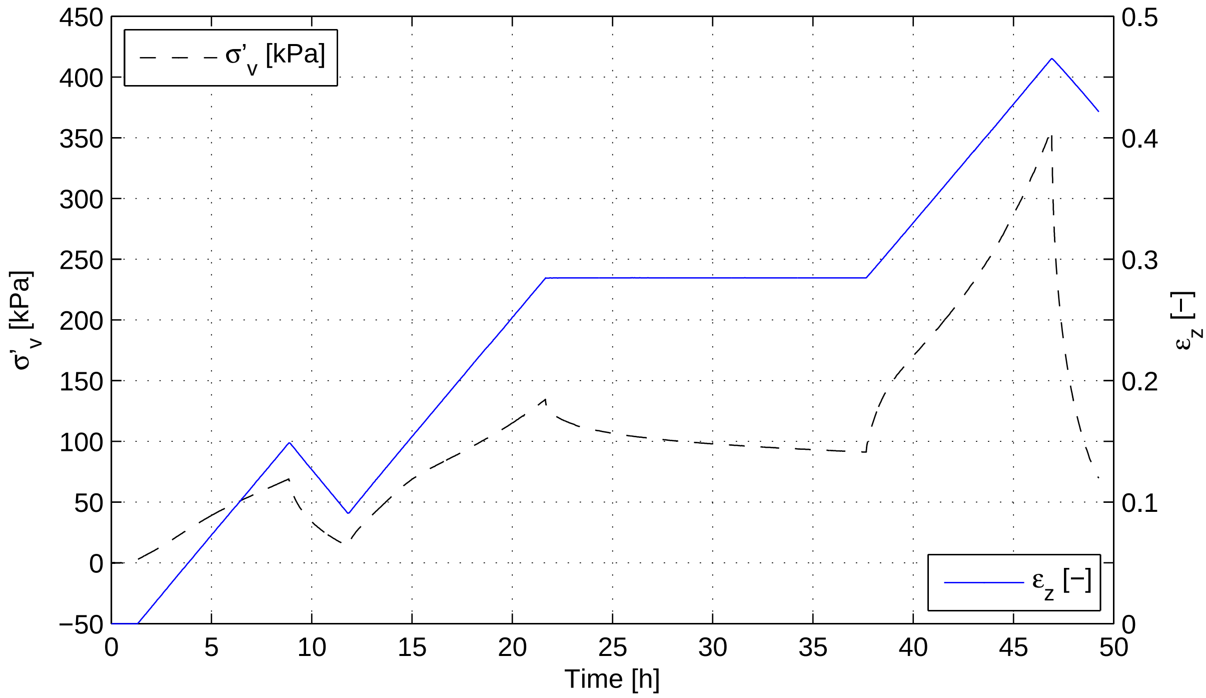
	date: 2016−07−04	signed: luije_sa
Contribution study program EQ Groningen field Boring NW1A2−C, sample NW1A2−C1−1D, depth: −5.45 m to −5.47 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSNW1A2−C1−1D	page: 4



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, rietr..
Unit weight saturated soil [kN/m^3]	10.0
Unit weight dry soil [kN/m^3]	1.8
Water content [%]	469.2
Water content final [%]	283.1
Void ratio − initial [−]	5.27 (e)
Sample disturbance index [%]	5.9, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	139
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

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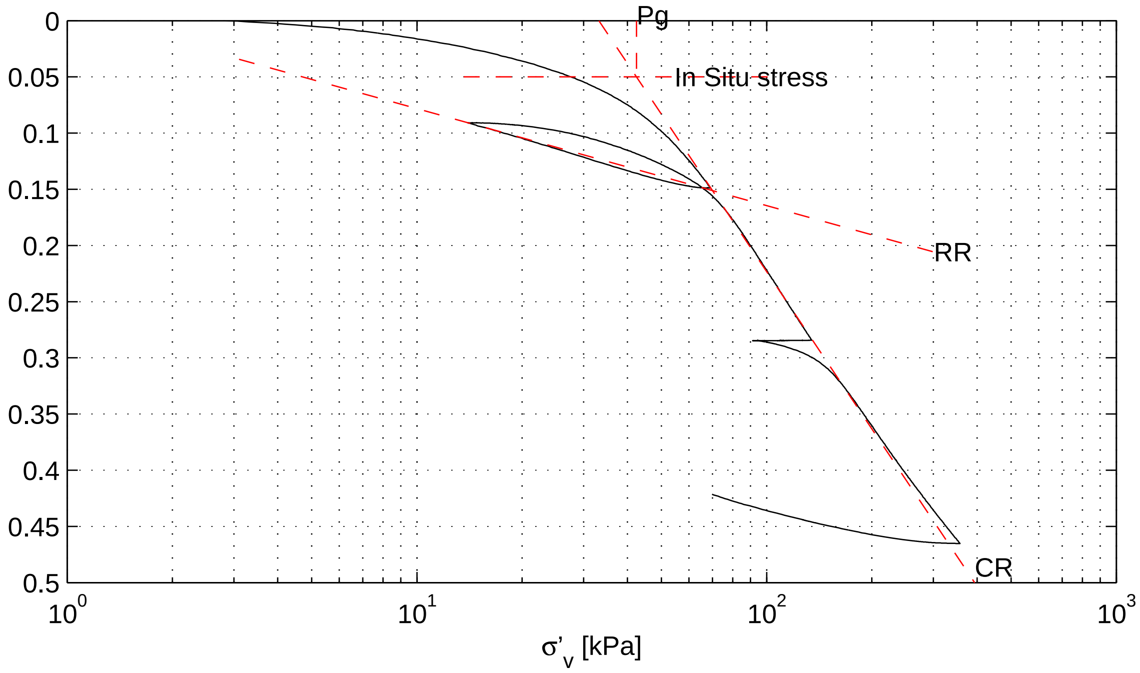
Contribution study program EQ Groningen field		date 2016−09−22	signed luije_sa
Boring NW1A2−D, sample NW1A2−D1−1B, depth: −5.36 m to −5.38 m NAP		project 1209862.11	version 1.1
K0−CRS TEST		appendix CRSNW1A2−D1−1B	page 1

*) Checked and released by ess on 22 September 2016

NEN method

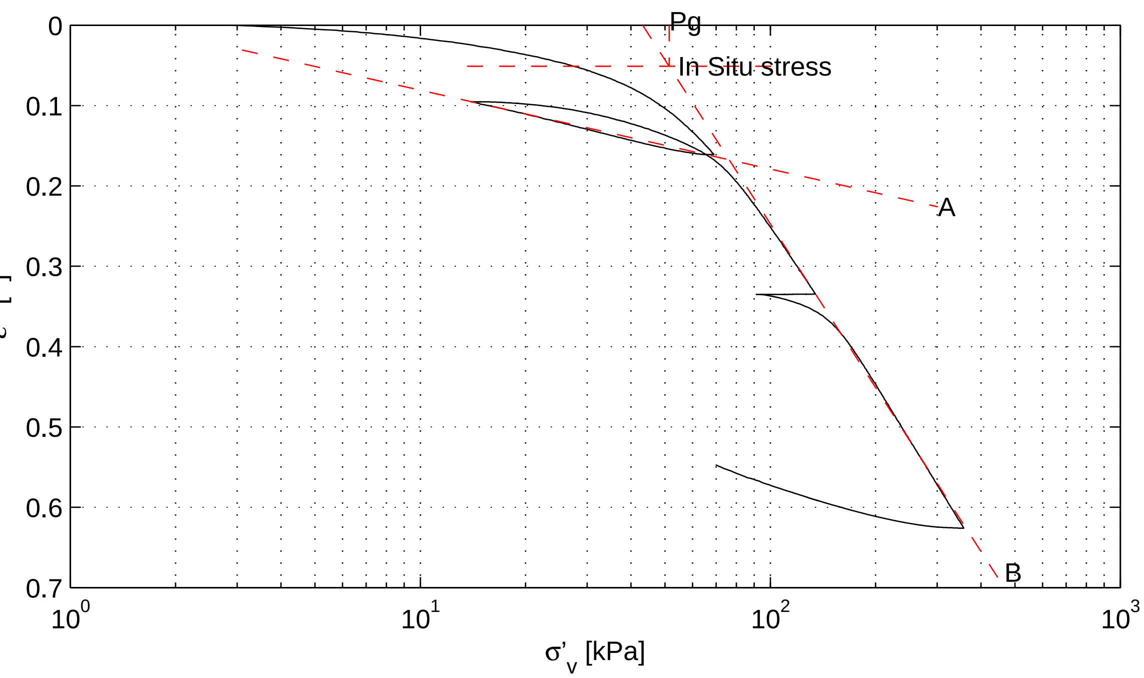


RR = 8.6e−02
CR = 4.7e−01

C_α = 4.3e−02

Pg = 42.5 kPa

Isotachen method



A = 4.3e−02
B = 2.9e−01

C = 2.7e−02

Pg = 51.4 kPa

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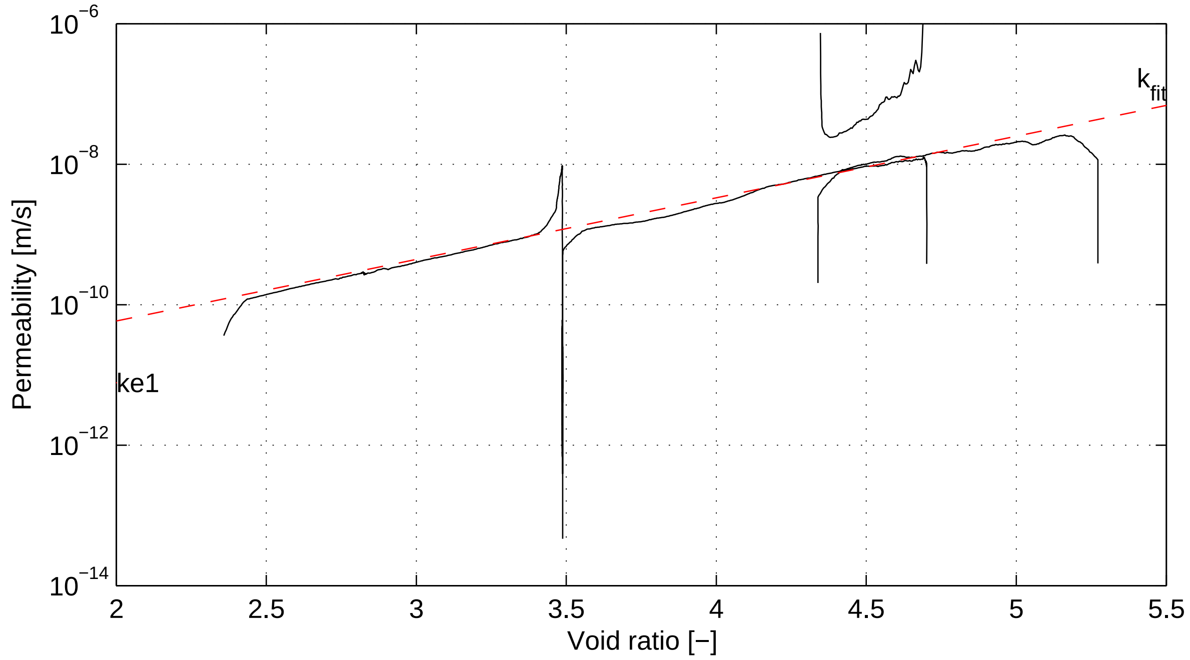
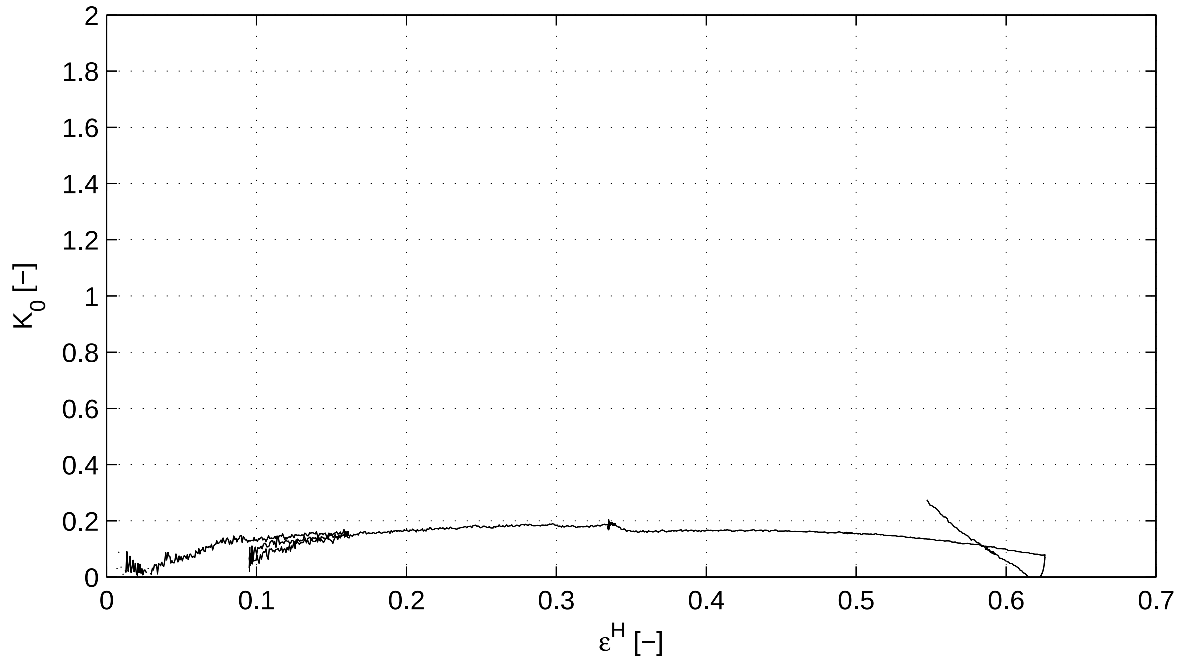
Contribution study program EQ Groningen field	date: 2016−09−22	signed: luije_sa	
Boring NW1A2−D, sample NW1A2−D1−1B, depth: −5.36 m to −5.38 m NAP	project: 1209862.11	version: 1.1	
K0−CRS TEST	appendix: CRSNW1A2−D1−1B	page: 2	

*) Checked and released by ess on 22 September 2016



k_{e1} = 7.7e−12 m/s k_{e0} = 4.3e−08 m/s slope = 8.77e−01



ν = 0.15 K_{0c} = 0.18 K_{0e} = 0.09

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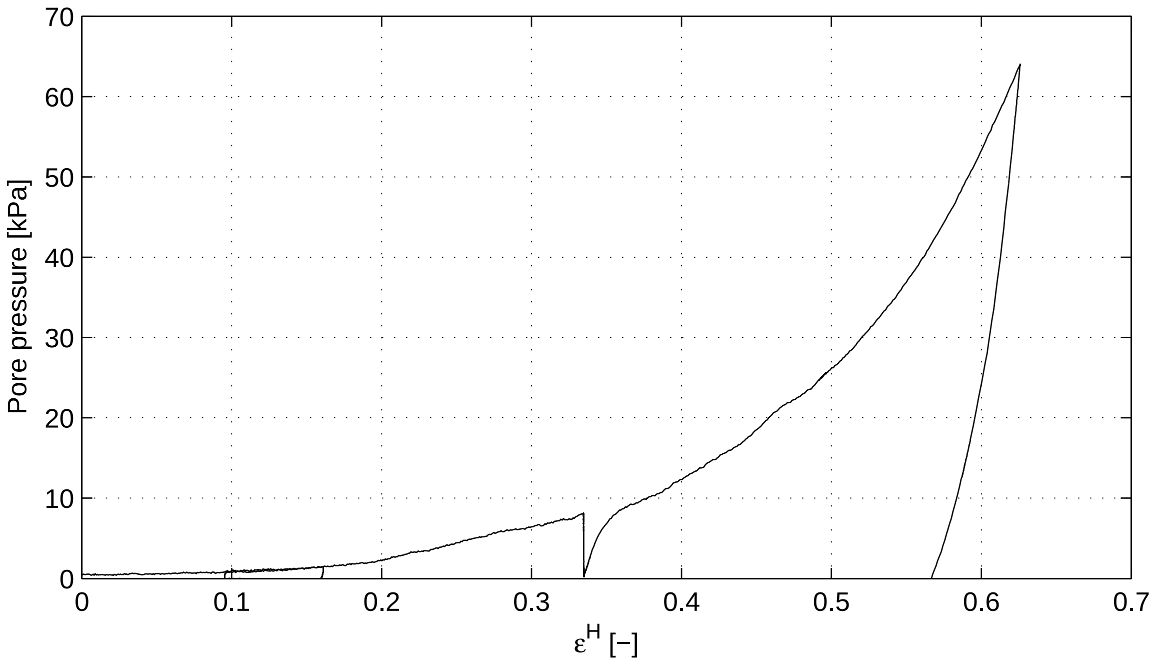
project	version
1209862.11	1.1
appendix	page
CRSNW1A2−D1−1B	3

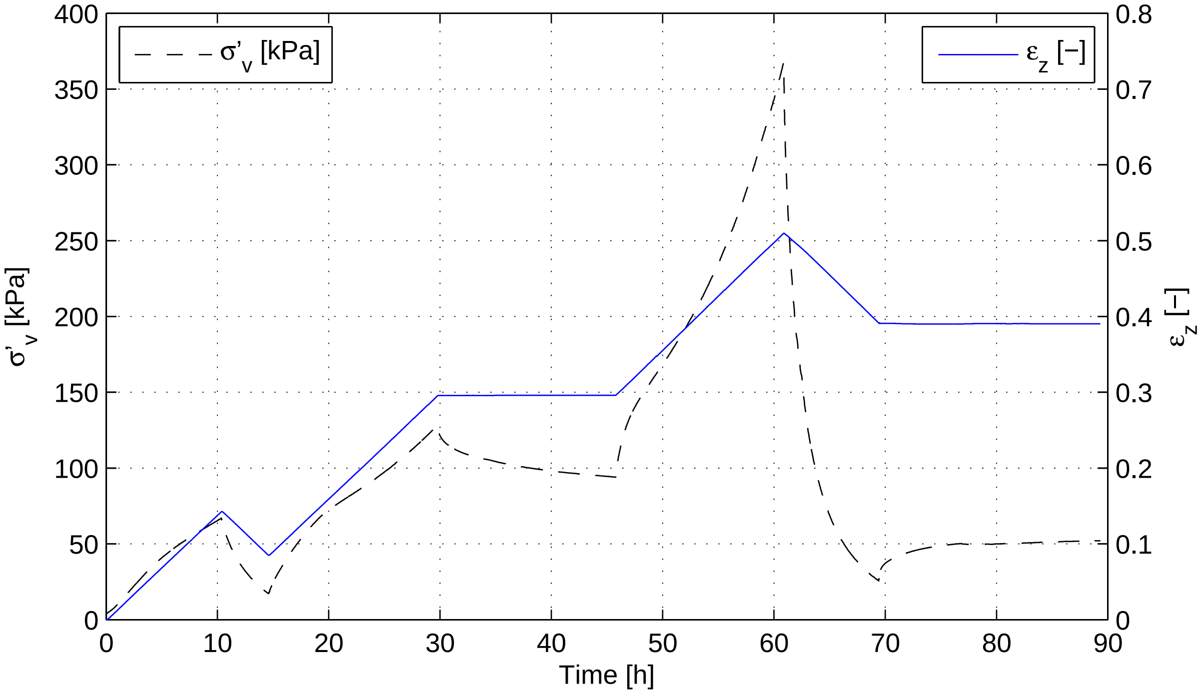
Contribution study program EQ Groningen field

Boring NW1A2−D, sample NW1A2−D1−1B, depth: −5.36 m to −5.38 m NAP

K0−CRS TEST

*) Checked and released by ess on 22 September 2016


Pore pressure [kPa]
70
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
εH [−]



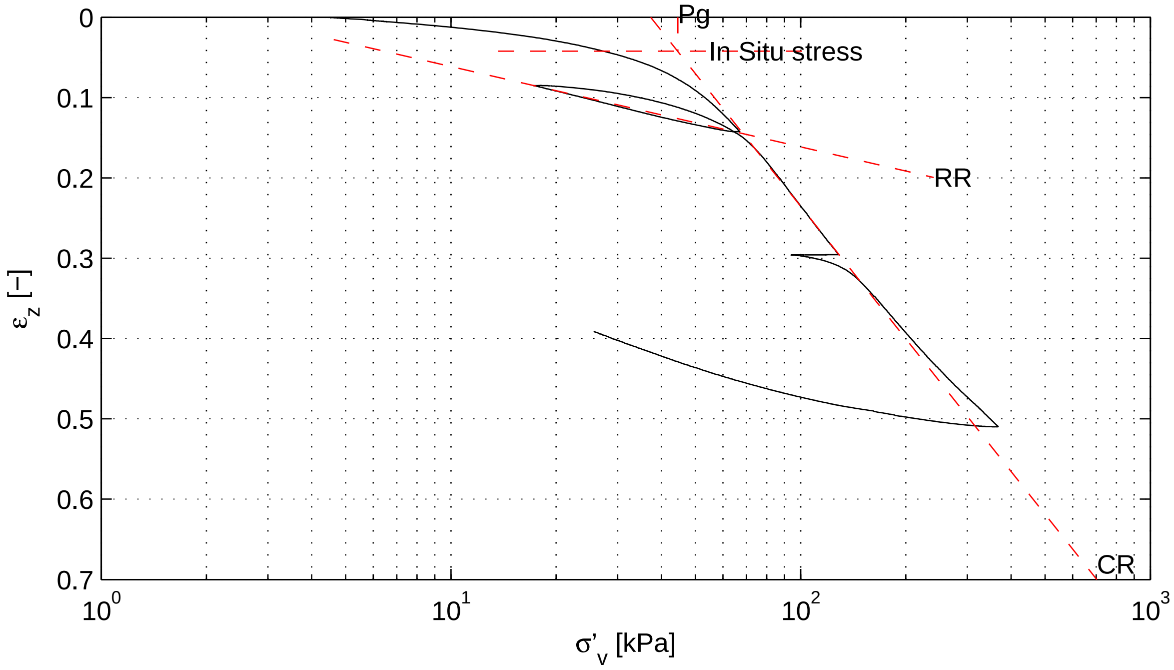
Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, plan..
Unit weight saturated soil [kN/m^3]	10.0
Unit weight dry soil [kN/m^3]	1.7
Water content [%]	479.7
Water content final [%]	319.7
Void ratio − initial [−]	5.48 (e)
Sample disturbance index [%]	5.0, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	140
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

NEN method

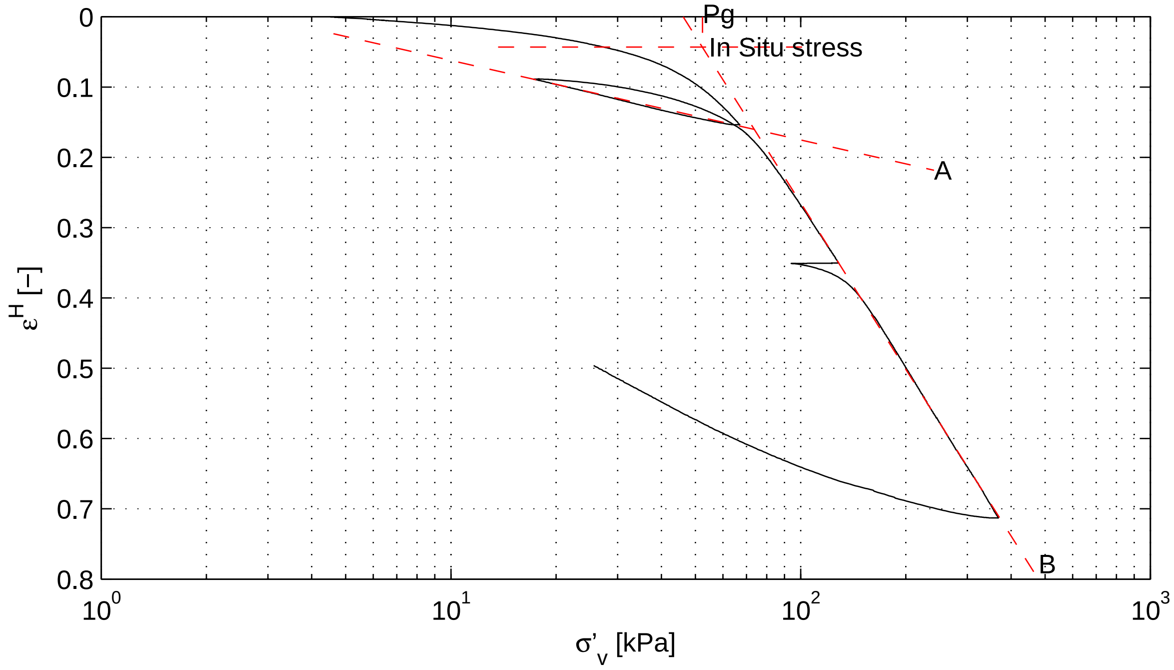


RR = 1.0e−01
CR = 5.5e−01

C_α = 4.3e−02

Pg = 44.5 kPa

Isotachen method



A = 4.9e−02
B = 3.4e−01

C = 2.7e−02

Pg = 52.4 kPa

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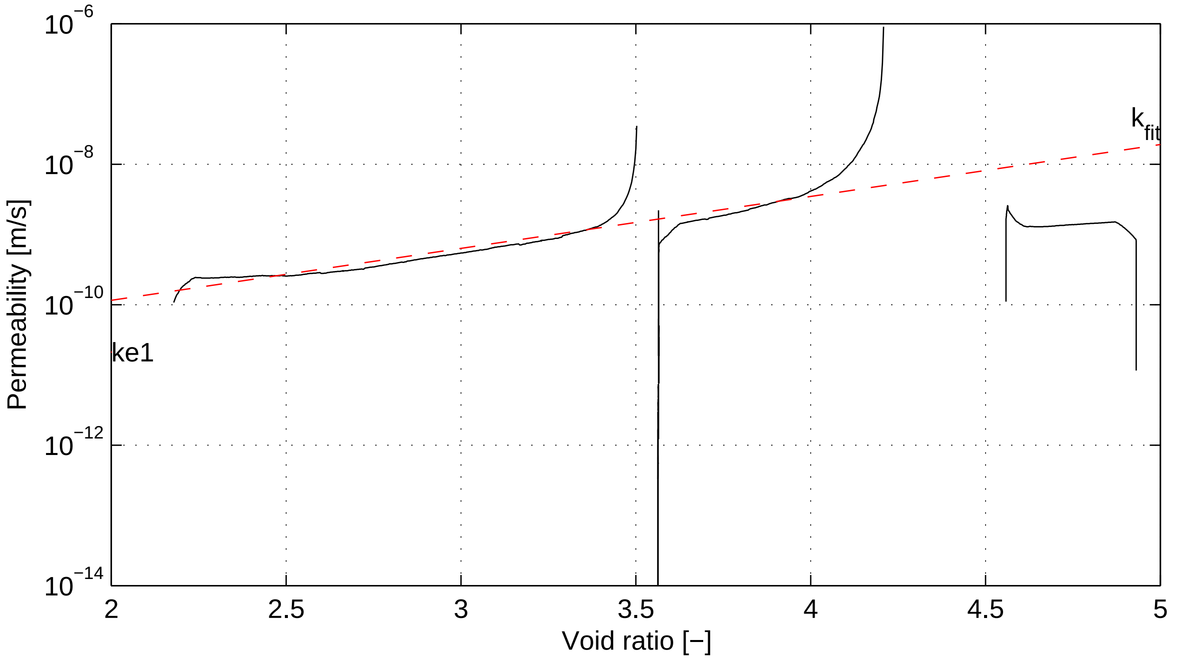
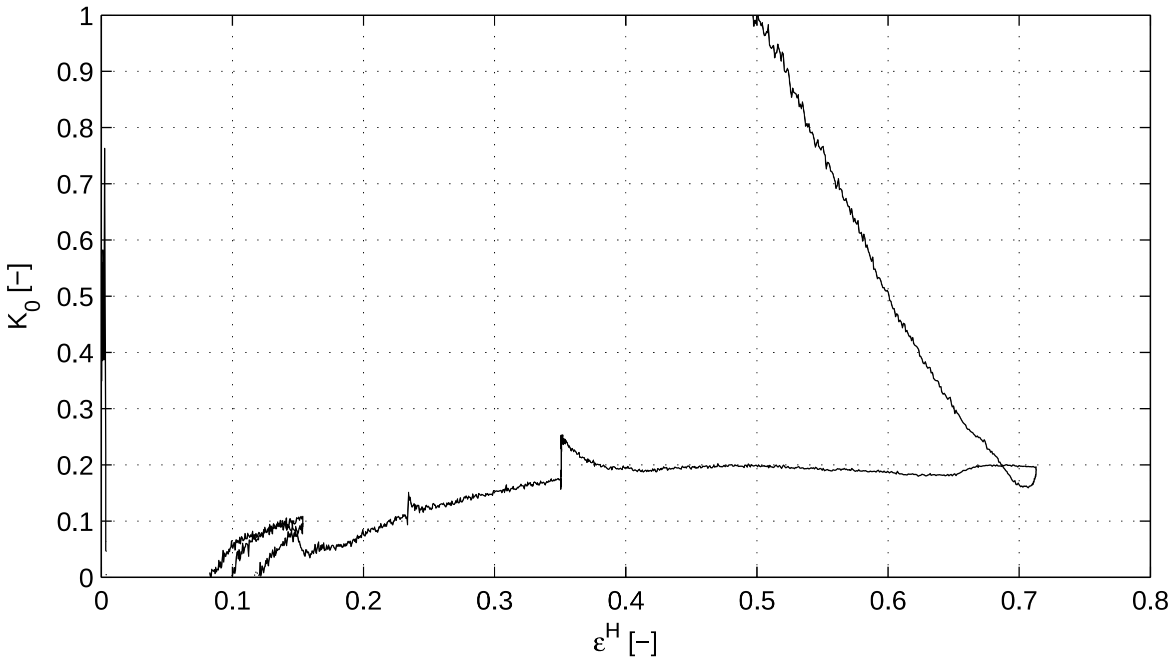
Contribution study program EQ Groningen field	date 2016−06−14	signed luije_sa
Boring NW1A2−D, sample NW1A2−D1−1C, depth: −5.41 m to −5.43 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−D1−1C	page 2



k_{e1} = 2.1e−11 m/s k_{e0} = 4.3e−08 m/s slope = 7.39e−01



ν = 0.17 K_{0m} = 0.19 K_{0e} = 0.20

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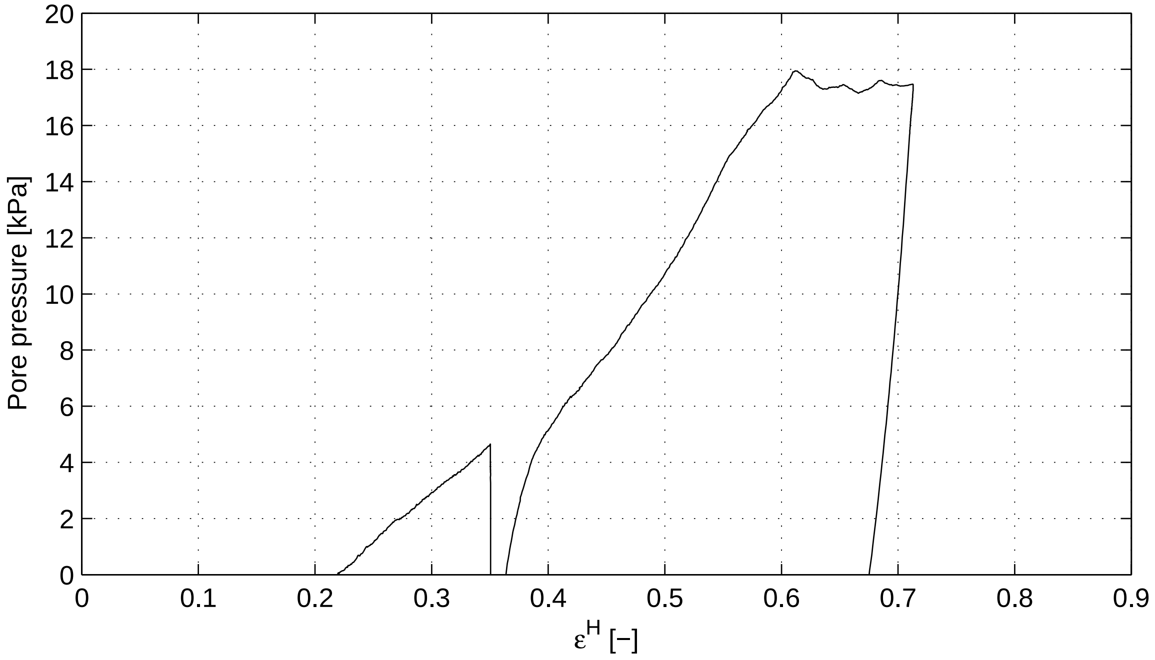
	date 2016−06−14	signed luije_sa
Contribution study program EQ Groningen field Boring NW1A2−D, sample NW1A2−D1−1C, depth: −5.41 m to −5.43 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−D1−1C	page 3



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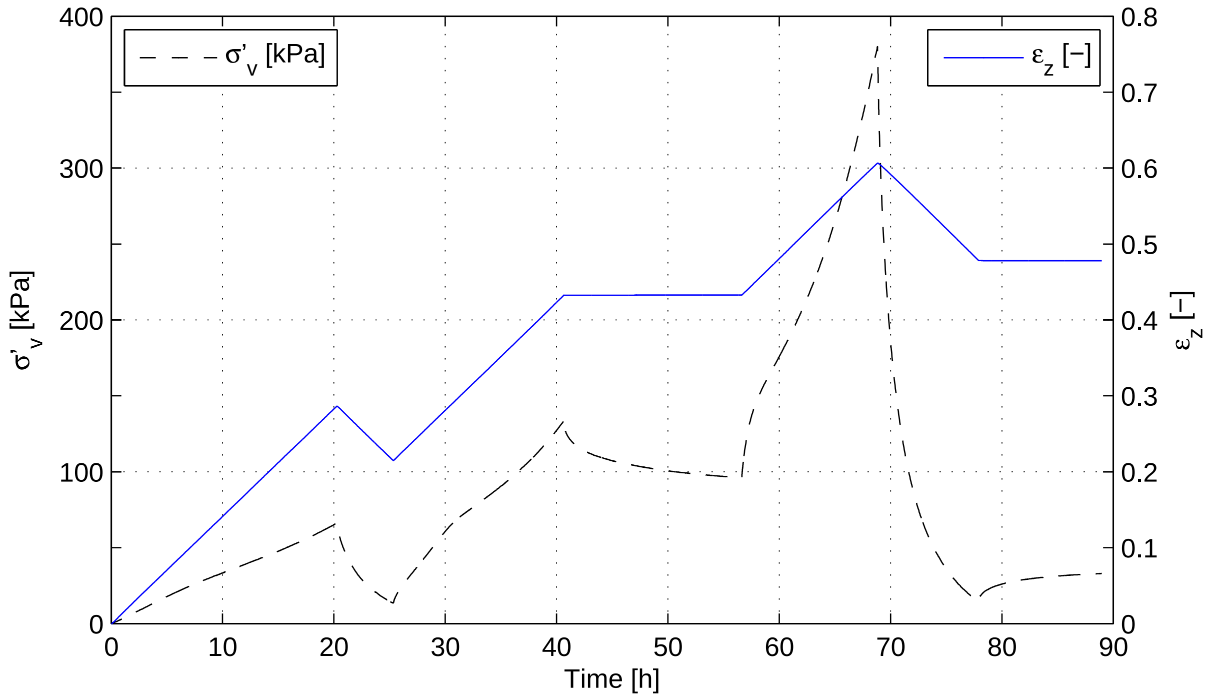
Contribution study program EQ Groningen field	date: 2016−06−14	signed: luije_sa
Boring NW1A2−D, sample NW1A2−D1−1C, depth: −5.41 m to −5.43 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSNW1A2−D1−1C	page: 4



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, wort..
Unit weight saturated soil [kN/m^3]	9.2
Unit weight dry soil [kN/m^3]	1.3
Water content [%]	591.4
Water content final [%]	357.7
Void ratio − initial [−]	4.01 (e)
Sample disturbance index [%]	14.6, very bad quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	140
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

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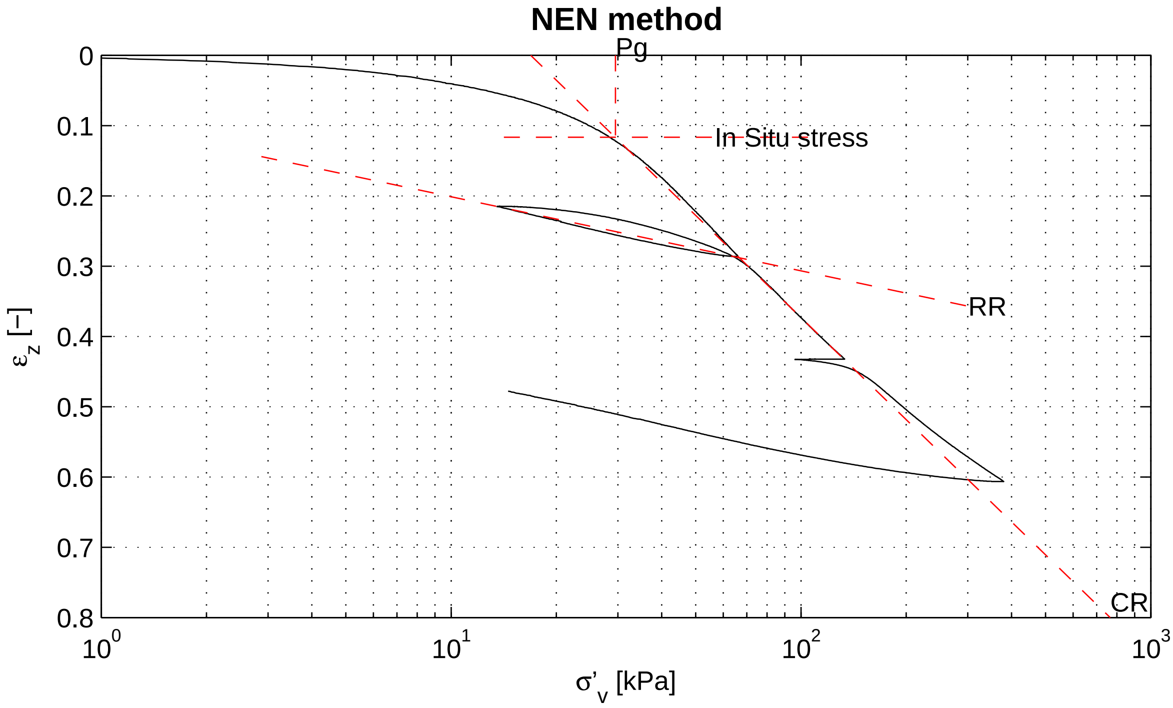
Contribution study program EQ Groningen field	date 2016−06−21	signed luije_sa
Boring NW1A2−D, sample NW1A2−D2−1A, depth: −6.29 m to −6.31 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSNW1A2−D2−1A	page 1

NEN method

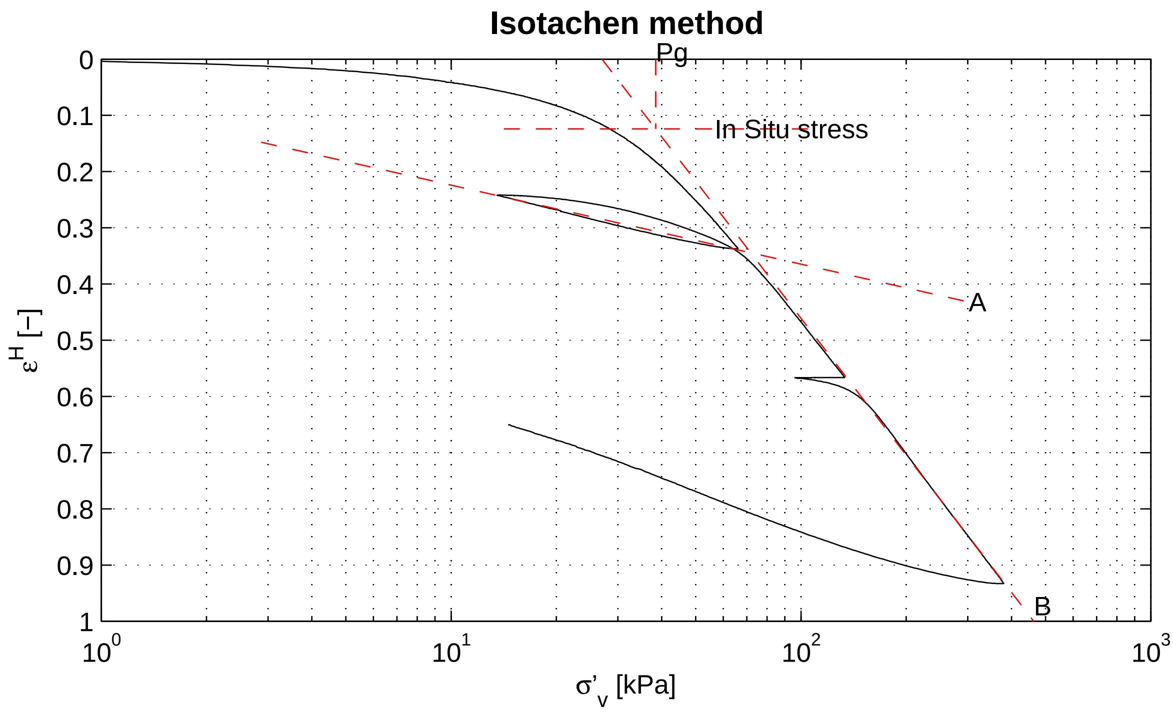


RR = 1.1e−01
CR = 4.8e−01

C_α = 3.8e−02

Pg = 29.5 kPa

Isotachen method



A = 6.1e−02
B = 3.5e−01

C = 2.8e−02

Pg = 38.4 kPa

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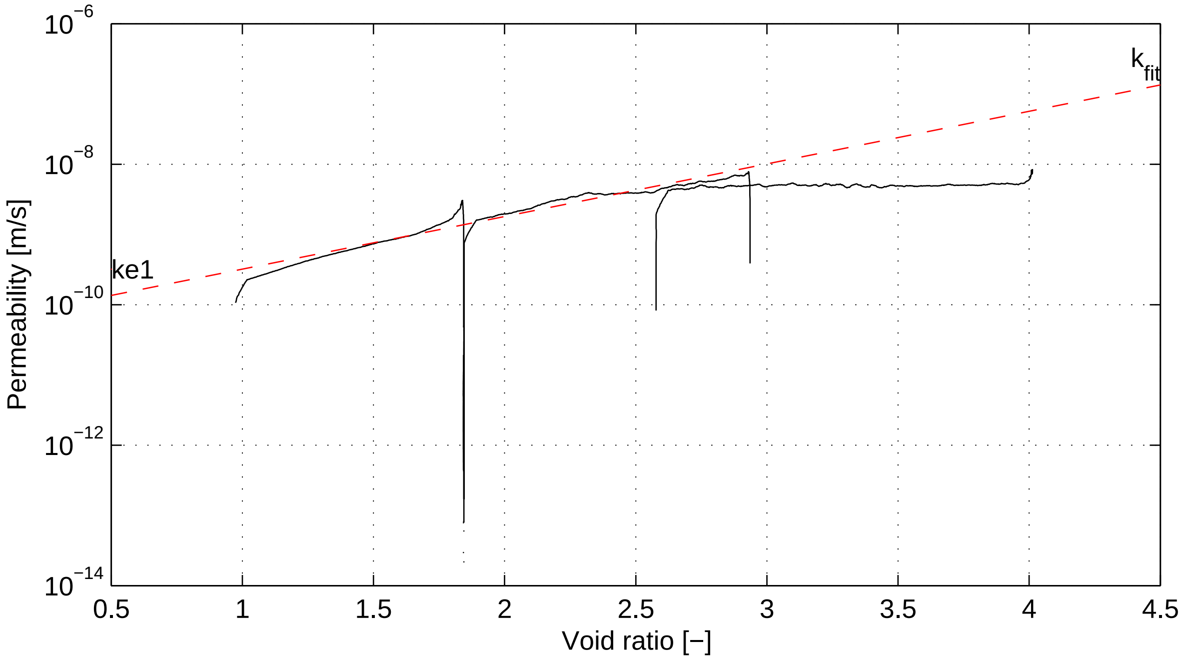
CRSNW1A2−D2−1A	2

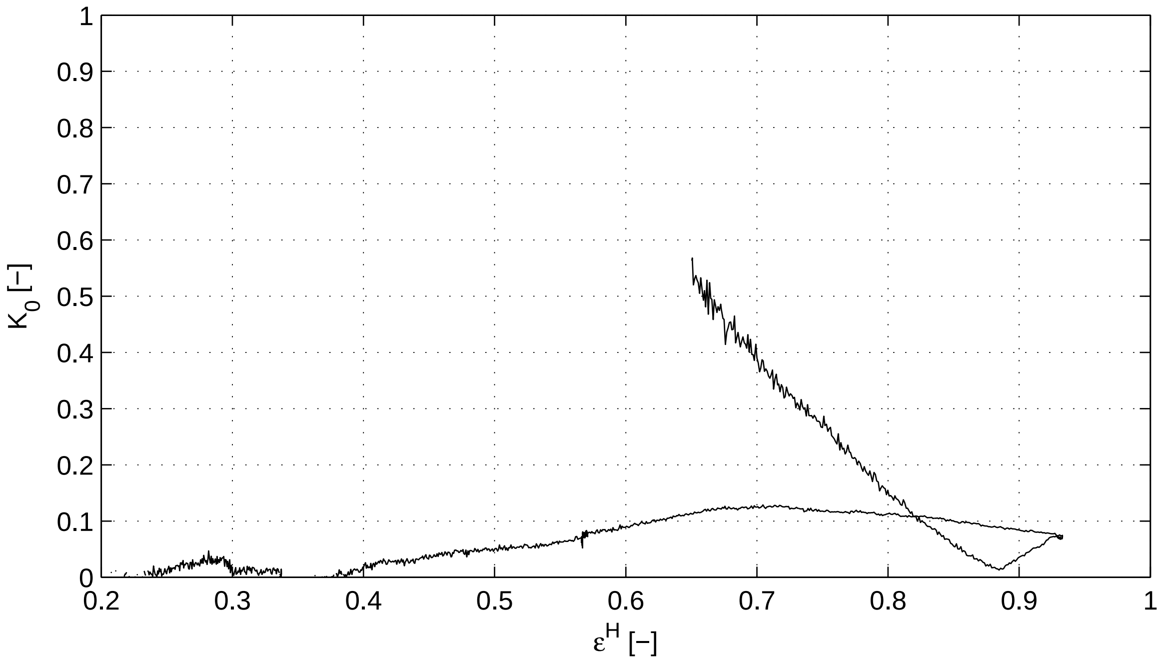
Contribution study program EQ Groningen field

Boring NW1A2−D, sample NW1A2−D2−1A, depth: −6.29 m to −6.31 m NAP

K0−CRS measurement



k_{e1} = 3.2e−10 m/s k_{e0} = 5.8e−08 m/s   slope = 7.49e−01



ν = 0.13 K_{0c} = 0.12 K_{0e} = 0.08

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Contribution study program EQ Groningen field	date 2016−06−21	signed luije_sa
Boring NW1A2−D, sample NW1A2−D2−1A, depth: −6.29 m to −6.31 m NAP	project 1209862.11	version 1.1
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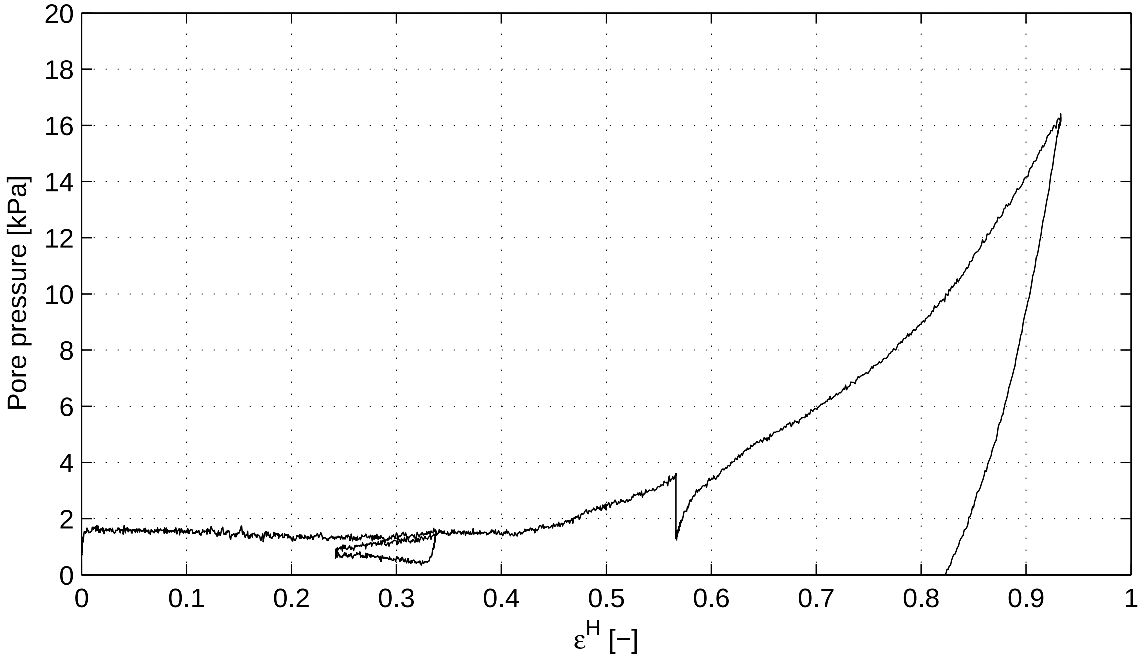
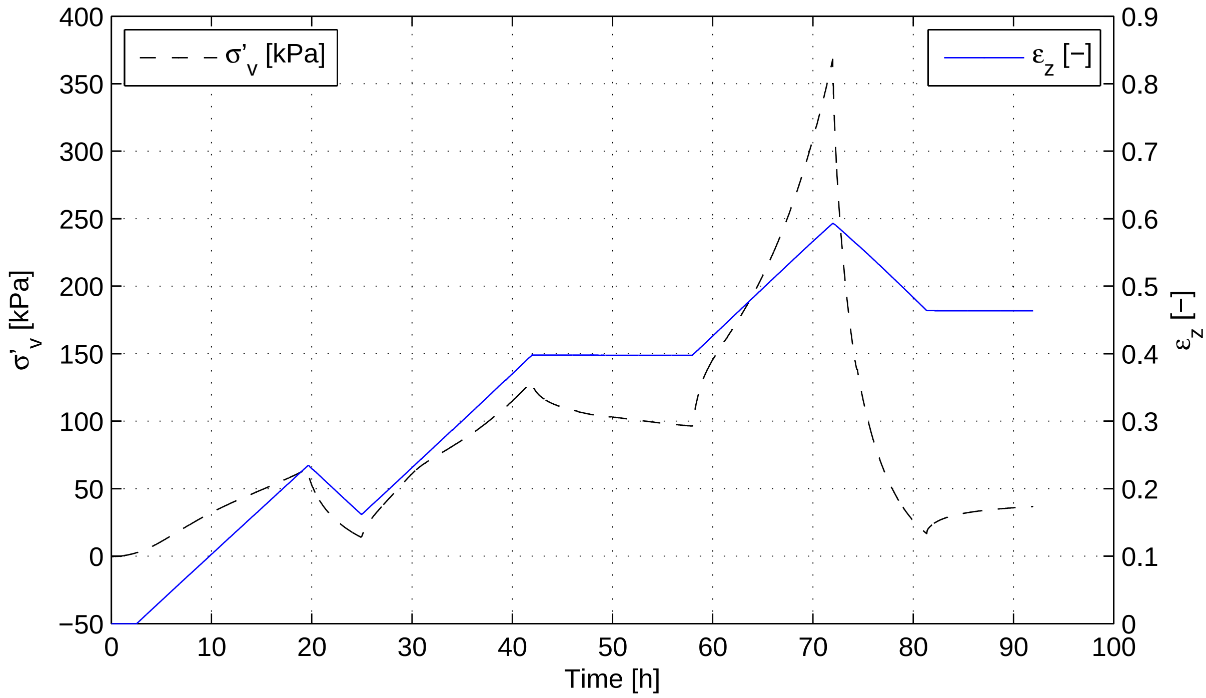


Pore pressure [kPa]
0
2
4
6
8
10
12
14
16
18
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
ε^H [−]



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, wort..
Unit weight saturated soil [kN/m^3]	9.6
Unit weight dry soil [kN/m^3]	1.3
Water content [%]	637.1
Water content final [%]	357.1
Void ratio − initial [−]	5.49 (e)
Sample disturbance index [%]	10.7, bad quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	70
Stress unloading phase [kPa]	14
Stress reloading phase [kPa]	140
Stress relaxation phase [kPa]	140
Maximum stress [kPa]	400

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Contribution study program EQ Groningen field Boring NW1A2−D, sample NW1A2−D2−2B, depth: −6.69 m to −6.71 m NAP	project 1209862.11	version 1.1
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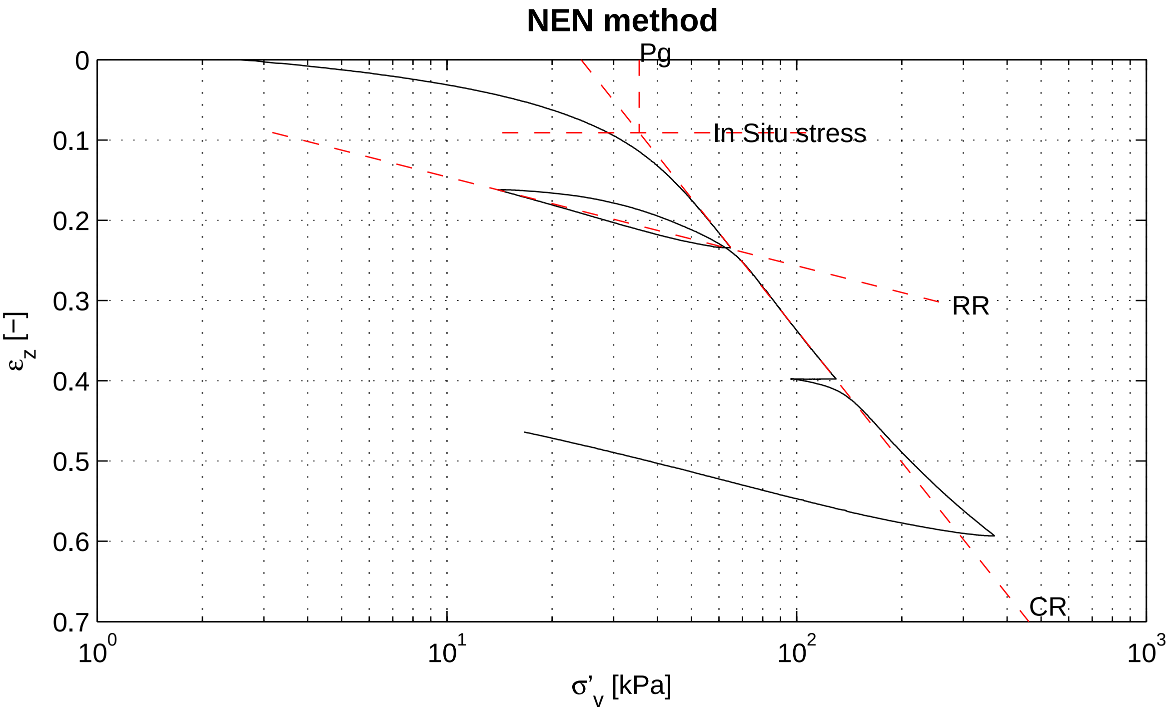
*) Checked and released by ess on 23 September 2016

NEN method

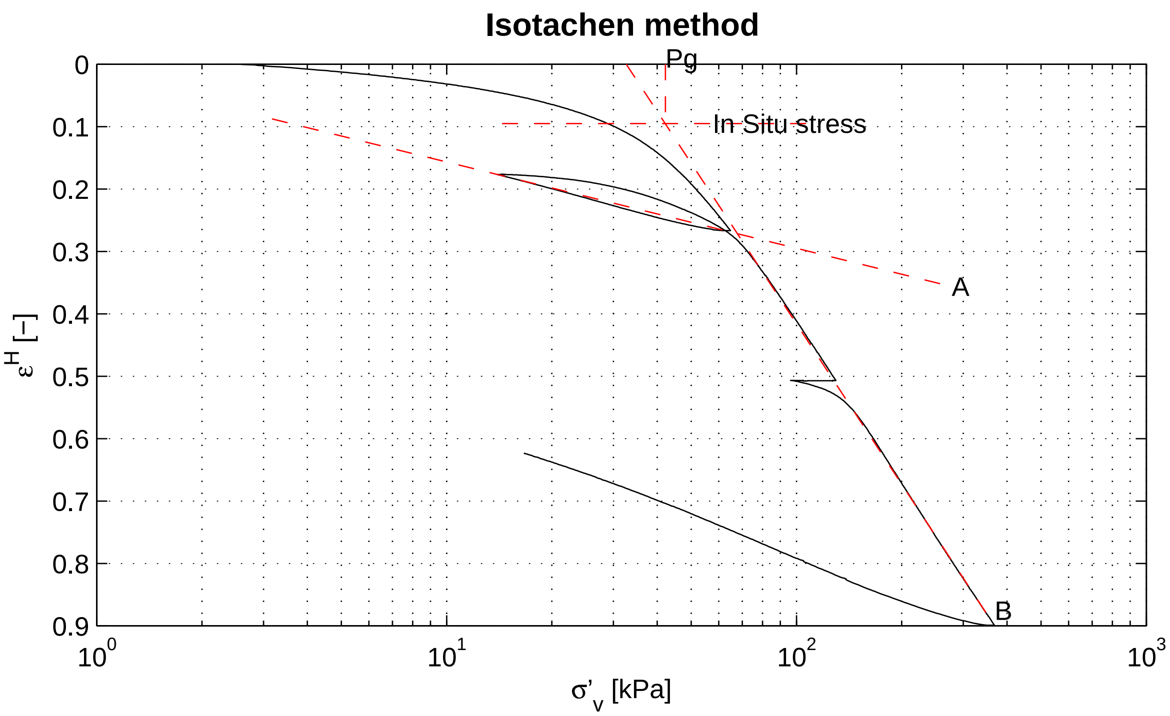


RR = 1.1e−01
CR = 5.5e−01

C_α = 4.4e−02

Pg = 35.5 kPa

Isotachen method



A = 6.0e−02
B = 3.7e−01

C = 3.0e−02

Pg = 42.2 kPa

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Contribution study program EQ Groningen field Boring NW1A2−D, sample NW1A2−D2−2B, depth: −6.69 m to −6.71 m NAP				project 1209862.11	version 1.1
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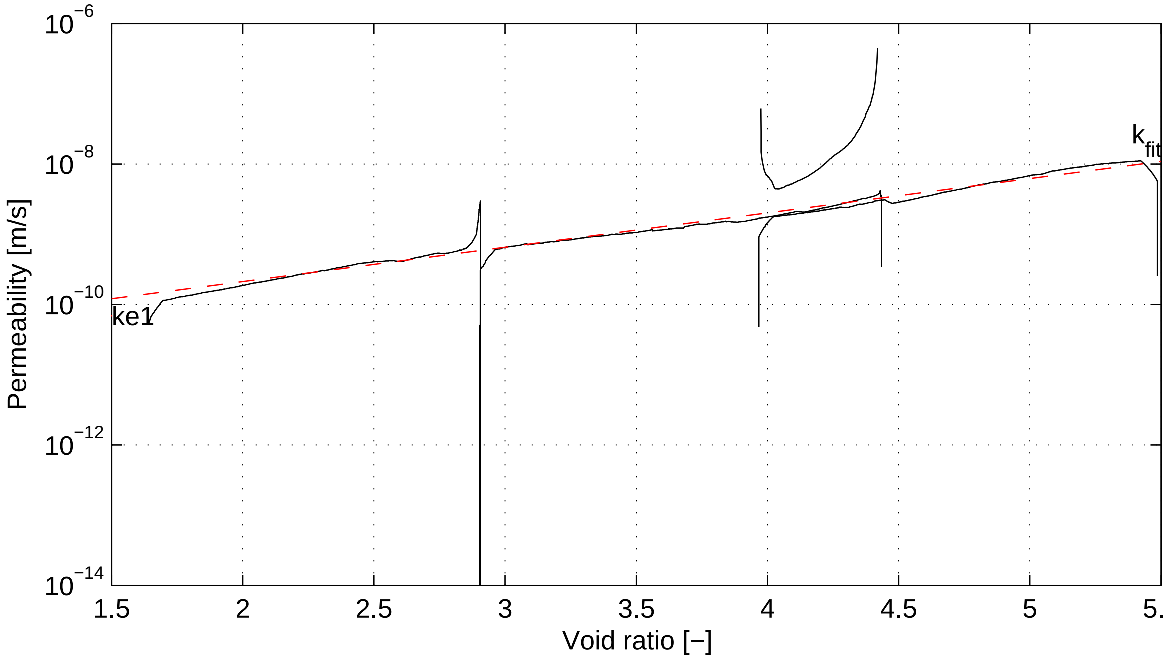
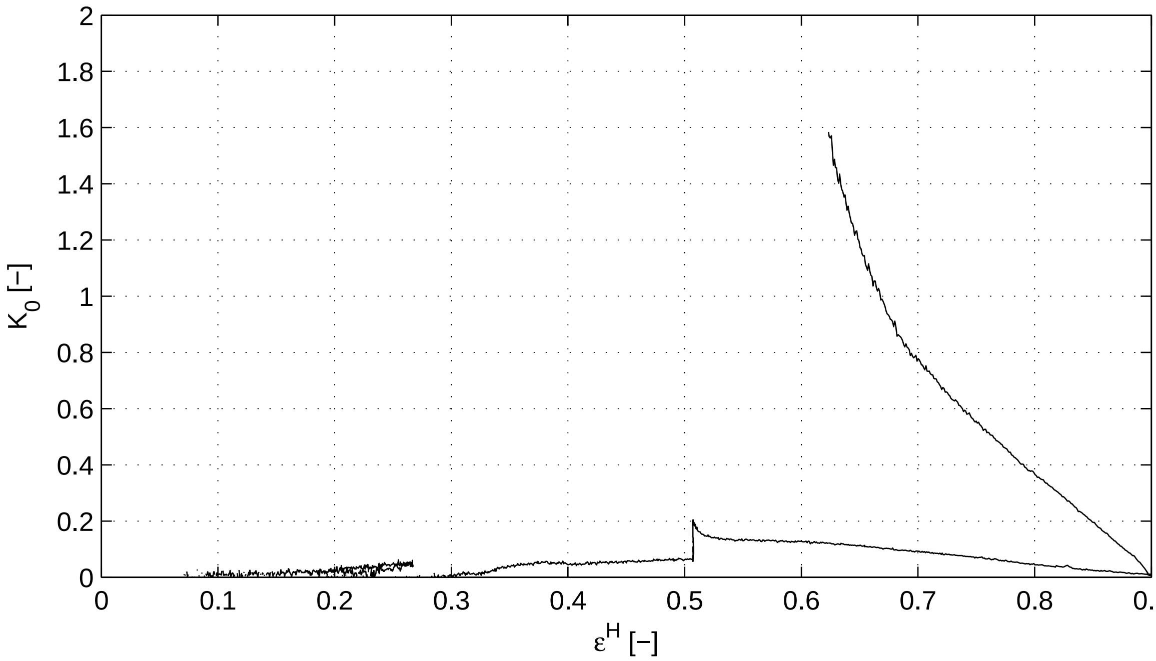


k_{e1} = 6.9e−11 m/s k_{e0} = 1.1e−08 m/s slope = 4.89e−01



ν = 0.08 K_{0c} = 0.13 K_{0e} = 0.01

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	date: 2016−09−23	signed: ess
Contribution study program EQ Groningen field Boring NW1A2−D, sample NW1A2−D2−2B, depth: −6.69 m to −6.71 m NAP	project: 1209862.11	version: 1.1
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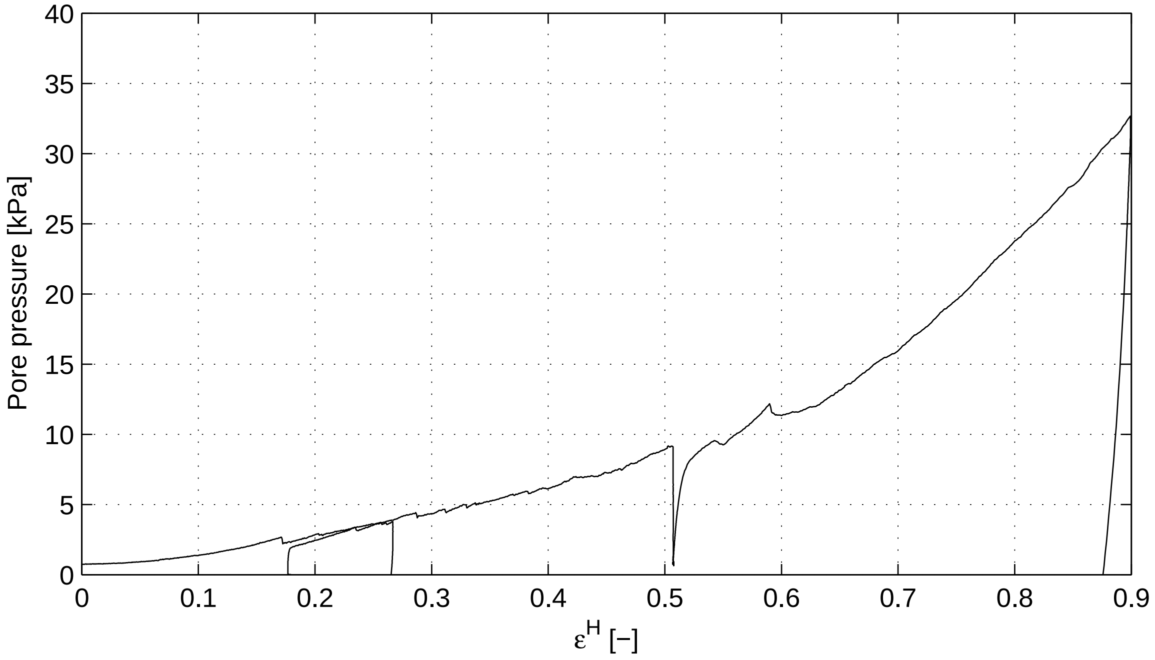

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Contribution study program EQ Groningen field

Boring NW1A2−D, sample NW1A2−D2−2B, depth: −6.69 m to −6.71 m NAP

K0−CRS measurement

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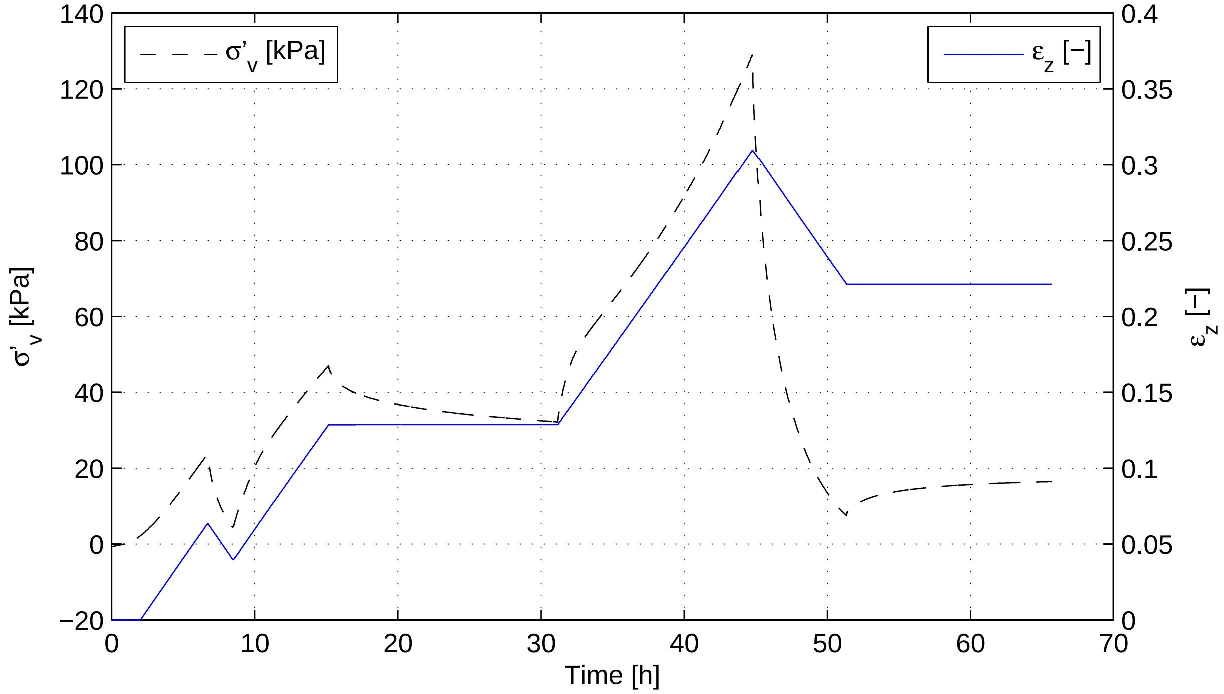

Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, rietr..
Unit weight saturated soil [kN/m^3]	9.9
Unit weight dry soil [kN/m^3]	2.0
Water content [%]	397.1
Water content final [%]	397.1
Void ratio − initial [−]	4.25 (e)
Sample disturbance index [%]	2.2, good quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	25
Stress unloading phase [kPa]	5
Stress reloading phase [kPa]	50
Stress relaxation phase [kPa]	50
Maximum stress [kPa]	150

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Contribution study program EQ Groningen field	date 2016−09−28	signed luije_sa
Boring SB4A−A, sample SB4A−A2−1A, depth: −3.04 m to −3.06 m NAP	project 1209862.11	version 1.1
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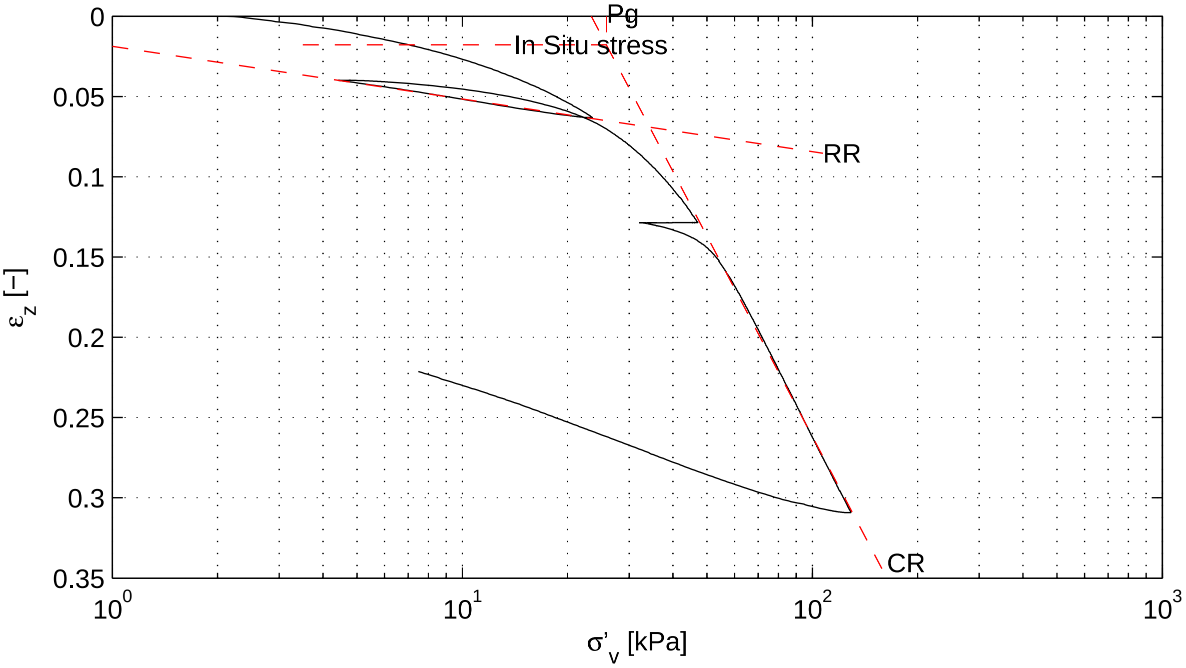
*) Checked and released by ess on 28 September 2016

NEN method

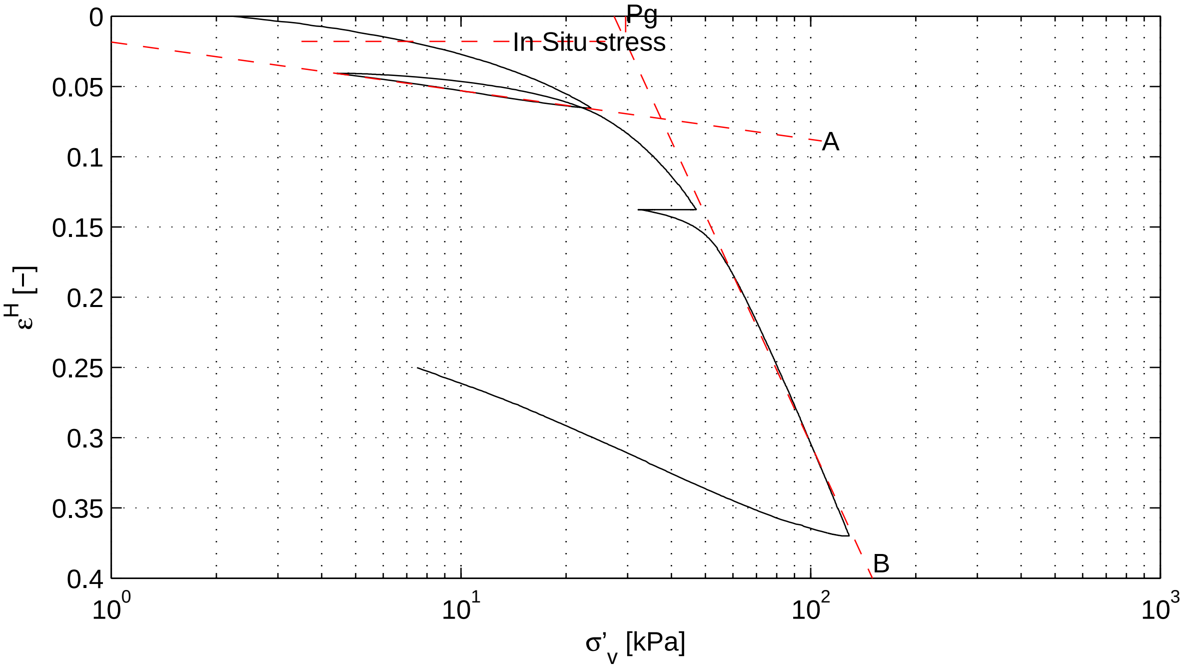


RR = 3.3e−02
CR = 4.1e−01

C_α = 4.5e−02

Pg = 25.8 kPa

Isotachen method



A = 1.5e−02
B = 2.4e−01

C = 2.5e−02

Pg = 29.6 kPa

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Contribution study program EQ Groningen field	date: 2016−09−28	signed: luije_sa
Boring SB4A−A, sample SB4A−A2−1A, depth: −3.04 m to −3.06 m NAP	project: 1209862.11	version: 1.1
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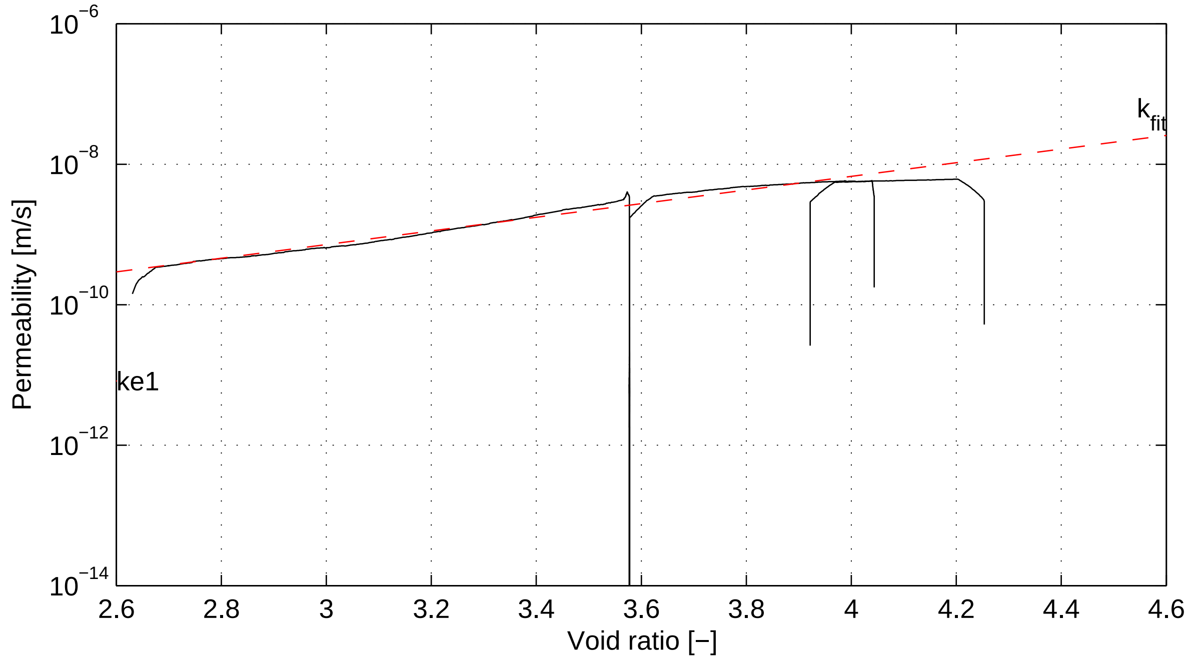
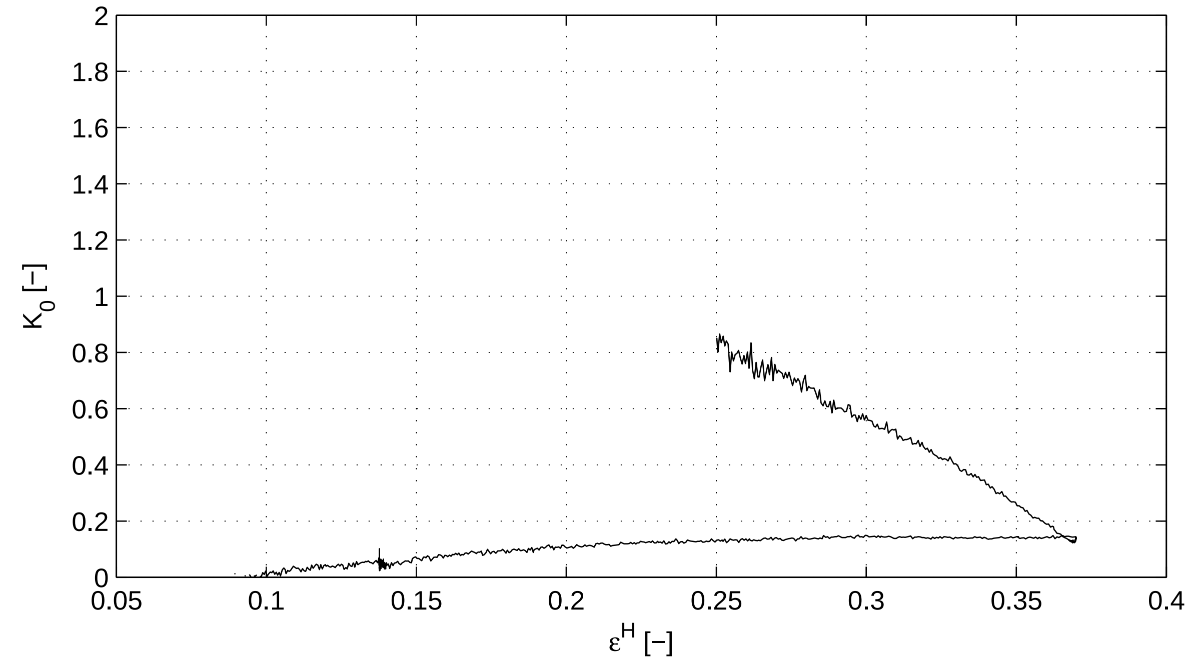


k_{e1} = 8.2e−12 m/s

k_{e0} = 1.2e−08 m/s

slope = 9.71e−01



ν = 0.14

K_{0m} = 0.14

K_{0e} = 0.14

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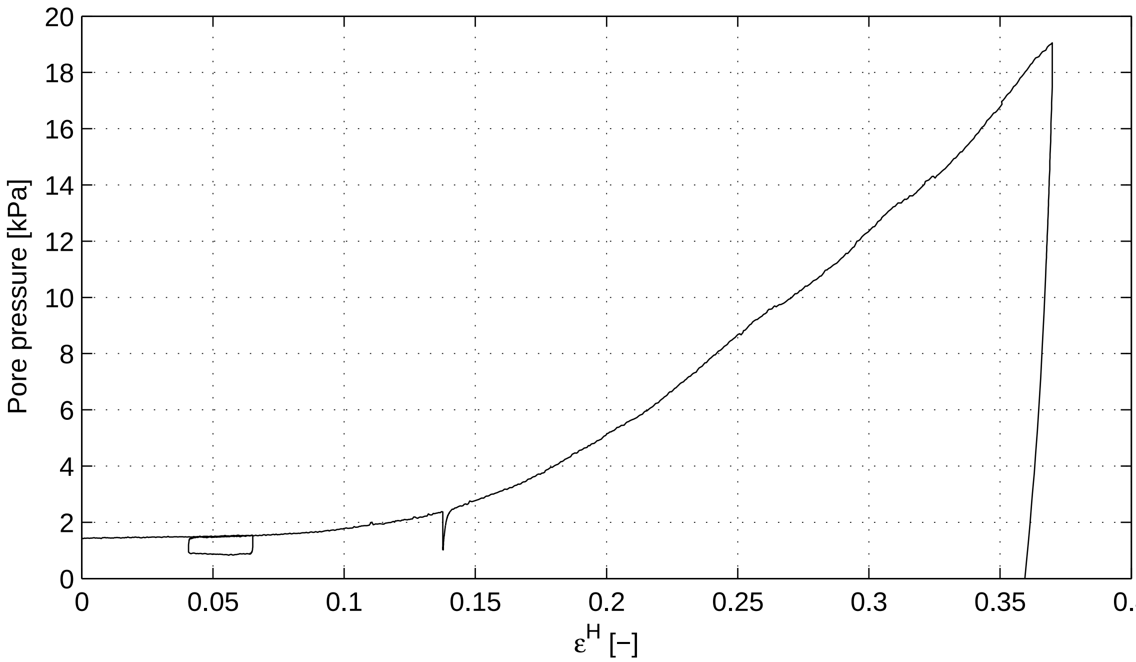
Contribution study program EQ Groningen field

Boring SB4A−A, sample SB4A−A2−1A, depth: −3.04 m to −3.06 m NAP

K0−CRS measurement

*) Checked and released by ess on 28 September 2016



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	date 2016−09−28	signed luije_sa
Contribution study program EQ Groningen field Boring SB4A−A, sample SB4A−A2−1A, depth: −3.04 m to −3.06 m NAP	project 1209862.11	version 1.1
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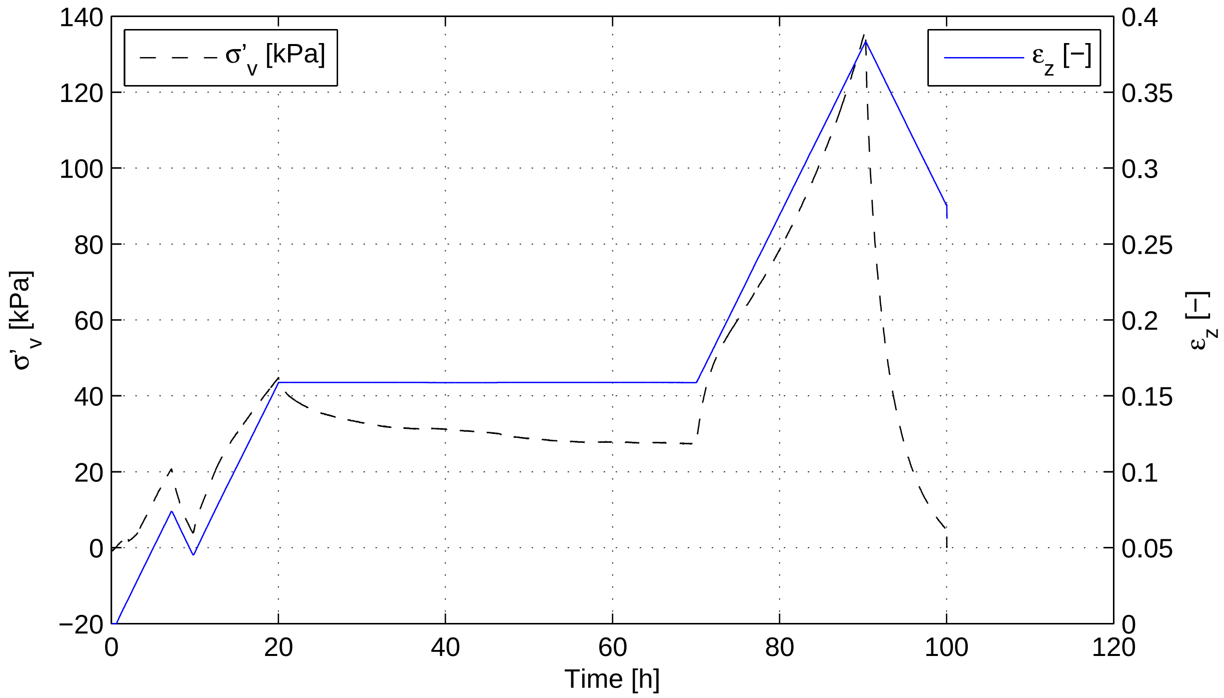

Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, plan..
Unit weight saturated soil [kN/m^3]	9.7
Unit weight dry soil [kN/m^3]	1.5
Water content [%]	558.9
Water content final [%]	417.8
Void ratio − initial [−]	5.13 (e)
Sample disturbance index [%]	4.2, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	25
Stress unloading phase [kPa]	5
Stress reloading phase [kPa]	50
Stress relaxation phase [kPa]	50
Maximum stress [kPa]	150

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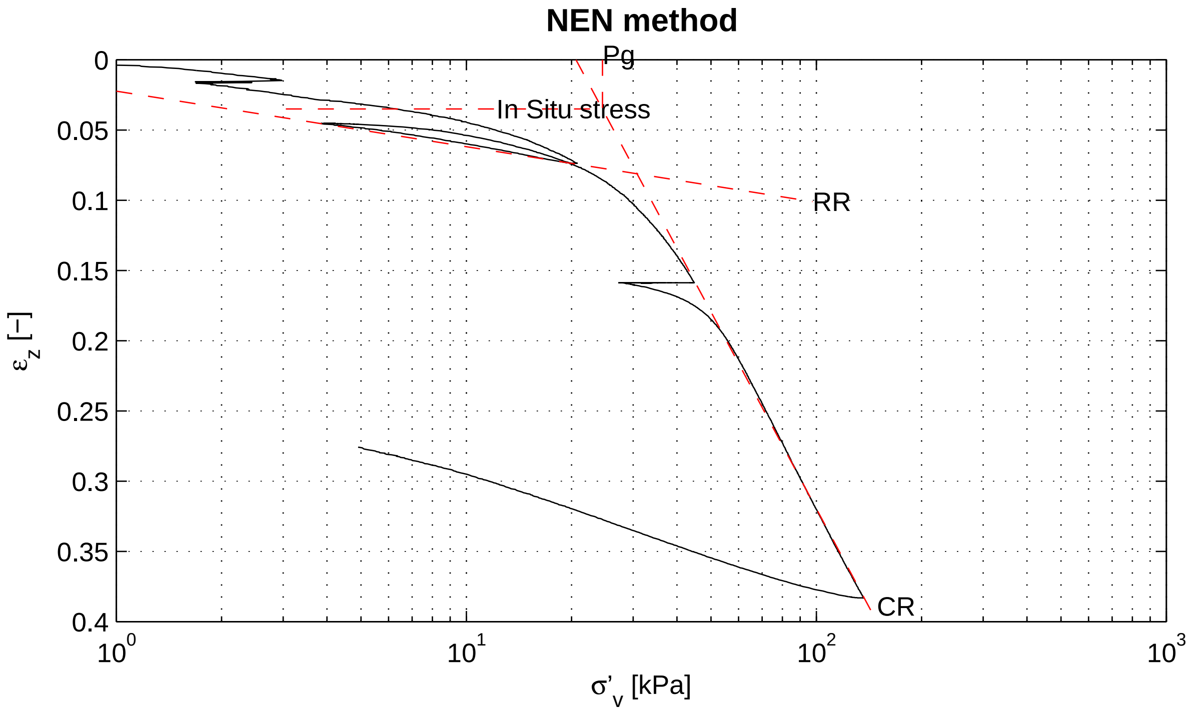
Contribution study program EQ Groningen field

Boring SB4A−A, sample SB4A−A2−2B, depth: −3.42 m to −3.44 m NAP

K0−CRS measurement

*) Checked and released by ess on 28 September 2016

NEN method

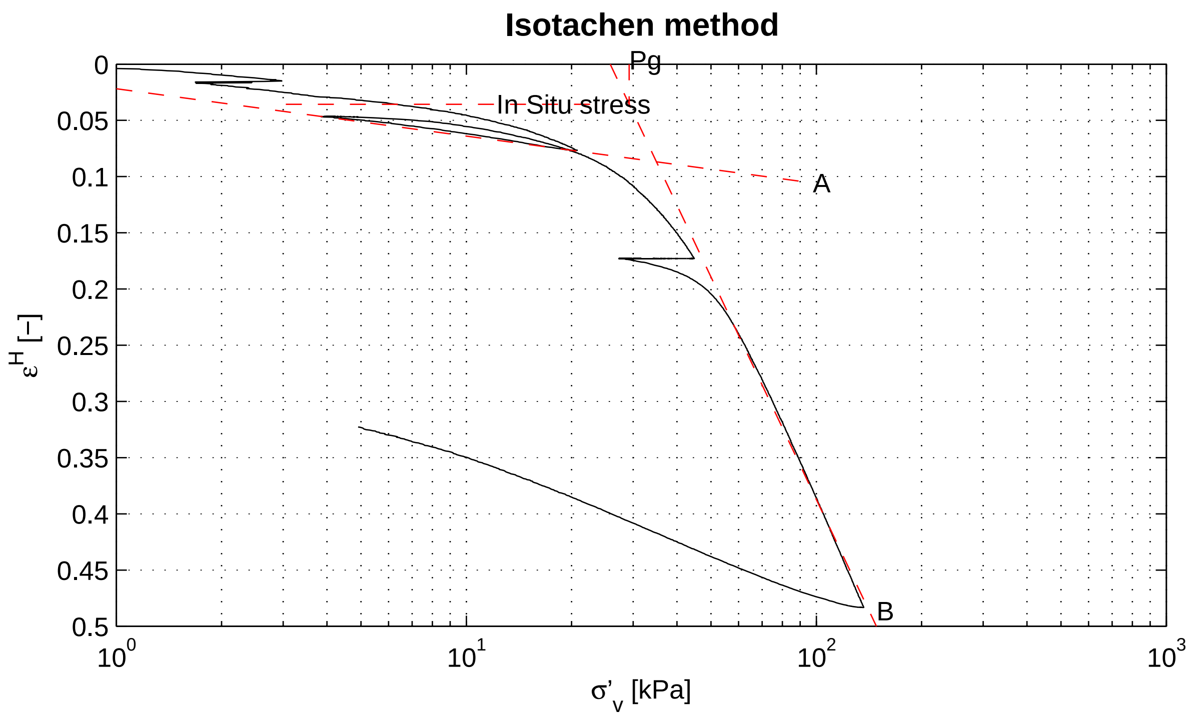


RR = 4.0e−02
CR = 4.7e−01

C_α = 5.8e−02

Pg = 24.5 kPa

Isotachen method



A = 1.8e−02
B = 2.9e−01

C = 3.6e−02

Pg = 29.2 kPa

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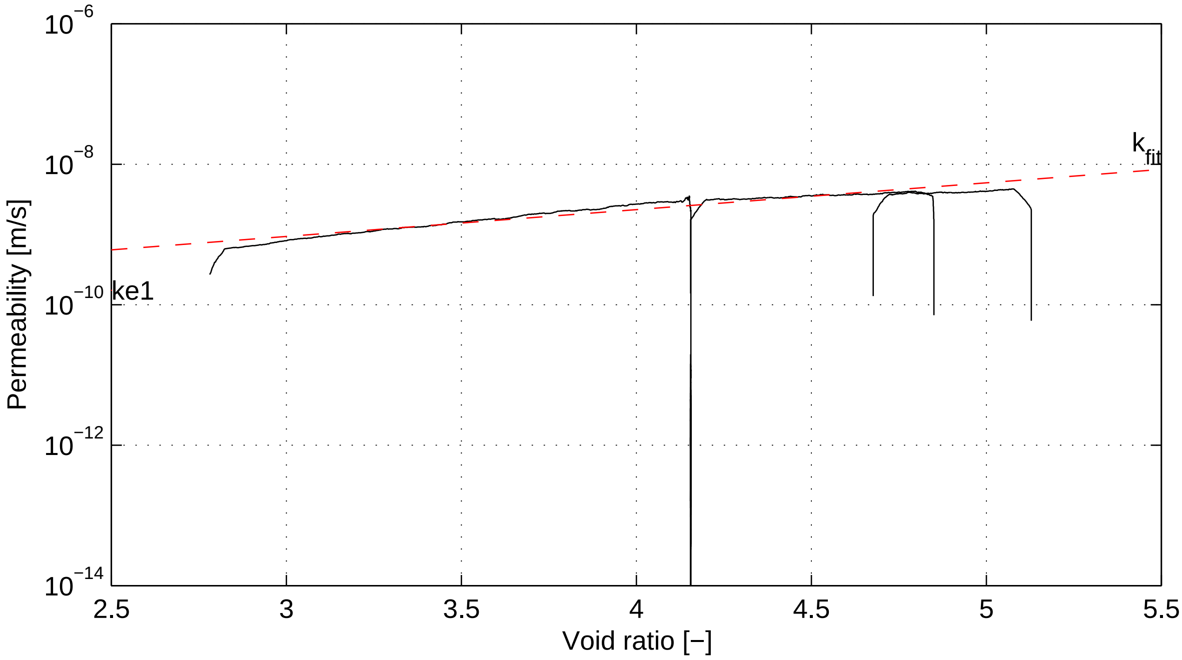
Contribution study program EQ Groningen field

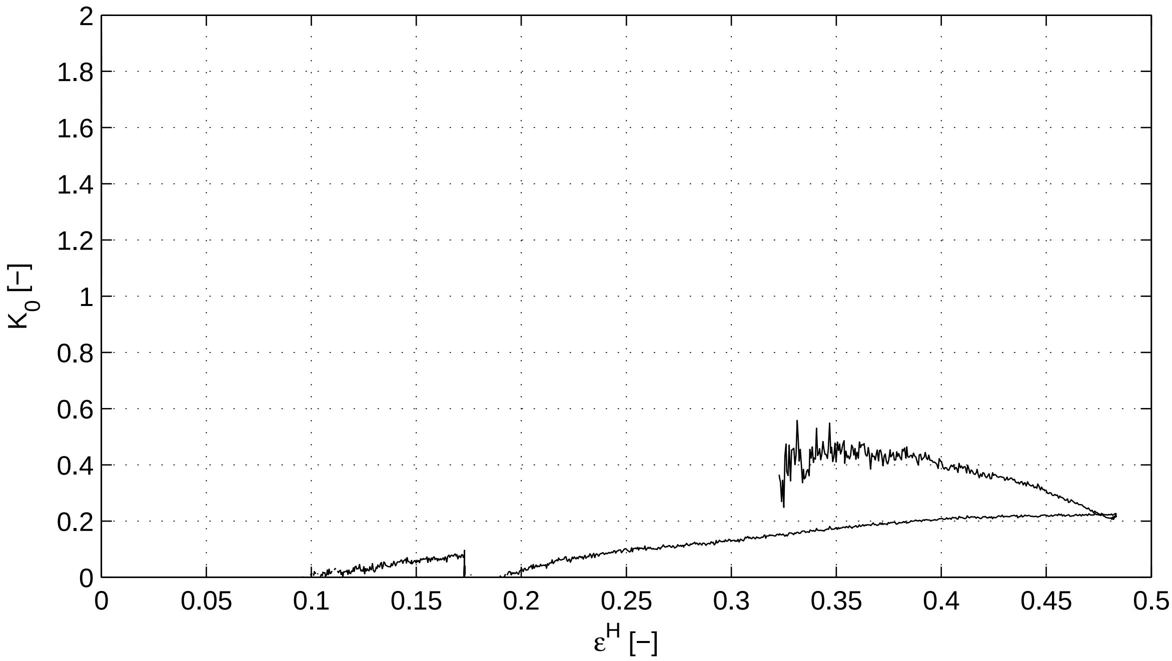
Boring SB4A−A, sample SB4A−A2−2B, depth: −3.42 m to −3.44 m NAP

K0−CRS measurement

*) Checked and released by ess on 28 September 2016



k_{e1} = 1.6e−10 m/s k_{e0} = 6.1e−09 m/s slope = 3.83e−01



ν = 0.13 K_{0m} = 0.22 K_{0e} = 0.22

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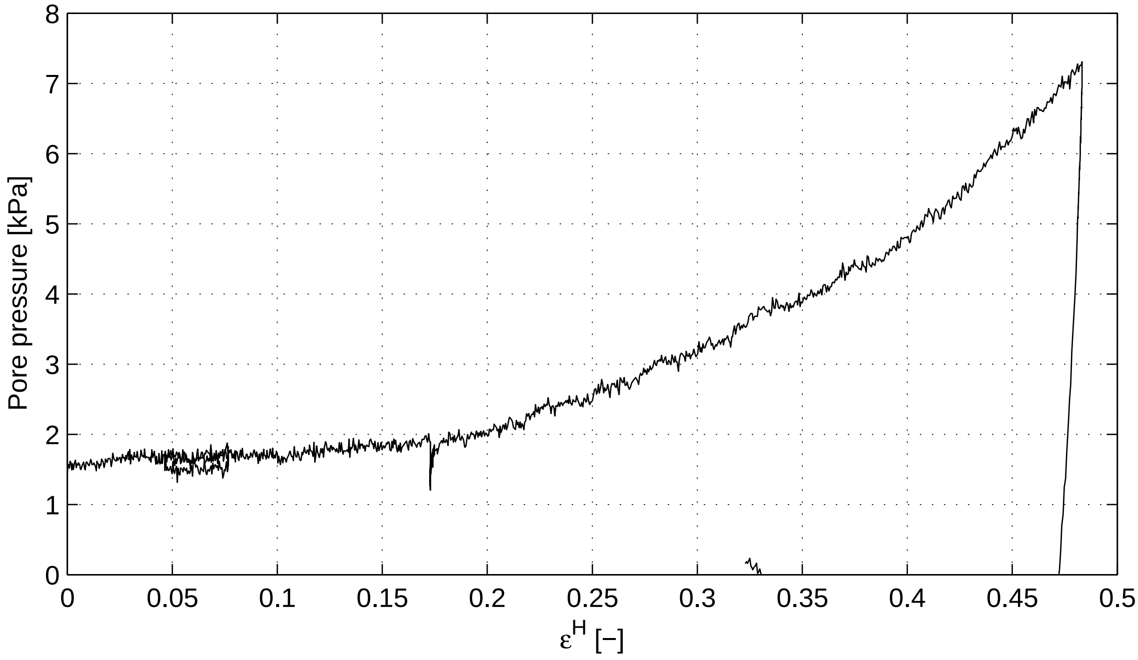
Contribution study program EQ Groningen field

Boring SB4A−A, sample SB4A−A2−2B, depth: −3.42 m to −3.44 m NAP

K0−CRS measurement

*) Checked and released by ess on 28 September 2016



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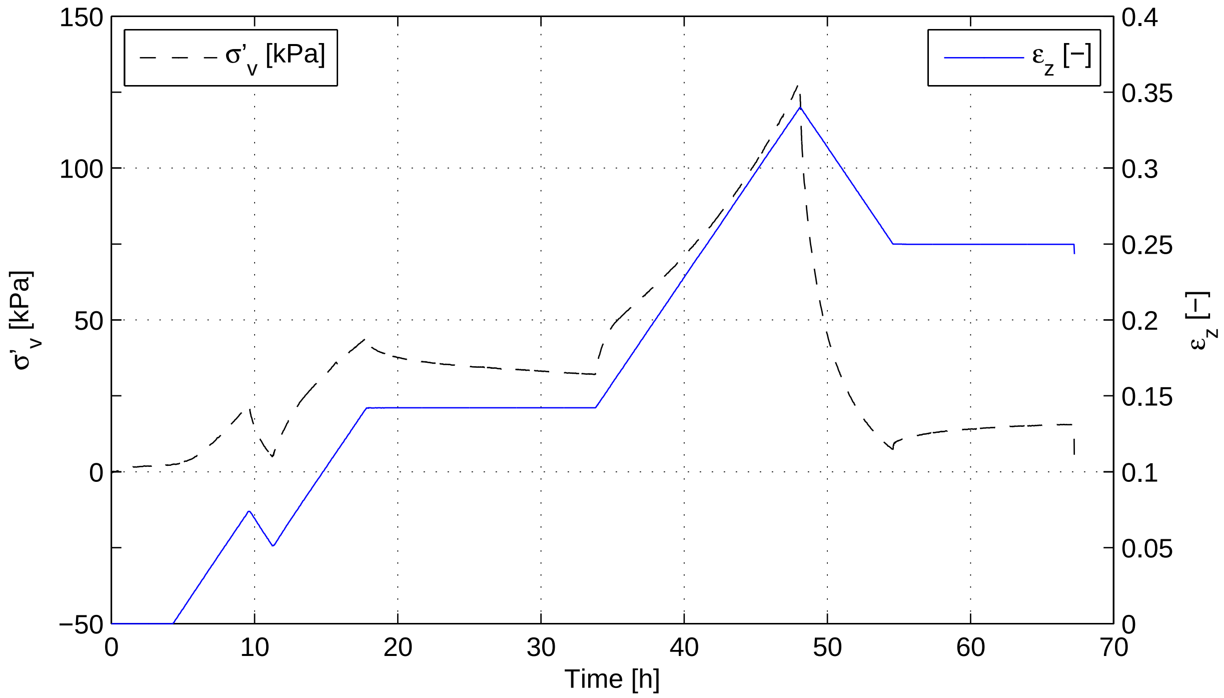
Contribution study program EQ Groningen field

Boring SB4A−A, sample SB4A−A2−2B, depth: −3.42 m to −3.44 m NAP

K0−CRS measurement

*) Checked and released by ess on 28 September 2016



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, rietr..
Unit weight saturated soil [kN/m^3]	9.9
Unit weight dry soil [kN/m^3]	2.1
Water content [%]	360.6
Water content final [%]	321.0
Void ratio − initial [−]	3.76 (e)
Sample disturbance index [%]	4.4, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	25
Stress unloading phase [kPa]	5
Stress reloading phase [kPa]	50
Stress relaxation phase [kPa]	50
Maximum stress [kPa]	150

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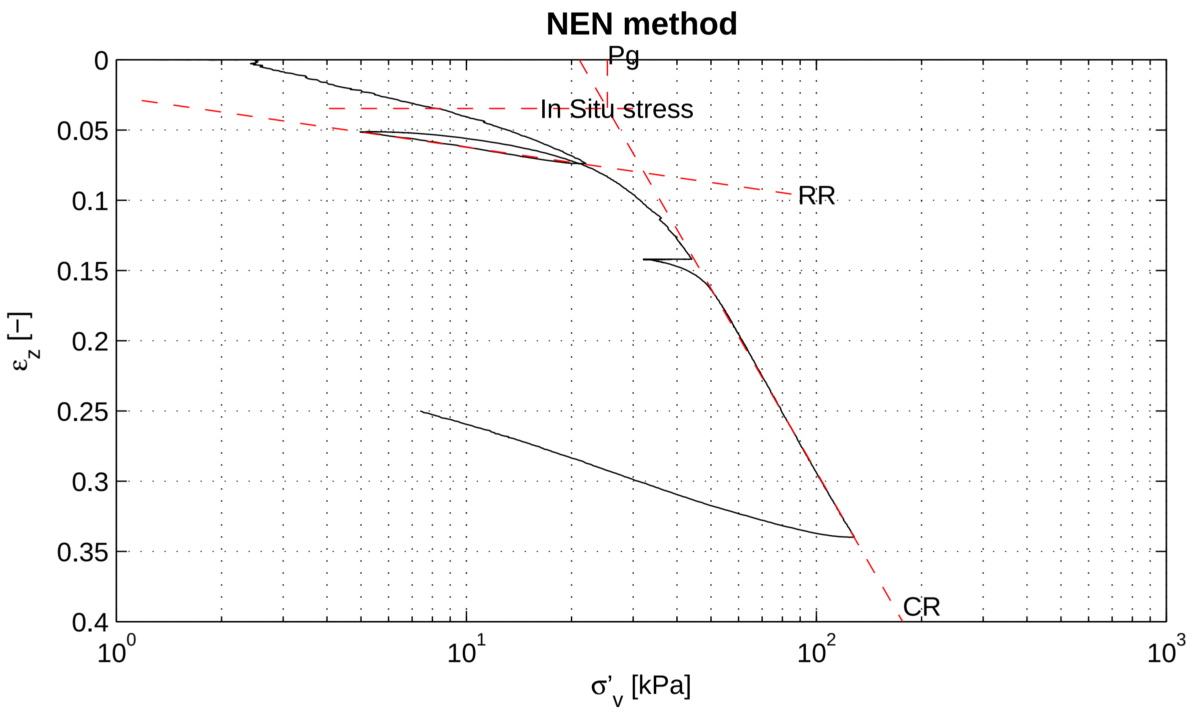
Contribution study program EQ Groningen field Boring SM2C−A, sample SM2C−A3−2A, depth: −3.82 m to −3.84 m NAP	date 2016−06−27	signed luije_sa
	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSSM2C−A3−2A	page 1

NEN method

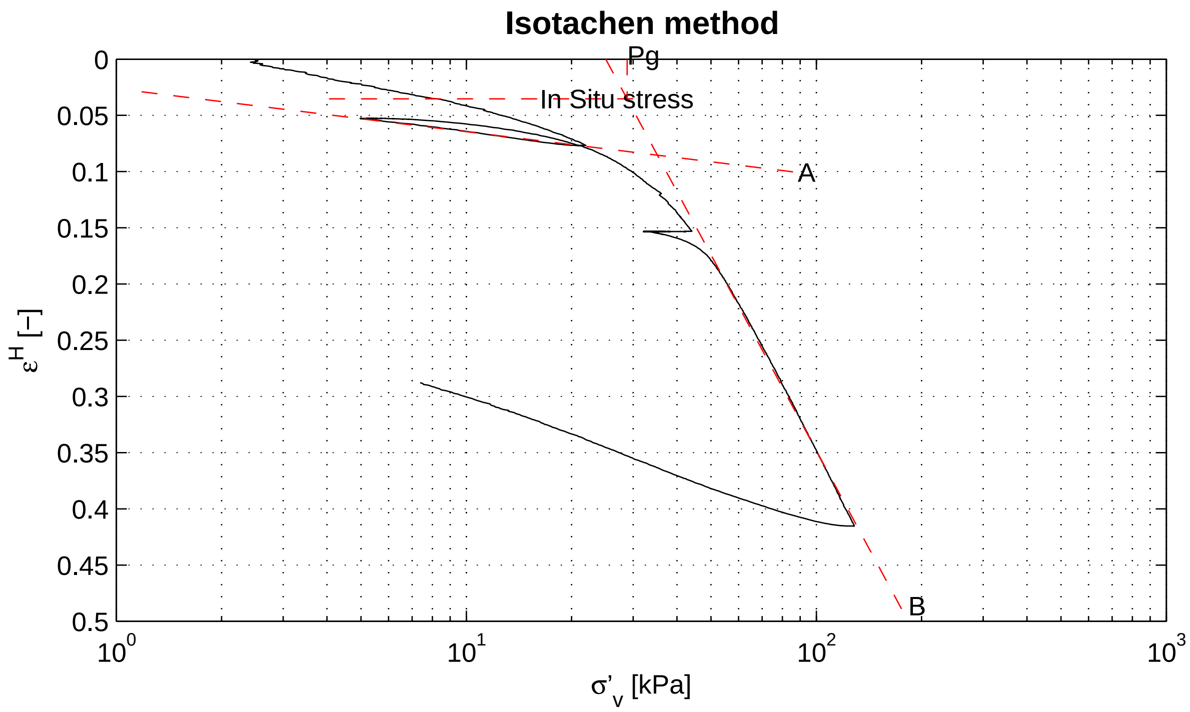


RR = 3.6e−02
CR = 4.3e−01

C_α = 3.3e−02

Pg = 25.3 kPa

Isotachen method



A = 1.7e−02
B = 2.5e−01

C = 1.9e−02

Pg = 28.8 kPa

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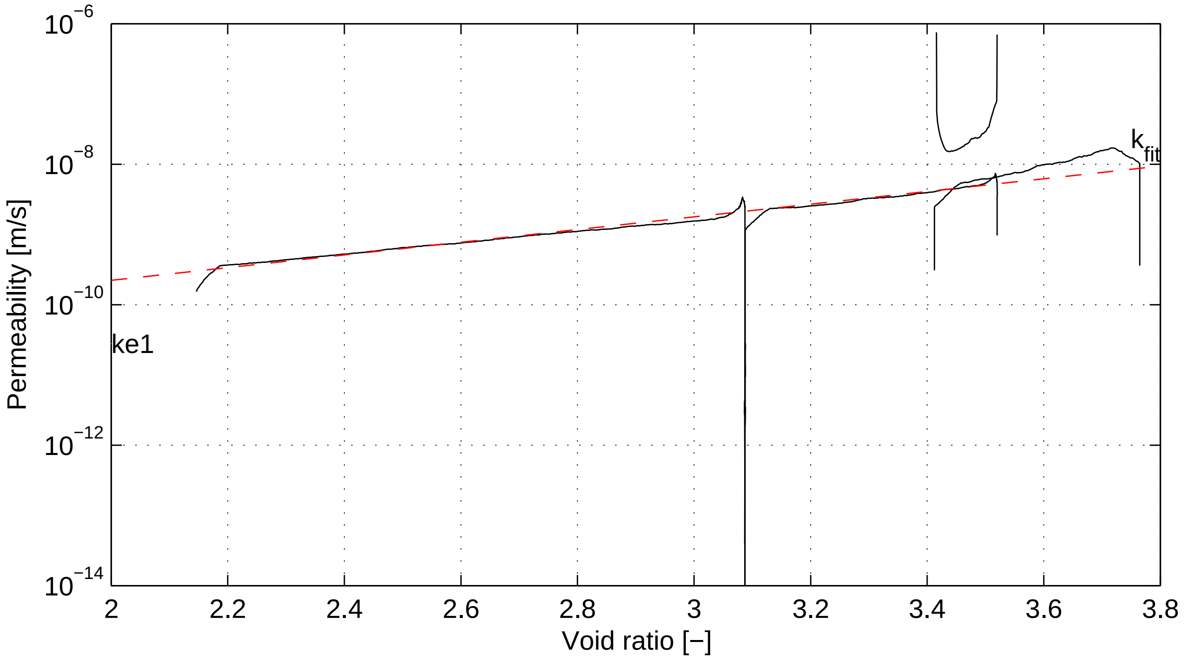
date	signed
2016−06−27	luije_sa
project	version
1209862.11	1.1
appendix	page
CRSSM2C−A3−2A	2

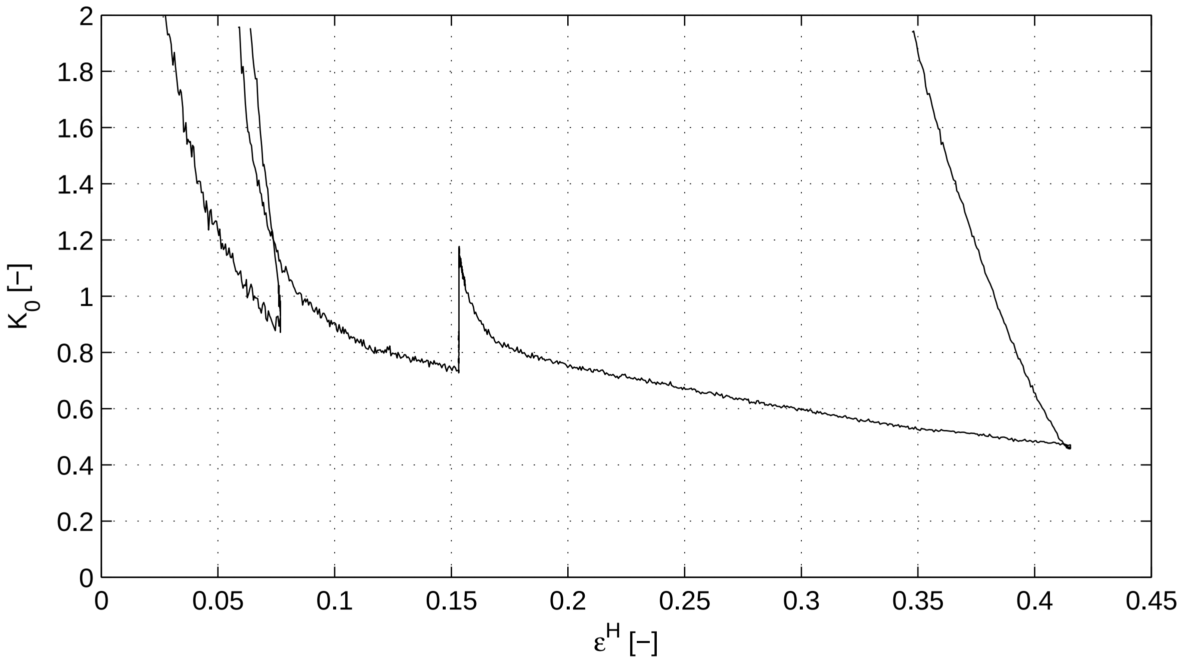
Contribution study program EQ Groningen field

Boring SM2C−A, sample SM2C−A3−2A, depth: −3.82 m to −3.84 m NAP

K0−CRS measurement



k_{e1} = 2.8e−11 m/s k_{e0} = 8.7e−09 m/s   slope = 9.02e−01



ν = 0.04 K_{0m} = 0.47 K_{0e} = 0.48

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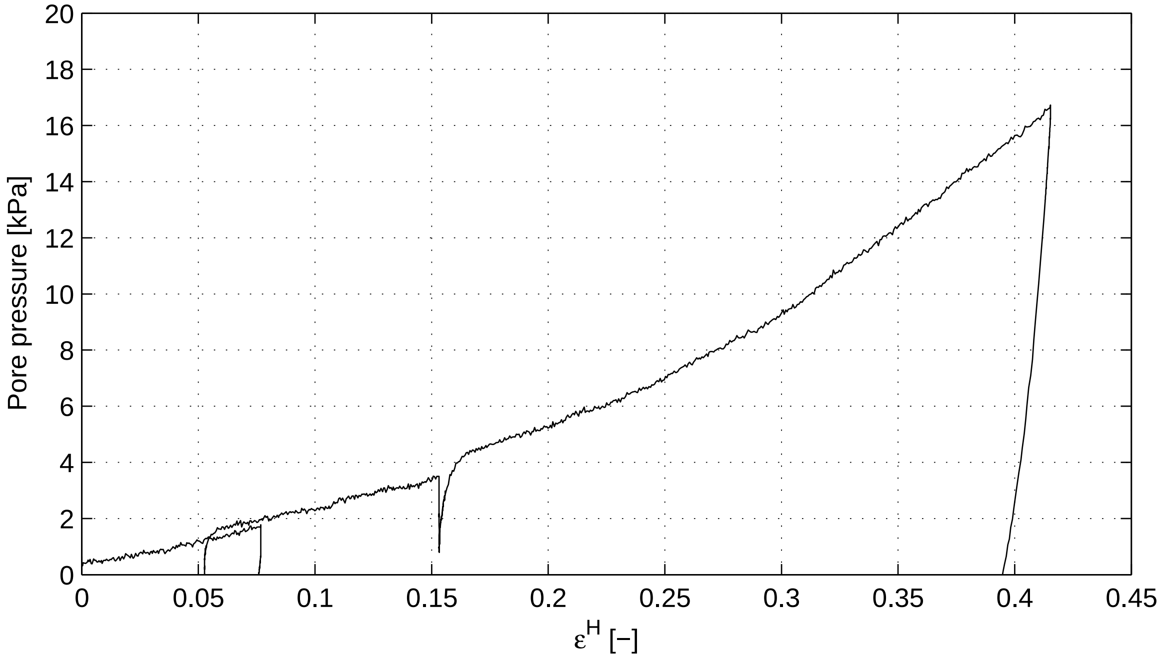
Contribution study program EQ Groningen field	date: 2016−06−27	signed: luije_sa
Boring SM2C−A, sample SM2C−A3−2A, depth: −3.82 m to −3.84 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSSM2C−A3−2A	page: 3



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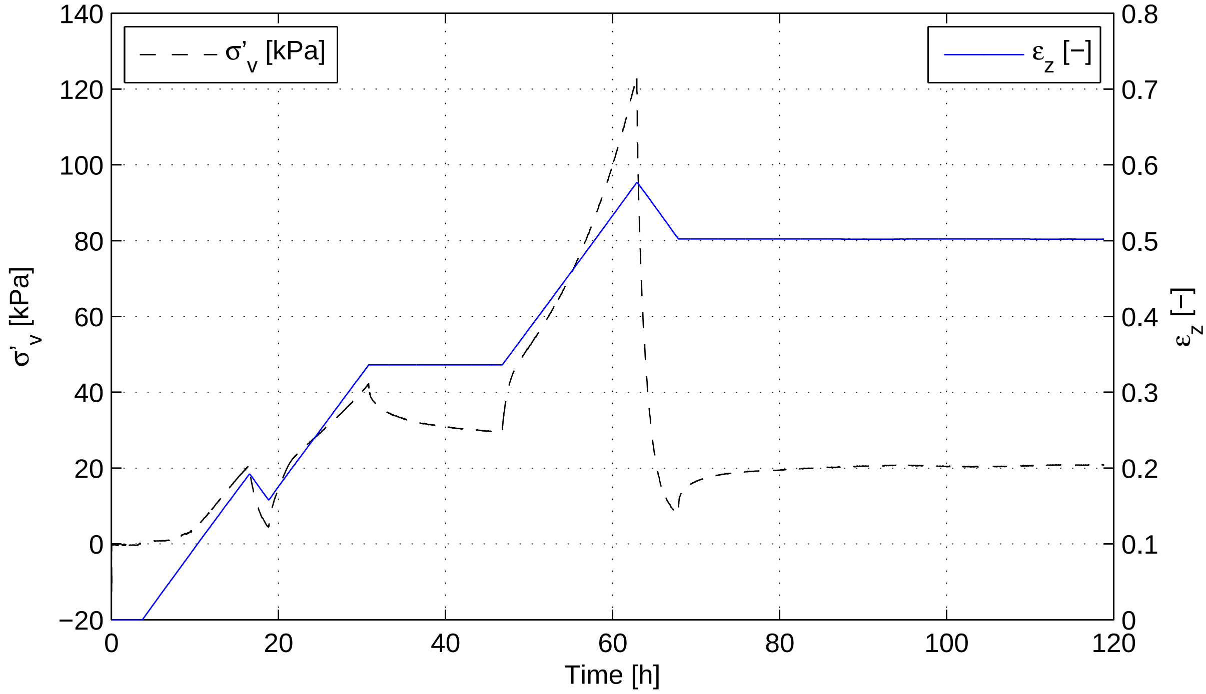
	date	signed
	2016−06−27	luije_sa
Contribution study program EQ Groningen field	project	version
Boring SM2C−A, sample SM2C−A3−2A, depth: −3.82 m to −3.84 m NAP	1209862.11	1.1
	appendix	page
K0−CRS measurement	CRSSM2C−A3−2A	4



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, hout..
Unit weight saturated soil [kN/m^3]	10.4
Unit weight dry soil [kN/m^3]	1.3
Water content [%]	718.2
Water content final [%]	423.2
Void ratio − initial [−]	12.69 (e)
Sample disturbance index [%]	13.7, bad quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	25
Stress unloading phase [kPa]	5
Stress reloading phase [kPa]	50
Stress relaxation phase [kPa]	50
Maximum stress [kPa]	150

Grote monsterverstoring hangt samen met grote initiele rek.

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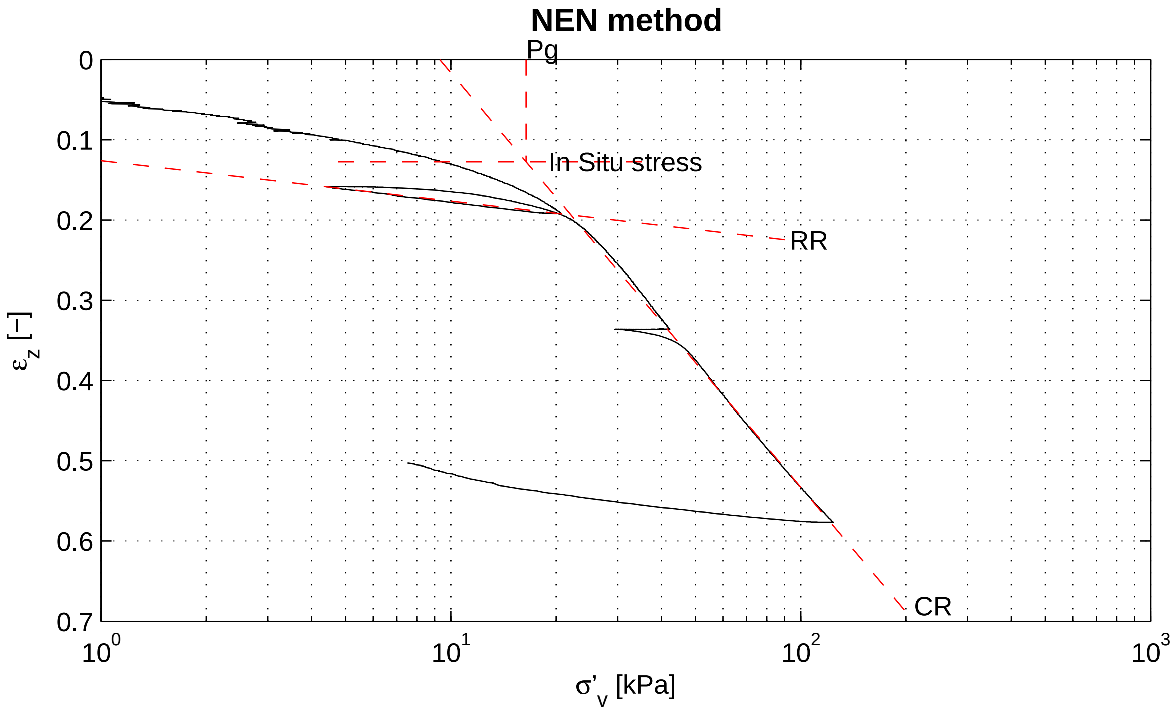
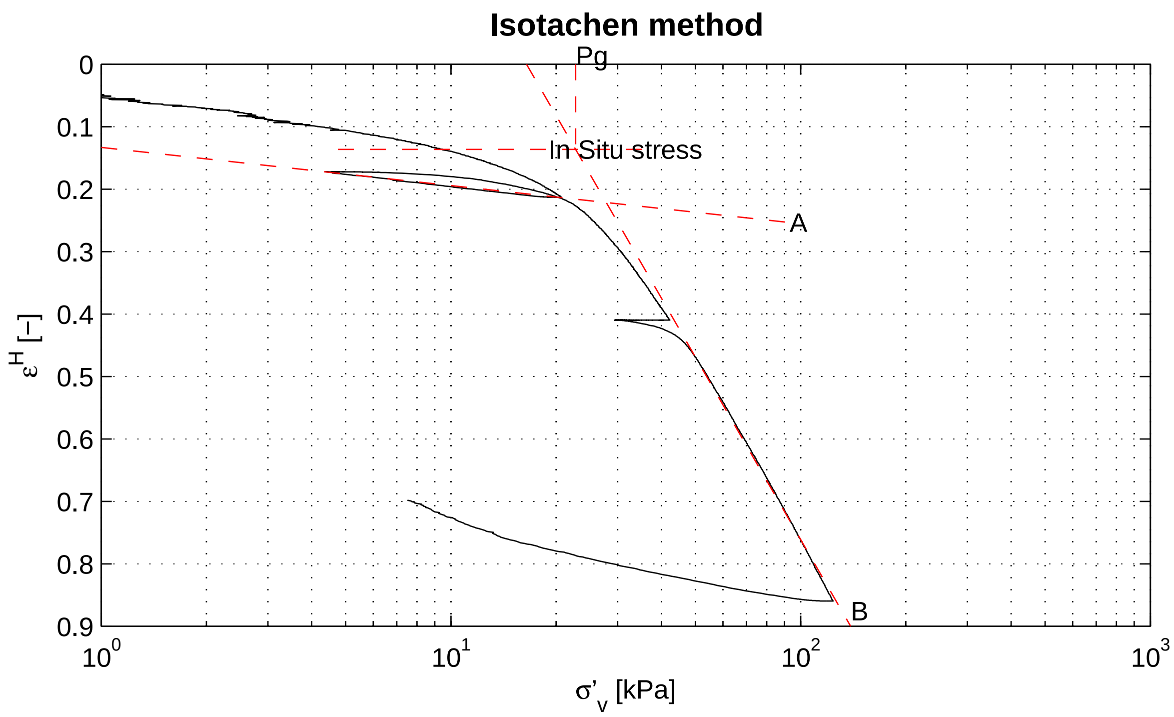
Contribution study program EQ Groningen field	date 2016−08−17	signed luije_sa
Boring SM2C−B, sample SM2C−B1−2A, depth: −3.69 m to −3.71 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSSM2C−B1−2A	page 1



RR = 5.0e−02
CR = 5.2e−01

C_α = 4.1e−02

Pg = 16.4 kPa



A = 2.7e−02
B = 4.2e−01

C = 3.3e−02

Pg = 22.7 kPa

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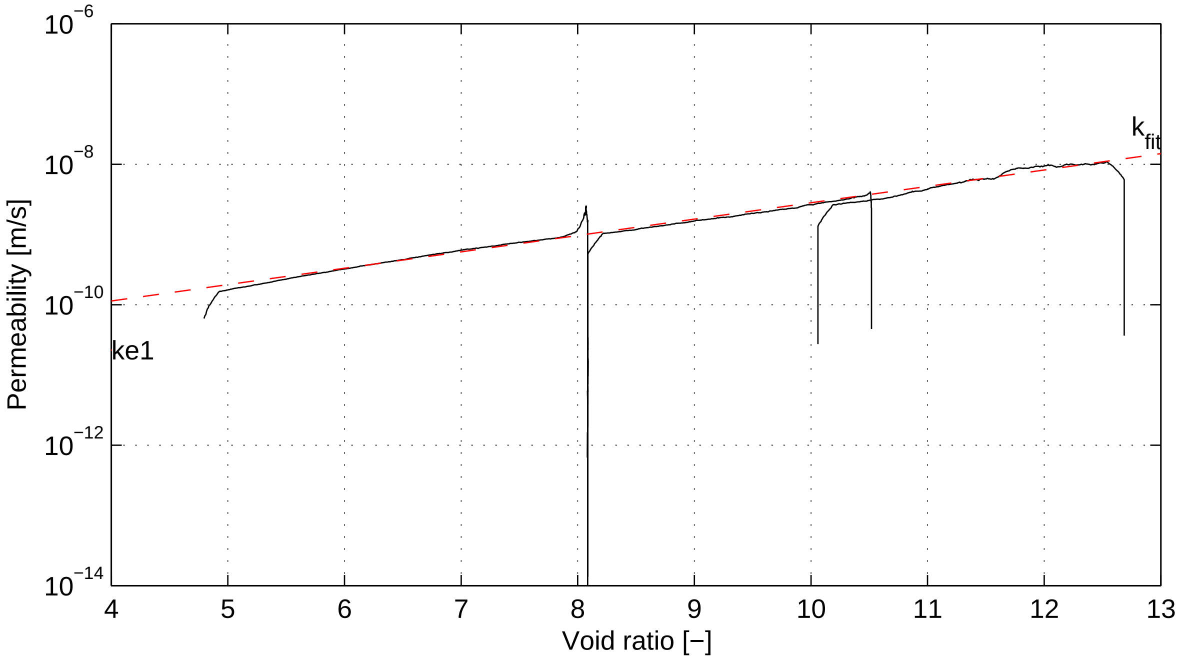
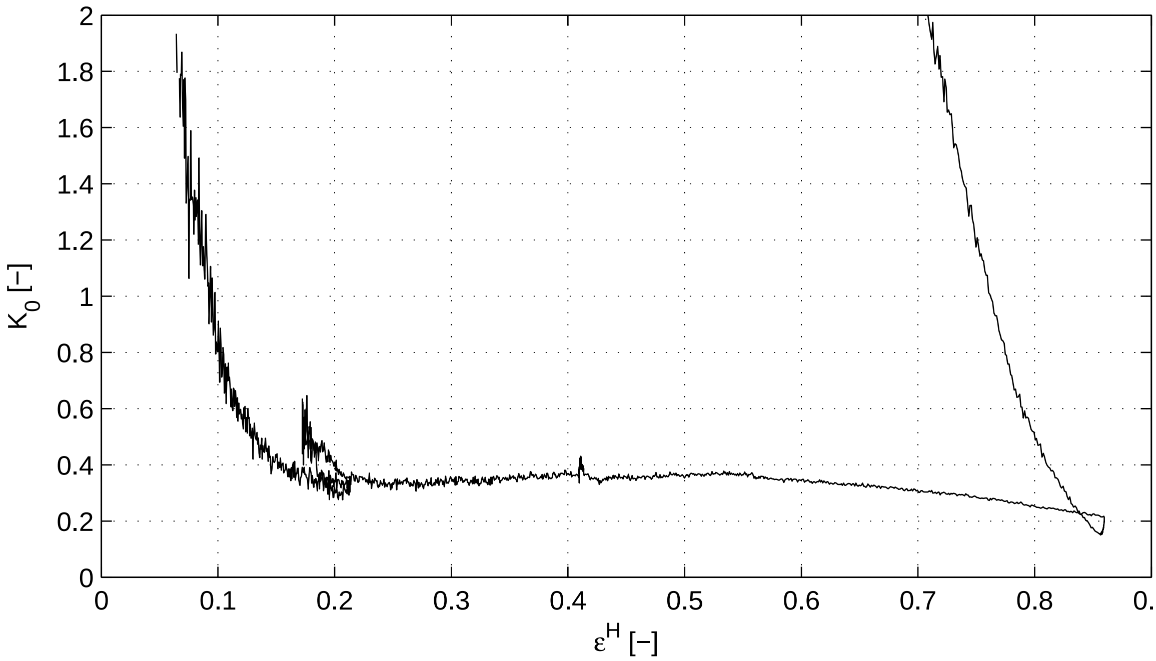
	date 2016−08−17	signed luije_sa
Contribution study program EQ Groningen field Boring SM2C−B, sample SM2C−B1−2A, depth: −3.69 m to −3.71 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSSM2C−B1−2A	page 2



k_{e1} = 2.3e−11 m/s k_{e0} = 1.2e−08 m/s   slope = 2.33e−01



ν = 0.22 K_{0c} = 0.36 K_{0e} = 0.23

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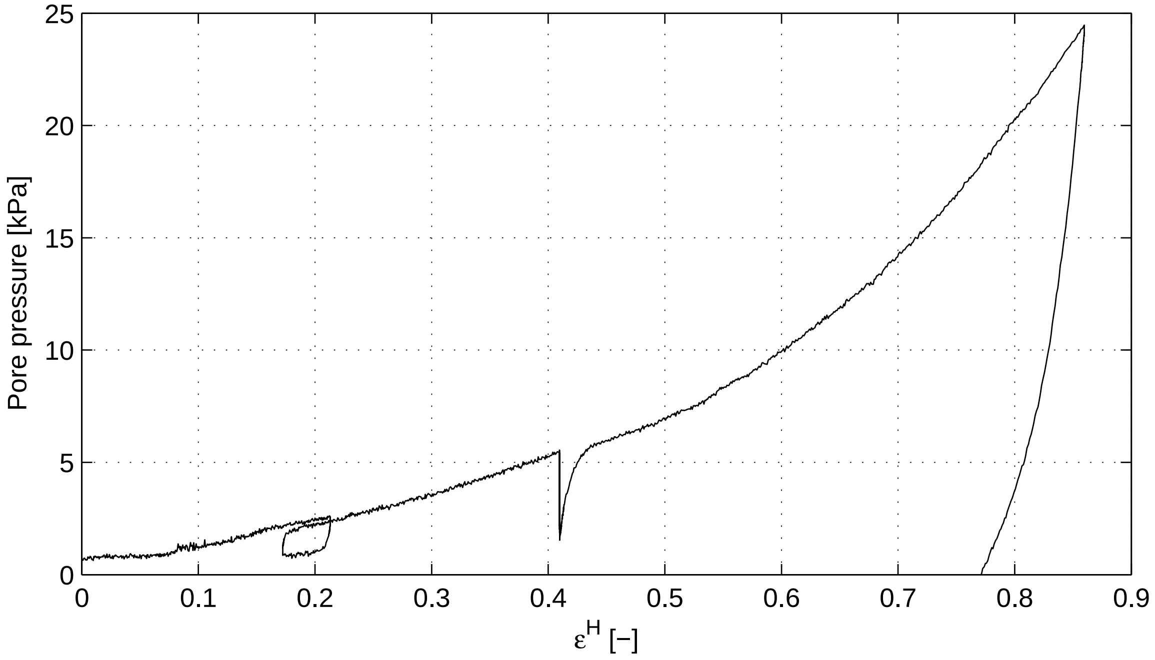
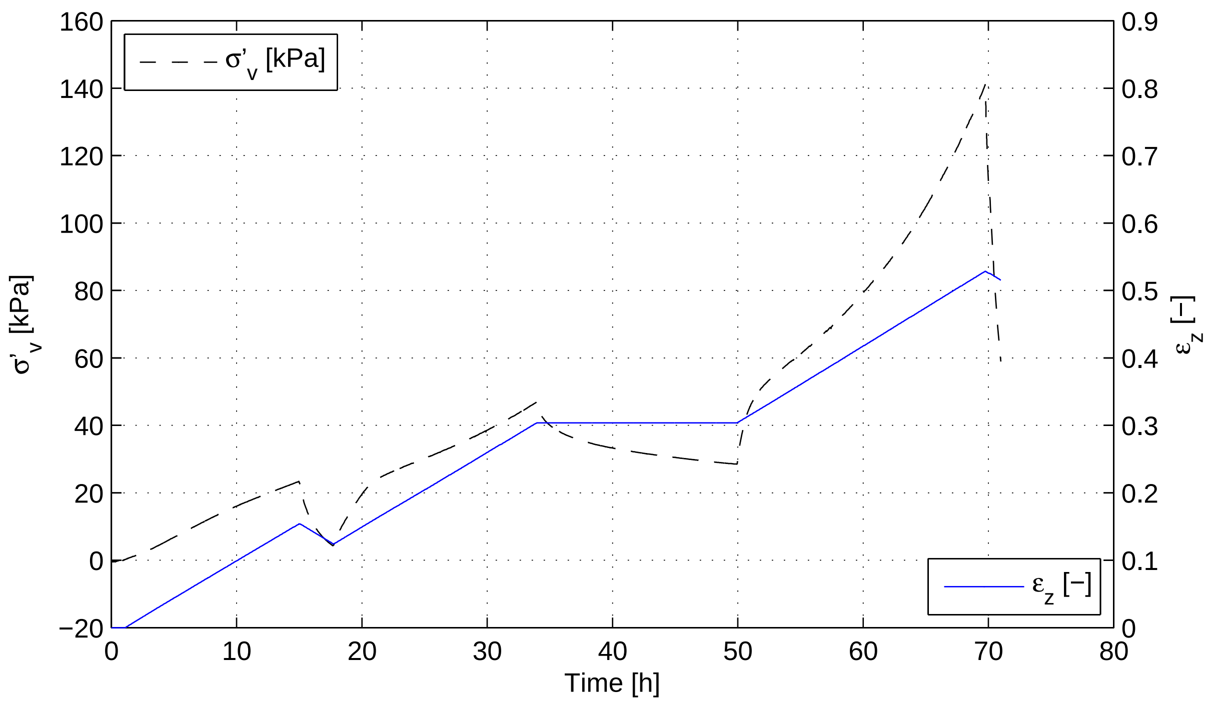
	date	signed
Contribution study program EQ Groningen field	2016−08−17	luije_sa
Boring SM2C−B, sample SM2C−B1−2A, depth: −3.69 m to −3.71 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSSM2C−B1−2A	page: 3



Pore pressure [kPa]
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
εH [−]



Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm, grov..
Unit weight saturated soil [kN/m^3]	9.1
Unit weight dry soil [kN/m^3]	1.1
Water content [%]	748.7
Water content final [%]	440.4
Void ratio − initial [−]	4.52 (e)
Sample disturbance index [%]	7.2, bad quality
e calculated with assumed complete saturation	

Test overview (test plan):

Stress loading phase [kPa]	25
Stress unloading phase [kPa]	5
Stress reloading phase [kPa]	50
Stress relaxation phase [kPa]	50
Maximum stress [kPa]	150

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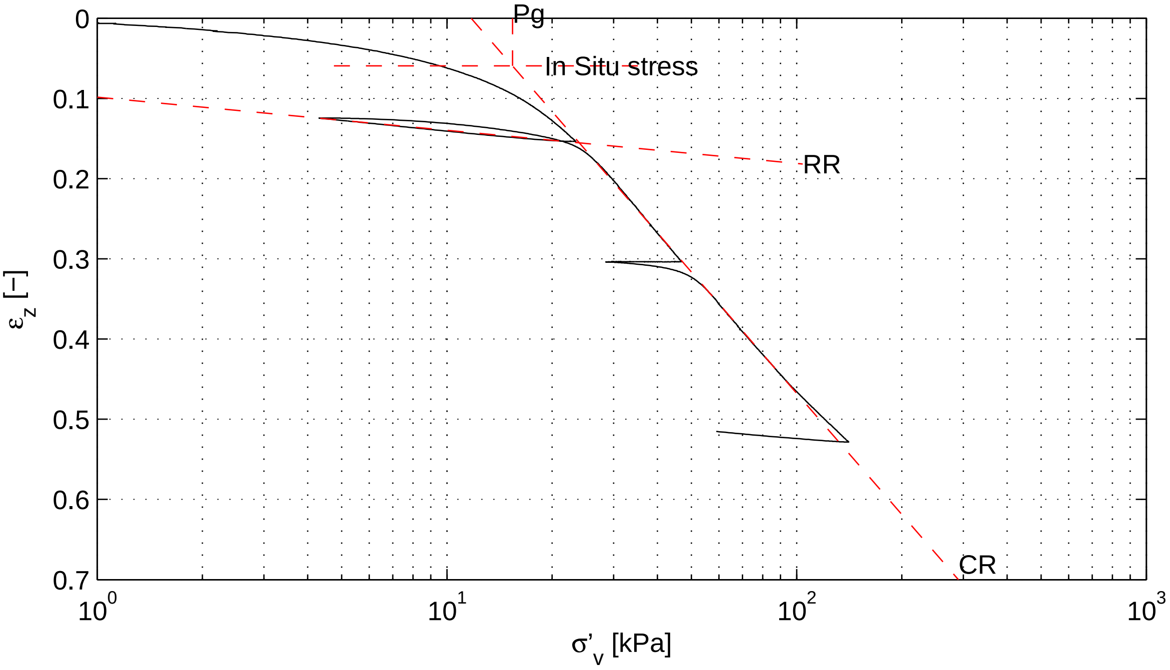
Shear degradation and damping curves for peat	date: 2016−07−06	signed: ess
Boring SM2C−B, sample SM2C−B1−1B, depth: −3.47 m to −3.49 m NAP	project: 1209862.11	version: 1.1
K0−CRS measurement	appendix: CRSSM2C−B1−1B	page: 1

*) Checked and released by ess on 22 September 2016

NEN method

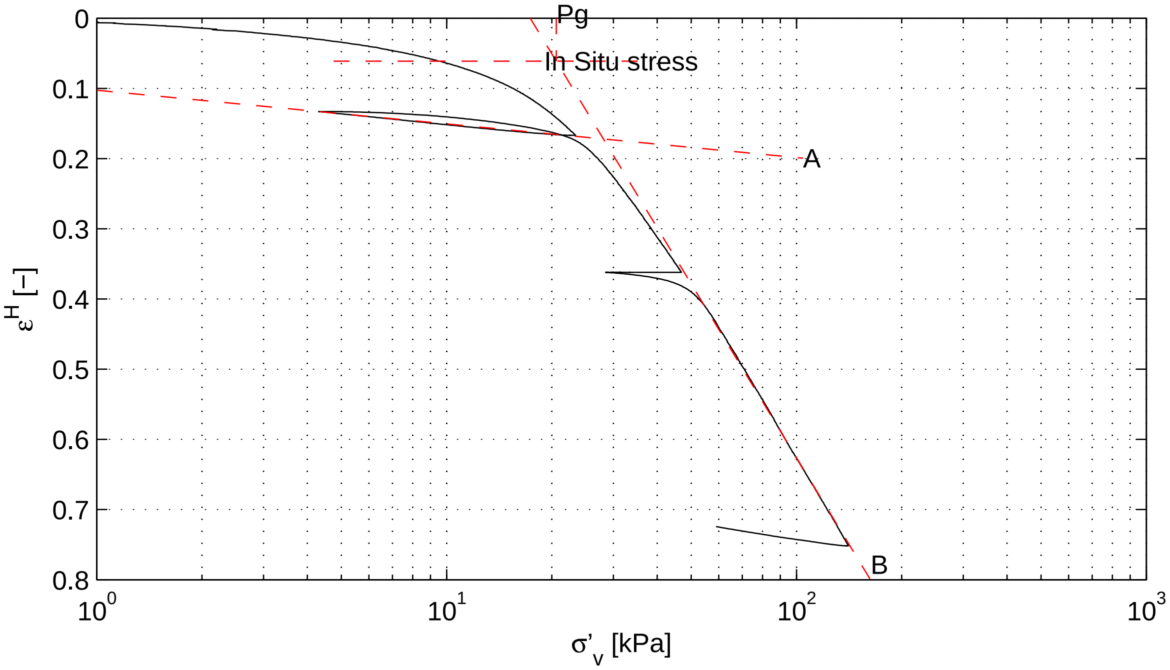


RR = 4.1e−02
CR = 5.0e−01

C_α = 7.2e−02

Pg = 15.4 kPa

Isotachen method



A = 2.1e−02
B = 3.6e−01

C = 5.1e−02

Pg = 20.6 kPa

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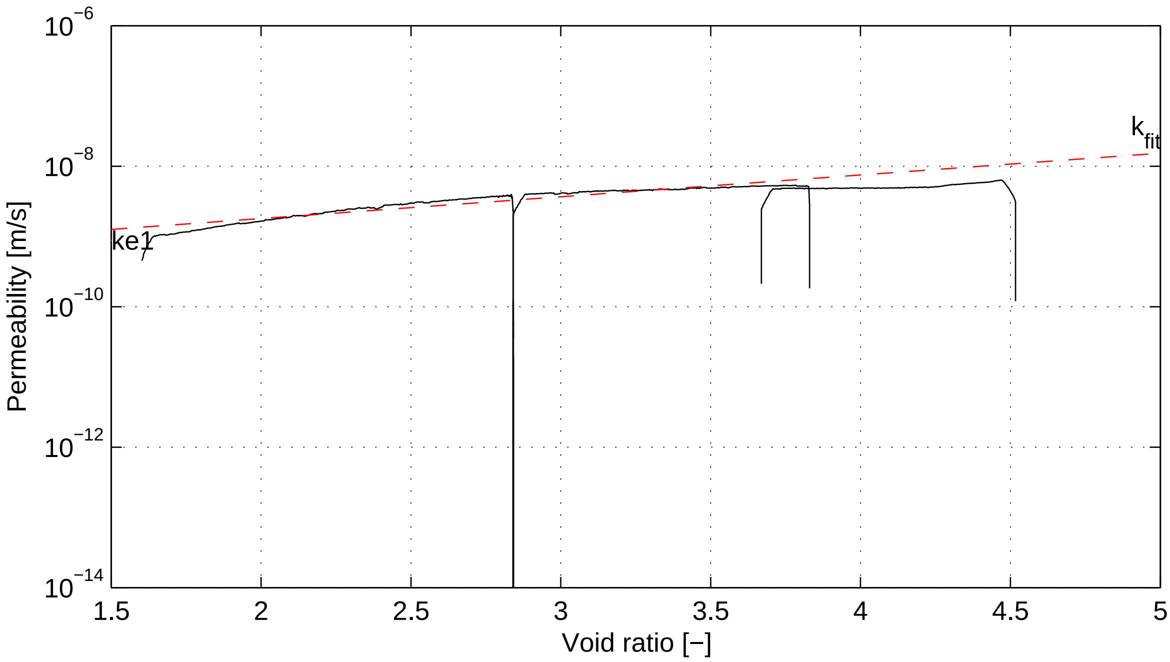
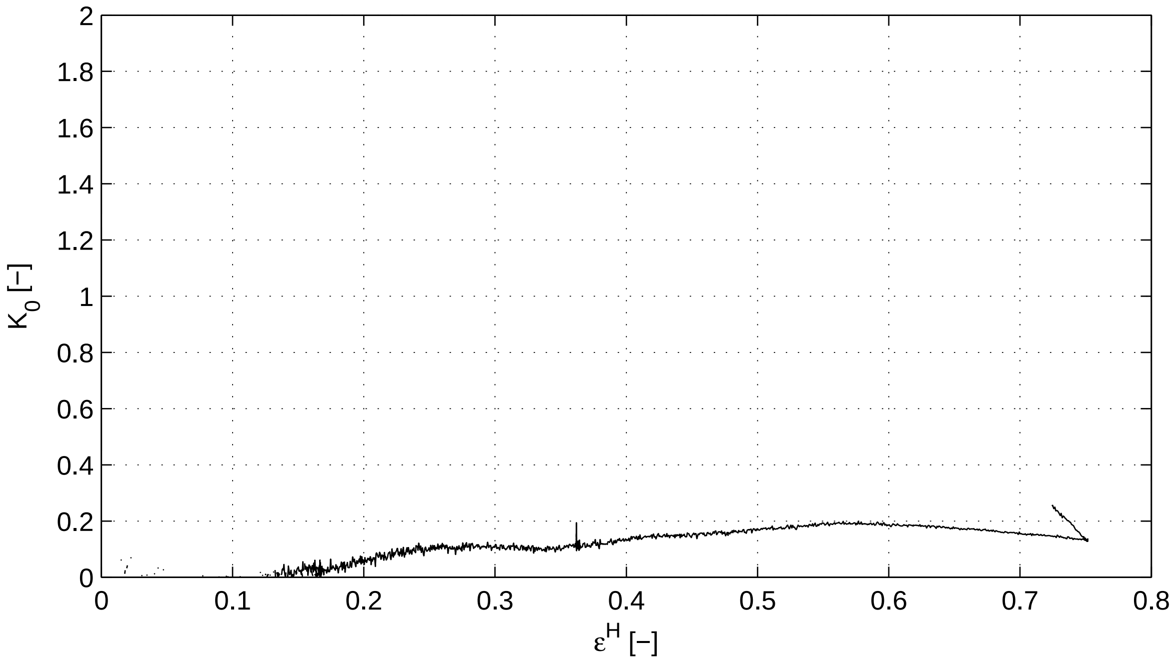
Shear degradation and damping curves for peat		date 2016−07−06	signed ess
Boring SM2C−B, sample SM2C−B1−1B, depth: −3.47 m to −3.49 m NAP		project 1209862.11	version 1.1
K0−CRS measurement		appendix CRSSM2C−B1−1B	page 2

*) Checked and released by ess on 22 September 2016



k_{e1} = 8.8e−10 m/s k_{e0} = 1.1e−08 m/s   slope = 3.10e−01



ν = 0.09 K_{0c} = 0.19 K_{0e} = 0.14

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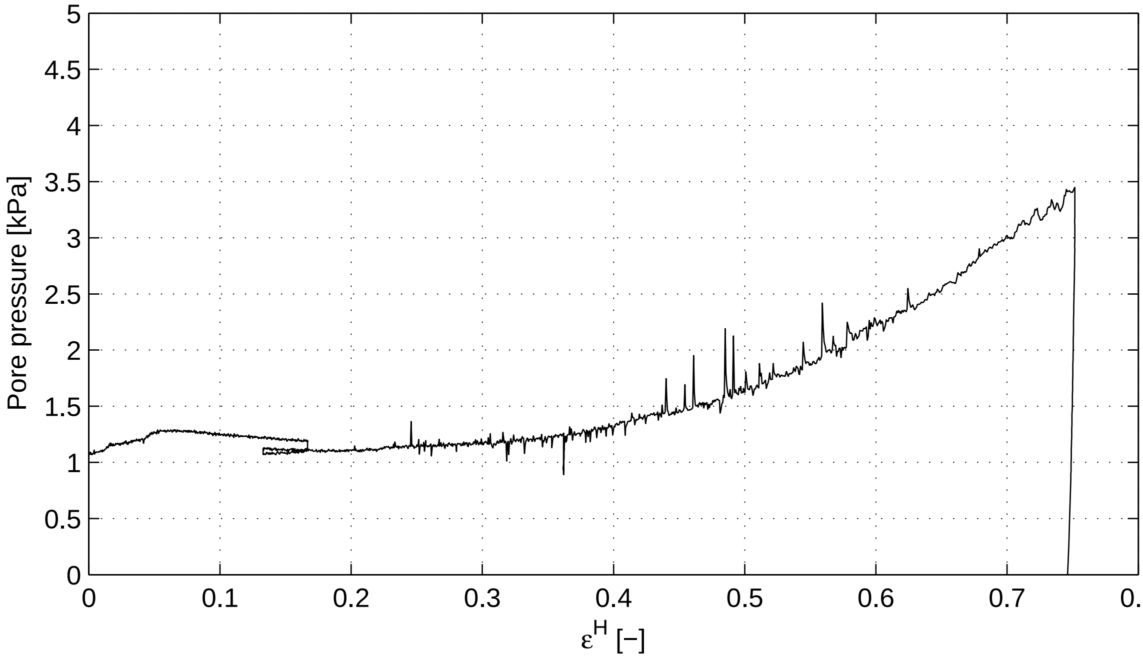
date	signed
2016−07−06	ess
project	version
1209862.11	1.1
appendix	page
CRSSM2C−B1−1B	3

Shear degradation and damping curves for peat

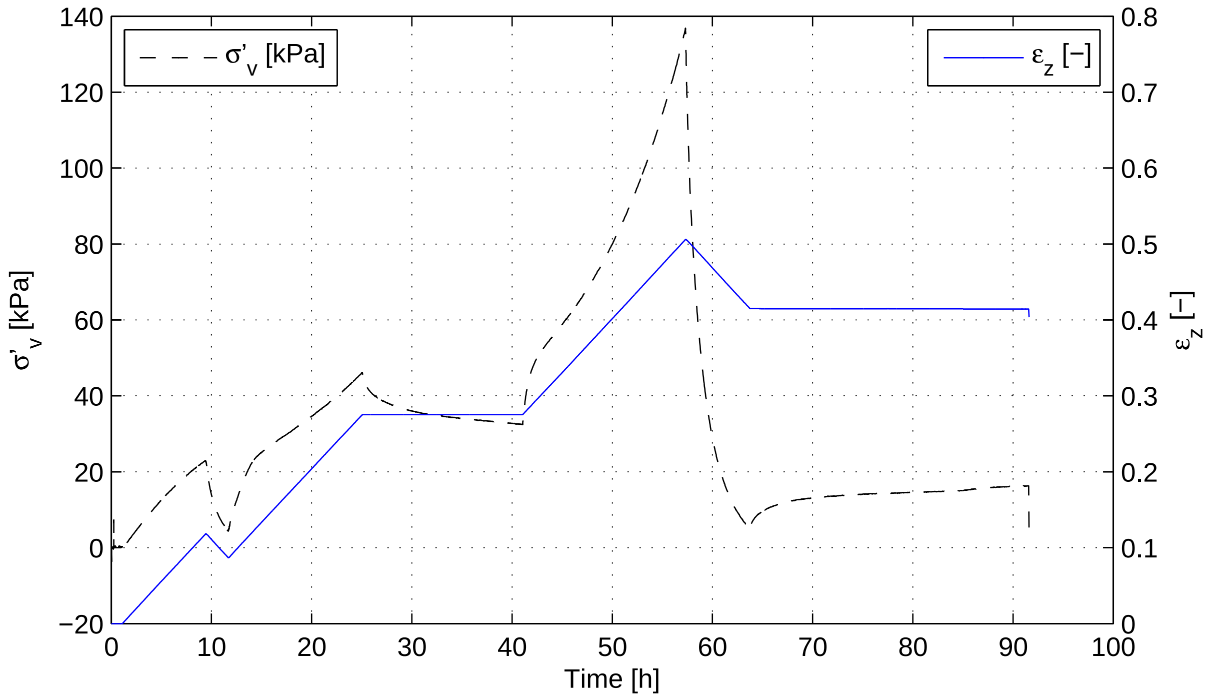
Boring SM2C−B, sample SM2C−B1−1B, depth: −3.47 m to −3.49 m NAP

K0−CRS measurement

*) Checked and released by ess on 22 September 2016



Pore pressure [kPa]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
ε^H [−]

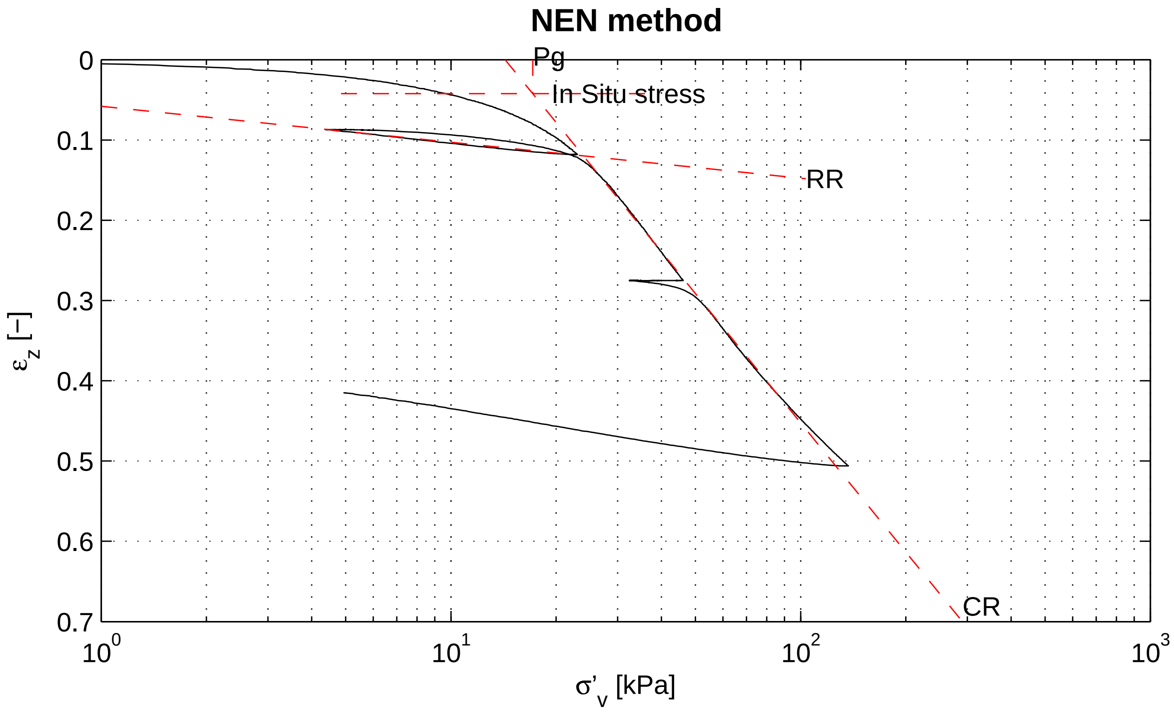


Description of soil sample:

Soil description (NEN 5104)	Veen, mineraalarm
Unit weight saturated soil [kN/m^3]	9.6
Unit weight dry soil [kN/m^3]	1.2
Water content [%]	691.7
Water content final [%]	430.3
Void ratio − initial [−]	5.94 (e)
Sample disturbance index [%]	4.9, moderate quality
e calculated with assumed complete saturation	

Test overview (test plan):

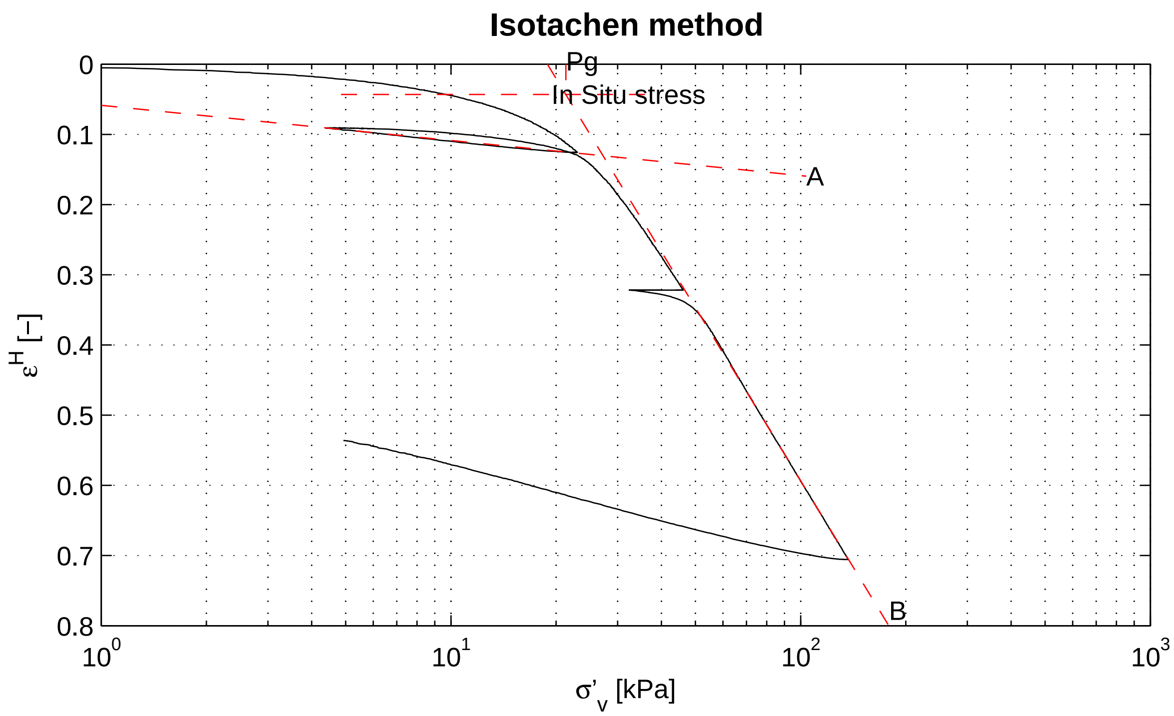
Stress loading phase [kPa]	25
Stress unloading phase [kPa]	5
Stress reloading phase [kPa]	50
Stress relaxation phase [kPa]	50
Maximum stress [kPa]	150



RR = 4.5e−02
CR = 5.4e−01

C_α = 4.7e−02

Pg = 17.1 kPa



A = 2.2e−02
B = 3.6e−01

C = 3.1e−02

Pg = 21.3 kPa

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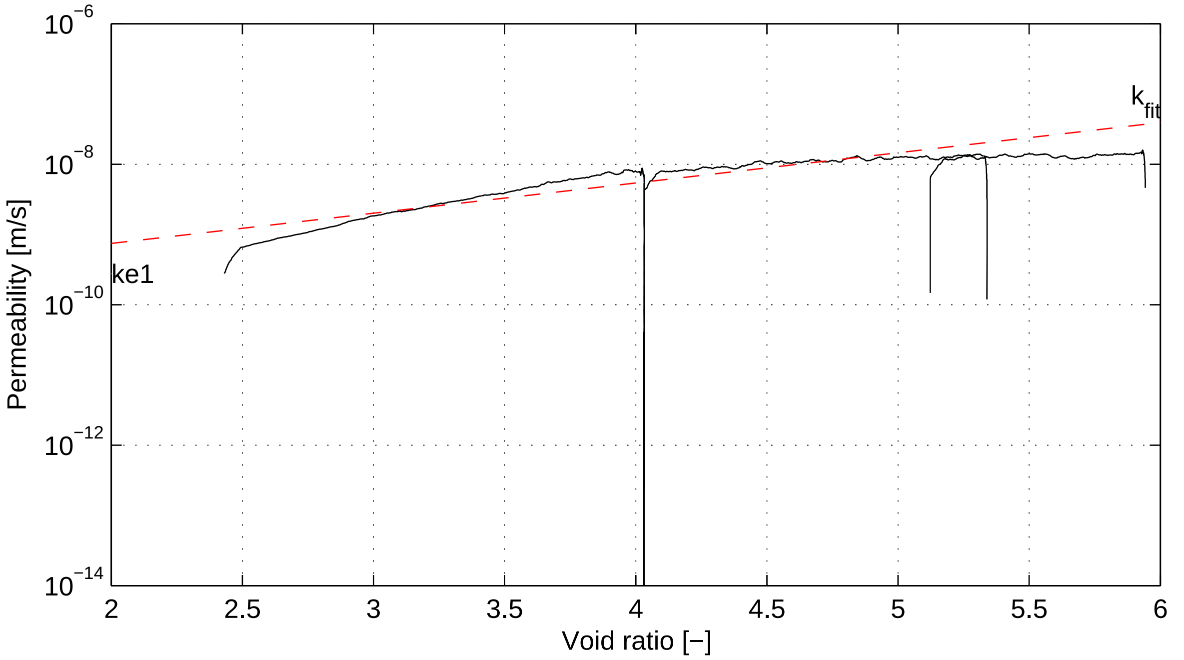
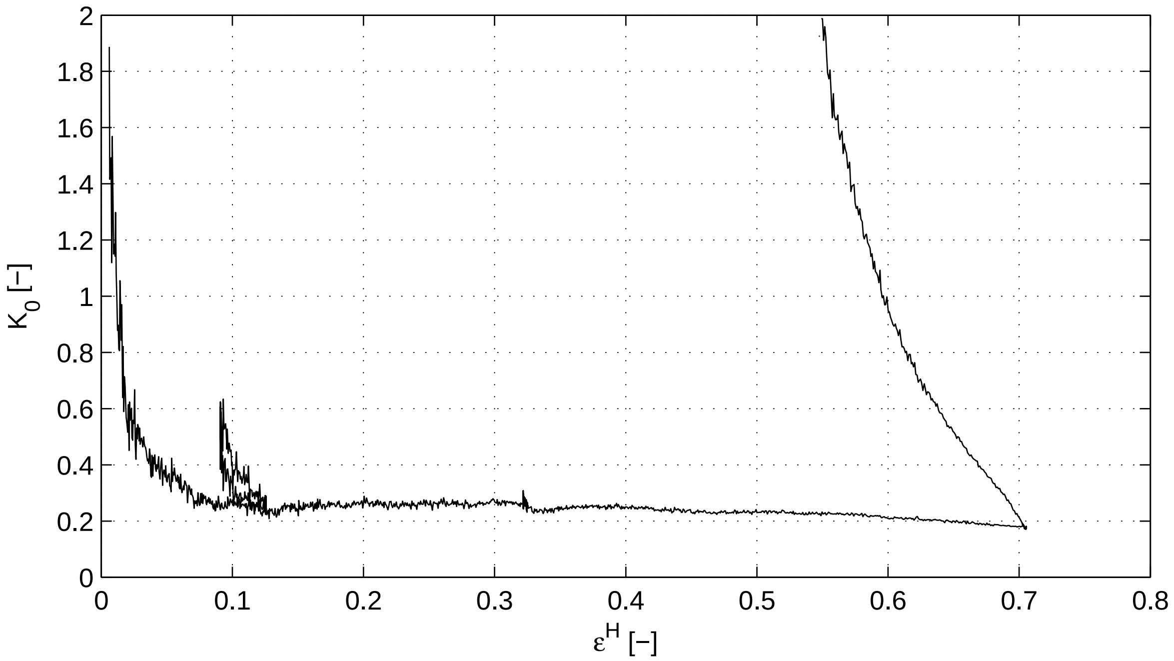
Contribution study program EQ Groningen field		date 2016−07−11	signed luije_sa
Boring SM2C−B, sample SM2C−B1−2B, depth: −3.75 m to −3.77 m NAP		project 1209862.11	version 1.1
K0−CRS measurement		appendix CRSSM2C−B1−2B	page 2



k_{e1} = 2.8e−10 m/s k_{e0} = 3.7e−08 m/s   slope = 4.31e−01



ν = 0.17 K_{0c} = 0.27 K_{0e} = 0.18

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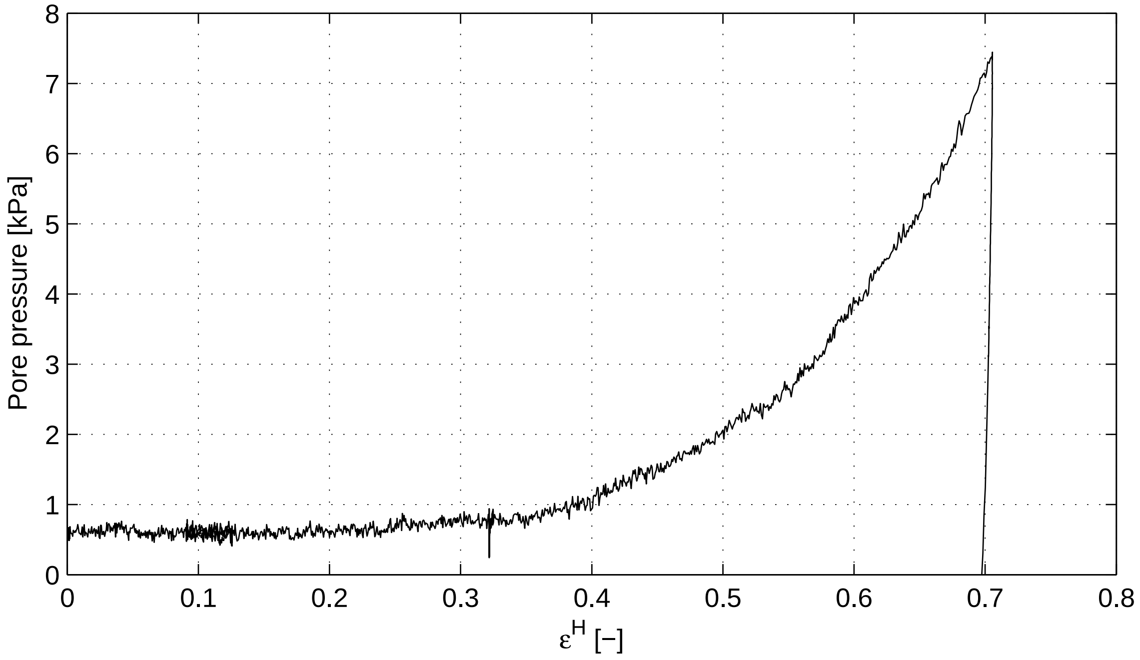
Contribution study program EQ Groningen field	date 2016−07−11	signed luije_sa
Boring SM2C−B, sample SM2C−B1−2B, depth: −3.75 m to −3.77 m NAP	project 1209862.11	version 1.1
K0−CRS measurement	appendix CRSSM2C−B1−2B	page 3


Pore pressure [kPa]
0
1
2
3
4
5
6
7
8
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
εH [−]

I Dynamic DSS tests (dynamic or cyclic DSS tests?)

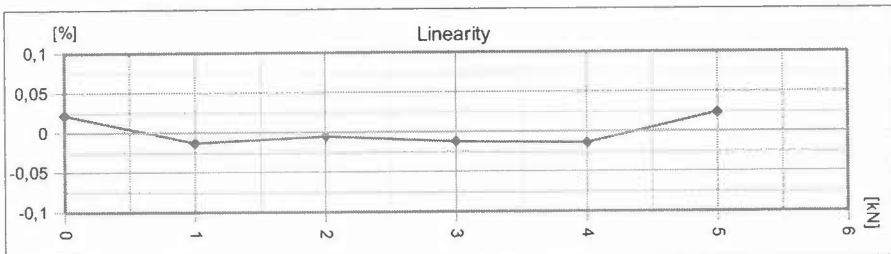
TESTING SYSTEMS FOR • SOIL • ROCK • ASPHALT • BUILDING MATERIALS

APS — Wille GEOTECHNIK

Calibration Sheet: DSS-B Load Vertical 5kN

	Equipment Signal-Chain				Reference Signal-Chain	
	Sensor	Connector / Signal Amplifier	Sensor Plug / Testing Machine	Measuring System	Sensor	Display Unit
Type:	Kraftmeßbügel		Sensorstecker	Maschinenregler	Kraftmeßbügel	Digitalanzeige 5 st
Manufacturer:	APS		APS	APS	A.S.T.	A.S.T.
Order number:	KAS		00580	WDC 220 2100.007	KAS	AE 703
Serial number:	1000861		09434	1052	0905644	2009023855
Year of manufacture:	2010					2004
Measuring range [kN]:	5		5		5	
Resolution [kN]:			2mV/V	0,0001		0,0001
Supply [V]:			10,0			
Offset [kN]:			-0,83			
Output signal:	2mV/V		2,0007mV/V		2mV/V	
Accuracy Class:	0,1			0,05	0,05	0,010
Calibration Sign:					1314 D-K-17303-01-00 2014-09	1469 D-K-17303-01-00 2015-08
Firmware:				9133.020		

Performance Results:



Calibration Values	
Load [kN]	Display [kN]
0,0000	-0,0002
1,0016	-1,0000
2,0012	-2,0000
3,0015	-3,0000
4,0016	-4,0000
4,9998	-5,0000

Accuracy Class:	0,1
max., relative Zero Point deviation:	0,012 %
max., relative Display deviation:	0,084 %
min., relative Repetition accuracy:	0,498 %
max., relative Hysteresis error:	0,200 %
max. Linearity deviation:	0,024 %
Correction factor:	1,0000

Testing temp. [℃]: 20

Measuring procedure: konstante, Lasterhöhung und -verminderung in zwei Meßreihen, mit um 180°gedrehter Referenzkraftmeßdose

Remark: montiert, stehend auf Prüfmaschinenschertisch / Lasteintrag geregelt über Prüfmaschine

Display [kN] averaged over all Series of Measurements and between rising and falling Force

Inspection date: 10.05.2016

suggested Inspection: 10.05.2018

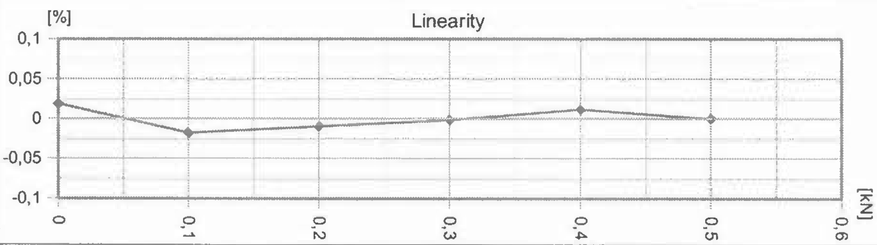
Calibration Sign: 1102908-04ThS-1606

Document index: V11.0

Calibration Sheet: ASA-C Load Horizontal 500N

	Equipment Signal-Chain				Reference Signal-Chain	
	Sensor	Connector / Signal Amplifier	Sensor Plug / Testing Machine	Measuring System	Sensor	Display Unit
Type:	Kraftmeßdose		Prüfmaschine	SPS	Kraftmeßbügel	Digitalanzeige 5 st
Manufacturer:	APS		APS	APS	A.S.T.	A.S.T.
Order number:	K3D		ASA-1 /S	TD200	KAP-S	AE 703
Serial number:	13304292		23120026		1400716	2009023855
Year of manufacture:	2012		2011		2014	2004
Measuring range [kN]:	0,5			507,73N	1	
Resolution [kN]:				0,0001		0,0001
Supply [V]:			230V~	24		
Offset [kN]:				0,4N		
Output signal:	2,0mV/V				2mV/V	
Accuracy Class:	0,2			0,1	0,05	0,010
Calibration Sign:					1430 D-K-17303-01-00 2015-04	1469 D-K-17303-01-00 2015-08
Firmware:			4.0	V3.0.2.2		

Performance Results:



Calibration Values	
Load [kN]	Display [kN]
0,0000	0,0001
0,1000	0,0999
0,2000	0,2000
0,3000	0,3000
0,4000	0,4001
0,5000	0,5000

Accuracy Class:	0,2
max., relative Zero Point deviation:	0,040 %
max., relative Display deviation:	0,134 %
min., relative Repetition accuracy:	1,096 %
max., relative Hysteresis error:	0,299 %
max. Linearity deviation:	0,019 %
Correction factor:	1,0000

Testing temp. [℃]: 20
Measuring procedure: konstante, richtige Lasterhöhung und -verminderung in zwei Meßreihen mit, um 180° gedrehtem, Referenzsensor
Remark: montiert, liegend an Kalibriervorrichtung / Lasteintrag manuell über ASA-1-Prüfmaschine
Display [kN] averaged over all Series of Measurements and between rising and falling Force
Inspection date: 10.05.2016
suggested Inspection: 10.05.2018
Calibration Sign: 1402401-02CA-1605

Document index: V11.0

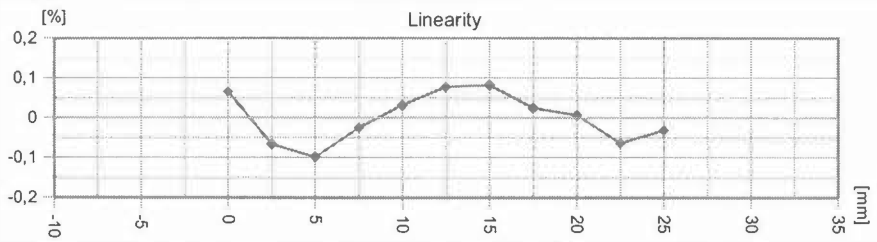
TESTING SYSTEMS FOR • SOIL • ROCK • ASPHALT • BUILDING MATERIALS

GEOTECHNIK

Calibration Sheet: DSS-B Potentiometer Vertical 25mm

	Equipment Signal-Chain				Reference Signal-Chain	
	Sensor	Connector / Signal Amplifier	Sensor Plug / Testing Machine	Measuring System	Sensor	Display Unit
Type:	Potentiometer		Sensorstecker	Maschinenregler	Endmaßsatz	
Manufacturer:	APS		APS	APS	Längenmeßtechnik GmbH	
Order number:	TRS25		00755	WDC 220 2100.007		
Serial number:	090319/A		00600	1052	diverse	
Year of manufacture:	2010					
Meas. range [mm]:	25		25		1..50	
Resolution [mm]:				0,001	0,0001	
Supply [V]:	1,24					
Offset:						
Output signal:			7,49V			
Accuracy Class:				0,01	0	
Calibration Sign:					61241 D-K-15190-01-00 2015-11	
Firmware:				9133.020		

Performance Results:



Calibration Values	
Travel [mm]	Display [mm]
-5,0000	
-2,5000	
0,0000	0,000
2,5000	2,469
5,0000	4,962
7,5000	7,482
10,0000	9,998
12,5000	12,510
15,0000	15,013
17,5000	17,500
20,0000	19,997
22,5000	22,481
25,0000	24,991
27,5000	
30,0000	

Accuracy Class:	0,2
max., absolute Display deviation:	0,204 %
averaged, relative Display deviation:	0,059 %
min., absolute Repetition accuracy:	- %
max. Linearity deviation nominal travel:	0,099 %
Correction factor:	0,9994

Measuring tip pulling in -->

Testing temp. [°C]: 20

Measuring procedure: potentiometrischer Wegsensor mit Rückstellfeder ohne Faltenbalg hängend im Meßstativ eingespannt \ Kalibriermeßreihe mit Endmaßen

Remark: Nennwert und Kennwert im Sensorstecker verändert

Inspection date: 09.05.2016

suggested Inspection: 09.05.2018

Calibration Sign: 1102905-04MT-1605

Document index: V6.4

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HRB Göttingen 4129
Geschäftsführer
Dipl. Min. Thorsten Wille
Gerichtstand ist Göttingen

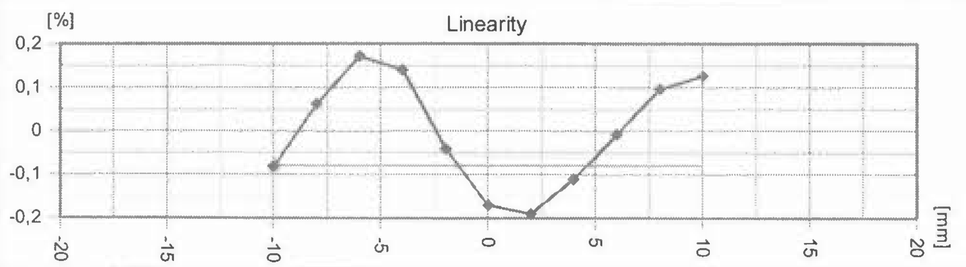
HypoVereinsbank AG
BLZ 200 300 00 / KTN 624 900 445
IBAN DE 95 2003 0000 06 24900 445
BIC HYVEDEMM300
UST-ID DE 162 092 653

Commerzbank Göttingen
BLZ 260 400 30 / KTN 627 926 900
IBAN DE 192 604 003006 27926900
BIC cobadeff260
St. Nr.: 20 200 14631

Calibration Sheet: DSS-B LVDT Horizontal ±12,5mm

	Equipment Signal-Chain				Reference Signal-Chain	
	Sensor	Connector / Signal Amplifier	Sensor Plug / Testing Machine	Measuring System	Sensor	Display Unit
Type:	LVDT		Sensorstecker	Maschinenregler	Endmaßsatz	
Manufacturer:	APS		APS	APS	Längenmeßtechnik GmbH	
Order number:	ACT500A		00753	WDC 220 2100.004		
Serial number:	3252		00300	715	diverse	
Year of manufacture:	2010					
Meas. range [±mm]:	10		640mV/V		1..50	
Resolution [mm]:				0,001	0,0001	
Supply [V]:	5					
Offset:						
Output signal:			975,51mV/V			
Accuracy Class:				0,01	0	
Calibration Sign:					61241 D-K-15190-01-00 2015-11	
Firmware:				9133.015		

Performance Results:



Accuracy Class: 0,4
max., absolute Display deviation: 0,380 %
averaged, relative Display deviation: -0,080 %
min., absolute Repetition accuracy: - %
max. Linearity deviation nominal travel: 0,191 %
Correction factor: 1,0008

Measuring tip pulling in -->

Calibration Values	
Travel [mm]	Display [mm]
-14,0000	
-12,0000	-11,918
-10,0000	-9,971
-8,0000	-7,947
-6,0000	-5,928
-4,0000	-3,931
-2,0000	-1,970
0,0000	0,000
2,0000	1,996
4,0000	4,010
6,0000	6,033
8,0000	8,047
10,0000	10,052
12,0000	11,970
14,0000	13,122

Testing temp. [℃]: 20
Measuring procedure: LVDT mit Rückstellfeder ohne Faltenbalg hängend im Meßstativ eingespannt \ Kalibriermeßreihe mit Endmaßen
Remark: bewertete Messung nur im Bereich ±10mm durchgeführt
Inspection date: 09.05.2016
suggested Inspection: 09.05.2018
Calibration Sign: 1102906-04MT-1605

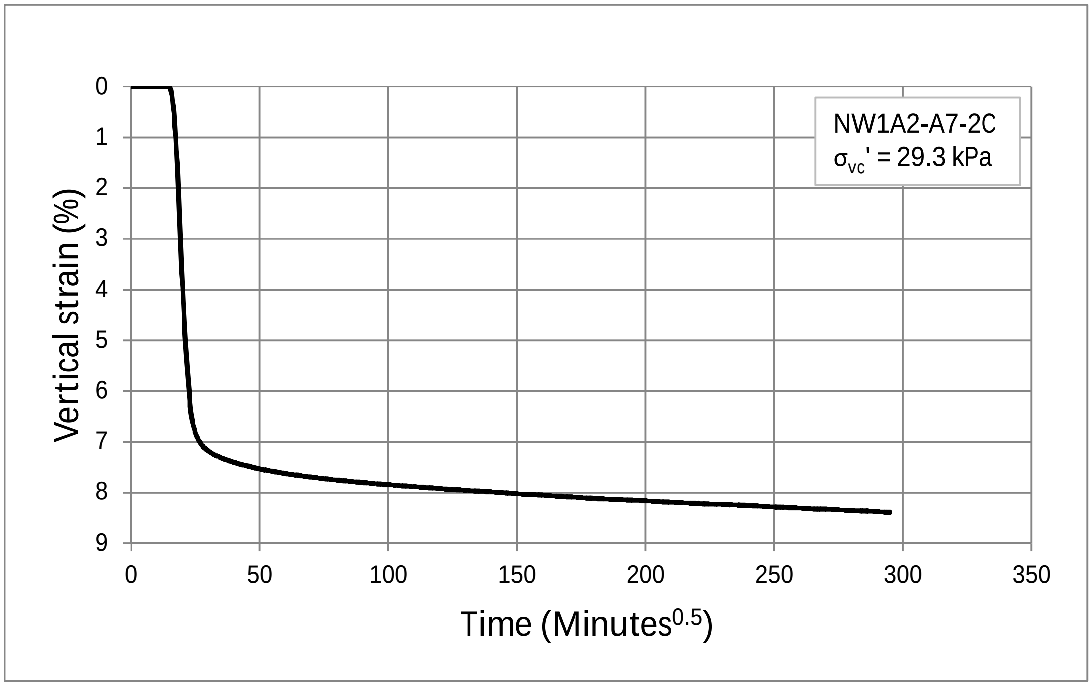
Document index: V6.4

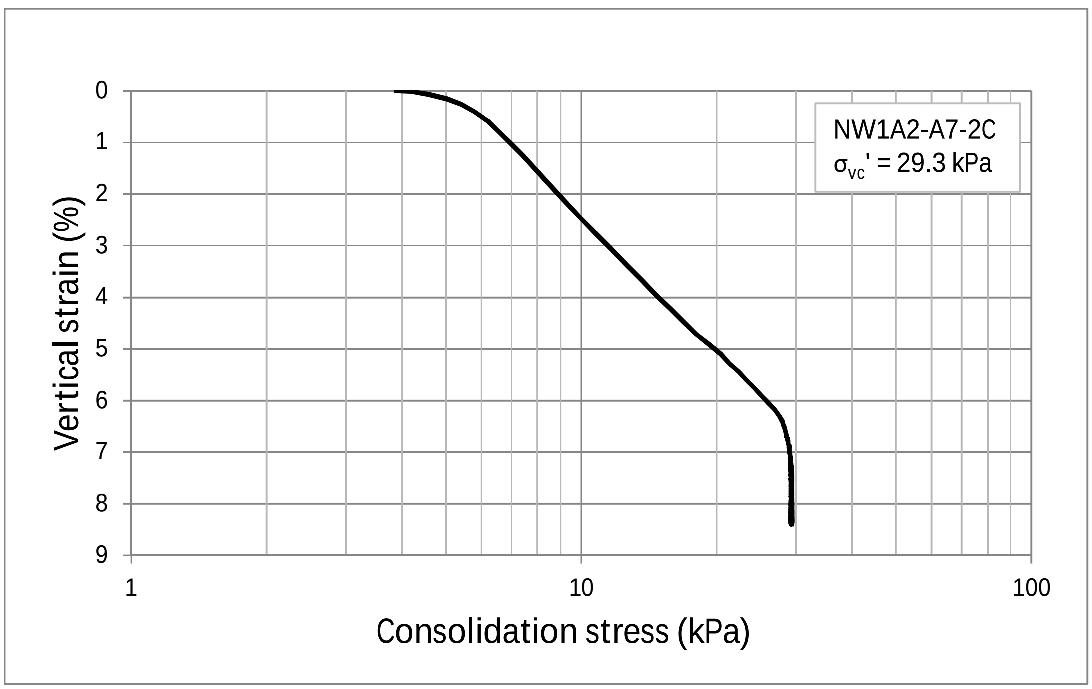
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

Borehole	NW1A2-A
Sample	NW1A2-A7-2C
Depth (m)	5.62 (At top of the sample)

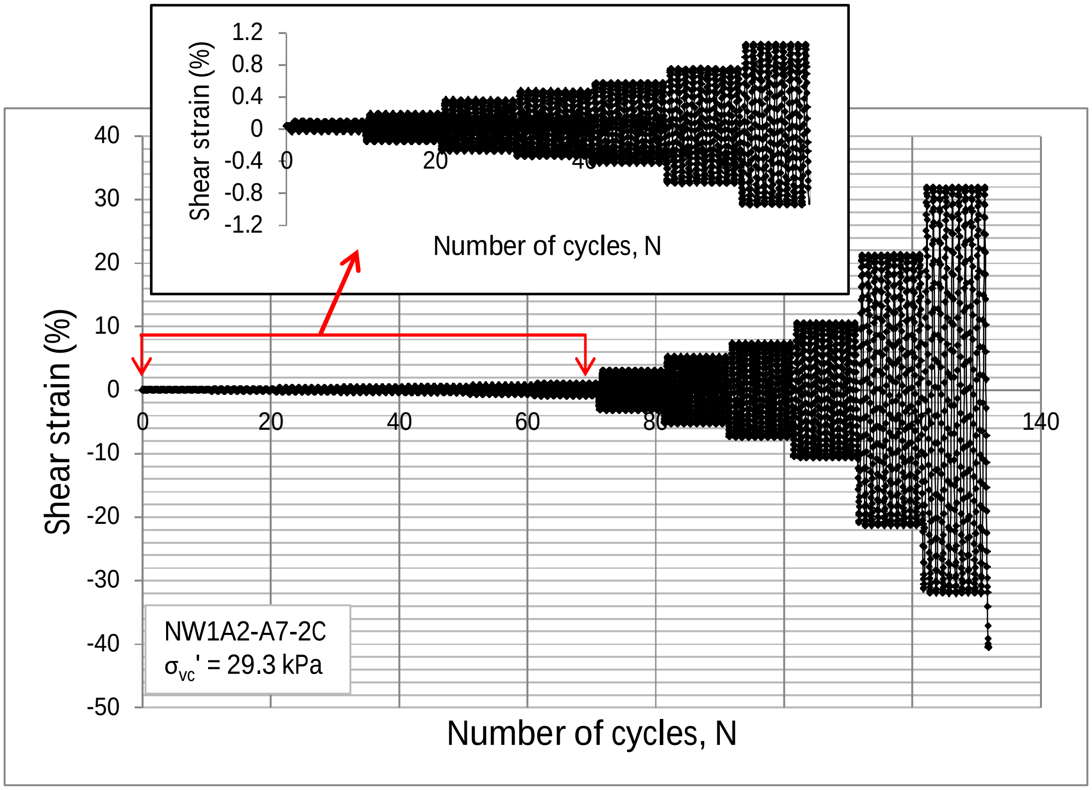
TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	20.08
Initial moisture content (%)	217.9
Initial dry density (kN/m^3)	3.50
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	29.3
Vertical strain at the end of consolidation (%)	8.39
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	201.5
Final dry density (kN/m^3)	4.03

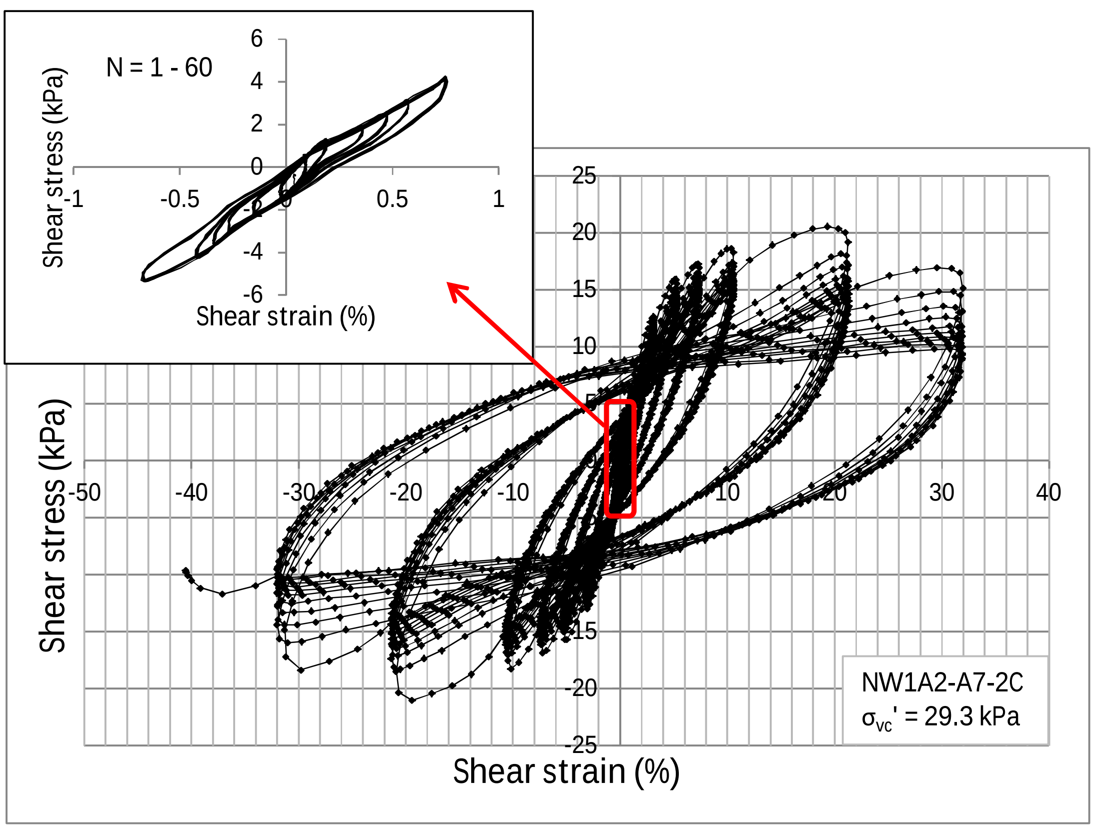
Specimen Photograph (after shearing)



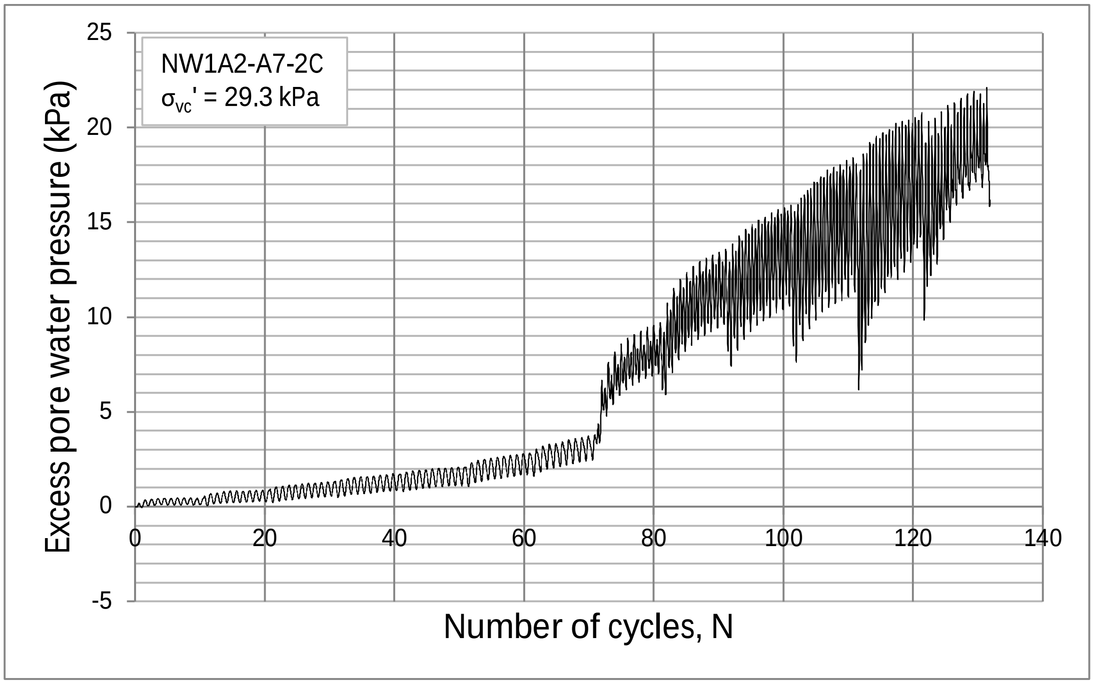


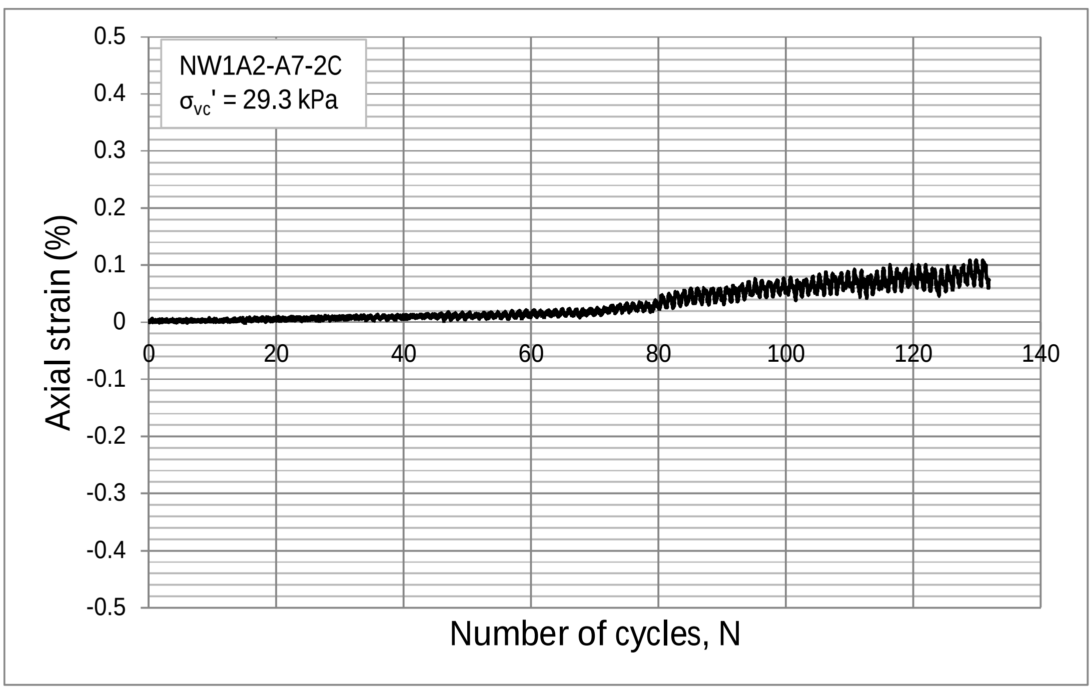
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE



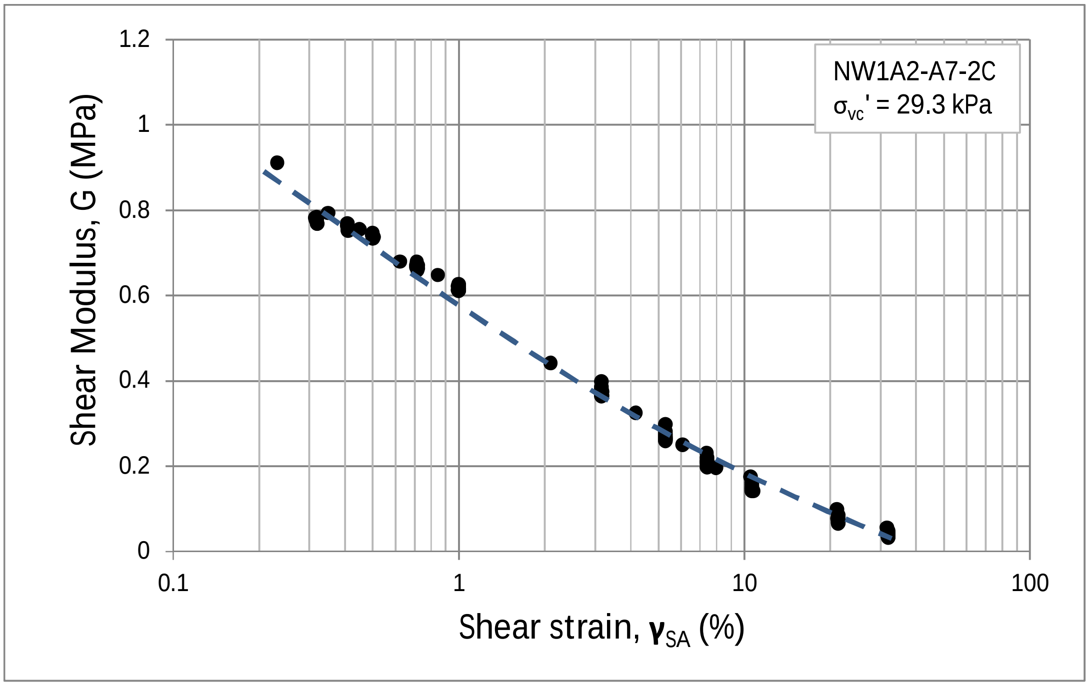


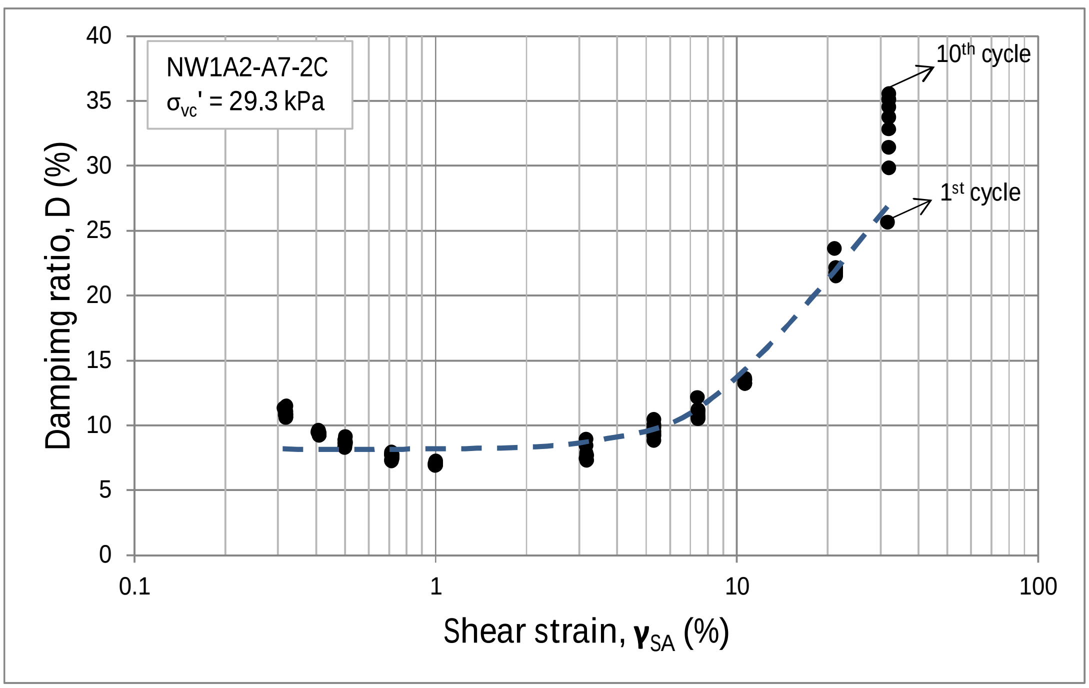
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





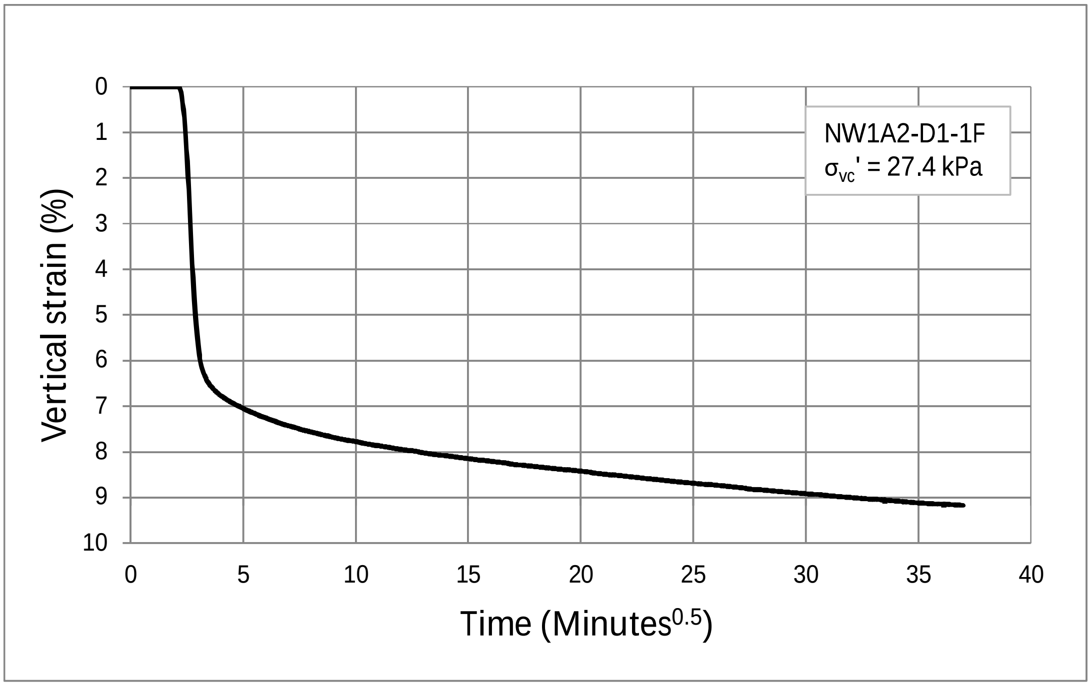
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE

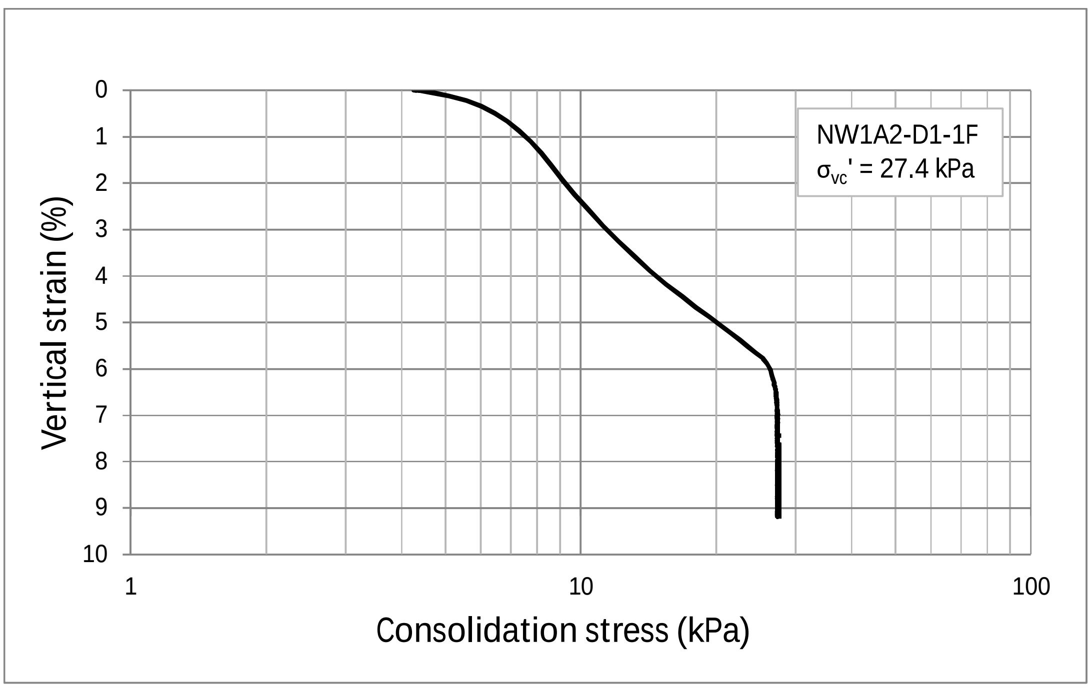
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

Borehole	NW1A2-D
Sample	NW1A2-D1-1F
Depth (m)	3.90 (At top of the sample)

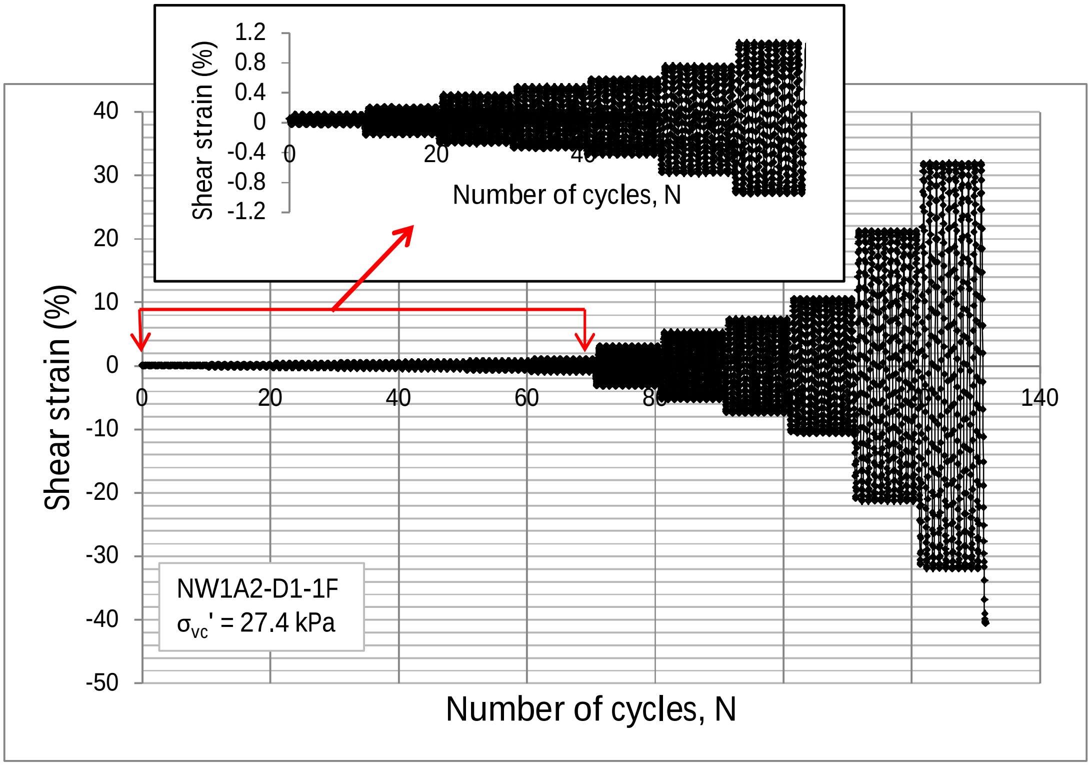
TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	20.28
Initial moisture content (%)	501.4
Initial dry density (kN/m^3)	1.63
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	27.4
Vertical strain at the end of consolidation (%)	9.18
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	540.1
Final dry density (kN/m^3)	1.68

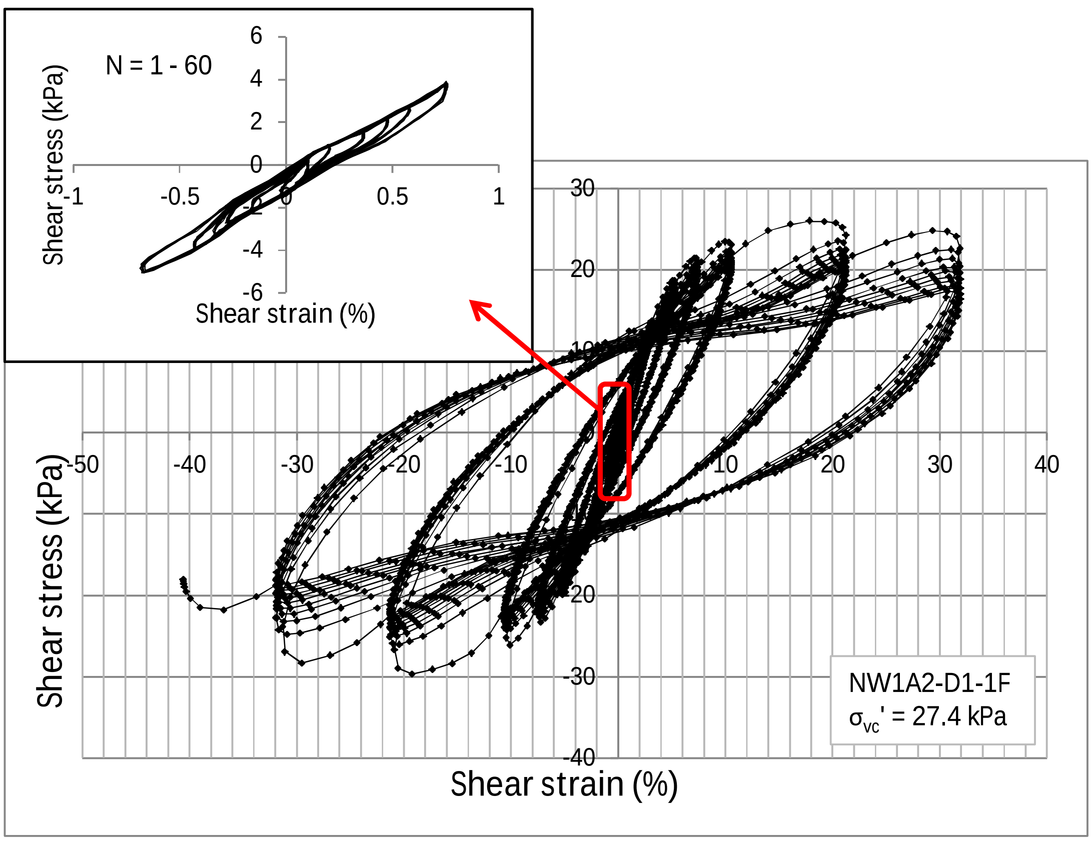
Specimen Photograph (after shearing)



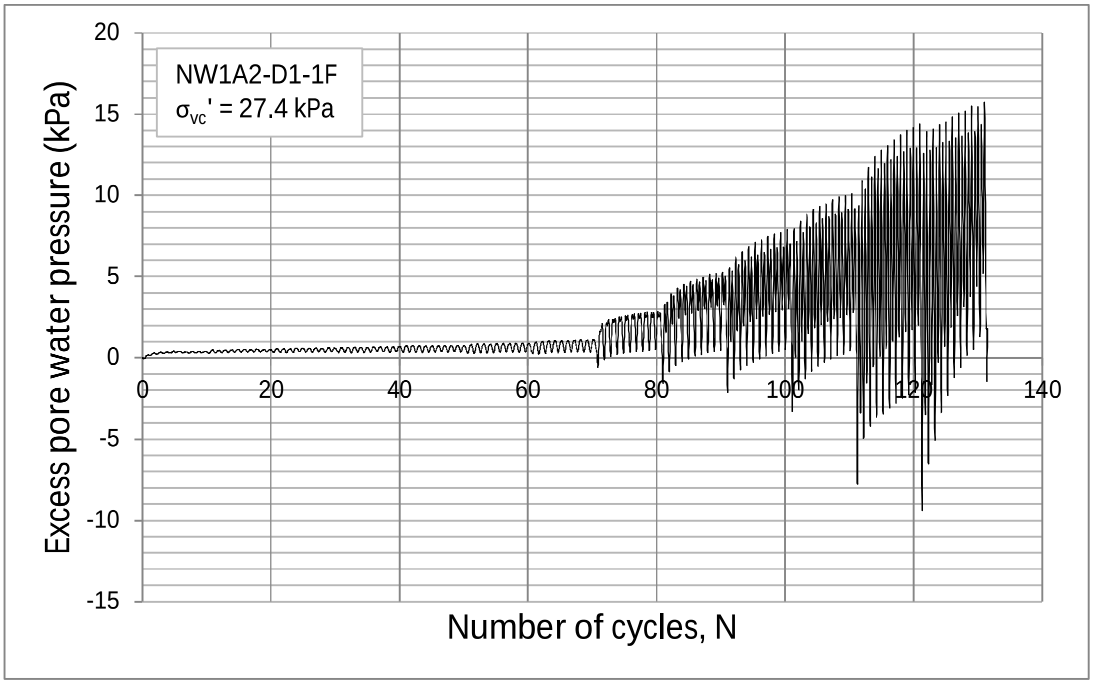


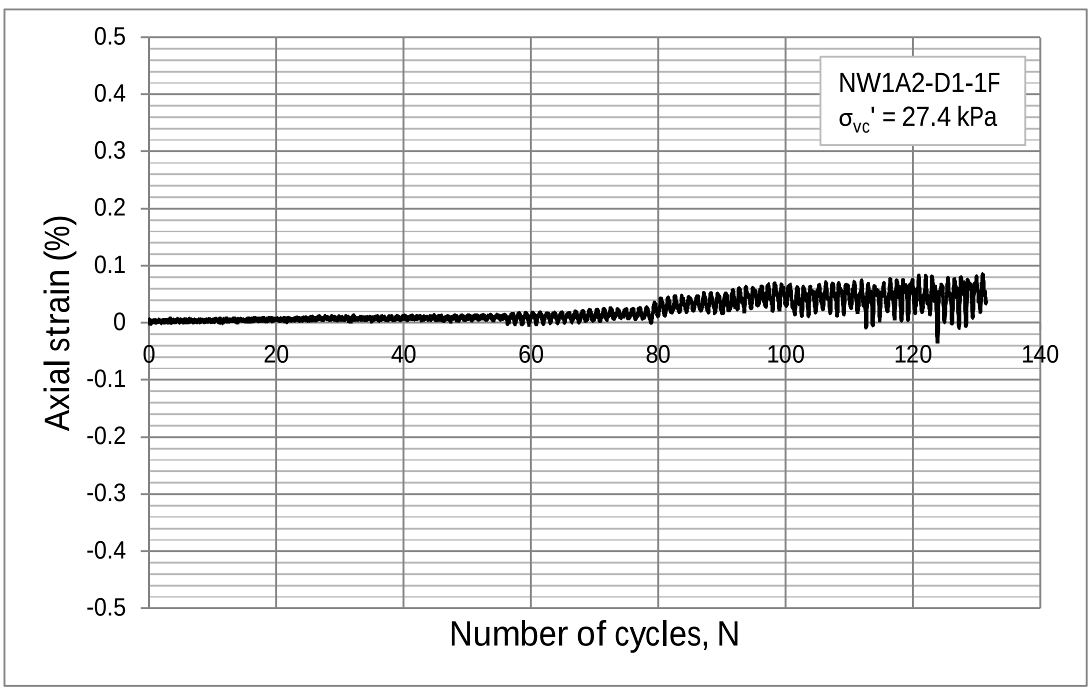
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE



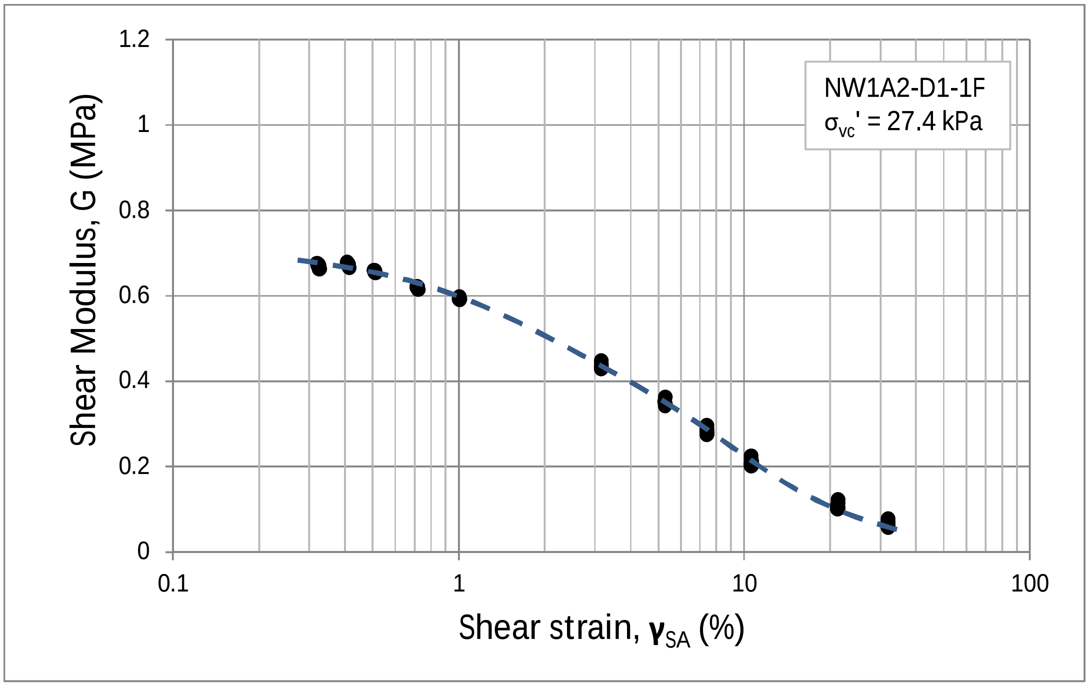


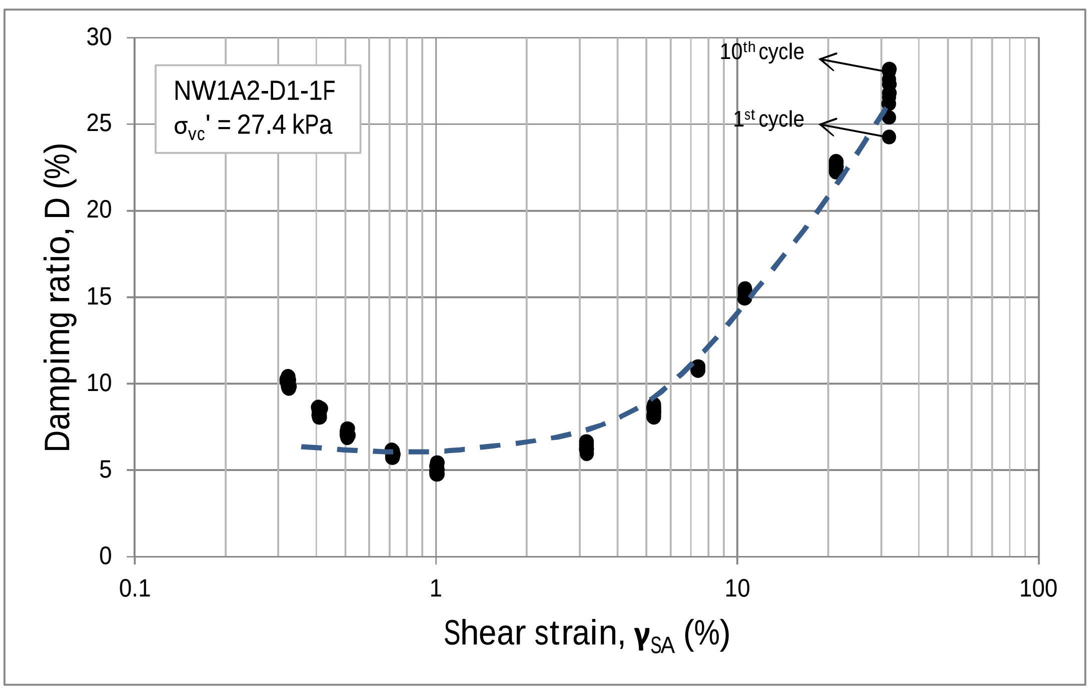
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





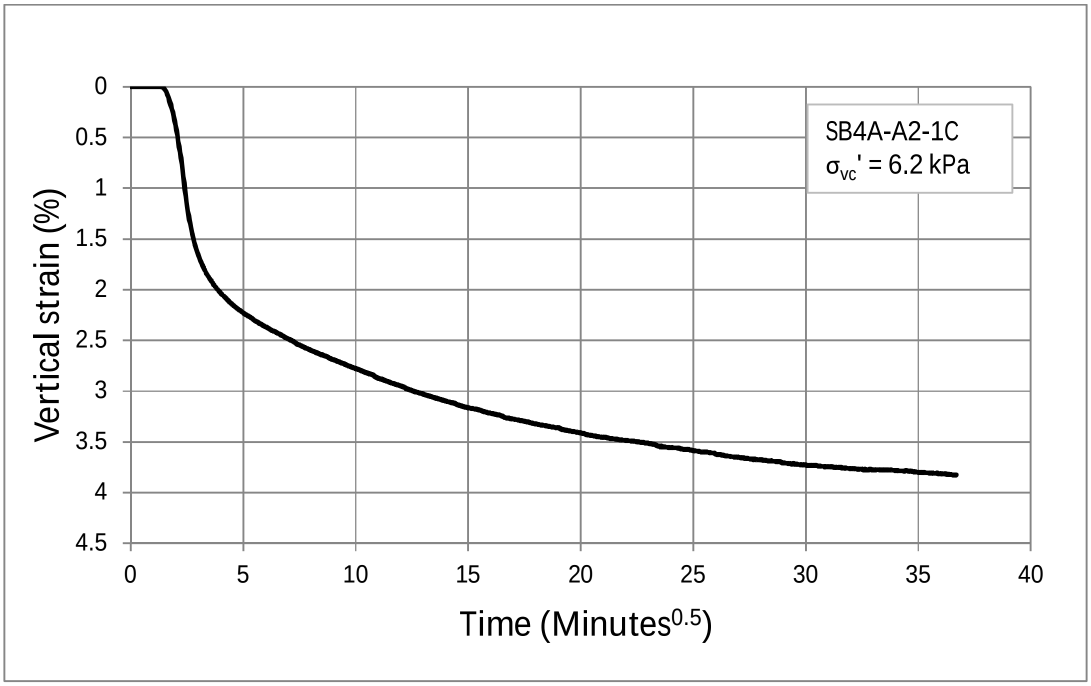
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE

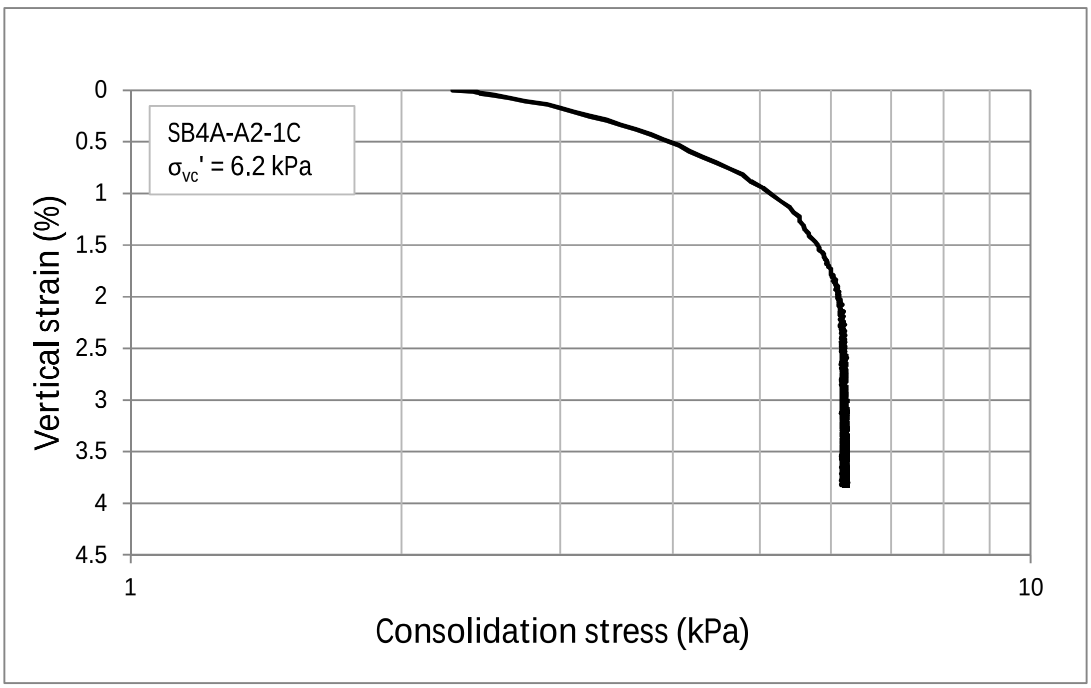
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

Borehole	SB4A-A
Sample	SB4A-A2-1C
Depth (m)	1.35 (At top of the sample)

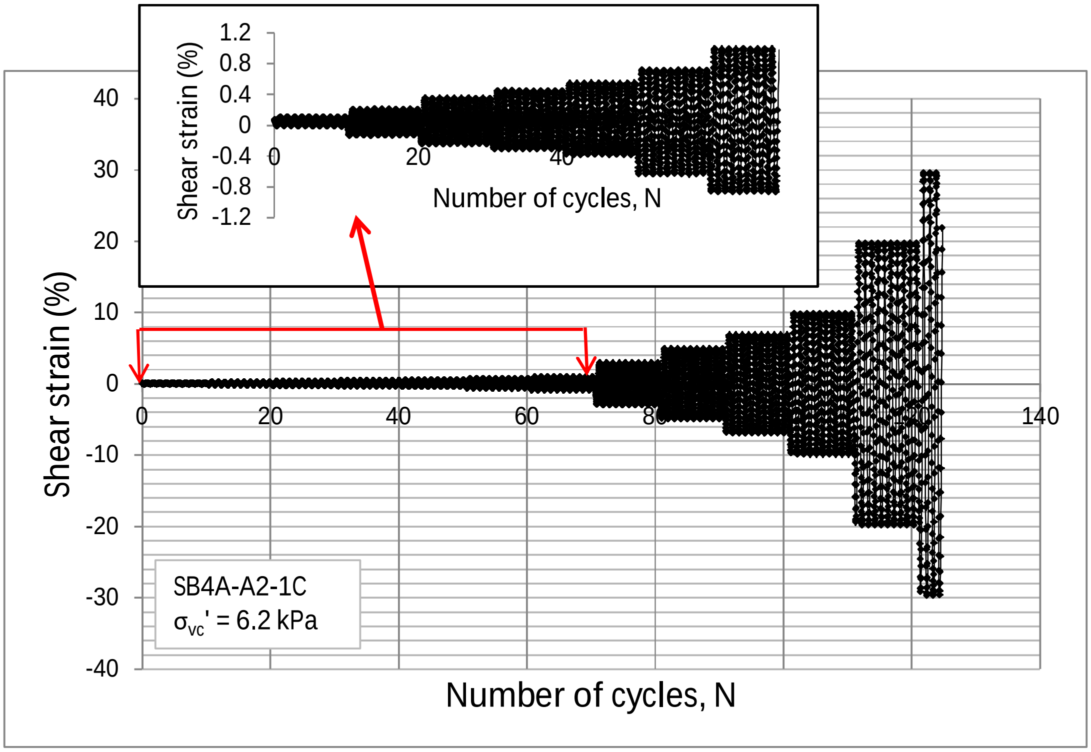
TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	20.66
Initial moisture content (%)	564.5
Initial dry density (kN/m^3)	1.40
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	6.2
Vertical strain at the end of consolidation (%)	3.82
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	547.1
Final dry density (kN/m^3)	1.49

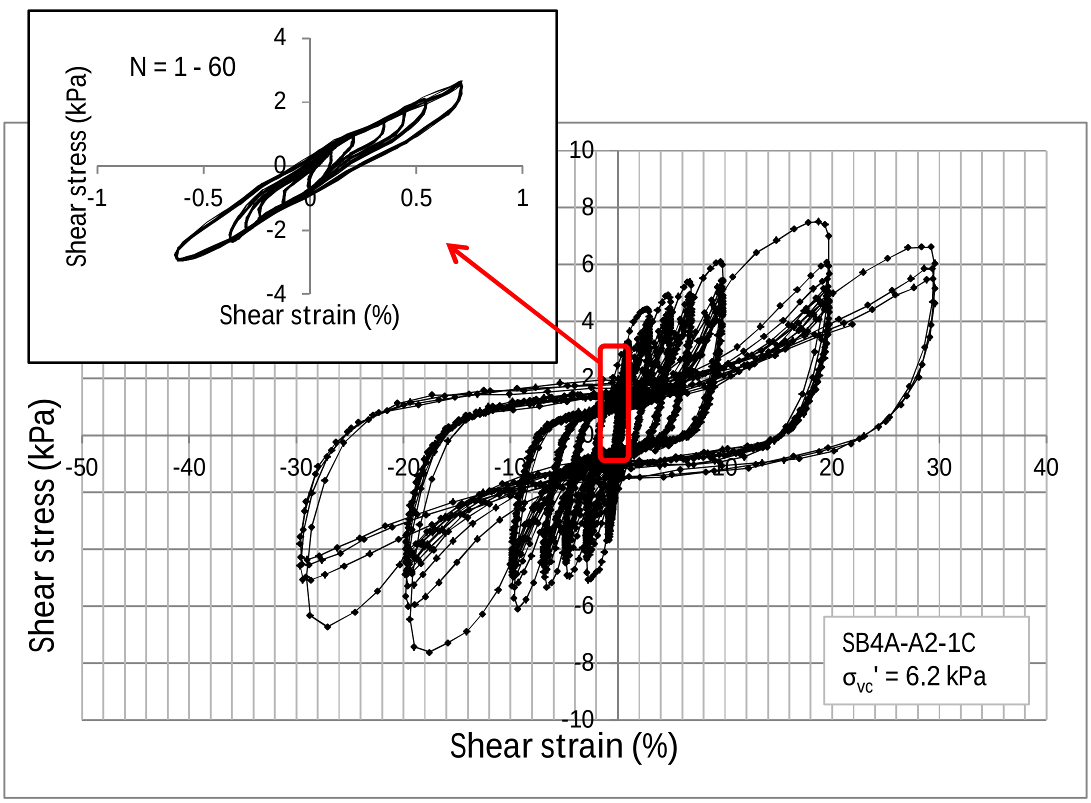
Specimen Photograph (after shearing)



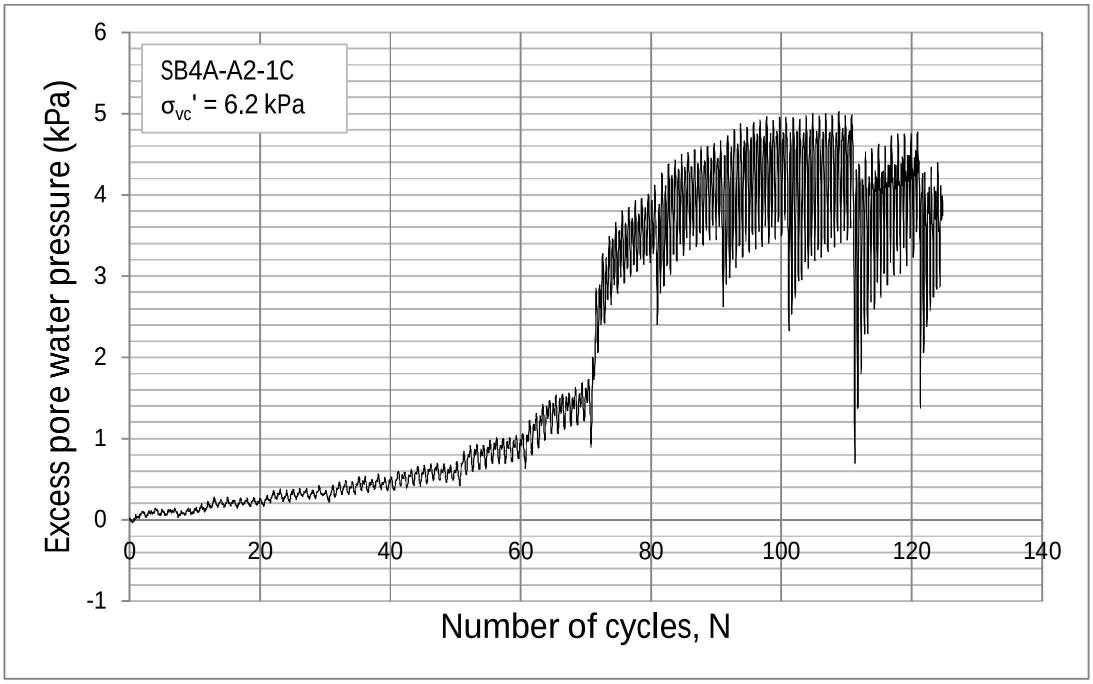


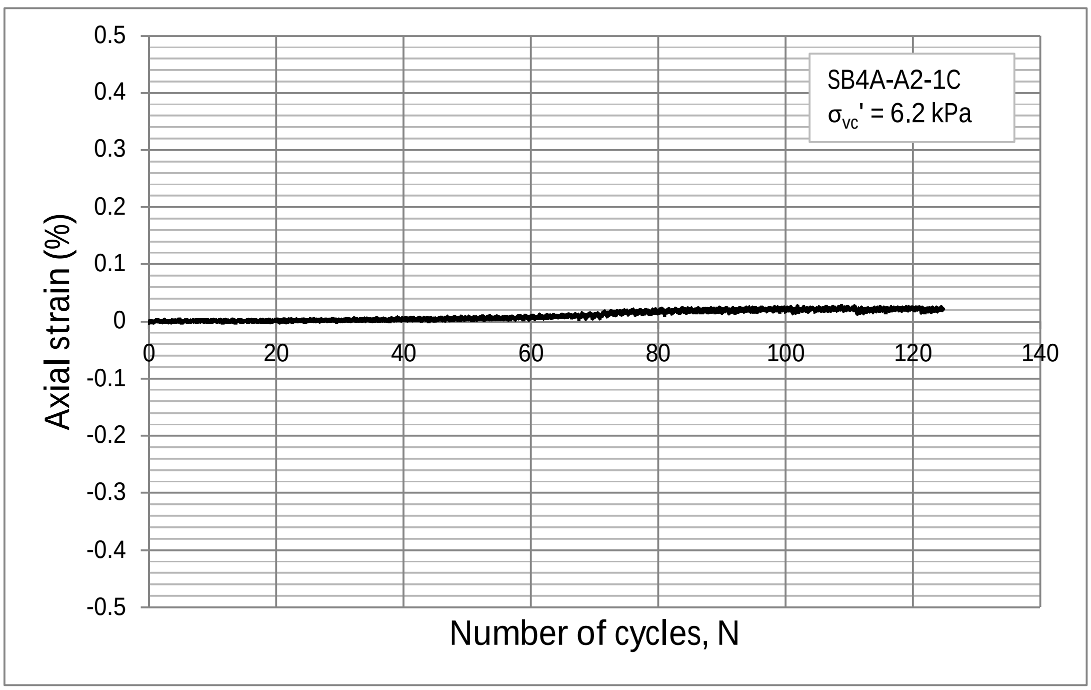
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE



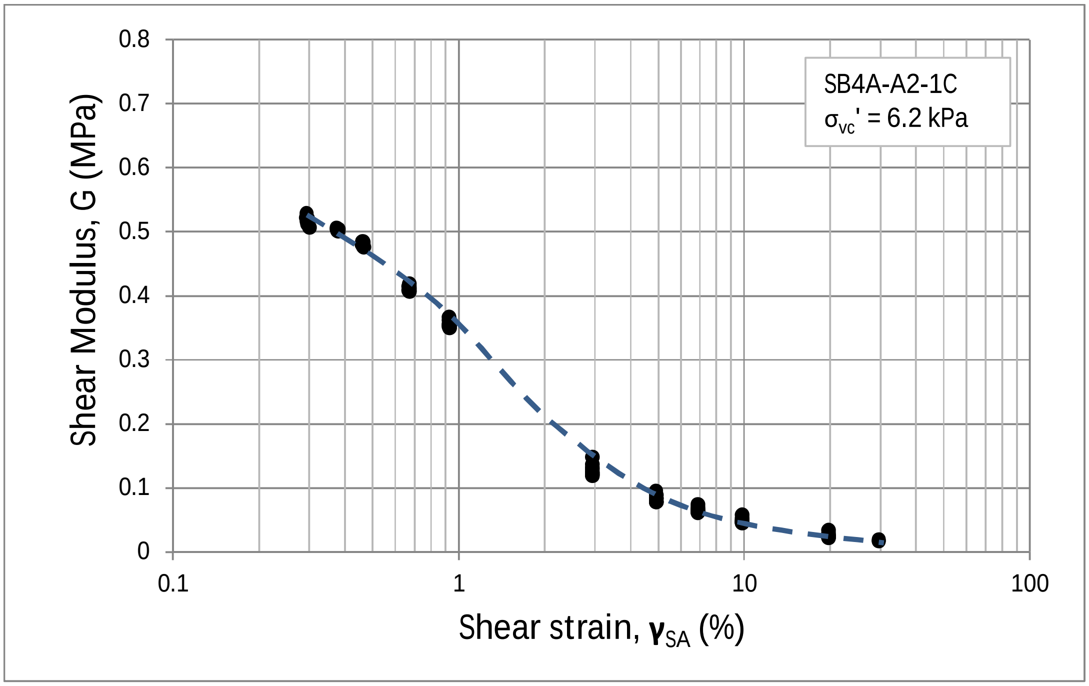


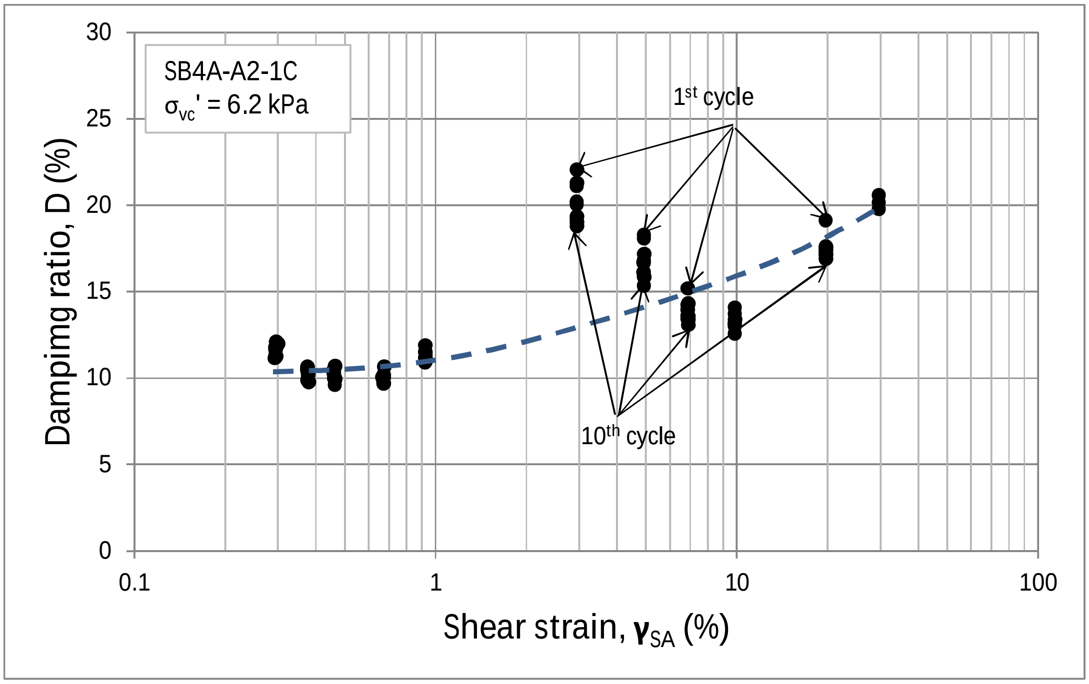
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





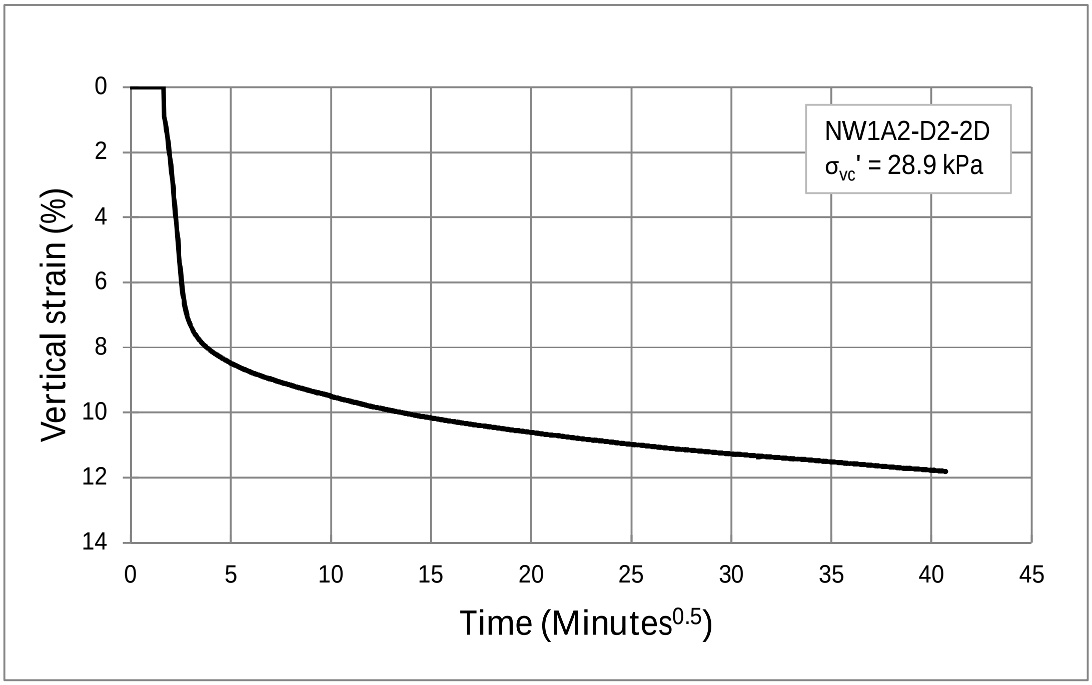
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE

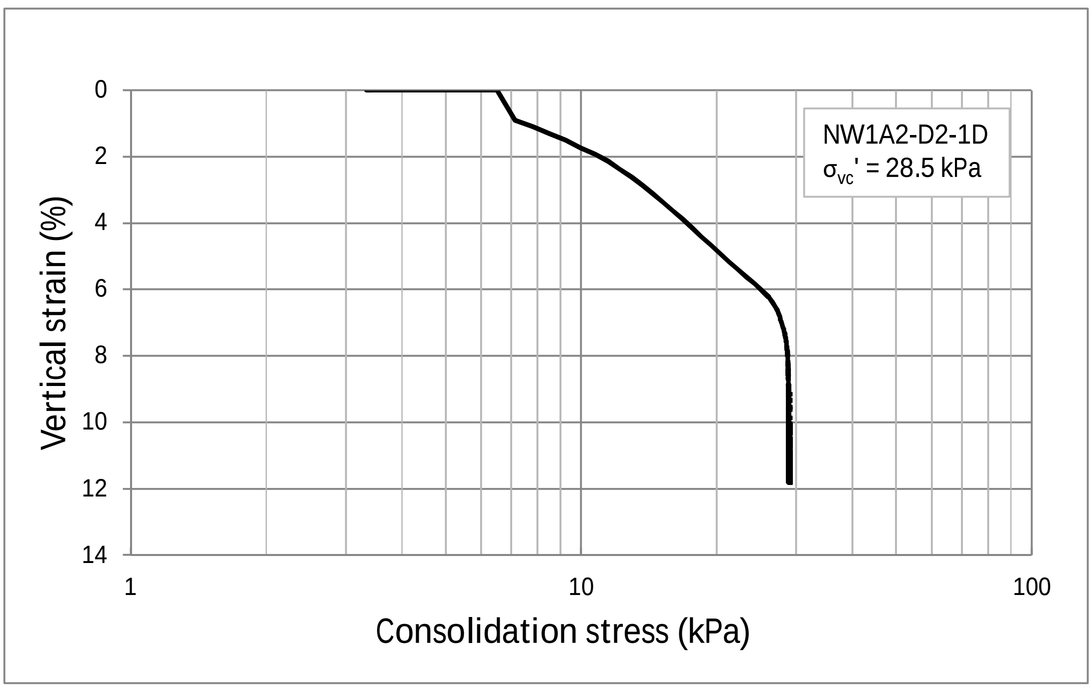
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

Borehole	NW1A2-D
Sample	NW1A2-D2-2D
Depth (m)	5.18 (At top of the sample)

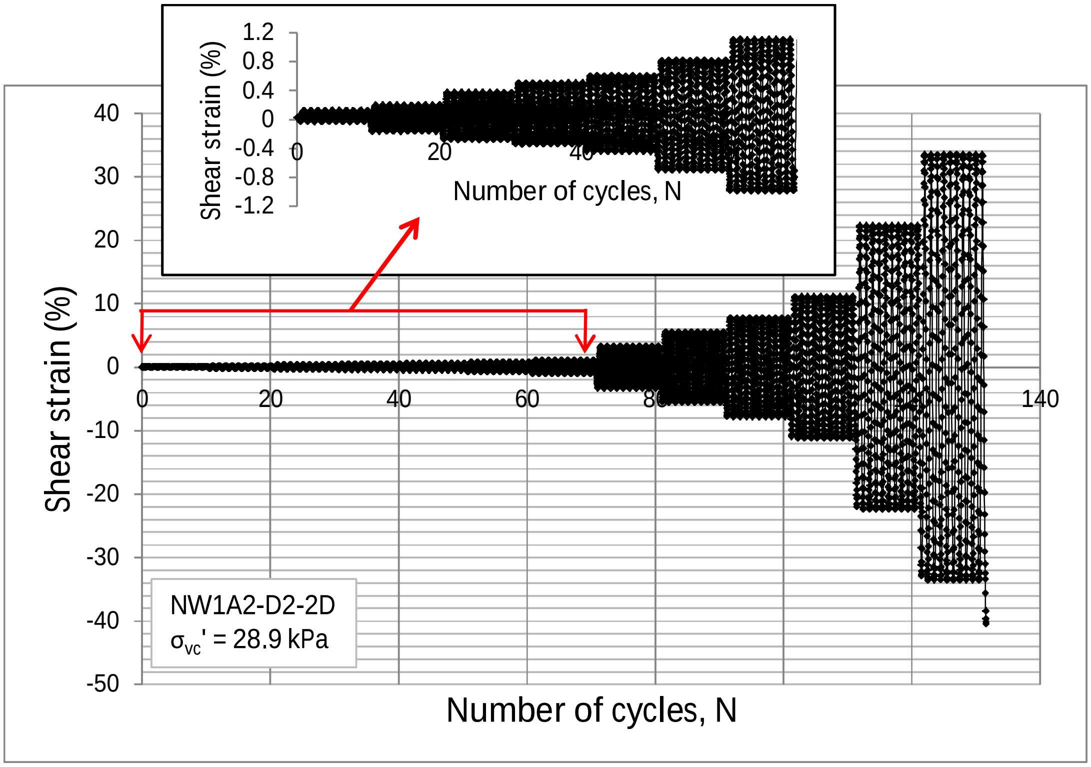
TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	19.88
Initial moisture content (%)	550.0
Initial dry density (kN/m^3)	1.48
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	28.9
Vertical strain at the end of consolidation (%)	11.81
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	563.6
Final dry density (kN/m^3)	1.64

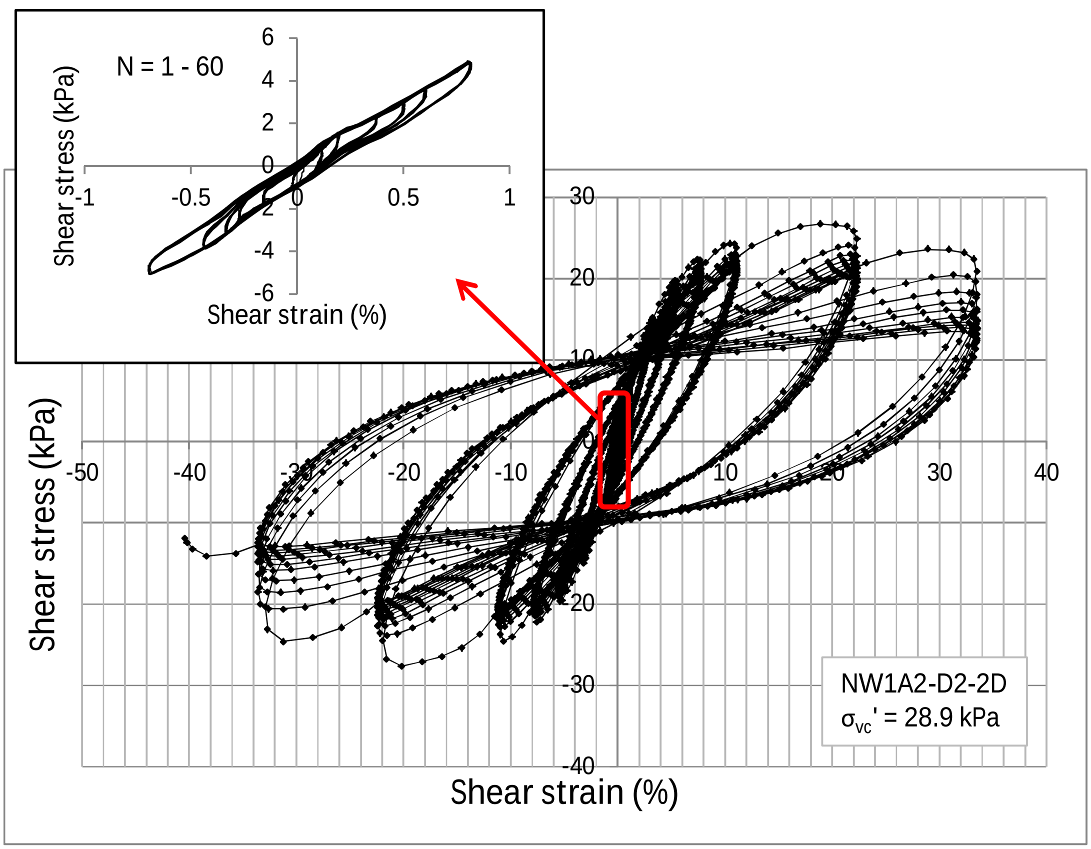
Specimen Photograph (after shearing)



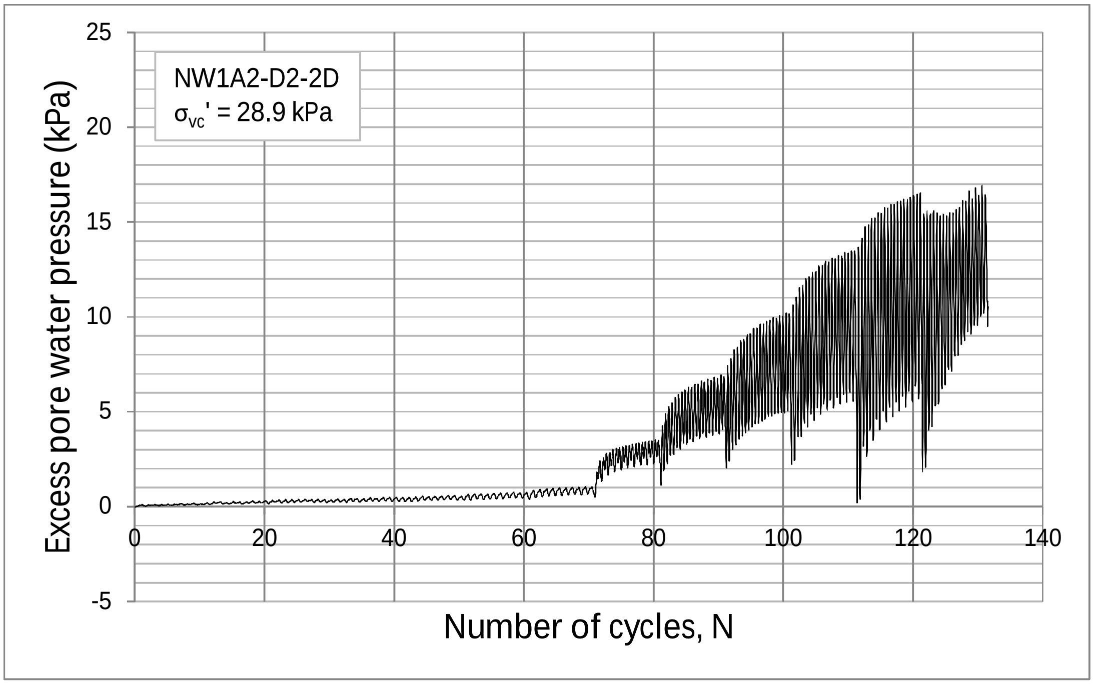


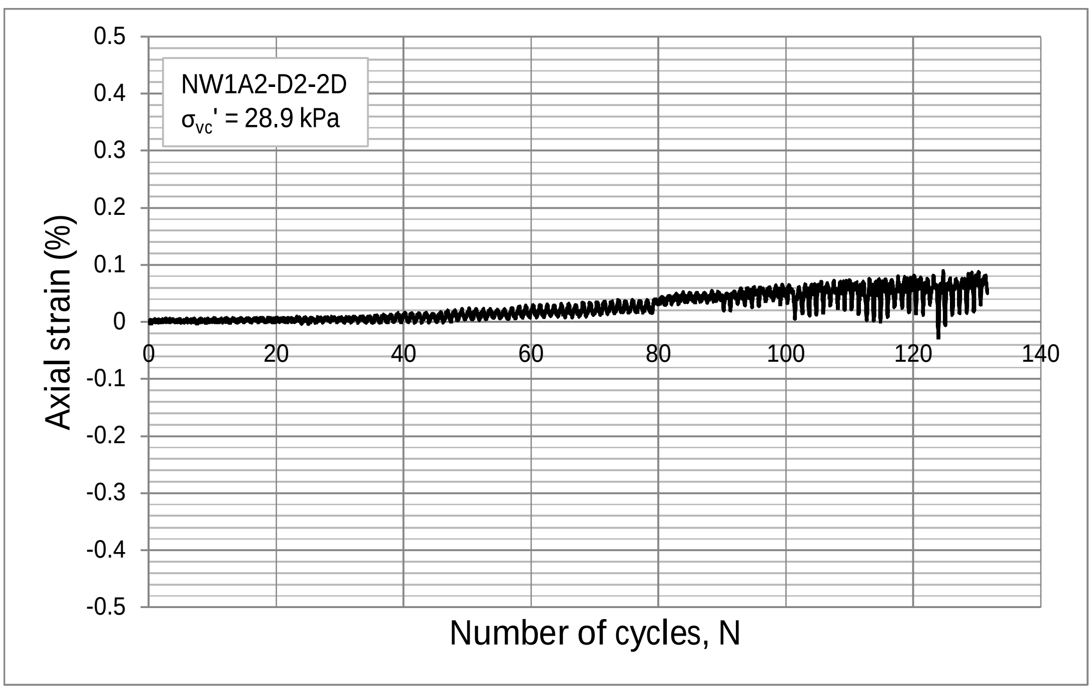
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE



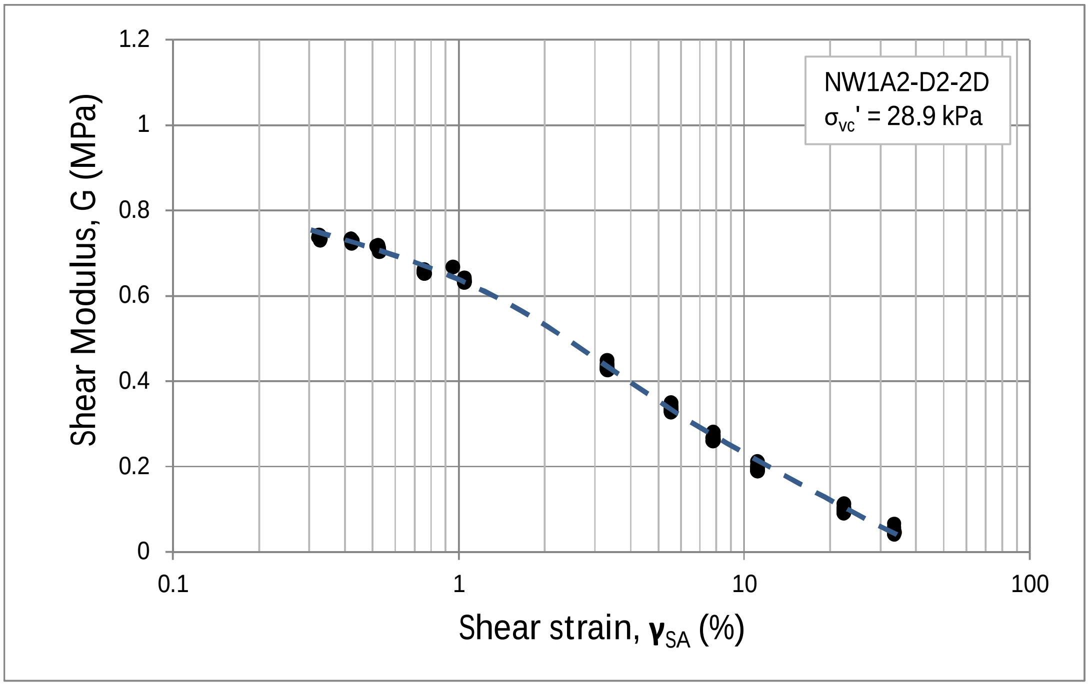


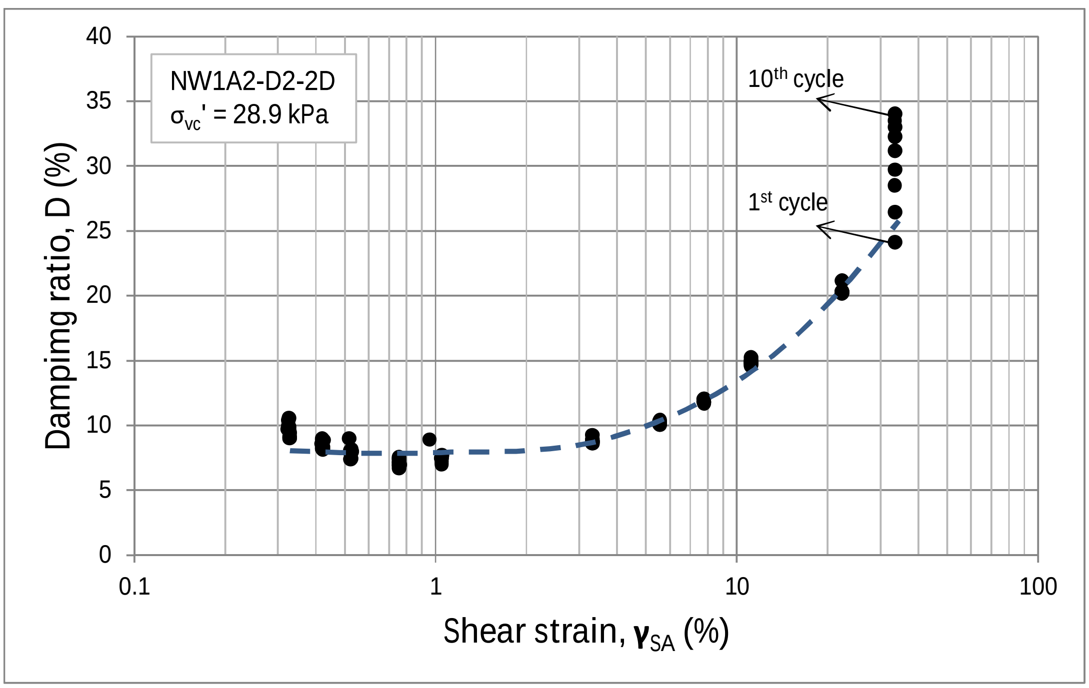
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





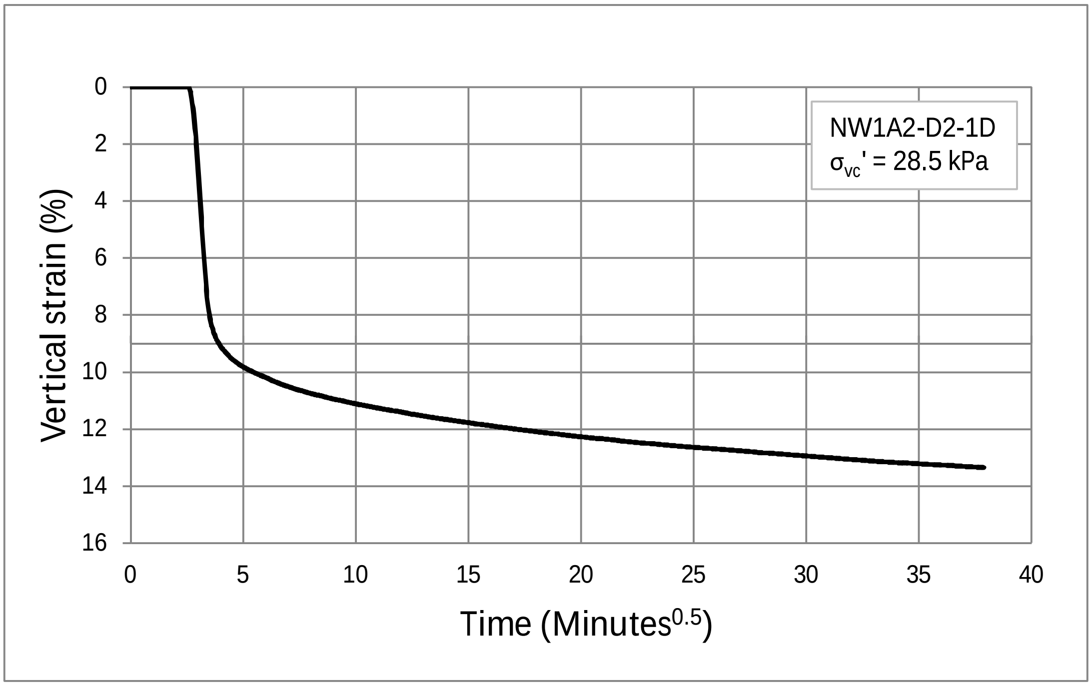
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE

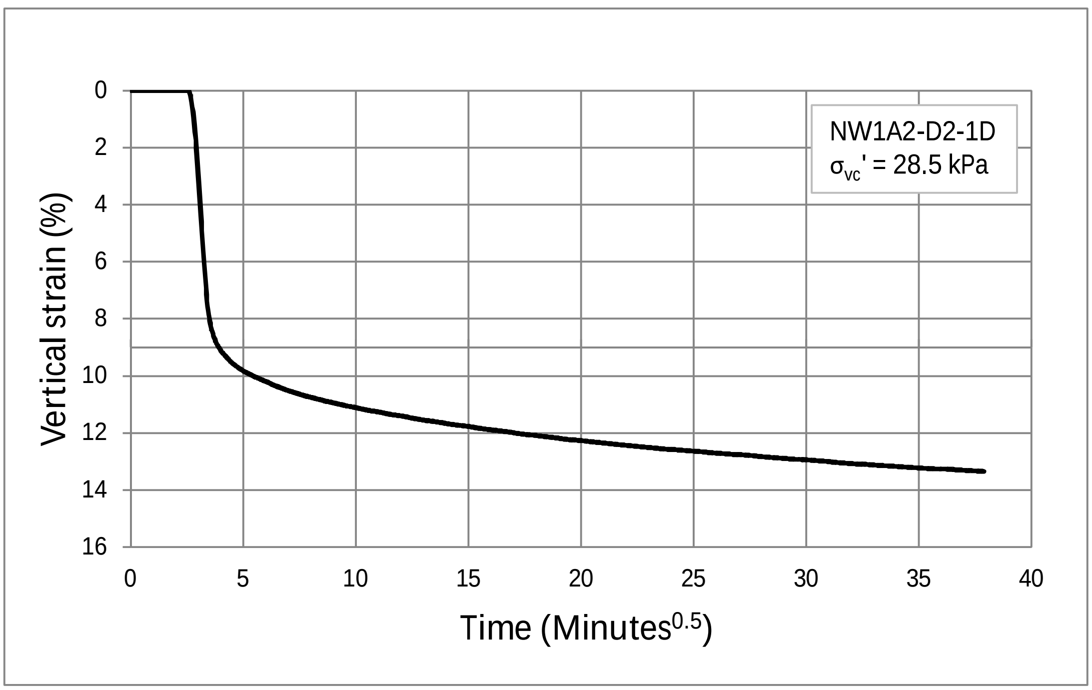
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

Borehole	NW1A2-D
Sample	NW1A2-D2-1D
Depth (m)	4.78 (At top of the sample)

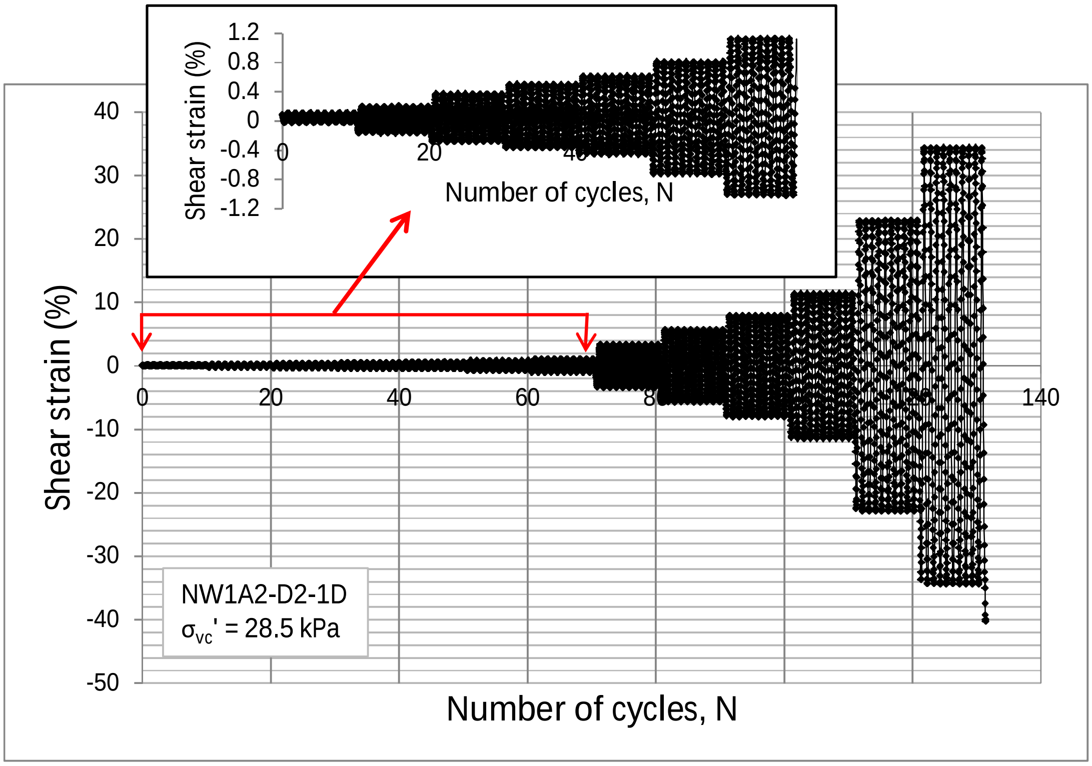
TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	19.73
Initial moisture content (%)	635.1
Initial dry density (kN/m^3)	1.29
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	28.5
Vertical strain at the end of consolidation (%)	13.35
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	620.5
Final dry density (kN/m^3)	1.52

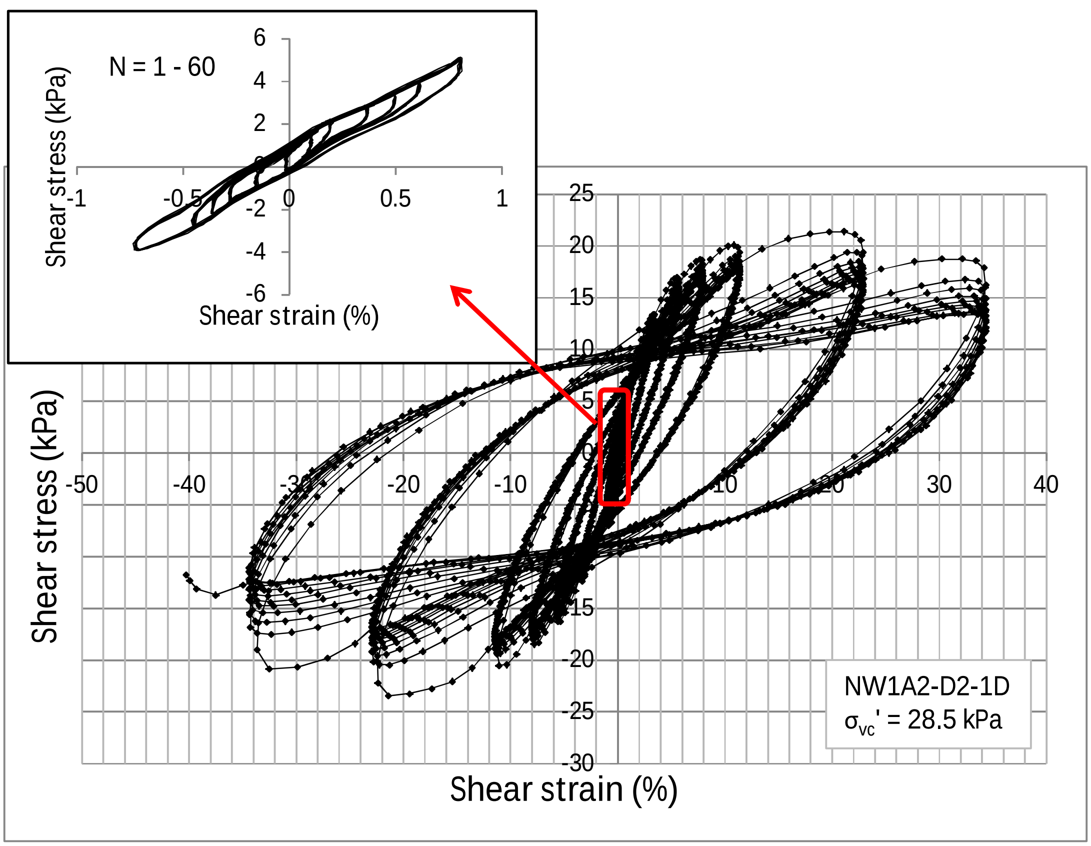
Specimen Photograph



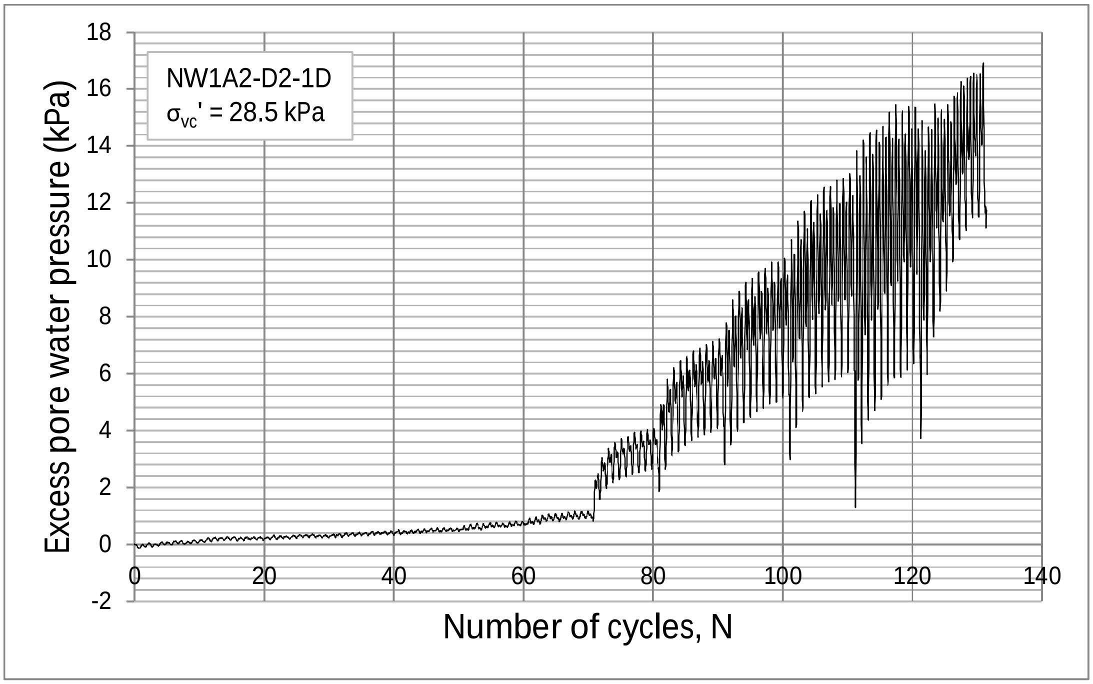


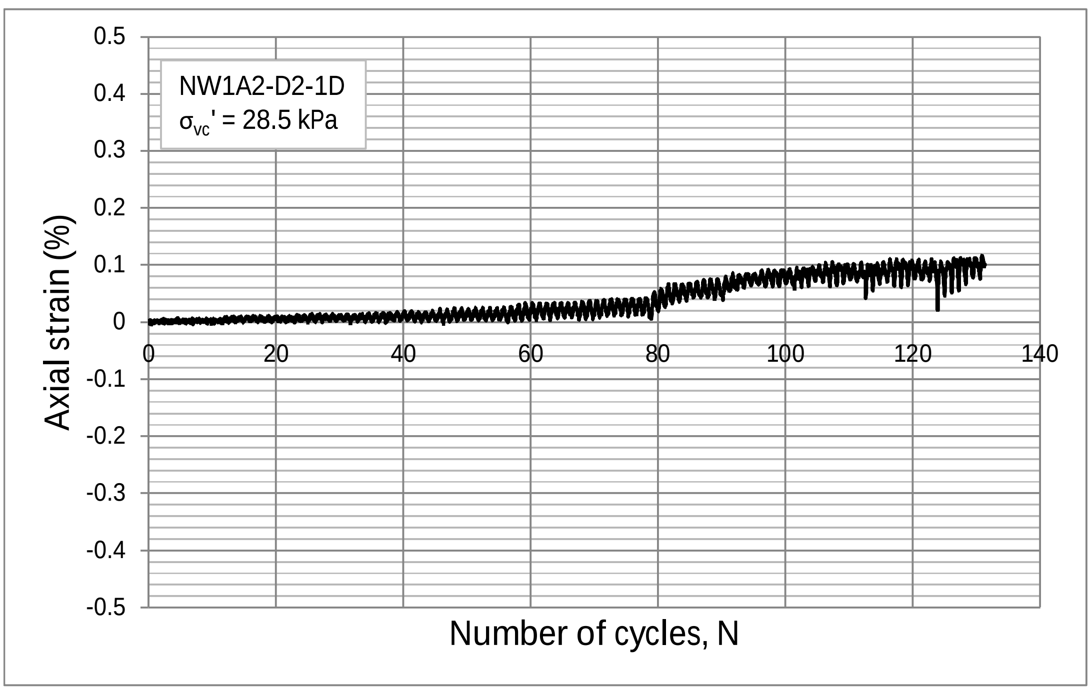
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE



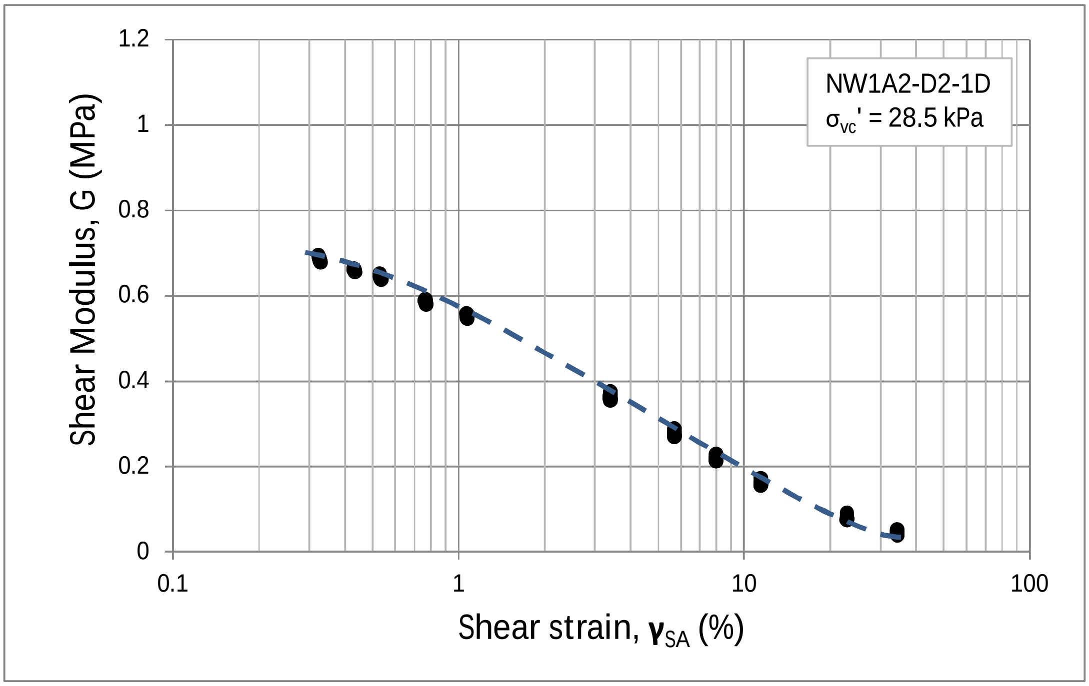


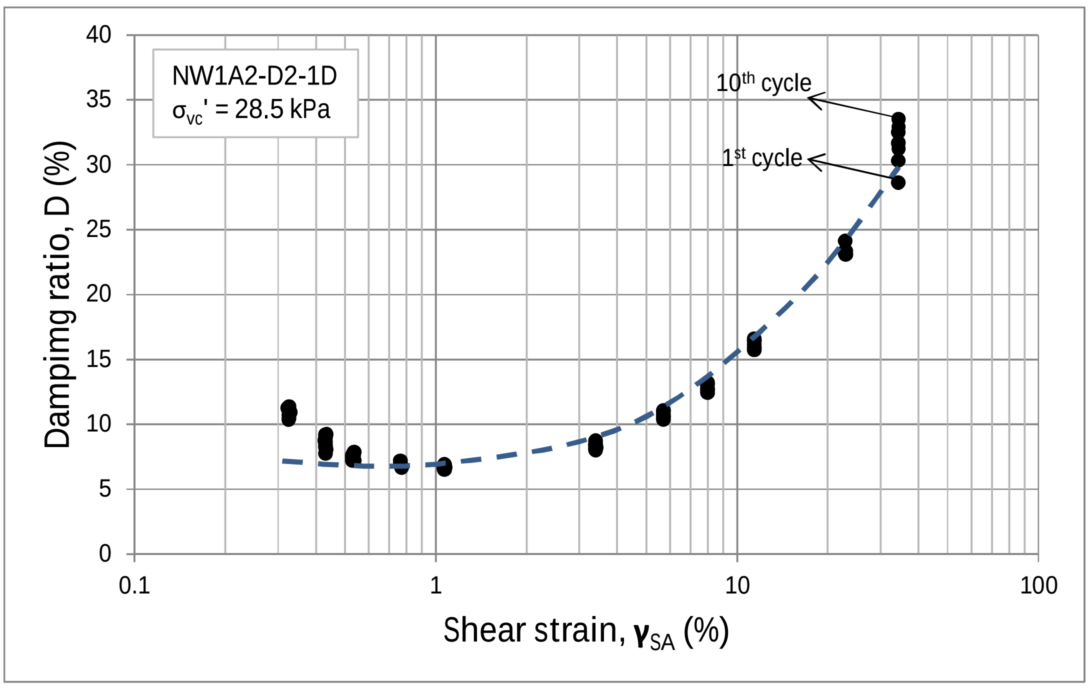
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





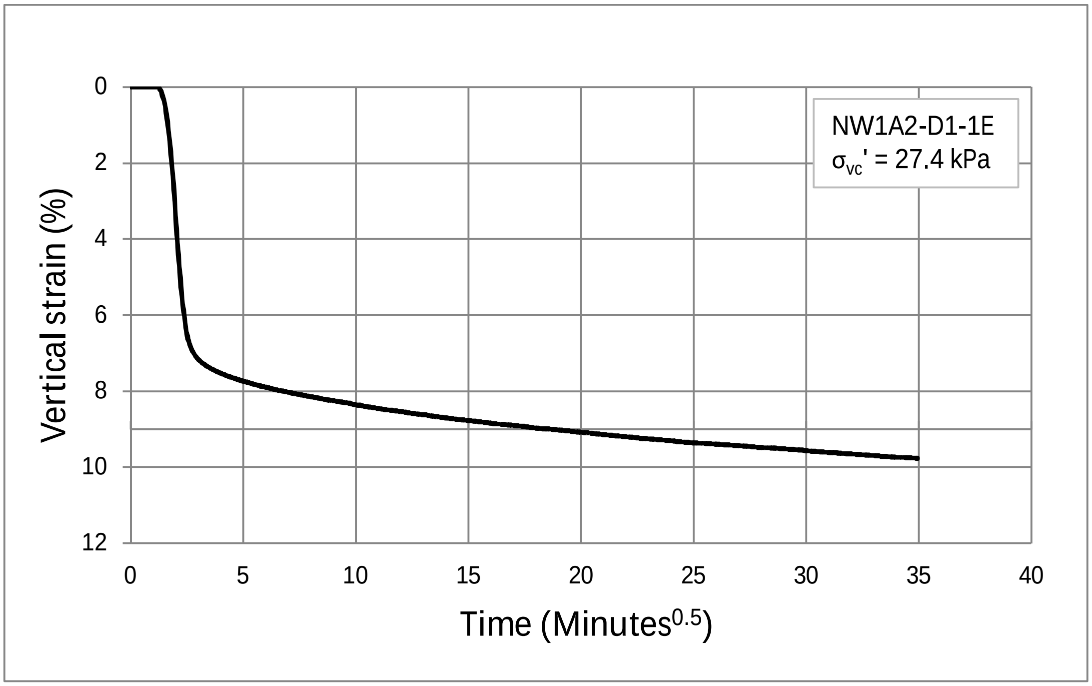
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE

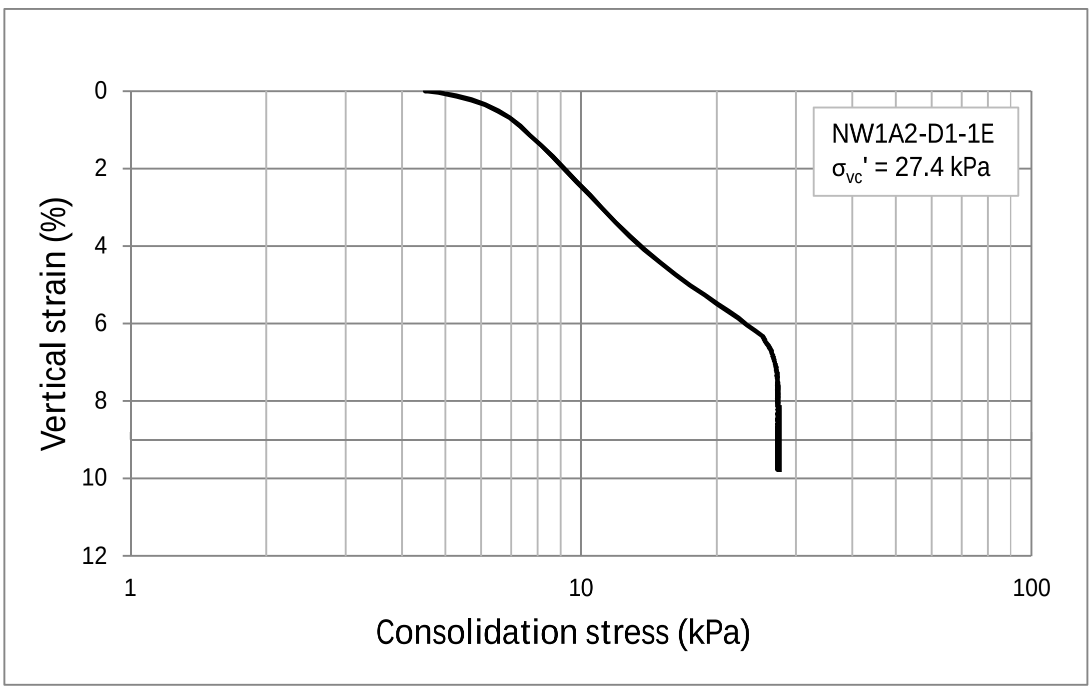
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

Borehole	NW1A2-D
Sample	NW1A2-D1-1E
Depth (m)	3.85 (At top of the sample)

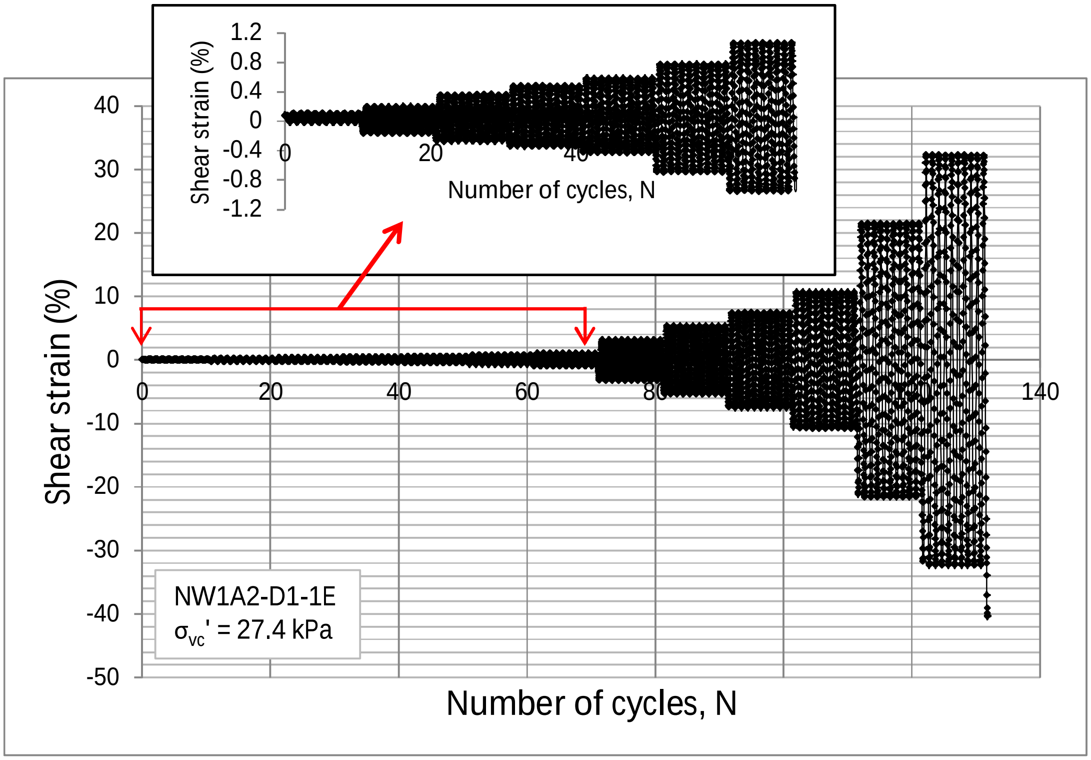
TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	20.16
Initial moisture content (%)	471.8
Initial dry density (kN/m^3)	1.69
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	27.4
Vertical strain at the end of consolidation (%)	9.77
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	442.2
Final dry density (kN/m^3)	1.97

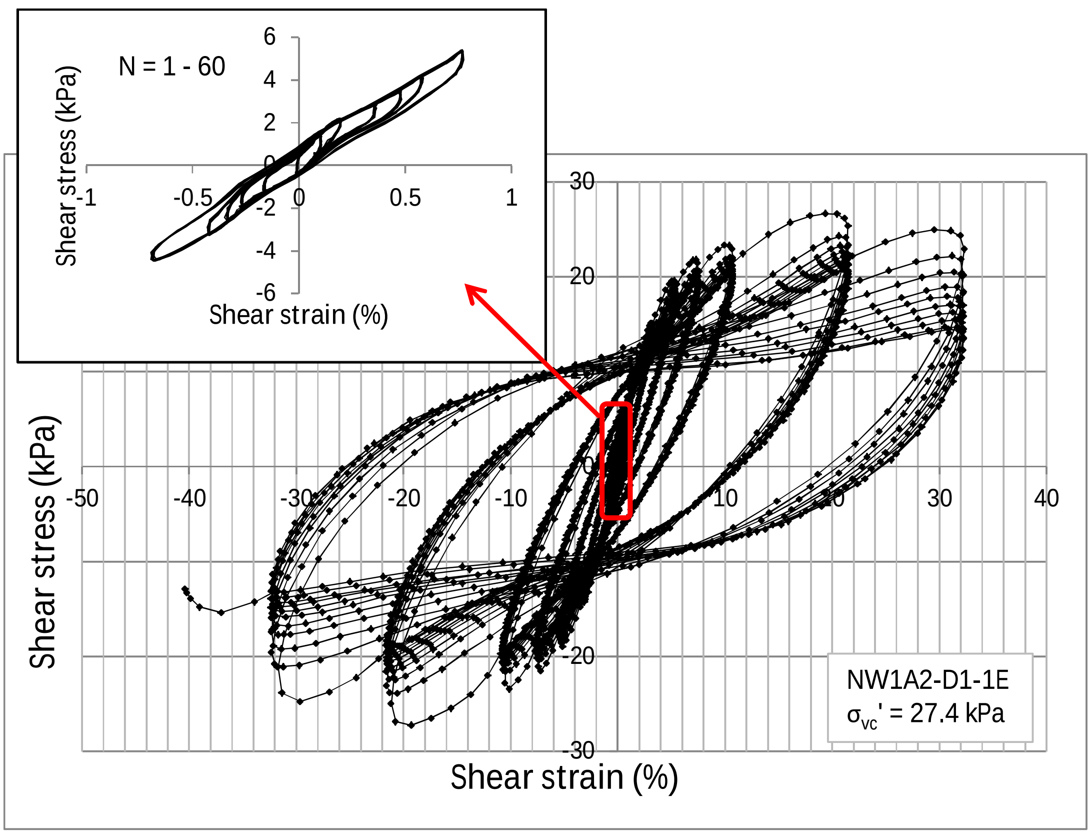
Specimen Photograph



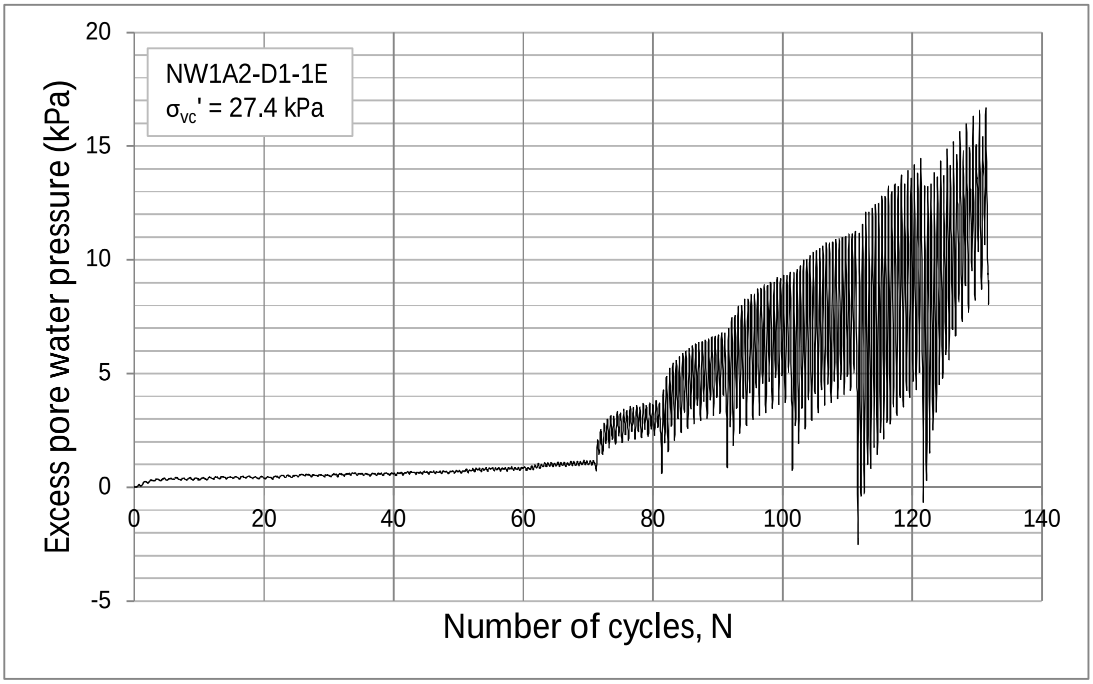


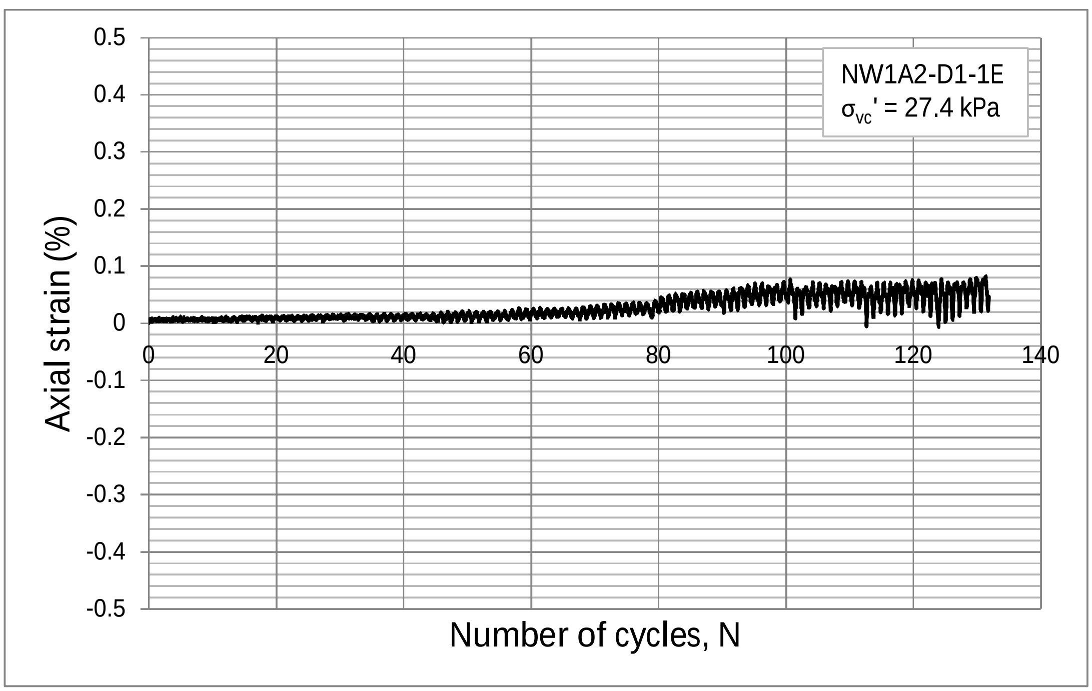
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE



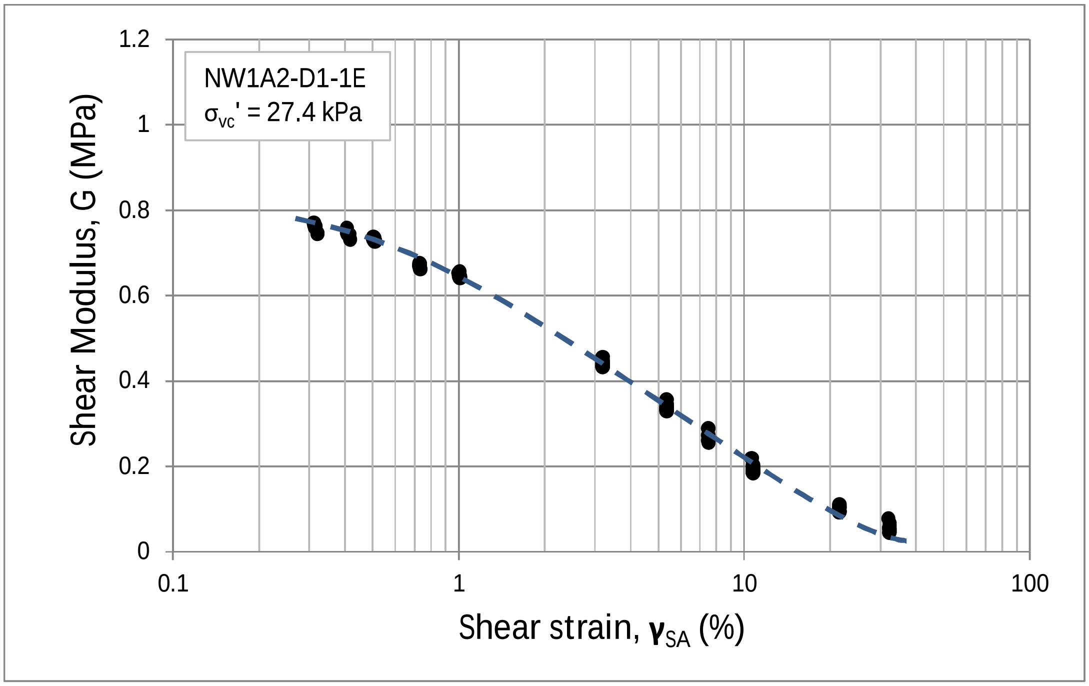


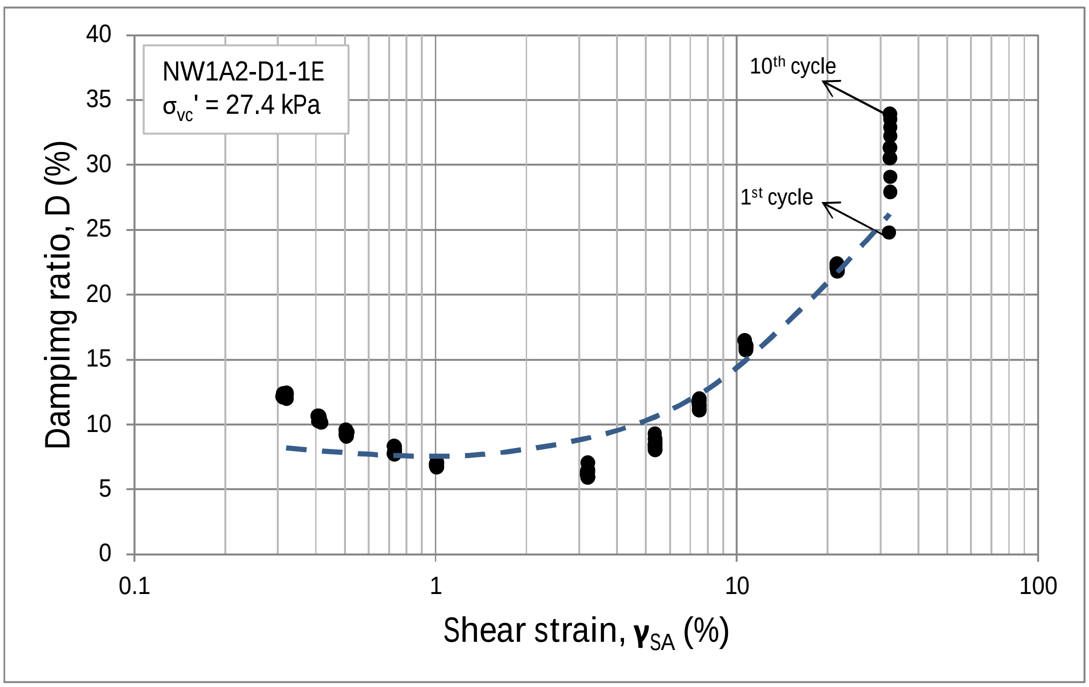
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE





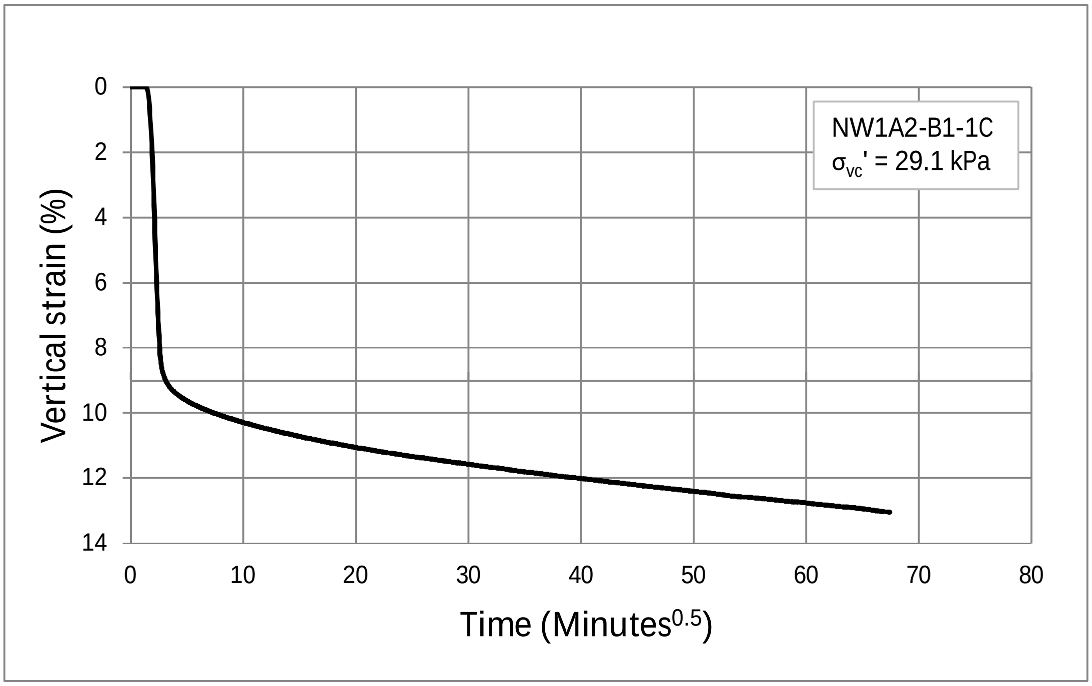
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE

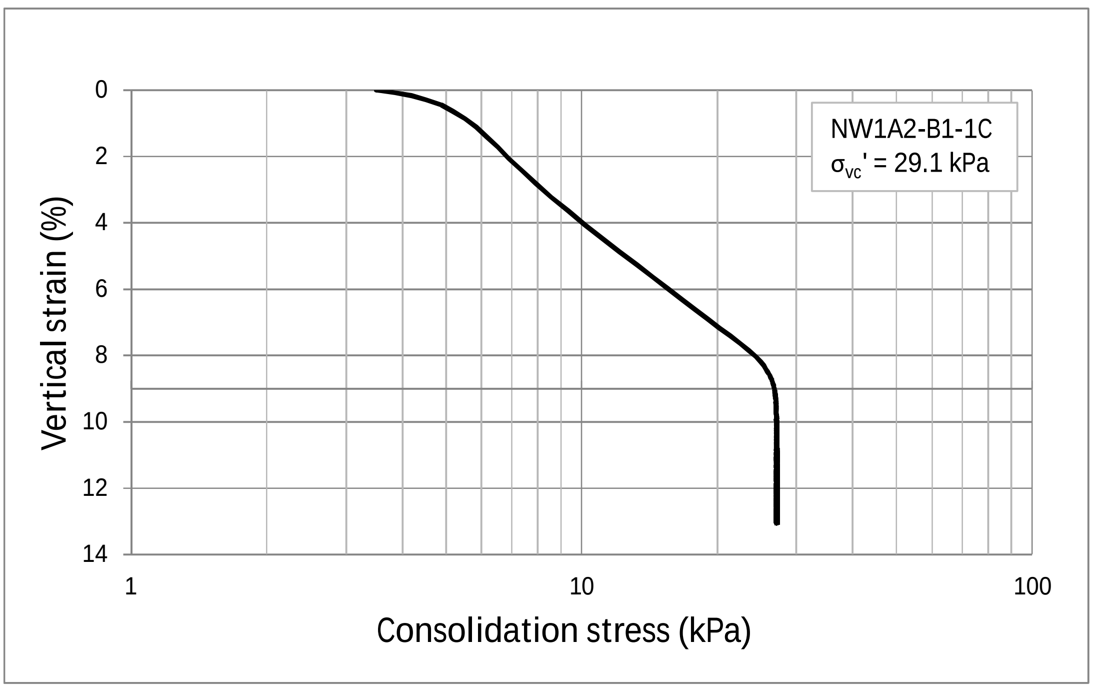
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

Borehole	NW1A2-B
Sample	NW1A2-B1-1C
Depth (m)	3.62 (At top of the sample)

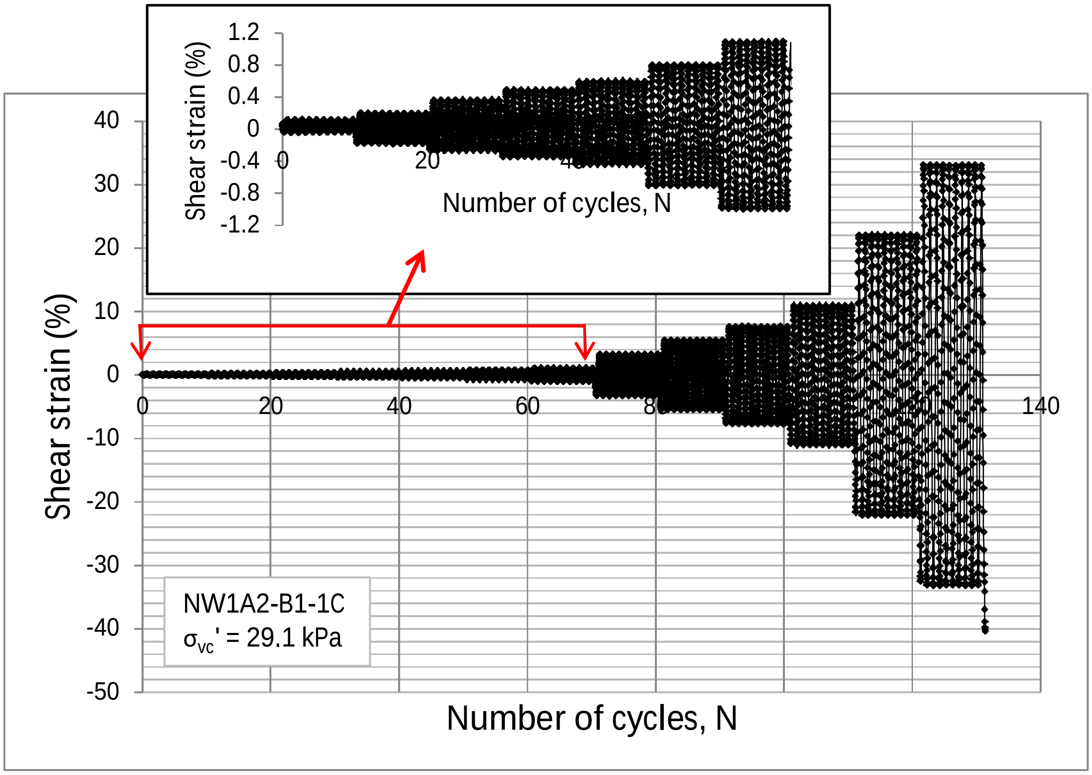
TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	20.41
Initial moisture content (%)	500.9
Initial dry density (kN/m^3)	1.51
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	27.1
Vertical strain at the end of consolidation (%)	13.04
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	494.8
Final dry density (kN/m^3)	1.76

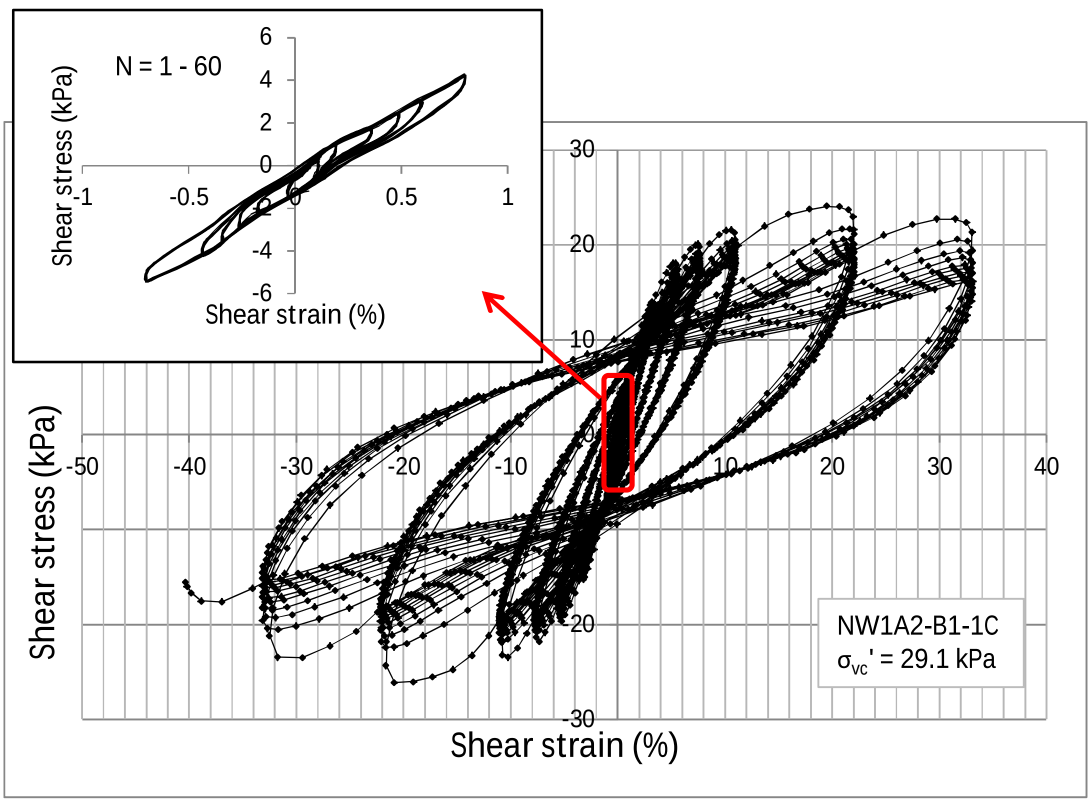
Specimen Photograph (after shearing)



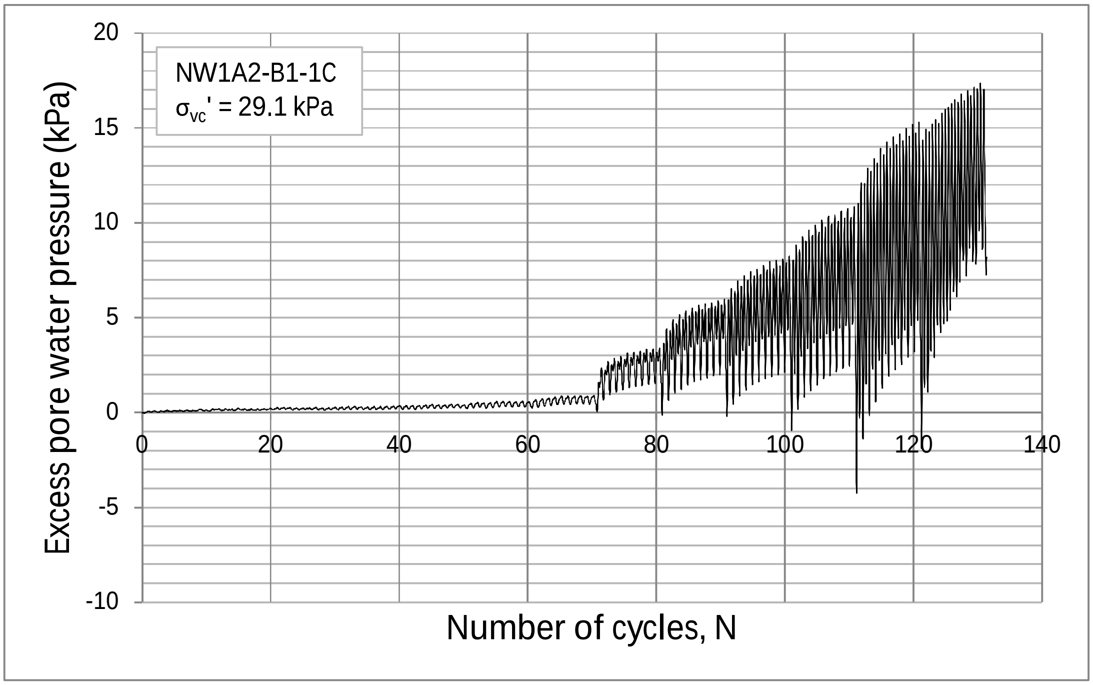


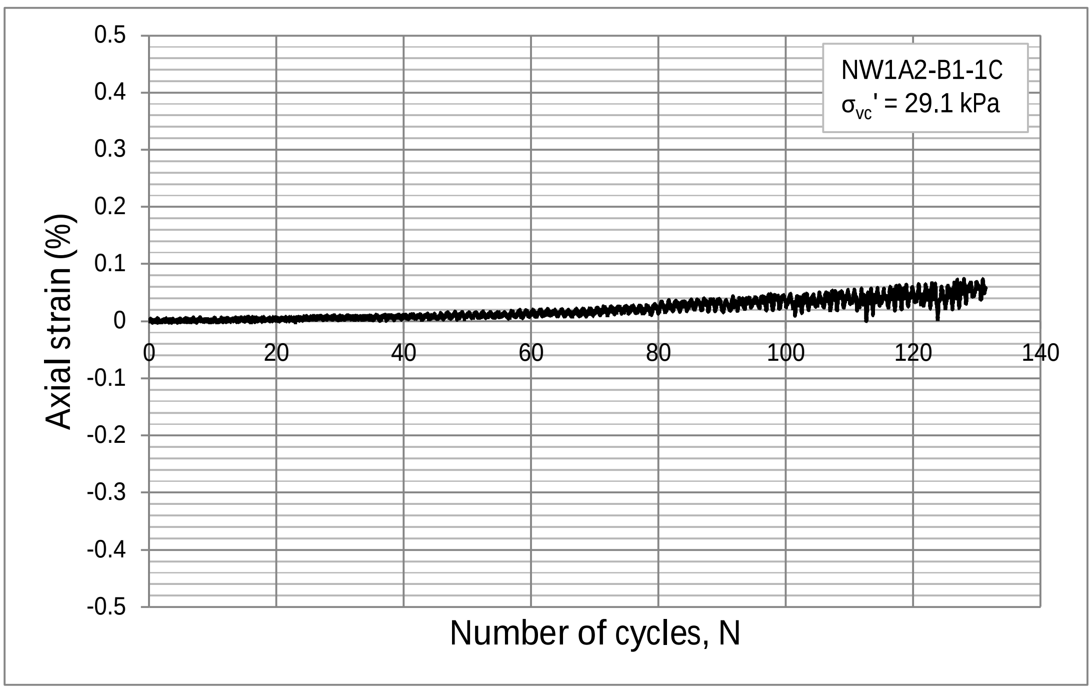
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE



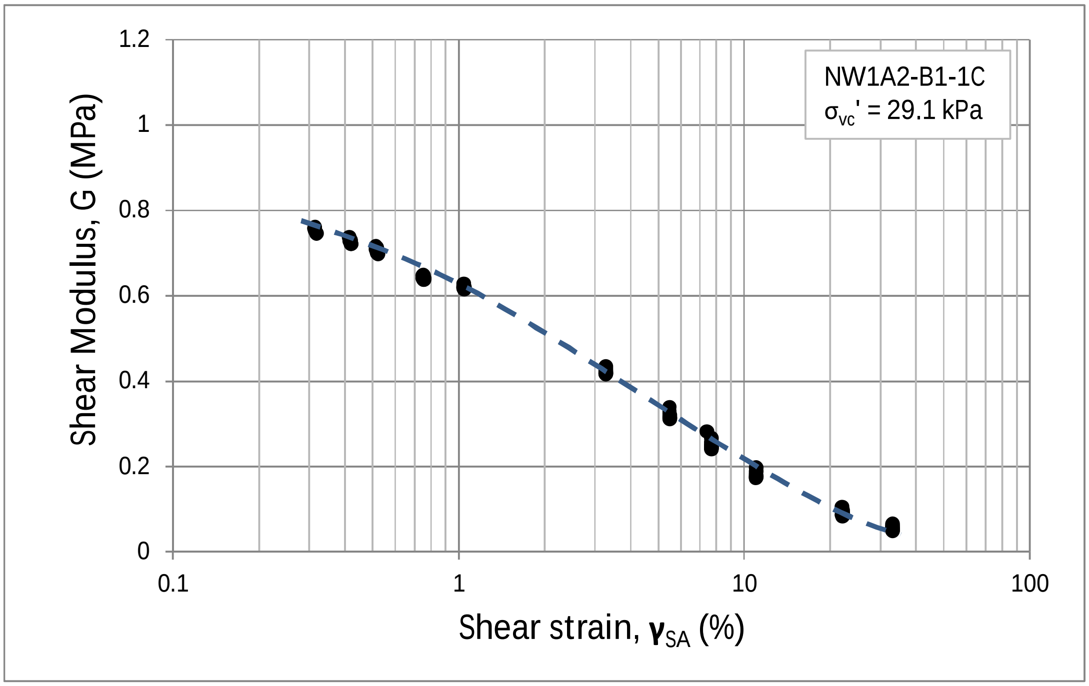


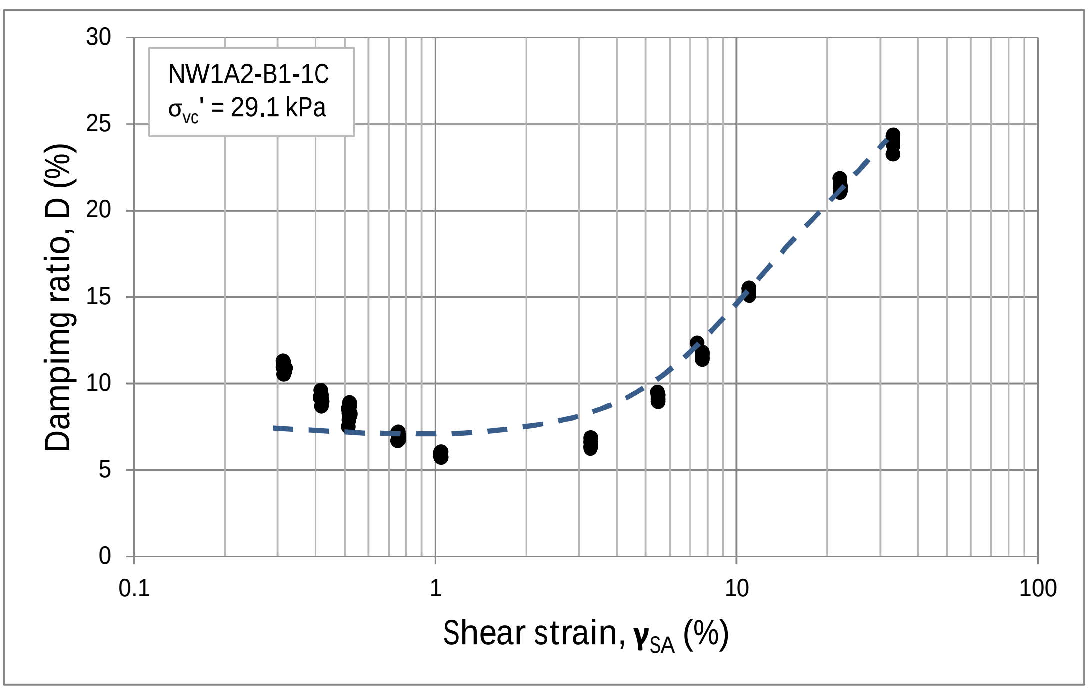
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





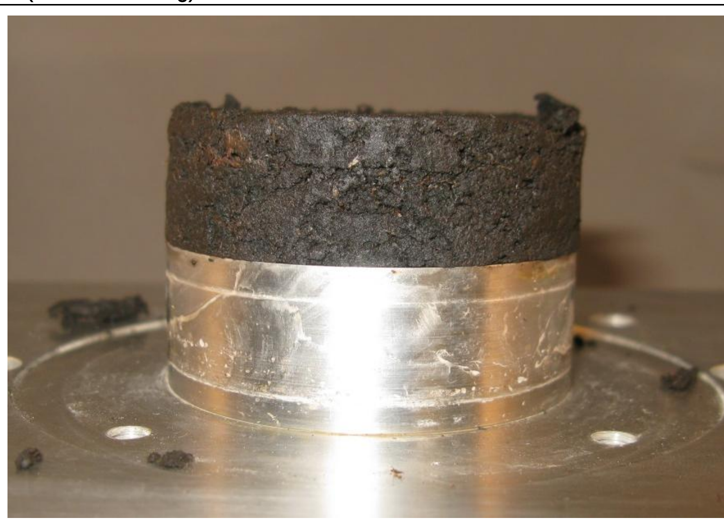
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE

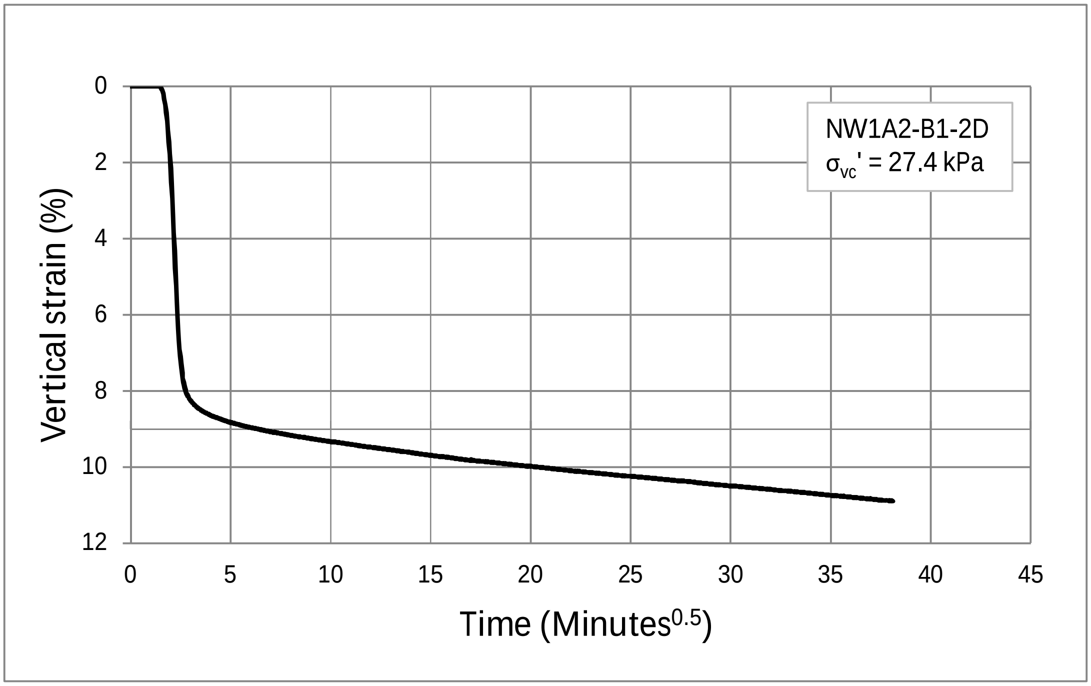
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

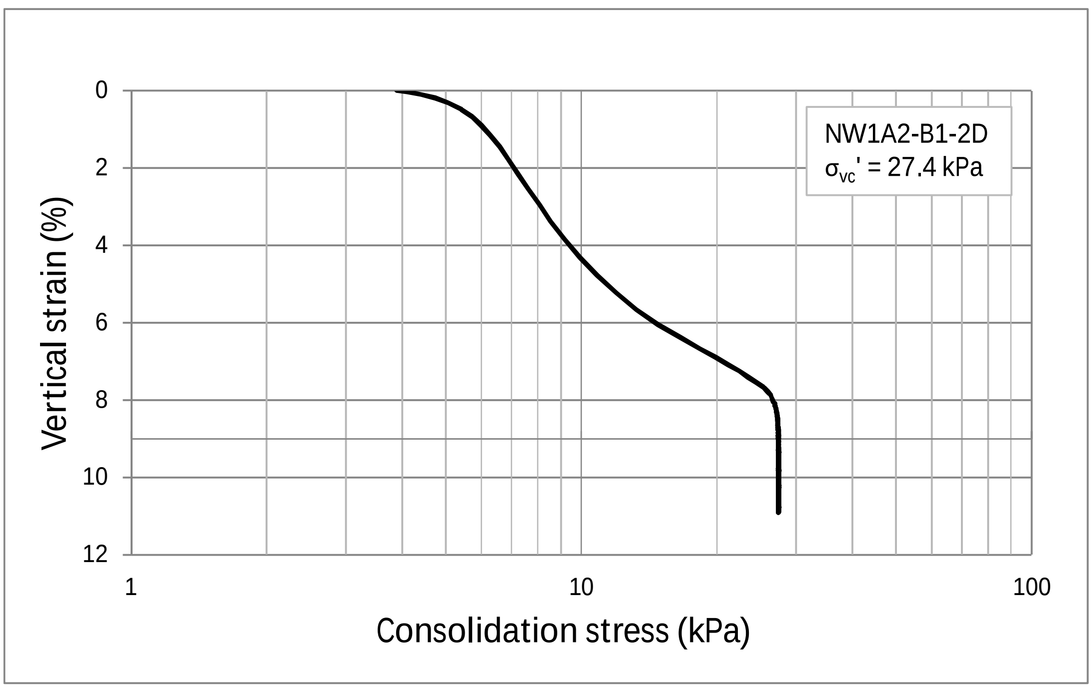
Borehole	NW1A2-B
Sample	NW1A2-B1-2D
Depth (m)	4.02 (At top of the sample)

TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	20.65
Initial moisture content (%)	462.6
Initial dry density (kN/m^3)	1.69
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	27.4
Vertical strain at the end of consolidation (%)	10.89
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	468.7
Final dry density (kN/m^3)	1.88

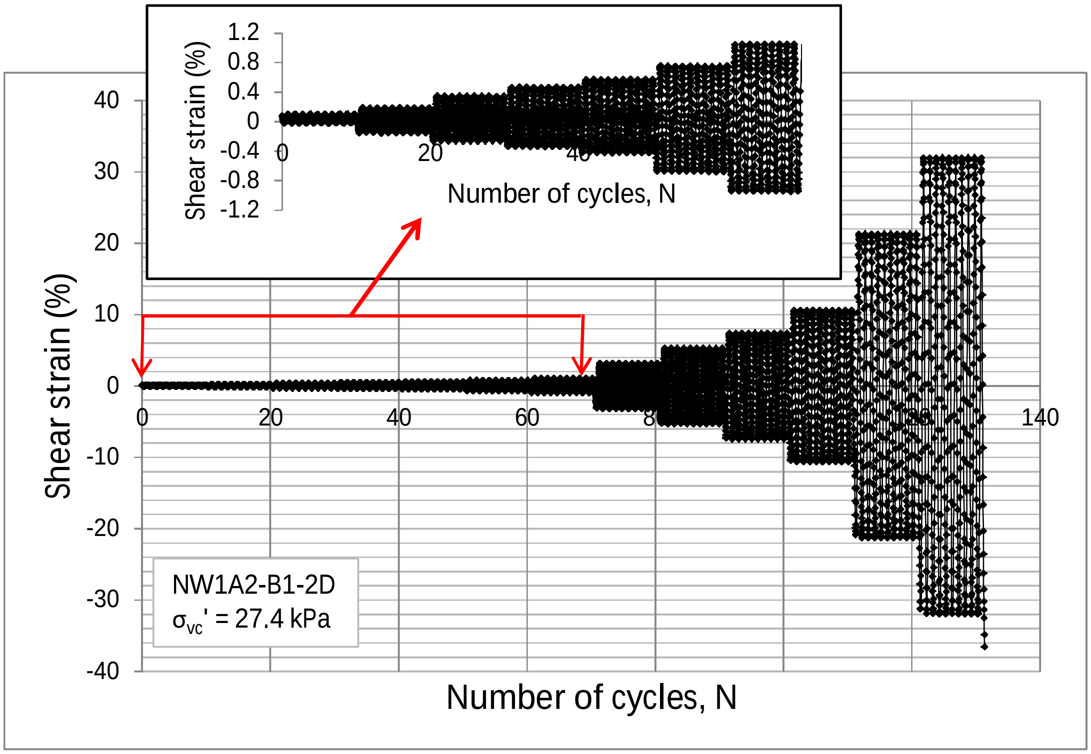
Specimen Photograph (after shearing)

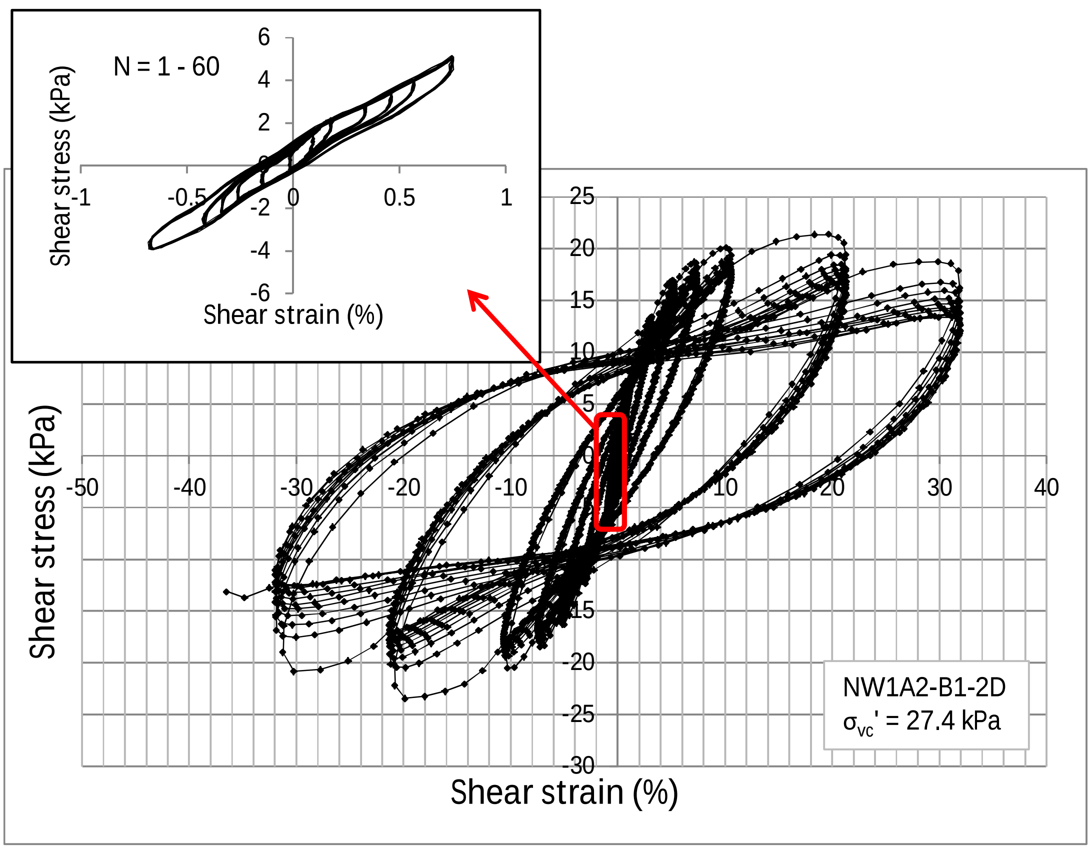






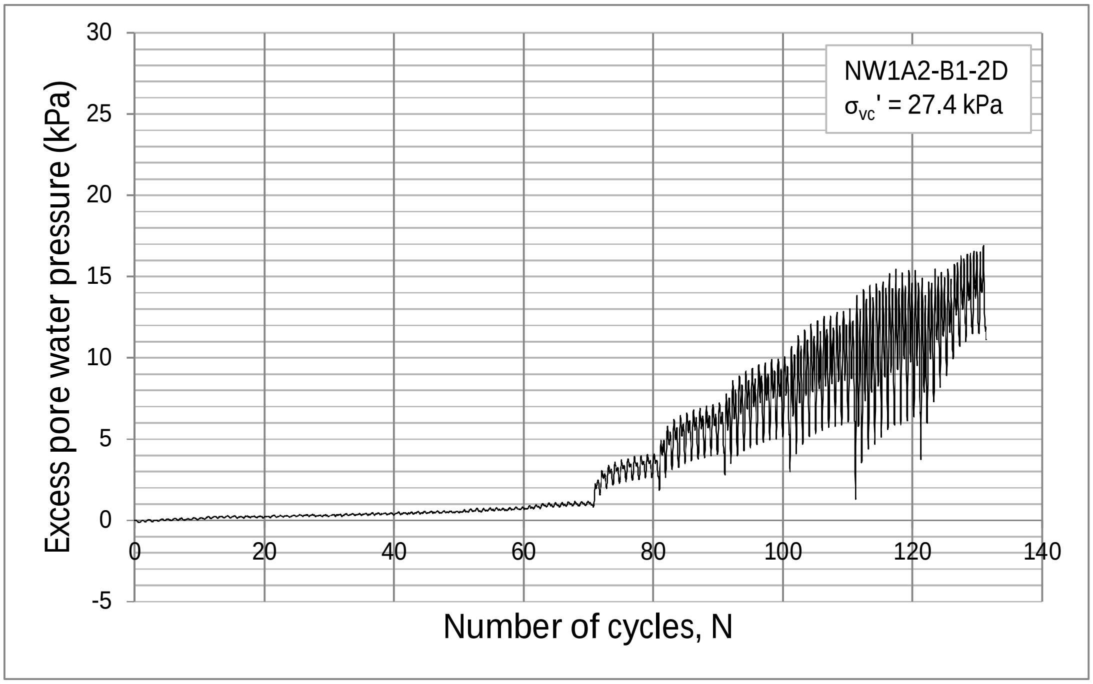
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE

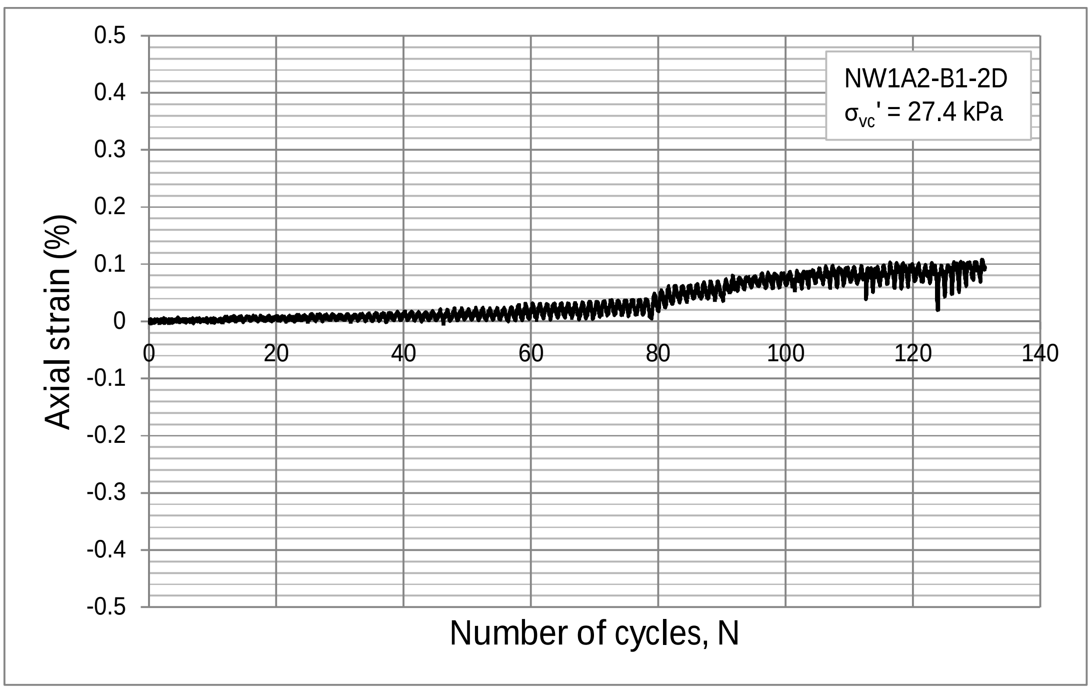




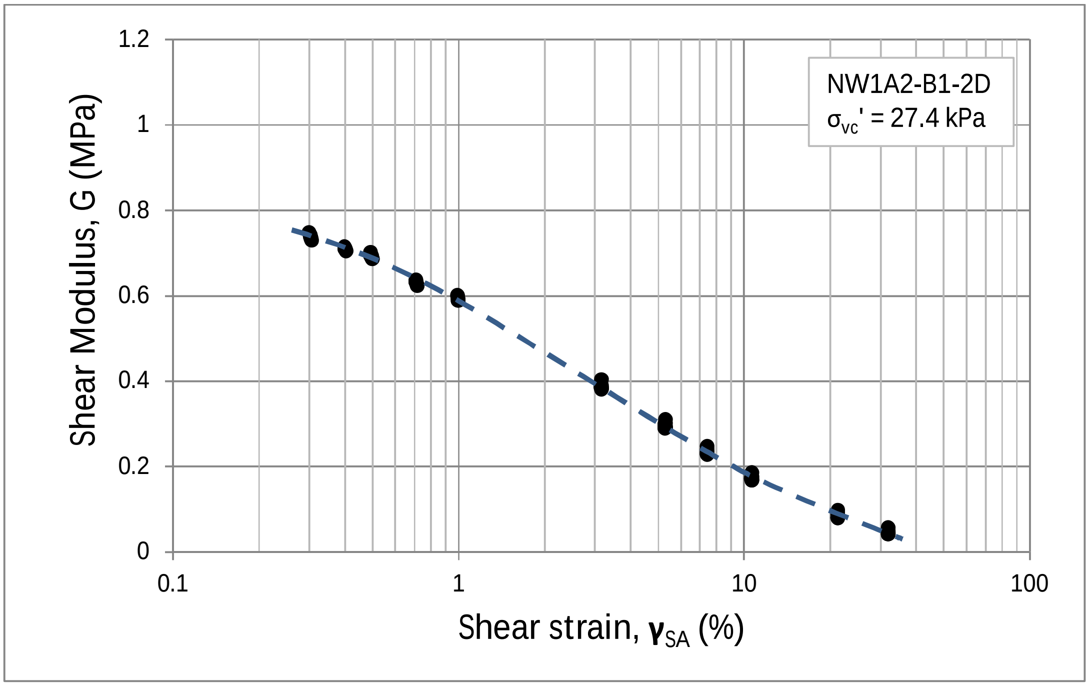
CONSOLIDATED CONSTANT VOLUME DSS TEST

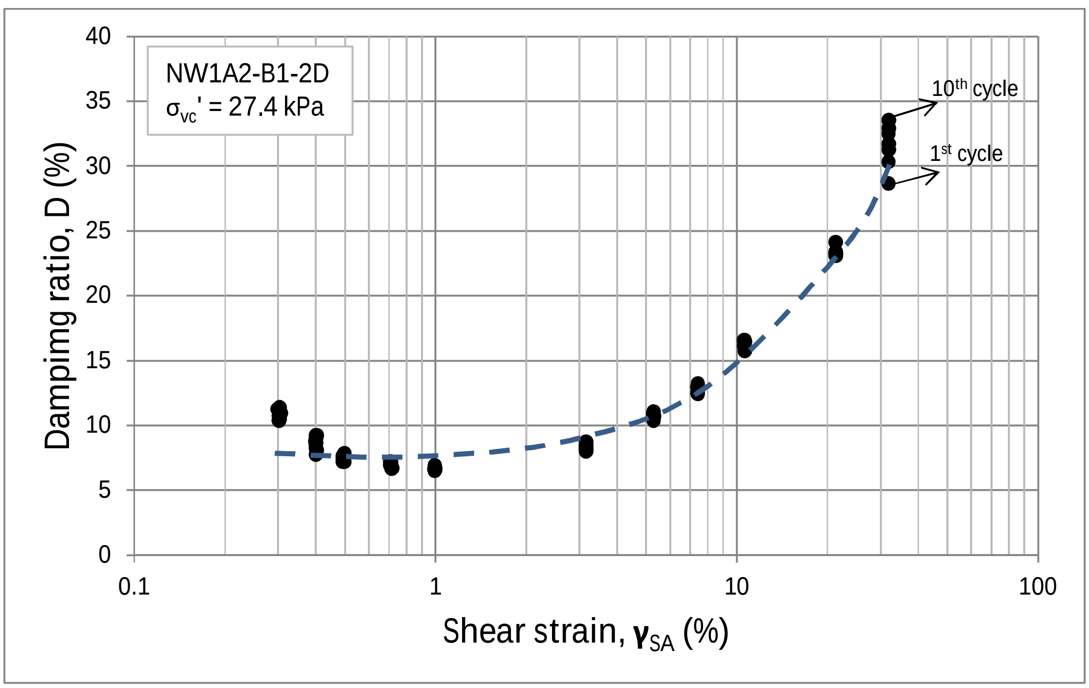
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





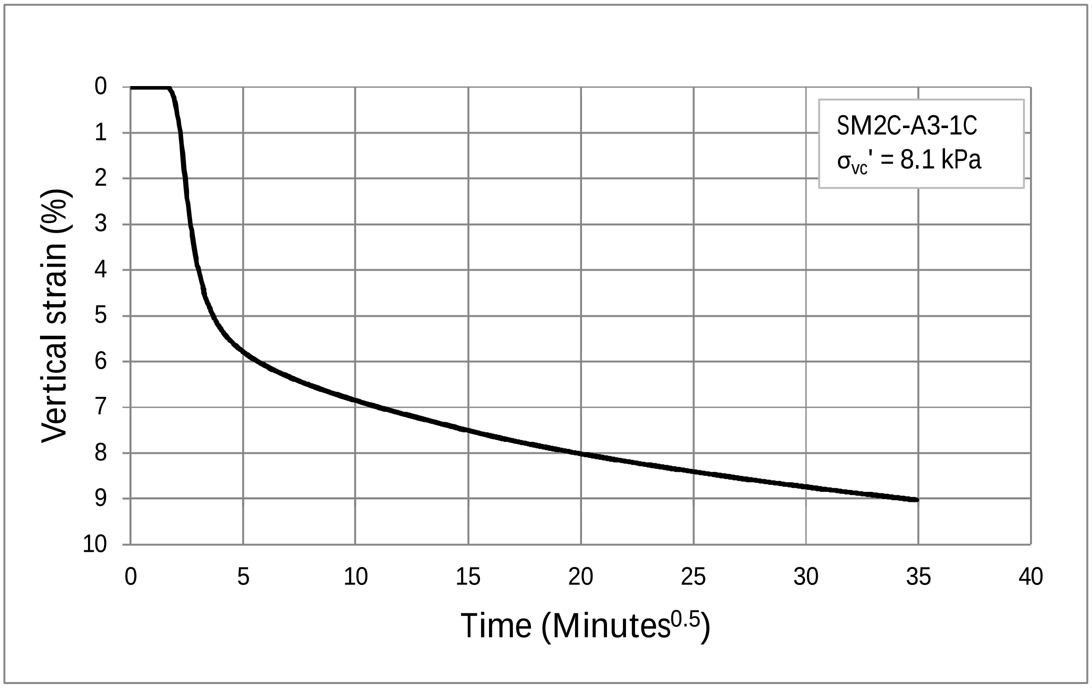
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE

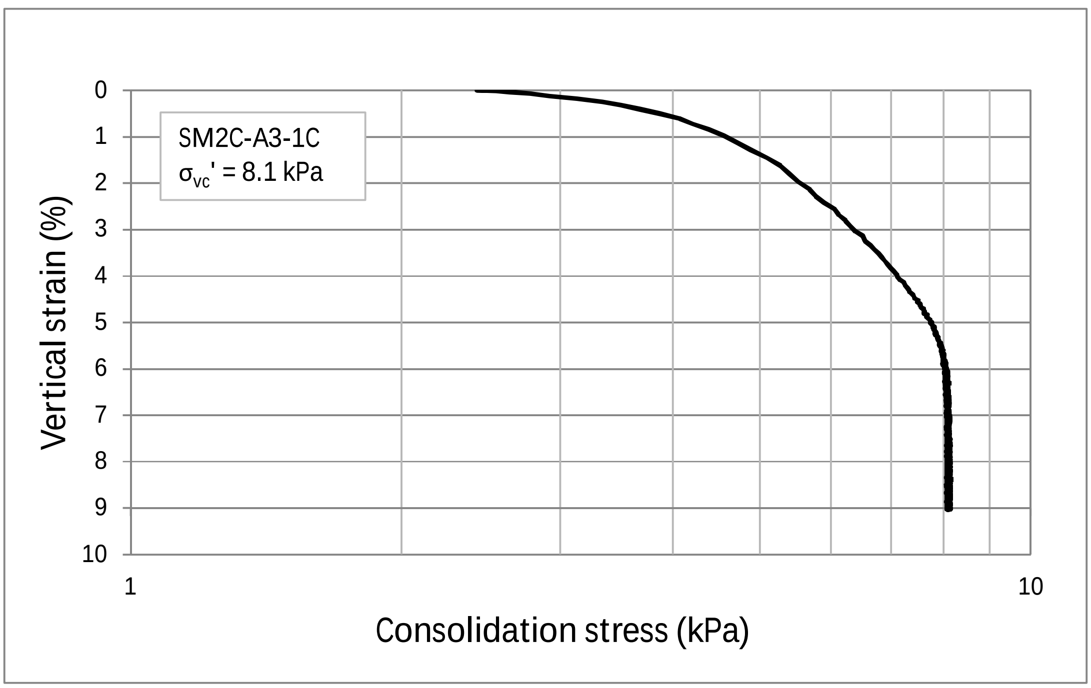
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

Borehole	SM2C-A
Sample	SM2C-A3-1C
Depth (m)	2.07 (At top of the sample)

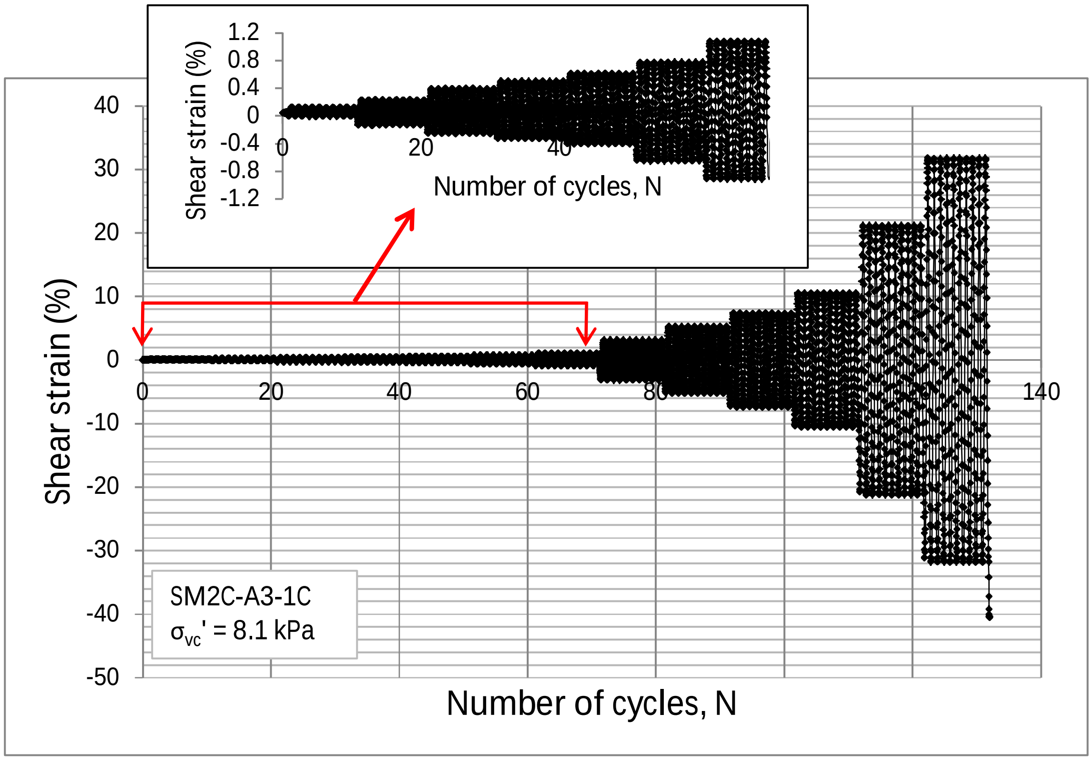
TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	20.33
Initial moisture content (%)	472.0
Initial dry density (kN/m^3)	1.51
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	6.2
Vertical strain at the end of consolidation (%)	3.82
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	528.6
Final dry density (kN/m^3)	1.61

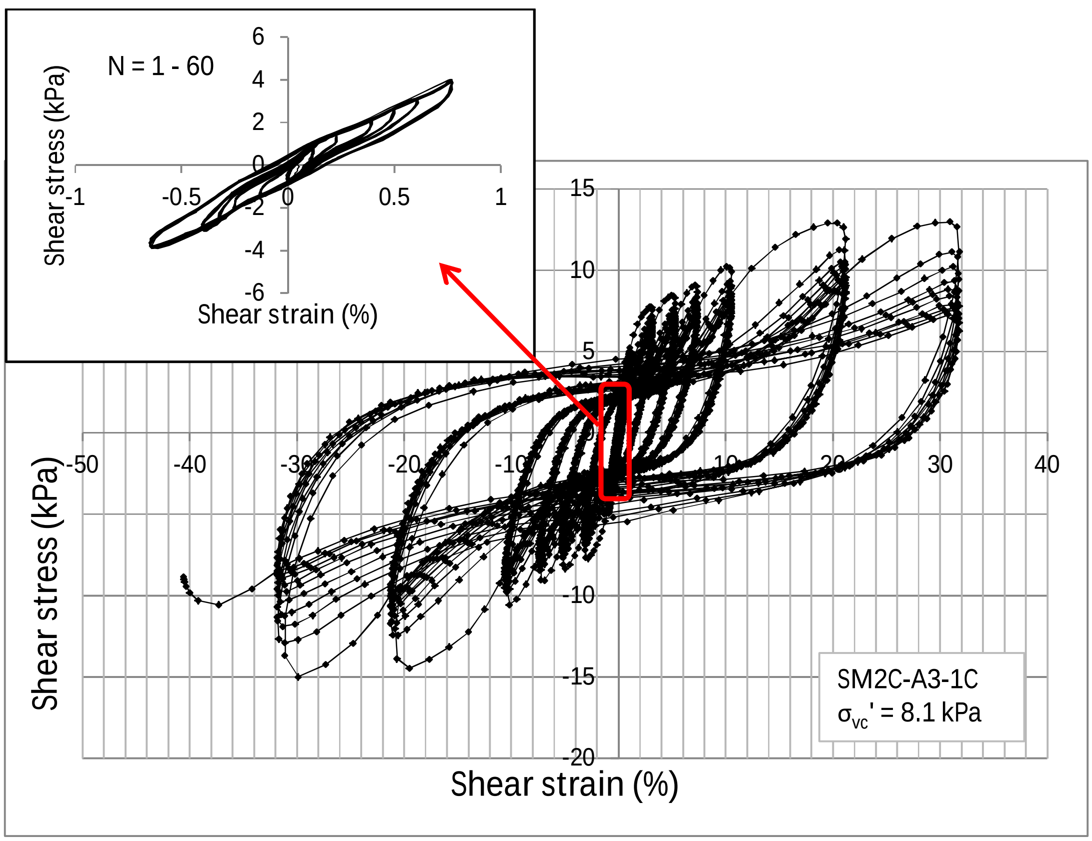
Specimen Photograph



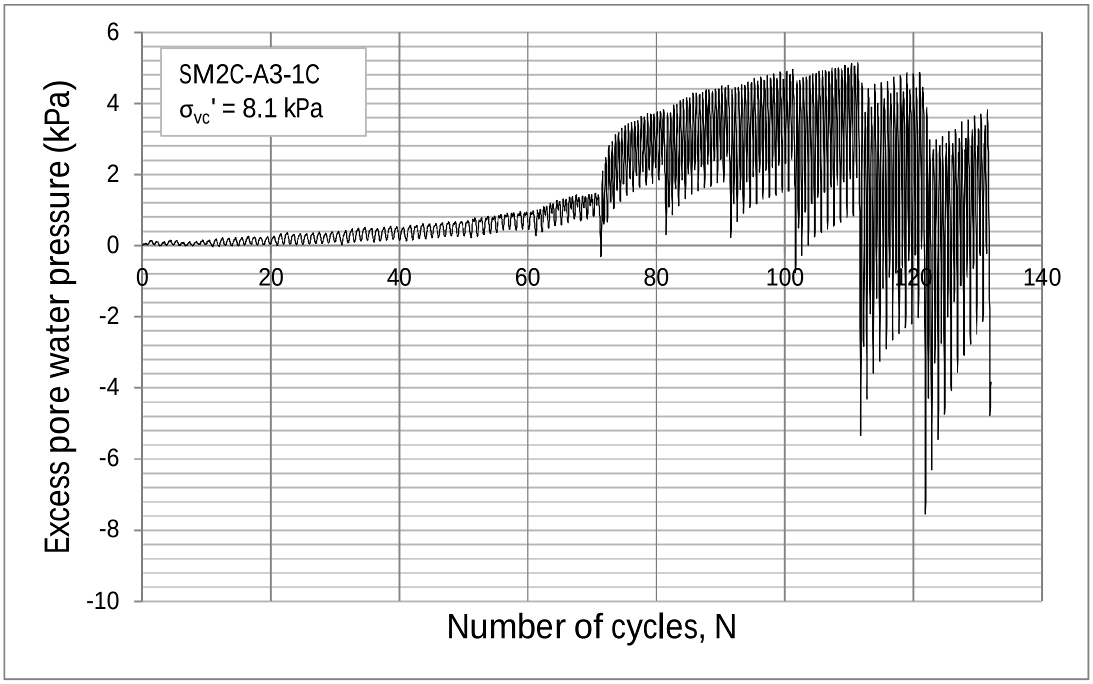


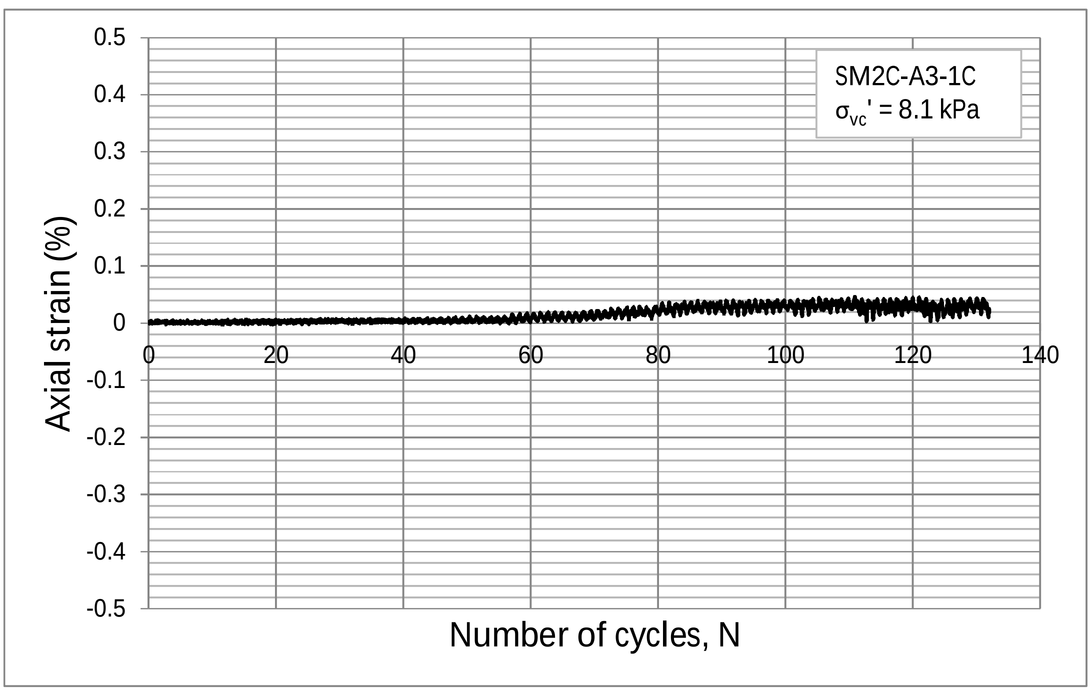
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE



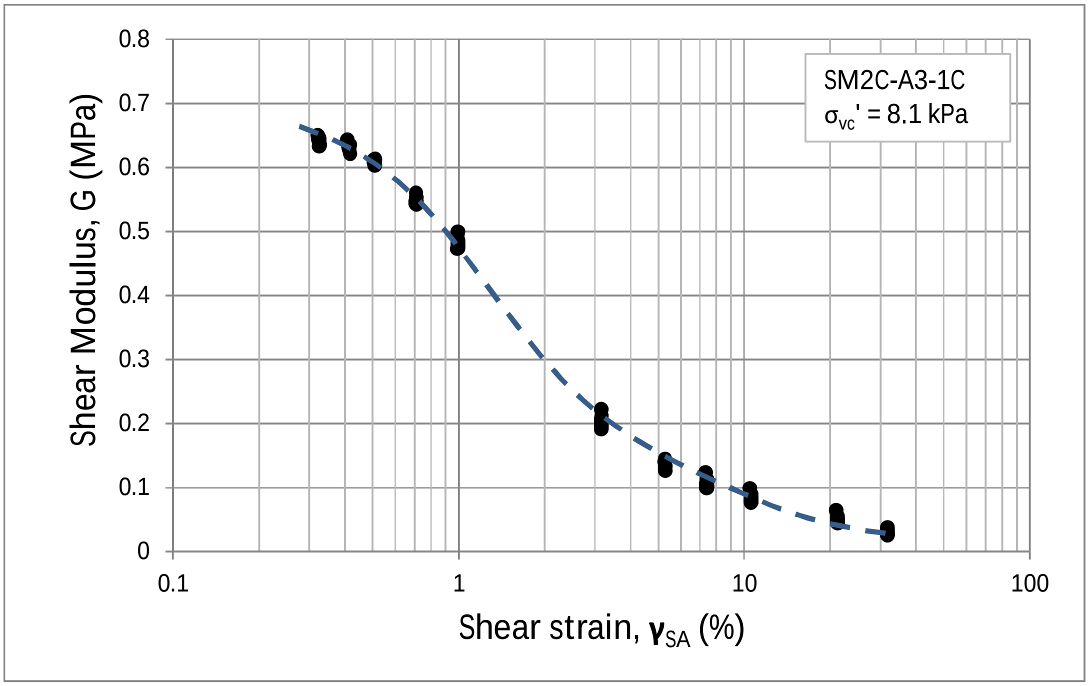


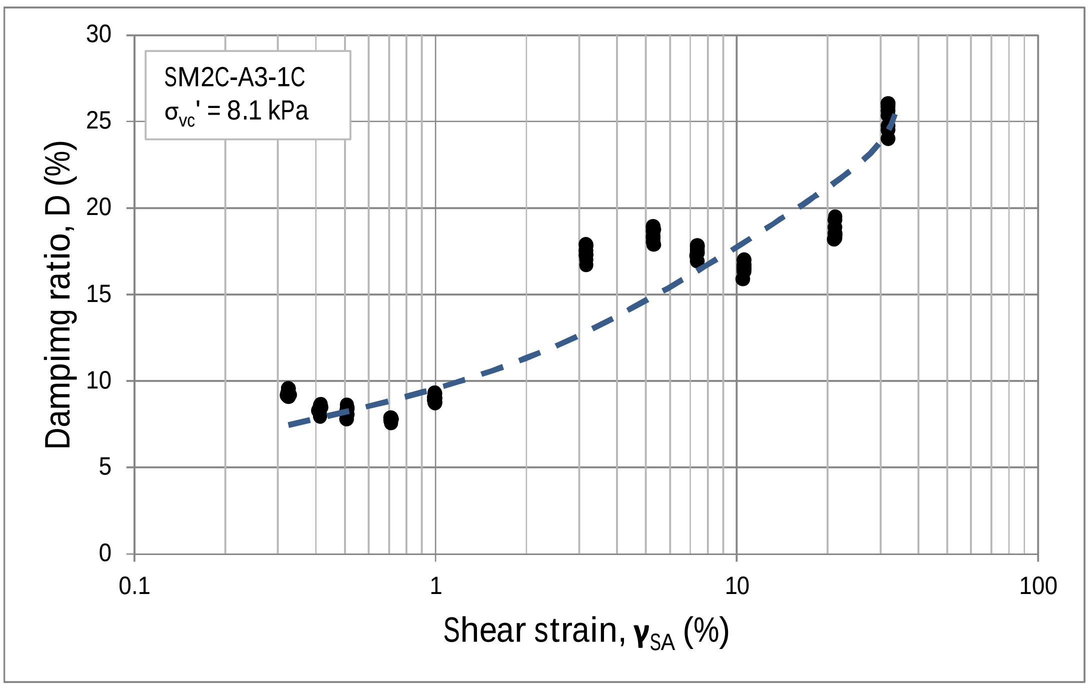
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





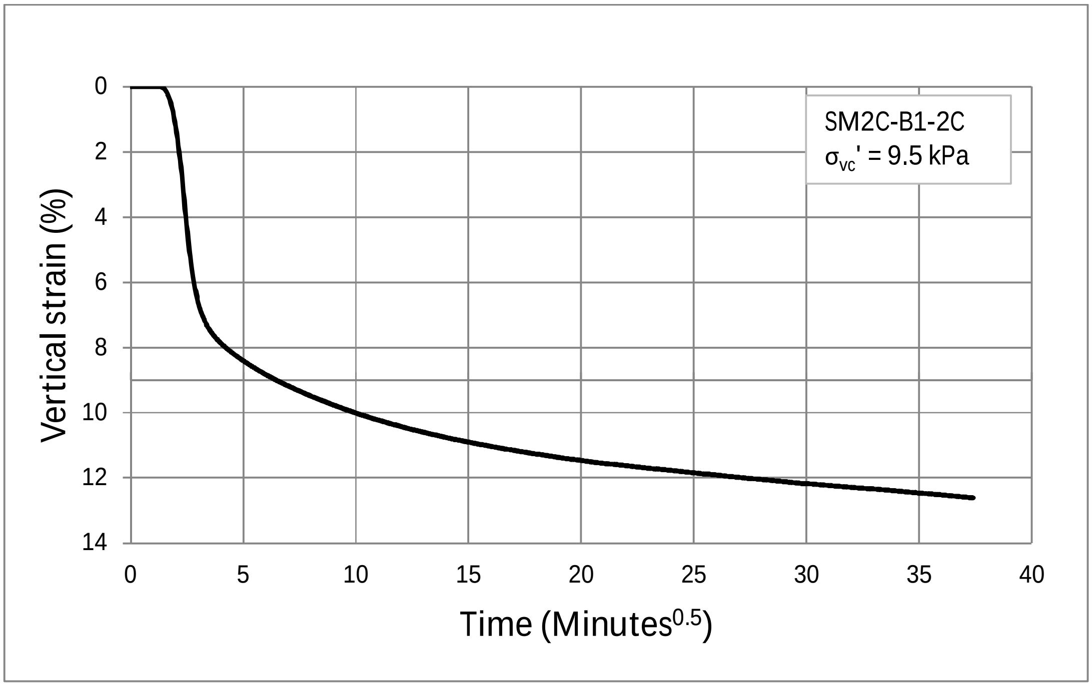
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE

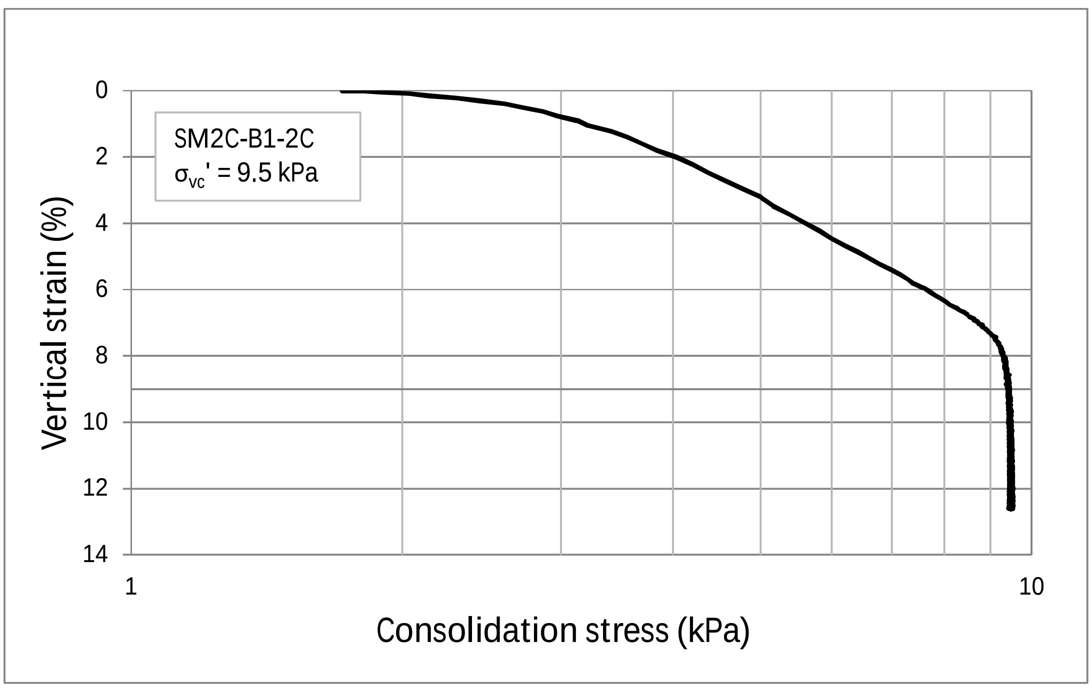
SUMMARY OF CONSOLIDATED CONSTANT VOLUME STRAIN CONTROLLED CYCLIC DIRECT SIMPLE SHEAR TEST

Borehole	SM2C-B
Sample	SM2C-B1-2C
Depth (m)	2.22 (At top of the sample)

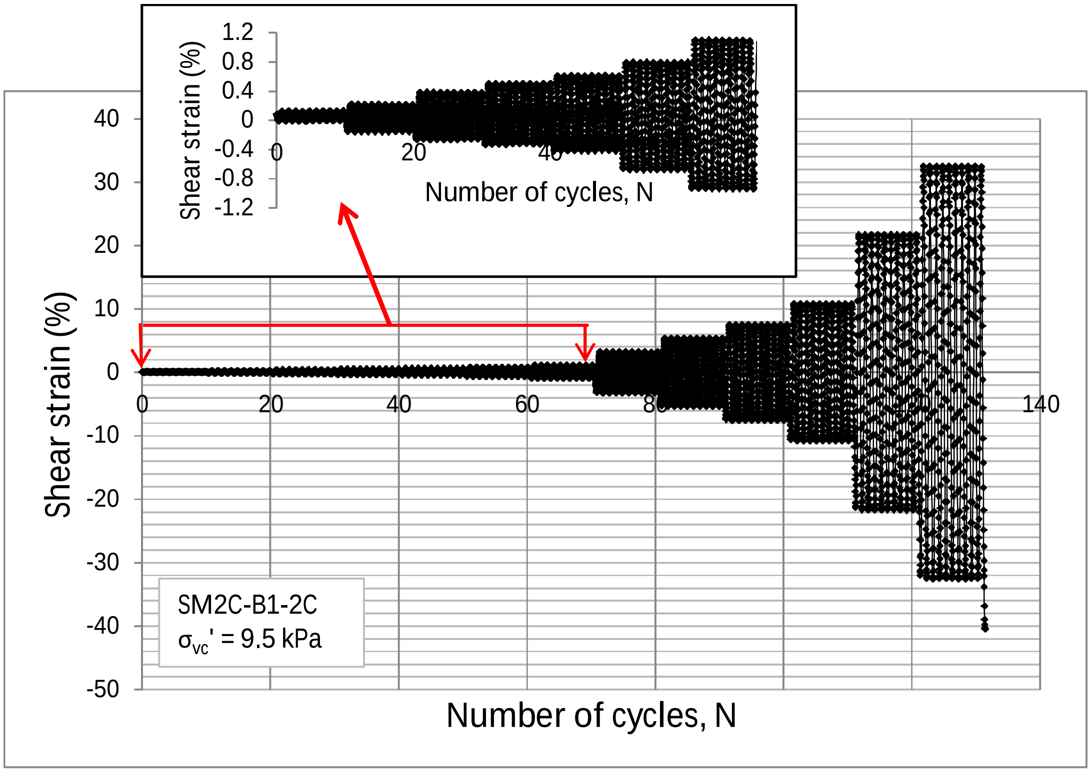
TESTING CONDITIONS	
INITIAL	
Material	Peat
Diameter (mm)	63
Height at start of consolidation (mm)	20.70
Initial moisture content (%)	490.7
Initial dry density (kN/m^3)	1.57
CONSOLIDATION	
Consolidation stress, σ_{vc}' (kPa)	9.5
Vertical strain at the end of consolidation (%)	12.61
CYCLIC LOADING, STRAIN CONTROL, CONSTANT HEIGHT	
Frequency (Hz)	0.1
Shear strain amplitude (mm)	Sequence of shear strain amplitudes starting from 0.01 mm up to 8 mm
Number of cycles	Ten cycles per shear strain amplitude
Final moisture content	505.5
Final dry density (kN/m^3)	1.76

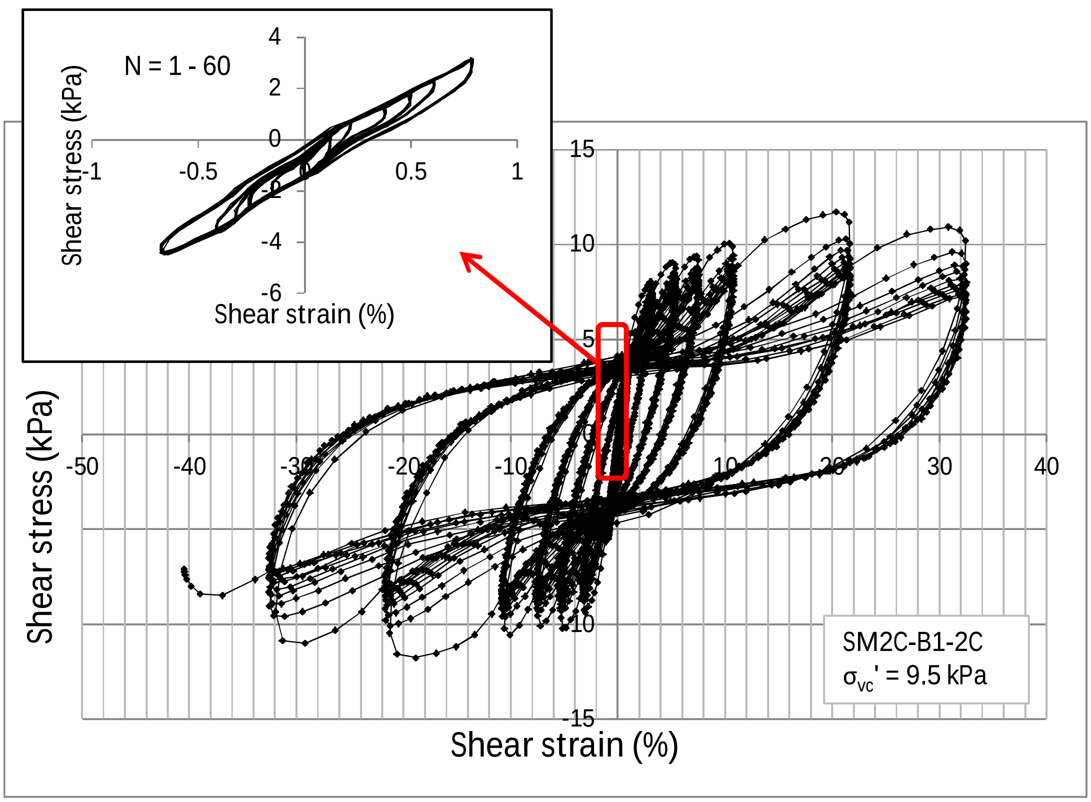
Specimen Photograph (after shearing)



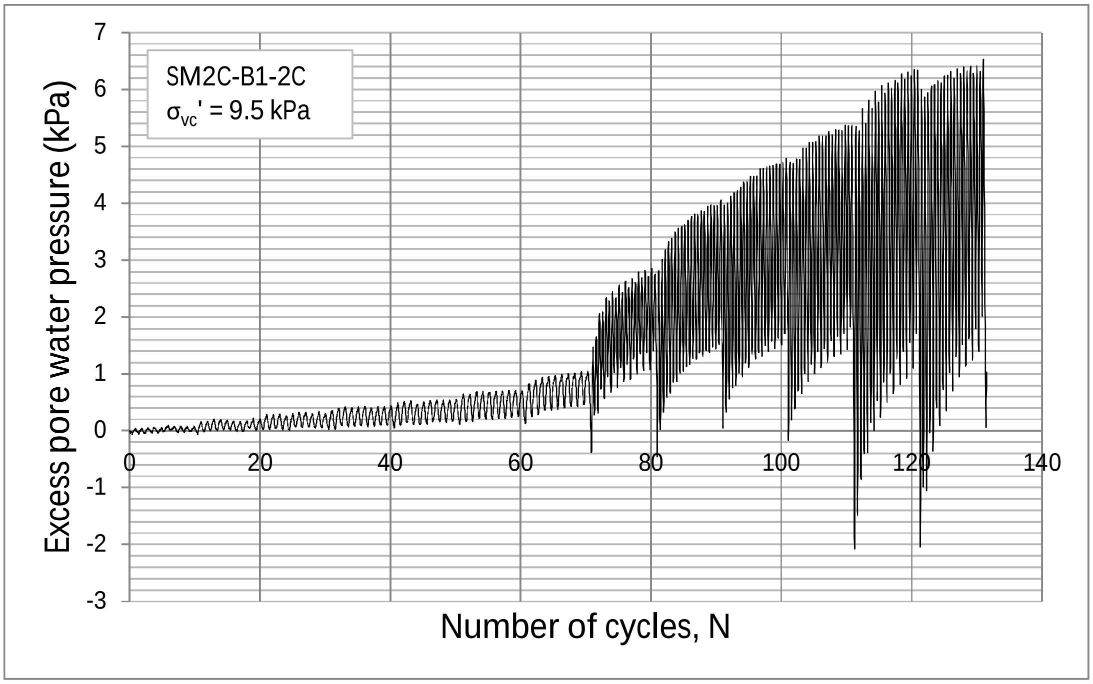


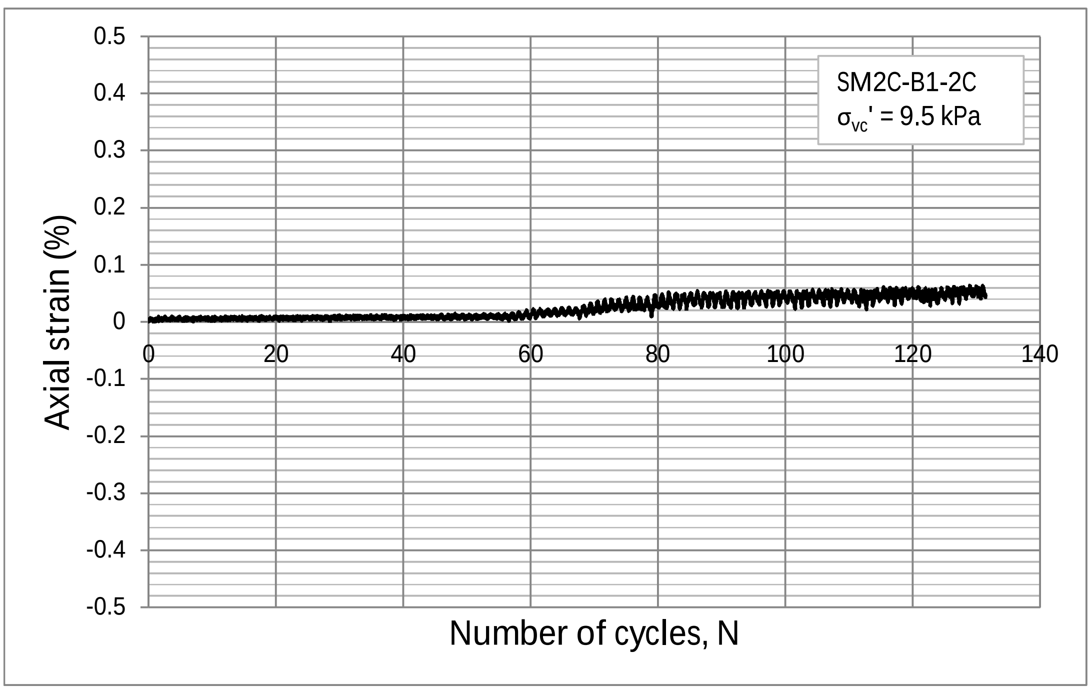
CONSOLIDATED CONSTANT VOLUME DSS TEST
CONSOLIDATION STAGE



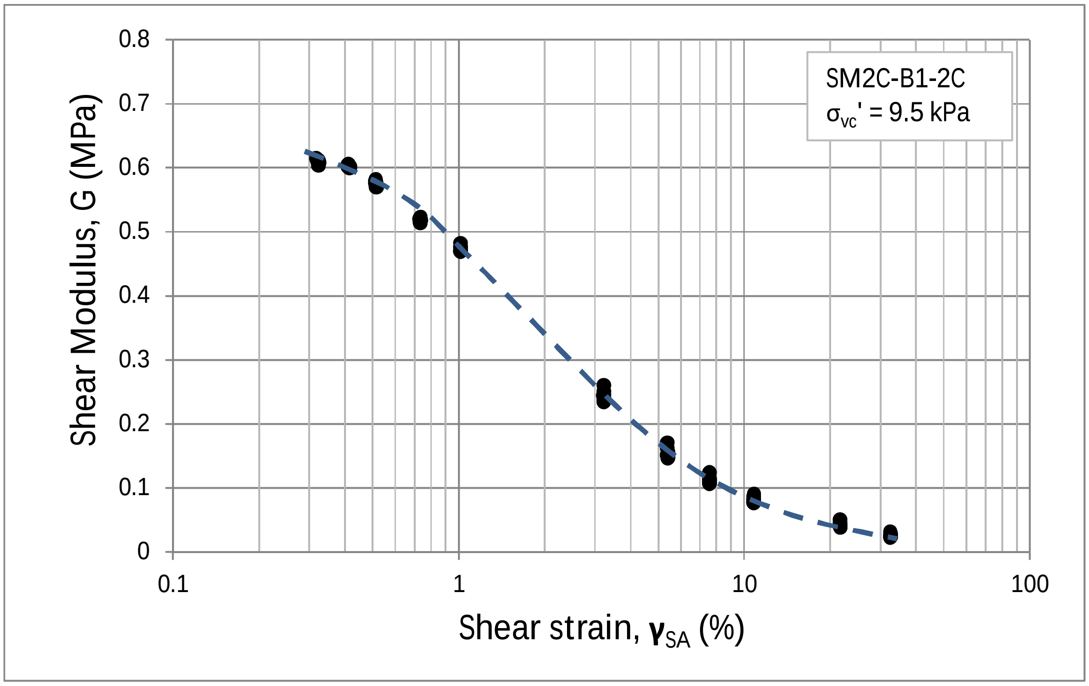


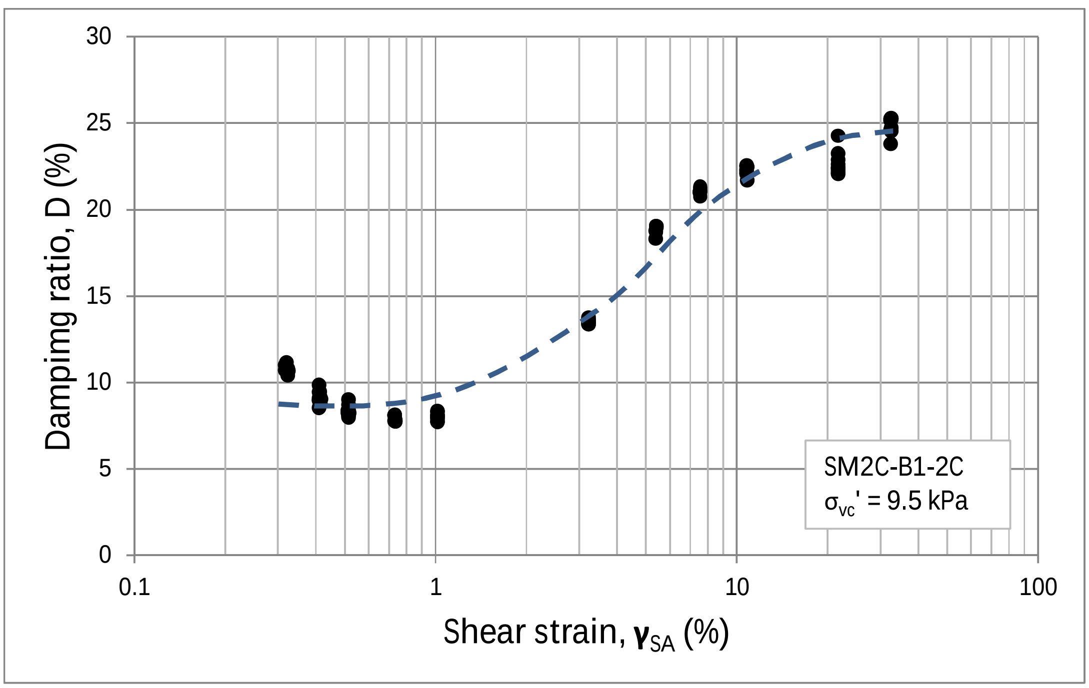
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE



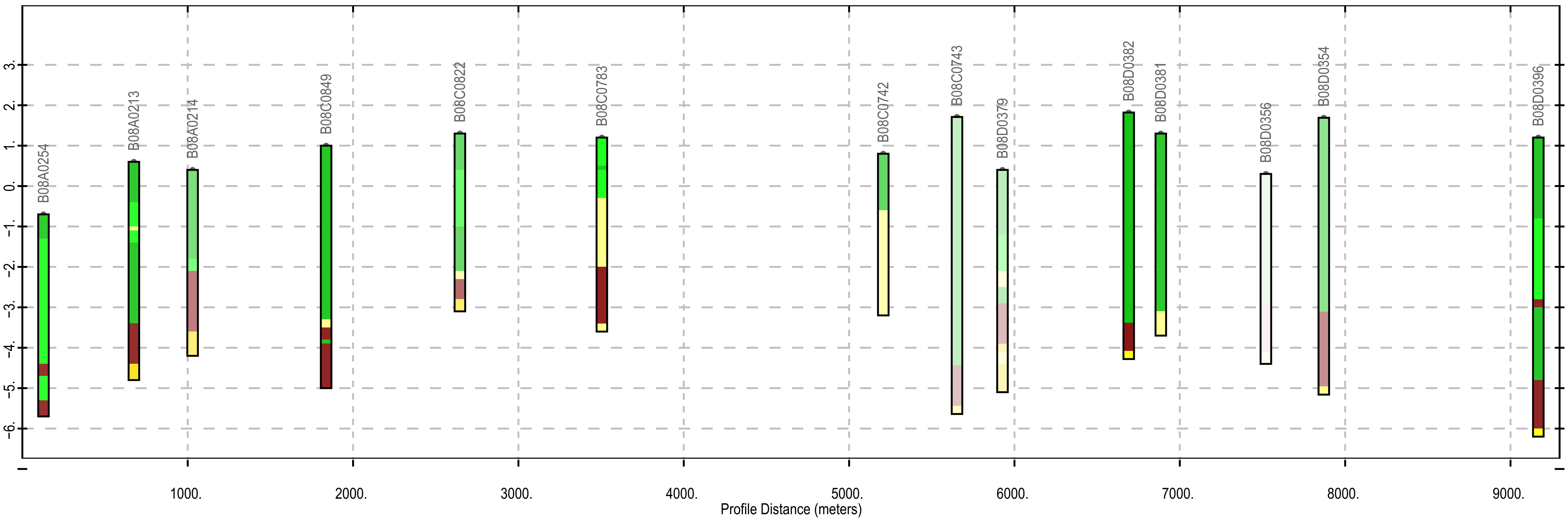


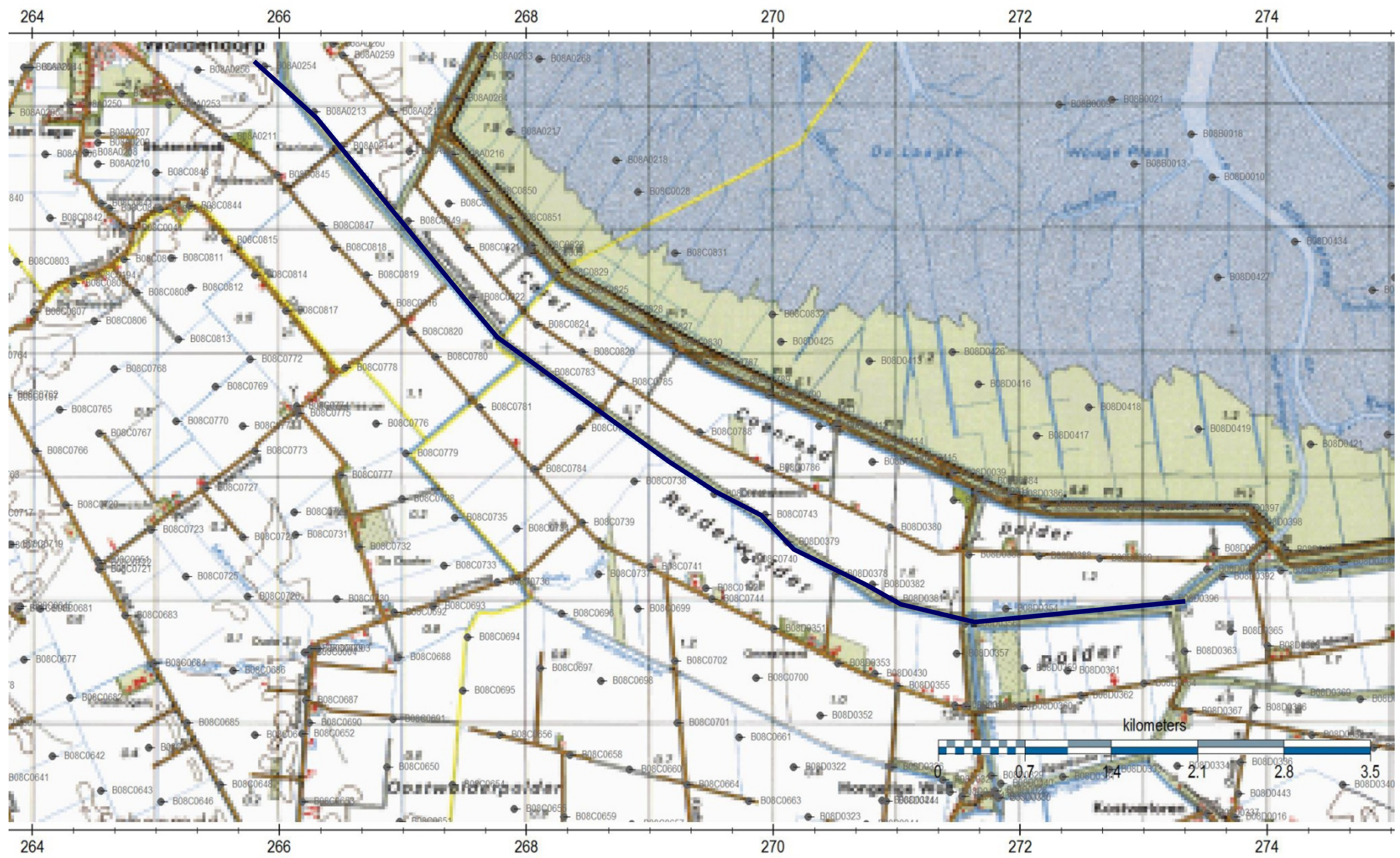
CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





CONSOLIDATED CONSTANT VOLUME DSS TEST
CYCLIC LOADING STAGE





- Zand onbekend
- Veen
- Klei
- Zandige klei/leem
-
- Fijn zand
- Matig fijn/grof zand
- Grof zand
- Grind
-
- Zand onbekend