

Oedometer tests on frozen cores from Qaanaaq, Greenland

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1 Introduction

This report summarizes incremental loading oedometer tests conducted on specimens of frozen fine grained sediments from the Qaanaaq area. As part of the site investigations conducted in Qaanaaq in the summer of 2017, 23 boreholes were drilled using a Nordmeyer DSB 3 drill rig. As the area is affected by continuous permafrost, the boreholes were drilled using a special hollow stem auger (ice auger) for coring of fine grained frozen sediments, while coarser sediments and rock were drilled using down-the-hole (DTH) hammer. Intact permafrost cores were described and photo-documented on-site. They were then packed in Tubolit foam tubes for insulation and placed in core boxes in a temperature controlled container at a temperature of -10 °C for shipment to Denmark, where they were classified and tested in the Permafrost Laboratory of the Technical University of Denmark.

1.1 Sample preparation and selection

Most formations encountered during drilling operations in Qaanaaq were relatively coarse grained and unsuitable for consolidation testing in the small-ring (35 mm diameter) setup available in the temperature controlled DTU permafrost laboratory. Samples were thus selected from the few available intact frozen cores of silty and clayey soils retrieved from boreholes QAA2017-14 (airport), QAA2017-18 (beach east of town) and QAA2017-22 (by power plant). The locations of these boreholes are illustrated on the map in figure 1.1, and borehole profiles are available in appendix A. The cores and final samples selected are listed in tables 1.1 and 1.2.

Sample classification was conducted according to the Danish practice for engineering geological sample description (Larsen et al., 1995), and ice contents were classified according to the visual/manual procedure (ASTM-D4083-89, 2007).

	Borehole	Lab no.	Depth [mbgs]	Location in core	thaw branch σ' [kPa]	Reference
1	QAA2017-14	06B	2.50-2.78	Bottom	114 kPa	[2]
2	QAA2017-14	09A2	4.46-4.66	Bottom	149 kPa	[2]
3	QAA2017-14	09B	4.73-4.77	-	160 kPa	[1]
4	QAA2017-14	23A	10.98-11.01	-	280 kPa	[1]
5	QAA2017-18	03C	1.25-1.35	Тор	32 kPa	[3]
6	QAA2017-22	27B	12.67-12.77	Bottom	309 kPa	[3]
7	QAA2017-22	27A	12.63-12.67	-	200 kPa	n.a.

Table 1.1: Cores selected for oedometer testing and the requested load in the thaw branch for each test. References to reports where data were first reported are given in the last column.

[1] Experiment reported in Vakulenko (2018a)

[2] Experiment reported in Vakulenko (2018b)

[3] Experiment reported in Kristensen (2019)

[n.a.] Experiment is not reported elsewhere

According to the borehole logs, all cores were classified as CLAY with varying components of silt and sand. All core material was classified as "well bonded" with no visible ice (Nbn or Nbe) or visible ice in the form of distinctly oriented ice formations (Vs) or individual inclusions (Vx). No separate classification has been carried out of the samples selected for oedometer tests. Cores and specific material for the consolidation tests were selected to avoid segments with larger grains (gravel), as such grains would dominate the experimental results in the small specimens used. Segments with high excess ice contents were also avoided, as the presence of excess ice significantly complicates the preparation of a regular shaped test specimen.

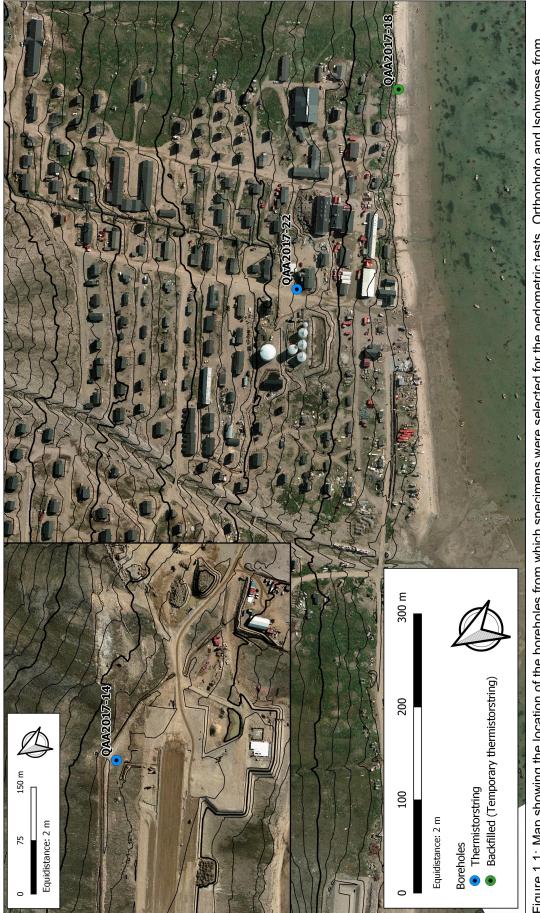


Figure 1.1: Map showing the location of the boreholes from which specimens were selected for the oedometric tests. Orthophoto and Isohypses from Asiaq, Greenland Survey.

Table 1.2: Final samples prepared for oedometer tests. Soil classification and description of ice contents relate to the full core runs from which the samples were selected, and were obtained from the borehole logs.

	Borehole	Lab	Depth	Description
1	QAA2017-14	06B	2.77 m	CLAY, silty, shell fragments, black, saline. ICE: Nbe, Vs at the bottom of core
2	QAA2017-14	09A2	4.65 m	CLAY, black, ICE: Nbn
3	QAA2017-14	09B	4.75 m	CLAY, black, ICE: Nbn
4	QAA2017-14	23A	11.00 m	CLAY, silty, Very dark gray, ICE: Nbn
5	QAA2017-18	03C	1.26 m	CLAY, v. silty, saline, ICE: Nbn
6	QAA2017-22	27B	12.76 m	CLAY, silty, sandy to v. sandy, very dark gray to black, saline. ICE: Nbn/Vs
7	QAA2017-22	27A	12.65 m	CLAY, silty, sandy to v. sandy, very dark gray to black, saline. ICE: Nbn/Vs

Originally cores were drilled with ice augers of 70 mm inner diameter. Sub-sampling of the frozen core material was performed using a core drill mounted in an upright drilling machine at -10 °C. Subsequently the samples were manually adapted to the test ring using a Stanley knife.

2 Oedometer testing

2.1 Test method

The test specimens were trimmed to an initial height of approximately 20 mm and a ring inner diameter of approximately 35.7 mm and installed in a liquid free standard geotechnical oedometer apparatus as illustrated in figure 2.1. Except for sample dimensions, the test procedure follows DS/CEN ISO/TS 17892-5 with necessary modifications to allow for testing at sub-zero temperatures.

The oedometers were placed in a temperature-controlled environment, with continuous temperature measurements by PT100 sensors installed in the drainage channel below the filter stone. Furthermore, the temperature of the climate chamber and the computer room (where loggers and signal conditioners were located) was continuously monitored using thermistors.

The consolidation process has been divided in a frozen branch (loading), a thawing branch (constant load), and an unfrozen branch (unloading and reloading). In the frozen branch, the samples were initially loaded incrementally at constant temperature to the load levels given listed in table 1.1 as [Thaw branch σ']. This selected thaw branch loads were typically selected based on the in-situ stress levels experienced by the samples. In the thawing branch, the sample temperature was gradually increased at constant load, to allow thawing to occur and to register the effects of increasing unfrozen water content. In the unfrozen branch, the samples were incrementally unloaded and reloaded to a maximum load of 2400 kPa in order to determine the unfrozen deformation properties. The load and temperature scheme is shown in table 2.1 for two of the samples. The duration of each load step was individually adjusted to ensure primary consolidation had completed and the creep phase was well described. For thaw branch temperature steps, the duration was adjusted to ensure stabilization at the new temperature level. The remaining samples were tested with similar programs, adjusted for the relevant thaw branch loads.

The sample deformation was logged at a one second interval for the first hour of each new step and with an interval of 30 s for the remainder of the step. Temperatures of sample, climate chamber and computer room were continuously logged at an interval of 30 s.

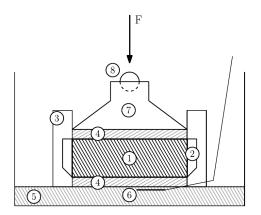


Figure 2.1: Sketch of the oedometer cell. 1) Specimen, 2) specimen ring, 3) constraining steel ring, 4) top and bottom filter stone, 5) steel base, 6) PT-100 sensor for sample temperature monitoring, 7) pressure head and 8) LVDT for strain readings is mounted here. F indicates direction of load application (Agergaard, 2017)

Thaw b	oranch load 114	kPa	Thaw I	oranch load 149	kPa
Stress level	Temperature	Duration	Stress level	Temperature	Duration
1.5 kPa	−9.0 °C	2 h	1.5 kPa	−9.3 °C	2 h
12 kPa	−10.0 °C	3 h	12 kPa	−10.2 °C	3 h
22 kPa	−10.9 °C	16 h	22 kPa	−11.0 °C	16 h
42 kPa	−11.0 °C	25 h	42 kPa	−11.1 °C	25 h
73 kPa	−11.0 °C	25 h	80 kPa	−11.1 °C	25 h
114 kPa	−11.0 °C	21 h	149 kPa	−11.1 °C	21 h
114 kPa	−11.6 °C	48 h	149 kPa	−9.3 °C	48 h
114 kPa	−7.5 °C	24 h	149 kPa	−7.6 °C	24 h
114 kPa	−6.2 °C	54 h	149 kPa	−6.3 °C	54 h
114 kPa	−5.2 °C	42 h	149 kPa	−5.3 °C	42 h
114 kPa	-4.2 °C	33 h	149 kPa	−4.3 °C	33 h
114 kPa	−3.3 °C	39 h	149 kPa	−3.5 °C	39 h
114 kPa	−2.4 °C	24 h	149 kPa	−2.5 °C	24 h
114 kPa	−1.2 °C	45 h	149 kPa	−1.4 °C	45 h
114 kPa	4.0 °C	26 h	149 kPa	3.9 °C	26 h
73 kPa	4.7 °C	1 h	83 kPa	4.6 °C	1 h
27 kPa	4.8 °C	1 h	22 kPa	4.6 °C	1 h
1.5 kPa	4.7 °C	14 h	1.5 kPa	4.5 °C	14 h
155 kPa	4.8 °C	14 h	155 kPa	4.8 °C	14 h
308 kPa	6.8 °C	17 h	308 kPa	6.7 °C	17 h
614 kPa	6.2 °C	24 h	614 kPa	5.7 °C	24 h
1226 kPa	5.4 °C	22 h	1226 kPa	5.1 °C	22 h
2451 kPa	5.2 °C	41 h	2451 kPa	5.0 °C	41 h
1226 kPa	5.2 °C	1 h	1226 kPa	5.0 °C	1 h
614 kPa	5.2 °C	1 h	614 kPa	5.1 °C	1 h
308 kPa	5.3 °C	1 h	308 kPa	5.1 °C	1 h
155 kPa	5.3 °C	1 h	155 kPa	5.1 °C	1 h
1.5 kPa	5.3 °C	3 h	1.5 kPa	5.1 °C	3 h

Table 2.1: Two examples of the program for load and temperature steps for temperature controlled consolidation tests with the initial frozen loading branch extending to either 114 kPa or 149 kPa. The other tests followed similar programs, with the load in the thaw branch adjusted accordingly.

2.2 Results

The result of the oedometer tests are fully documented in appendices C to I. For each sample the appendices present the following:

- the final stress-strain curve
- the full table of classification parameters for the tested sample
- an overview table of the applied load and temperature steps and the corresponding interpreted results
- · an overview graph of the complete timeseries of strains throughout the experiment

2.2.1 Classification parameters for test specimens

Classification properties of the test specimens were determined by weighing and measuring dimensions of each sample before and after the oedometer tests. The post-testing sample height (used for volume and density calculation) was calculated from the LVDT strain (ε_f) at the end of the final unloading step. One exception is the sample QAA2017-14 S23A, which experienced an unreasonably large rebound during the unloading. In this case the sample was physically measured after disassembling the setup. A summary of the results is presented in Table 2.2, and full details are available in appendices C to I. Table 2.2 summarize all classification data available for the samples; the referenced tests were conducted on material from the same frozen core samples, but not necessarilry on the actual test specimens.

Void ratios (*e*) and ice and water saturations ($S_{r,i}$ before test, $S_{r,w}$ after test) are calculated based on grain densities (ρ_s) measured on the sample material. For samples 1, 2 and 7, grain densities were not measured, so the nearest available measurement from the same borehole was used in the calculations.

The void ratios before test typically range from 0.4 to 0.91, and the ice saturations $(S_{r,i})$ are close to unity. As the unfrozen water characteristics of the samples are unknown, parameters were calculated with the assumption that all water exist as ice in the frozen sample. Similarly, after testing, in the unloaded, thawed state, the water saturation is typically close to unity. Sub-saturation is expected to some extent, as the tests were conducted without water in the chamber around the sample, and thus the samples will not necessarily take in water during unloading. A few samples show apparent water super-saturation after testing $(S_{r,i} > 1)$ which is not physically possible, and must be ascribed to measurement uncertainties (typically geometries or grain density).

All samples tested were saline, with Practical Salinities (S_p , unitless) ranging from 29.5 to 41.8. For comparison, standard seawater has a Practical Salinity of 35.0 by definition (IOC et al., 2010). All samples were relatively fine grained, with grain sizes in the clay and silt fractions constituting between 16 and 89%. Samples classify as Lean Clays (CL) to Silty/Clayey Sands (SC/SM) according to the Unified Soil Classification System (ASTM-D2487-11, 2011). Surprisingly, the two specimens (sample 6 and 7, specimen 27A and 27B) from borehole QAA2017-22 have very different fines content, despite the fact that the specimens are adjacent subsamples of the same core.

2.2.2 Oedometer results

The main results of the oedometer tests are shown in figures 2.3a to 2.3g in the form of stressstrain curves for each tested specimen. During the first two load steps (1.5 kPa and 10 kPa) the system is readjusting to the sample, and thus intial zero strain is typically defined at the end of the 10 kPa load step.

Most samples show limited deformation upon thawing, with thaw branch strains in the range from 2 to 4%. Exceptiona are samples 1 and 4 (QAA2017-14 S06B and QAA2017-14 S23A) which experience 7% to 8% deformation during the thaw branch.

Due to multiple climate chamber malfunction events, a well described thaw branch with several complete temperature steps are only available for samples 1 and 2 (QAA2017-S06B and QAA2017-14 S09A2). These tests document that most of the thaw related strain occurs at temperatures lower than -1.5 °C, which is consistent with the high Practical Salinities of the samples causing a freezing point depression of the porewater. For the remaining samples, the climate chamber malfunction events and resulting uncontrolled (in some cases partial) thaw of the specimens, mean that the thaw branch can be mainly used to estimate the total thaw related strain of the samples. More details of the loading, strain and temperature history of the tests is available in appendices C to I.

In the reloading branch after thawing, where time curves are well-behaved, these have been interpreted using the squareroot-of-time method as described in DS/CEN ISO/TS 17892-5 (2004). The deformation at end of primary consolidation (ε_{100}) and the final deformation (ε_f) at each step is indicated on the stress-strain curves in figure 2.3.

Based on the interpreted 90 % consolidation time, t_{90} [s], the coefficient of consolidation, c_v [m²/s], was calculated as:

$$c_v = \frac{0.848 \cdot L^2}{t_{90}}$$

where L [m] is the drainage path, which equals half of the sample height at 50 % consolidation. The coefficient of secondary compression, C_{α} [%/Ict], is taken as the slope of the linear portion (in a

Table 2.2: Characterization parameters of samples used for oedometer testing, before and after test. See full details in appendices C to I.

Parameter		Unit	Before test	After test
Sample 1: QAA2	017-14	S06B		
Water content	w	[%]	21.15	16.88
Bulk density	$ ho_b$	[g/cm³]	1.96	2.18
Dry density	ρ_d	[g/cm ³]	1.62	1.87
Void ratio	e	[-]	0.62	0.40
Ice saturation	$S_{r,i}$	[-]	0.98	_
Water saturation	$S_{r,w}$	[-]	—	1.09
Sample 2: QAA2	017-14	S09A2 Top)	
Water content	w	[%]	16.45	15.08
Bulk density	$ ho_b$	[g/cm ³]	2.07	2.17
Dry density	ρ_d	[g/cm ³]	1.78	1.89
Void ratio	e^{-}	[-]	0.51	0.42
Ice saturation	$S_{r,i}$	[-]	0.95	_
Water saturation	$S_{r,w}$	[-]	_	0.97
Sample 3: QAA2	017-14	S09B Top		
Water content	w	[%]	14.54	11.82
Bulk density	ρ_b	[g/cm ³]	2.19	2.27
Dry density	ρ_d	[g/cm ³]	1.91	2.03
Void ratio	$e^{\rho u}$	[-]	0.40	0.32
Ice saturation	$S_{r,i}$	[-]	1.06	_
Water saturation	$S_{r,w}$	[-]	_	1.00
Sample 4: QAA2		S23A		
Water content	•w	[%]	18.43	12.96
Bulk density	ρ_b	[g/cm ³]	1.97	2.19
Dry density	ρ_d	[g/cm ³]	1.66	1.94
Void ratio	e^{pa}	[9/ 0111]	0.61	0.38
Ice saturation	$S_{r,i}$	[-]	0.88	-
Water saturation	$S_{r,w}$	[-]	-	0.91
Sample 5: QAA2				
Water content	w	[%]	26.43	20.72
Bulk density	ρ_b	[g/cm ³]	1.96	2.17
Dry density	ρ_d	[g/cm ³]	1.55	1.80
Void ratio	e^{p_a}	[9/0111]	0.77	0.53
Ice saturation	$S_{r,i}$	[-]	1.03	0.00
Water saturation	$S_{r,w}^{Dr,i}$	[-]	-	1.08
Sample 6: QAA2 Water content	017-22 w	527В [%]	14.47	12.22
Bulk density		[70] [g/cm ³]	2.04	2.21
	$ ho_b$			
Dry density Void ratio	$ ho_d$	[g/cm ³]	1.79	1.97
	e	[-]	0.54 0.80	0.40
Ice saturation Water saturation	$S_{r,i}$	[-]	0.80	0.84
	$S_{r,w}$	[-]		0.04
Sample 7: QAA2			00.00	00.44
Water content	w	[%]	30.38	22.44
Bulk density	$ ho_b$	[g/cm ³]	1.88	1.90
Dry density	$ ho_d$	[g/cm ³]	1.44	1.55
Void ratio	e	[-]	0.91	0.77
Ice saturation	$S_{r,i}$	[-]	1.00	_
Water saturation	$S_{r,w}$	[-]		0.80

B	Borehole	Lab no	depth [m.b.g.s.]	w_{tot} [%]	S_p	$ ho_s$ [g/cm3]	$ ho_b$ [g/cm3]	$ ho_d$ [g/cm3]	e 🗆	$S_{r,i}$	[%]	Reference -
QAA	QAA2017-14	06B	2.50-2.78	17.3 ± 1.9	37.8 ± 2.17	n.d.	1.96	1.62	0.62	0.98	n.d.	[2]
QAA	\2017-14	09A2	4.46-4.66	18.4 ± 6.7	37.0 ± 0.98	n.d.	2.07	1.78	0.51	0.95	n.d.	[2]
QAA	\2017-14	09B	4.73-4.77	16.4 ± 0.8	51.1 ± 1.85	2.68	2.19	1.91	0.40	1.06	1.85	Ξ
QAA	\2017-14	23A	10.98-11.01	15.1 ± 2.1	29.6 ± 1.06	2.68	1.97	1.66	0.61	0.88	1.41	Ξ
QAA	QAA2017-18	03C	1.25-1.35	19.7 ± 0.9	$27.0 \pm 2.59^{a)}$	2.74	1.96	1.55	0.77	1.03	1.43	[3]
QAA	\2017-22	27B	12.67-12.77	10.9 ± 2.59^{a}	$41.8 \pm 2.59^{a)}$	2.75	2.04	1.79	0.54	0.80	1.40	[3]
QAA	QAA2017-22	27A	12.63-12.67	14.4	n.d.	.p.u	1.88	1.44	0.91	1.00^{b}	1.48	n.a.

			depth	w_{tot}	w_L	w_P	I_P	I_c	$< 63 \mu m$	C_{u}	C_{c}	USCS	Reference
	Borehole	Lab no	[m.b.g.s.]	[%]	[%]	[%]	[%]	I	[%]	I	Ξ	Ξ	·
-	QAA2017-14	06B	2.50-2.78	17.3 ± 1.9	n.d.	n.d.	n.d.	n.d.	89.1	d.a.	d.a.	n.d.	[2]
2	QAA2017-14	09A2	4.46-4.66	18.4 ± 6.7	n.d.	n.d.	n.d.	n.d.	68.2	d.a.	d.a.	n.d.	[2]
ო	QAA2017-14	09B	4.73-4.77	16.4 ± 0.8	25.1	17.6	7.5	0.49	88.2	d.a.	d.a.	С	[1]
4	QAA2017-14	23A	10.98-11.01	15.1 ± 2.1	26.1	14.4	11.6	0.76	70.6	d.a.	d.a.	С	[5]
2	QAA2017-18	03C	1.25-1.35	19.7 ± 0.9	n.d.	n.d.	n.d.	n.d.	16.7	d.a.	d.a.	n.d.	[3]
9	QAA2017-22	27B	12.67-12.77	10.9^{a}	29.6	16.1	13.5	1.38	17.6	d.a.	d.a.	SC/SM	[3]
2	QAA2017-22	27A	12.63-12.67	14.4	n.d.	n.d.	n.d.	n.d.	75.9	d.a.	d.a.	n.d.	n.a.

^a No documentation available for measurements. However, values correspond to measurements on adjacent samples. ^b Ice saturation assumed unity, ρ_b is derived based on this assumption.

n.d.: Measurement was not conducted, no data available. d.a.: Data is available but not yet processed. For references see table 1.1. The classification of sample 7 is not reported elsewhere.

log(time) transformation) of the creep part of the time curve. The consolidation modulus, K [kPa], is calculated as the ratio of the change in effective stress to the change in strain:

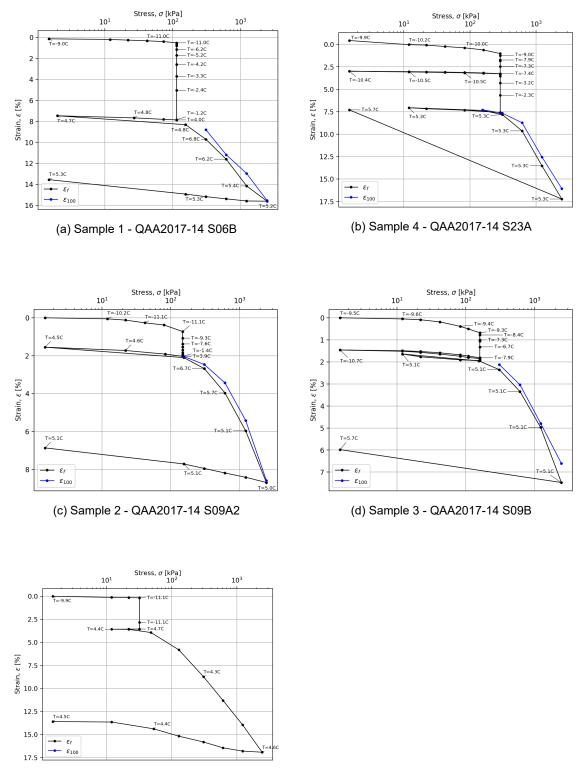
$$K = \frac{\Delta \sigma'}{\varepsilon_{100} - \varepsilon_0}$$

Finally, the coefficient of permeability, k_0 [m/s], is calculated as:

$$k_0 \quad = \quad c_v \cdot \frac{\gamma_w}{K} \quad ,$$

where γ_w [kN/m³] is the specific weight of water, here defined as 10 kN/m³.

The interpreted values of c_v , C_{α} , K and k_0 are tabelized for each test specimen in the respective appendix C to I. The full data sets of strain and temperature time series for each test specimen are available in digital form for further processing and interpretation.



(e) Sample 5 - QAA2017-18 S03C

Figure 2.3: Final Stress-strain curves for each oedometer test. Larger versions are included in appendix C to I.

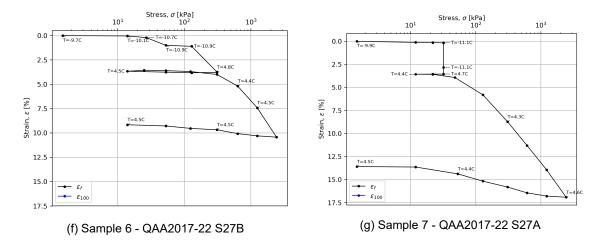


Figure 2.3: Final Stress-strain curves for each oedometer test. Larger versions are included in appendix C to I.

3 Summary

Under temperature controlled conditions, temperature controlled incremental loading oedometer tests have been conducted on 7 samples from the Qaanaaq area. The sample material is classified as CLAY with varying components of silt and sand (or in some cases in the USCS as silty/clayey sand, SC/SM). The samples were collected, transported and prepared in frozen condition for installation in the test setup. The conducted test procedure consisted of an initial frozen loading branch, where samples were loaded to stess levels in the range 32 kPa to 309 kPa, depending on the sampling depth and target test application. The samples where then allowed to thaw under constant load and using specified temperature steps from -10 °C to 5 °C (thawing branch). The following unloading/reloading sequence, where samples were loaded to a final stress level of 2400 kPa, was conducted in unfrozen state (unfrozen branch). Finally, the samples were unloaded and removed from the setup.

Stress-strain curves are presented for the 7 tests and show thaw strains varying from around 2 % to 4 % during the thawing branch, with one sample experiencing 8 % deformation. The samples experience the largest thaw strains at temperatures below -1.5 °C due to pore water of high salinities causing a freezing point depression. All samples are slightly pre-consolidated, most likely a result of the natural freezing process. Based on the test results we interpret these sediments as post-glacial deposits, as their pre-consolidation stresses are much lower than would be expected, had they experienced the load of an ice cap.

The tested specimens all had relatively low excess ice contents. Core segments with high excess ice contents were avoided where possible, as the presence of excess ice makes it very difficult (impossible with the tools available) to prepare a regularly shaped test specimen. For segments where gravimetric water contents or bulk densities indicate the presence of excess ice, the excess ice should be specifically considered when estimating the deformation properties.

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A Borehole logs

Weder table: 2017-08-19, 0.77 m b.g.s. Frost table: 2017-08-19, 1.64 m b.g.s. GRAVEL, st silly v. sandy, st. gravely, gray to black (Coarse boulder) Image: Coarse boulder) 10 GRAVEL, st silly v. sandy, st. gravely, gray to black (Coarse boulder) Image: Coarse boulder) 11 GRAVEL, st silly v. sandy, st. gravely, gray to black (Coarse boulder) Image: Coarse boulder) 11 Image boulder) Image boulder) 12 (Large boulder) Image boulder) 13 (Large boulder) Image boulder) 14 Image boulder) Image boulder) 15 (Large boulder) Image boulder) 16 Grave boulder) Image boulder) 17 Image boulder) Image boulder) 18 Unside ice crystably Image boulders, dask brownish gray 19 Visible ice crystably Image boulders, graysh brown 10 Image boulder) Image boulders, dask brownish gray 10 Image boulder) Image boulders, dask brownish gray 10 Image boulder, crystably Image boulders, graysh brown 10 Image boulder, crystably Image boulders, graysh brown 11 Image boulder, crystably Image boulders, graysh brown 11 I				20	01	7	-14 Oaanaaq, Airport, North o	f runway				
18 Frost table: 2017-08-19, 1.64 m b.g.s. 19 5 SARD. days, sliv, gravelly, w. boulders, dark graysh brown 10 SARD. days, sliv, gravelly, graysh brown 10 CLAY, sliv, v. sandy, sl. gravelly, graysh brown 11 CLAY, sliv, v. sandy, sl. gravelly, graysh brown 12 Gecoming gray) 12 (Large boulder) 13 (Large boulder) 14 Gecoming gray) 15 (Large boulder) 16 Gecoming gray) 16 Gecoming gray) 17 (Large boulder) 18 Gecoming gray) 19 Gecoming gray) 10 Gecoming gray) 10 Gecoming gray) 11 Gecoming gray) 12 Gecoming gray) 13 (Large boulder) 14 Gecoming gray) 15 (Large boulder) 16 Gecoming grayshible 17 (Gecoming crystals) 18 Gecoming grayshible 19 (Mabbe ice crystals) 19 (Mabbe ice crystals) 19	Depth (m)	Lithology	Sample color	Water/frost	Sample	Sample No.	Soil description / Observations		Construction	Drilling tool	SPT results	Denth (m)
1/1 1.6.5 m 1/2 SADD clayey, sity, gravely, graysh brown 1/3 SADD clayey, sity, gravely, graysh brown 1/4 CLAY, sity, v. sandy, sit gravely, graysh brown 1/4 CLAY, sity, v. sandy, sit gravely, graysh brown 1/4 Gravet, sit, gravely, redskin hrown 1/4 Gravet, sit, gravely, w. brutklers, dark brownish gray 1/4 Gravet, sit, gravely, w. brutklers, dark brownish gray 1/4 Gravet, sit, sit, w. sandy, sit, gravely, w. brutklers, graysh brown 1/4 Gravet, sit, sit, sit, w. brutklers, graysh brown 1/4 Gravet, sit, sit, w. brutklers, graysh brown 1/4 Gravet, sit, sit, sit, w. brutklers, graysh brown 1/4 Gravet, sit, sit, sit, w. brutklers, graysh brown 1/4 Gr	18 -											Ē
1/1 1/2 CRAVEL, sl. silly, v. sandy, w. boulders, dark graysh brown 1/2 1/2 CRAVEL, sl. silly, v. sandy, sl. gravelly, graysh brown 1/2 1/2 1/2 CRAVEL, sl. silly, v. sandy, sl. gravelly, graysh brown 1/2 1/2 1/2 CRAVEL, sl. silly, v. sandy, sl. gravelly, graysh brown 1/2 1/2 1/2 CRAVEL, sl. silly, v. sandy, sl. gravelly, graysh brown 1/2 1/2 1/2 CRAVEL, sl. silly, v. sandy, sl. gravelly, roddsh brown 1/2 1/2 1/2 CRAVEL, sl. silly, v. sandy, sl. gravelly, roddsh brown 1/2 1/2 1/2 CRAVEL, sl. silly, v. sandy, sl. gravelly, roddsh brown 1/2 1/2 1/2 CRAVEL, sl. silly, v. sandy, sl. gravelly, roddsh brown 1/2 1/2 1/2 CRAVEL, sl. silly, v. gravelly, w. boulders, graysh brown 1/2 1/2 1/2 Crave boulder) 1/2 1/2 1/2 1												È
16 2 2 SAND, clayer, sity, gravely, gravely, gravely, gravely or black 16 1	17 - - -						V					Ē
15	16 -	0.0		Ā						AUG		F
14 15 Coarse boulder) 16 13 17 8 (Becoming grey) 14 17 8 15 17 8 16 17 18 17 18 (Large boulder) 18 (Large boulder) 19 (Large boulder) 10 14 14 (Large boulder) 15 (Large boulder) 16 (Large boulder) 17 (Large boulder) 18 (Large boulder) 19 (Large boulder) 10 17 10 17 10 18 11 17 12 (Large boulder) 13 (Large boulder) 14 (Large boulder) 15 17 16 18 17 10 18 19 19 (Large boulder) 10 10 10 10 10 10 11 10 12 10 13 10 14 10 15 10 16 10 17 1	15	<i>∕</i> ^ ∕										È
13 0 </td <td>```‡</td> <td>\square</td> <td></td> <td></td> <td></td> <td>5</td> <td>(Coarse boulder)</td> <td></td> <td></td> <td>CUT</td> <td></td> <td>F</td>	```‡	\square				5	(Coarse boulder)			CUT		F
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12 1	13					7						Ē
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4 26 CLAY, Silly, sandy, gravelly, w. boulders, dark brwonish gray (Visible ice crystals) 3 28 (Many visible ice crystals) 4 29 (Visible ice crystals) 3 30 (Visible ice crystals) 4 33 (Visible ice crystals) 1 33 (Visible ice crystals) 2 34 (Visible ice crystals) 3 (Visible ice crystals) 4 34 (Visible ice crystals) 1 33 (Visible ice crystals) 1 34 (Visible ice crystals) 1 (Visible ice crystals) (no visible ice) 1 37 (Iarge boulder) 1 40 (Drilling terminated at 20.40 m.b.g.s.) 0 41 (Drilling terminated at 20.40 m.b.g.s.) 0 41 (Drilling information: 0 0 6' dry rotation / DTH / Coring 0 0 0' dry rotation / DTH / Coring 0 0 0' dry rotation / DTH / Coring 0 0' dry rotation / DTH / Coring 0' dry rotation / DTH / Coring 0 0' dry rota	5				F	23		+		IOL		F
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1 0 (Visible ice crystals) 1 31 (Visible ice crystals) 33 SAND, SI. silty, v. gravelly, w. boulders, grayish brown 0 33 4 (Visible ice crystals) (Visible ice crystals) (Visible ice crystals) (Invisible ice crystals) (Invisible ice crystals) (Invisible ice crystals) (Invisible ice) (Inv	2	0.0							Ŷ			Ē
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0 34 (Visible ice crystals) 1 35 (few visible ice crystals) 1 36 (few visible ice crystals) 1 36 (no visible ice) 2 36 (Large boulder) 4 (Drilling terminated at 20.40 m.b.g.s.) ICE 0 0 0 4 0 0 4 0 0 4 0 0 4 0 0 4 0 0 4 0 0 4 0 0 0 0 0 4 0 0 4 0 0 4 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 <td< td=""><td>1-</td><td></td><td></td><td></td><td></td><td></td><td>SAND, sl. silty, v. gravelly, w. boulders, grayish brown</td><td></td><td></td><td>DTH</td><td></td><td>F</td></td<>	1-						SAND, sl. silty, v. gravelly, w. boulders, grayish brown			DTH		F
(few visible ice crystals) (no visible ice) (no visible ice) (arge boulder) (Large boulder) (Drilling terminated at 20.40 m.b.g.s.) (Drilling information: x: 491004.7 m y: 8601163.3 m z: 16.5 m Ref sys: UTM Zone 19N / GR96 Height ref: Mean sea level Drilling with the system of the syst	0	0					(Visible ice crvstals)	ļ				Ē
2 37 38 39 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40		0			_			 				Ē
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x: 491004.7 m y: 8601163.3 m z: 16.5 m Drilled by: GEO / TBH Drilling method: 6" dry rotation / DTH / Coring Qaanaaq site investigations Ref sys: UTM Zone 19N / GR96 Completed: 2017-08-07 Drilling rig: Nordmeyer DSB-3 Drawn by: QC by: TIN NF Height ref: Mean sea level Logged by: CSL Sampling method: Bag / Core Status:	4	.•					(Drilling terminated at 20.40 m.b.g.s.)	• •	Ľ	ICE		Ē
c: 491004.7 m y: 8601163.3 m z: 16.5 m Drilled by: GEO/TBH Drilling method: 6° dry rotation / DTH / Coring Ref sys: UTM Zone 19N / GR96 Completed: 2017-08-07 Drilling rig: Nordmeyer DSB-3 Drawn by: QC by: TIN NF Height ref: Mean sea level Logged by: CSL Sampling method: Bag / Core Status:	1 oordina	ates:			<u> </u>	J	Drilling information:		Project:	1		1
Height ref: Mean sea level Logged by: CSL Sampling method: Bag / Core				-					Drawn by:		by:	ins
Draft: Field log	-							•	Status:			

Q	A	A :	20	17	-18	Qaanaaq, East town, be	each, possible p	ier loca	ntior	ו	
	Lithology	Sample color	Water/frost	Sample No.	Soil des	cription / Observations	0 25 25 25	- 100 Construction	Drilling tool	SPT results	
1					Water table: Not						F
2						2-08-11, 0.59 m.b.g.s.					F
. 1					0.9 m						ŧ
			E	1		dium, sorted, light yellowish brown	1		AUG		Ē
	0.		7	2 3		y, gravelly, dark gray bly at 0.5 m.b.g.s.?)	Į				ŀ
	ø				(becoming less s	andy and gravelly)			ICE		E
	0		1	4					ICL		F
	0			5	(1	and a dada and the			CUT		E
	/0			6	(Large boulder)	sandy, darker gray/black			CUT/ ICE		ŧ
-			Æ	7	(Large boulder)	, v. sandy, brownish gray			CUT ICE		
) C	э. о		1	8			f				ł
			Æ	9							E
	0.0		//-	10 11	(Large boulder)	, v. sandy, grayish brown					ŀ
].c	0.0		1/-	12	GRAVEL, SI. SIIIY	, v. sanuy, grayish blown					
	ò		1	13				Ų			
	o.e			14	(Large boulder)						
0	0 0	1	2	15 16	(Many visible ice	crystals, ice layer at 8.40 m.b.g.s.)					ł
). .0 (1	17	(Few visible ice c		•				
0	0	1	1	18	(Few visible ice c						ŀ
	o q			19	(Large boulder) (Few visible ice c	rystals)	N				ł
	<u></u>		//-	20 21	(Large boulder) SANDSTONE, qu	uartz, pale	/				
X	X		1/-	22			ł				ŀ
X	X			23			Ì		DTH		
-18	X		Æ	24 25			V				ŀ
18	প্ল		1	25	(w. shale layers -	-13.4-13.6 m.b.g.s.)	•				
18	8		1	27			•				ł
18	X	-	Æ	28	(w. shale layers -	-14.5 m.b.g.s.)					Ē
X	X		Æ	29 30	(w. shale layers -	15.0-15.4 m.b.g.s.)	Ţ				ŀ
X	X		/-	30			ł				E
X	X		1	32	(w. shale layers -	-16.5-16.8 m.b.g.s.)	•				ŀ
$\frac{1}{8}$	X			33			t				F
-₿	Ø			34 35			F				ŀ
₿ }	8		1	36		10 7 10 0 m h m c)	•				F
'Å	X		1	37	(w. shale layers -	.18.7-18.8 m.b.g.s.)	t				ŧ
12	8	1	/	38		· · · · · ·					F
1				39	(Drilling terminate	ed at 20 m.b.g.s.)					Ē
						Drilling information:		Project			1
		9 m	y:	85985	560.7 m z: 0.9 m	Drilling information: Drilled by: GEO / TBH Drilling method:	6" dry rotation / DTH / Coring	Project: Qaanaaq		-	ons
ef sys	: U	TM Z	one	19N / (Completed: 2017-08-12 Drilling rig:	Nordmeyer DSB-3	Drawn by: TIN	QC	by: NF	
eight r	ref:	Mea	n sea	level		Logged by: CSL Sampling method:	Bag / Core	Status: Dra	ıft: Field	log	

	ole name		20)1	7 .	-22 Qaanaaq, East town, next to	power pla	nt			
Leptn (m)	Lithology	Sample color	Water/frost	Sample	Sample No.	Soil description / Observations	0 25 50 ≪ 75	- 100 Construction	Drilling tool	SPT results	
2 .						Water table: 2017-08-15, 0.18 m.b.g.s.					E
- 1 -						Frost table: 2017-08-20, 1.30 m.b.g.s.					Ē
-						<u>15.3 m</u>					-
0 -			$\underline{\nabla}$		1	FILL?, SAND, sl. silty, gravelly, brown	- •				F
-					2	FILL?, GRAVEL, sandy, w. stones, brown			AUG		ŧ
1-					3 4	FILL?, SAND, gravelly, w. stones, brown FILL?, GRAVEL, sandy, dark yellowish brown. ICE: Nbn	•		СИТ		E
- 2 –					5	FILL?, SAND, medium to coarse, silty, brown		X			ŀ
-	9				6	SAND, fine, silty, shell fragments, olive gray	\neg	\diamond	DTH		F
3 -	· · · · ·				7 8	SILT, sandy, gravelly, shell fragments, black. ICE: Nf SILT, sandy, gravelly, shell fragments, black. ICE: Nf to Nbn	Å				E
-	<u>`````</u>				9	SILT, Sanuy, gravelly, shell lragments, black. ICE. Ni to Nbh	/		ICE		F
4 -	. 0 . 0	_			10	GRAVEL, v. sandy, w. stones, light olive brown to dark grayish brown	lf i				F
- 5 -	o				11		I				E
 -	· · • ·				12	(Large boulder, 5.4m to 6.2m)	Ĭ	1 A A A A A A A A A A A A A A A A A A A			F
- 6 –	.oo.				13 14						ŀ
-	e				15		+		DTH		F
7 -	· · · · ·			_	16		+				F
					17		\				ŀ
- 8	· 9 • • • • •				18	SAND, fine to medium, silty, gravelly, dark olive gray	İ				Ē
- 9 –					19	GRAVEL, sandy, light olive brown	1				F
-	· 9				20 21	SAND, fine, silty, very dark grayish brown	↓				ŀ
- 0					22	(Large boulder ~9.5-9.7 m.b.g.s.)	4				F
-					23	SILT, sandy, v. gravelly, black. ICE: Nbn			ICE		F
1 -					24	CLAY, sandy, black. ICE: Nbn GRAVEL, sl. silty, v. sandy, olive gray					ŀ
- 2 –	? <i>:/?</i> ;				25	CLAY, silty, sl. sandy, saline, very dark gray	\neg		DTH		t
- 2					26	CLAY, silty, sandy to v. sandy, very dark gray to black, saline. ICE: Nbn/Vs	Ţ				F
- 3 –					27 28	CLAY, silty, sandy to v. sandy, very dark gray to black, same. ICL. Non/Vs CLAY, silty, sandy, shell fragments, saline, dark olive gray	 4		ICE		ŀ
-				_	29	(Few visible ice crystals)	+				ŀ
4 -	· · · · ·			_	30	SAND, sl. silty, v. gravelly, w. stones, grayish brown	→				
-	• •				31	SAND, gravelly, light brownish gray	l f				ŀ
5 -	o 				32		Ì				ŀ
- 6 –	°.o.				33	SAND, sl. gravelly, olive brown	Ĭ				F
-	°				34 35	SAND, sl. silty, sl. gravelly, olive brown			DTH		ŀ
7 -	0.0				36		 				Ē
-	×			_	37	SANDSTONE, dark gray	_ •				ŀ
8 -	\otimes				38	(Weathered zone, 17.6 to 18.8 m)					ŧ
- - 9 –	\otimes				39		\boldsymbol{V}				Ē
-	\otimes				40	SANDSTONE, white	Į.				F
- 0 –	888				41 42	(Drilling terminated at 20.0 m.b.g.s.)	_₽				F
- - 1 -						(criming terminated at 20.0 m.b.g.s.)					Ē
1	inator					Drilling information		Project			[-
	linates: 194516.	.6 m	v	85	987 <i>f</i>	Drilling information: 62.7 m z: 15.3 m Drilled by: GEO / TBH Drilling method: 6" dry rot	ation / DTH / Coring	Project: Qaanaaq			n
	sys: U						ver DSB-3	Drawn by: TIN	QC	^{by:} NF	
leig	ght ref:	Me	an se	ea lev	vel	Logged by: CSL Sampling method: Bag / Co	re	Status:	boreho		-

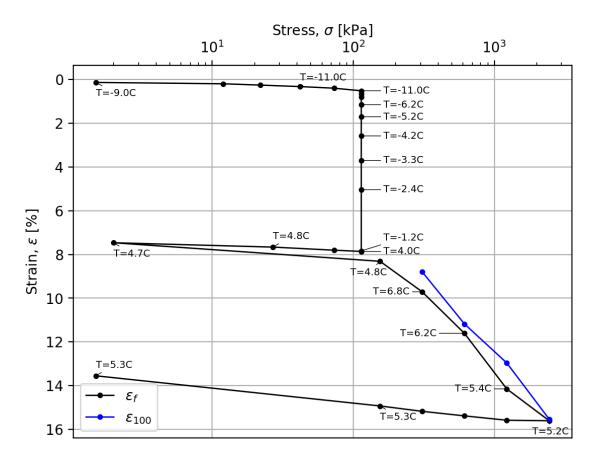
B Data anomalies

Table B.1: Description of observed data anomalies and events during the oedometer tests.

Step	Approx. time	Description
Sample 1: Q	AA2017-14 S06B, and	
Sample 2: Q	AA2017-14 S09A2 Top	
Step 7	2018-11-13 01:15	Cold room malfunction, temperature dropped to -25 °C.
Step 7	2018-11-13 09:00	Cold room control system reset.
Step 7	2018-11-13 11:00	Cold room temperature reached set point at -10°C
Step 12	2018-11-22 08:05	LVDTs register slight drop due to vibration from activity in adjacent room.
Steps 16-24	2018-11-26 to 2018-11-29	Vibrations from construction works outside building.
Sample 3: Q	AA2017-14 S09B Top, and	
Sample 4: Q	AA2017-14 S23A	
Step 9-10	2018-09-17 14:07	Datalogger was reset due to installation of voltage divider.
Step 11-12	2018-09-19 13:40	Cold room was opened to replace cables. Sample 2 shows high increase of strain in this period.
Step 12-13	2018-09-20 10:00	New LVDT were installed, defrost cycle was set to 8 hours, heating system enabled.
Sample 5: Q	AA2017-18 S03C, and	
Sample 6: Q	AA2017-22 S27B	
Step 1	2019-01-16 22:00	Cold room malfunction for about 2 hours, little impact on sample.
Step 5	2019-01-21 6:00	Cold room malfunction. Severe thawing of samples. Samples refroze upon cold room restart, but the thaw phase
		had progressed too far for additional meaningful T-steps,
		so samples were eventually thawed out.
Sample 7: Q	AA2017-22 S27A	
-	-	Noanomalies encountered.

C Sample "QAA2017-14 S06B"

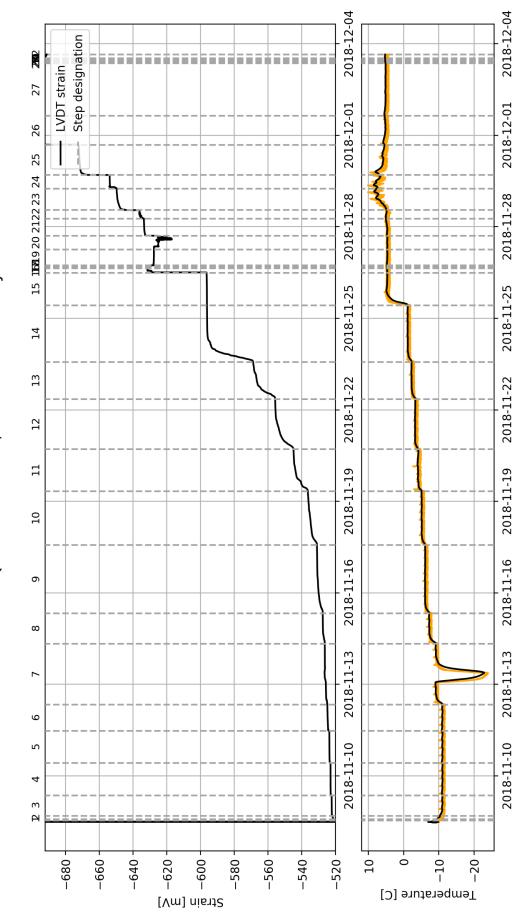
C.1 Consolidation curve



Parameter	Value
Name	QAA2017-14 S06B
Depth	2.71-2.75 m
Start date	2018-11-08
End date	2018-12-03

	1																											
$k_0 [m/s]$																				$8.796 imes10^{-9}$	1.894×10^{-10}	$4.876 imes10^{-9}$	$2.913 imes10^{-9}$					
K [kPa]																				17397	19475	25566	46537					
$c_v [m^2/s]$																				$1.530 imes10^{-5}$	$3.688 imes 10^{-7}$	$1.247 imes10^{-5}$	$1.356 imes 10^{-5}$					
C_{lpha} [%/lct]																				0.217	0.146	0.221	0.024					
ε_f [%]	0.129	0.191	0.251	0.319	0.392	0.512	0.670	0.793	1.145	1.697	2.576	3.694	5.032	7.838	7.862	7.804	7.663	7.464	8.314	9.709	11.609	14.151	15.608	15.585	15.385	15.177	14.932	13.552
ε_{100} [%]																				8.792	11.178	12.964	15.538					
ε_{50} [%]																				8.352	10.392	11.767	14.222					
ε_0 [%]																				7.913	9.606	10.570	12.906					
T [°C]	-9.0	-10.0	-10.9	-11.0	-11.0	-11.0	-11.6	-7.5	-6.2	-5.2	-4.2	-3.3	-2.4	-1.2	4.0	4.7	4.8	4.7	4.8	6.8	6.2	5.4	5.2	5.2	5.2	5.3	5.3	5.3
σ [kPa]	1.5	12.0	22.0	42.0	73.0	114.0	114.0	114.0	114.0	114.0	114.0	114.0	114.0	114.0	114.0	73.0	27.0	1.5	155.0	308.0	614.0	1226.0	2451.0	1226.0	614.0	308.0	155.0	1.5
Step	~	7	ო	4	5	9	7	8	б	10	7	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28

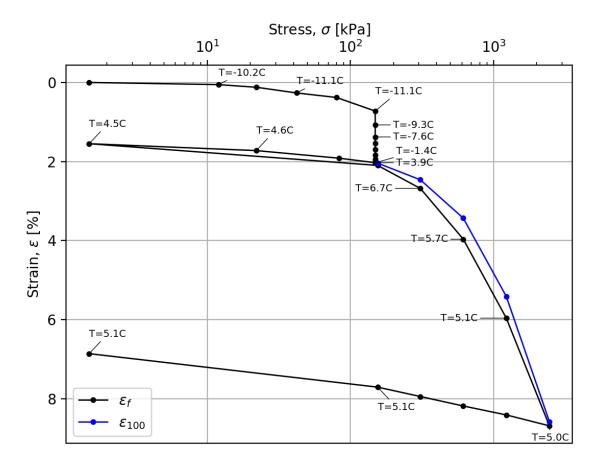
C.2 Overview of load steps and interpreted results



Name: QAA2017-14 S06, Duration: 25.1 days

D Sample "QAA2017-14 S09A2"

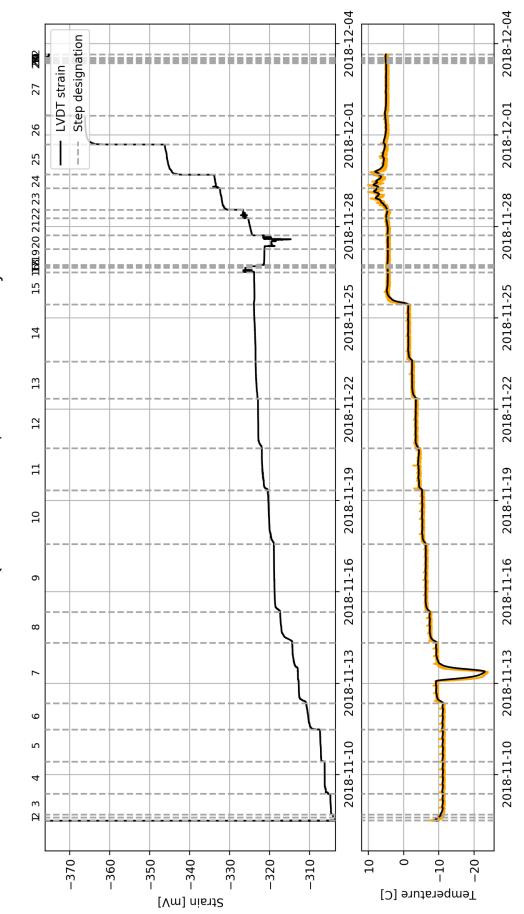
D.1 Consolidation curve

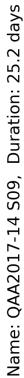


Parameter	Value
Name	QAA2017-14 S09A2
Depth	4.46-4.66 m
Start date	2018-11-08
End date	2018-12-03

ε_f [%] C_{α} [%/lct] c_v [m ² /s]	$arepsilon$ [%] $arepsilon_f$ [%] C_{lpha} [%/lct]	$arepsilon_0$ [%] $arepsilon_{100}$ [%] $arepsilon_{100}$ [%] $arepsilon_{100}$ [%/lcf]	$\int \varepsilon_0 [70] \varepsilon_{50} [70] \varepsilon_{100} [70] \varepsilon_f [70] C_{\alpha} [70/10]$	
0.001	0.001			-9.3
0.056	0.056			-10.3
0.123	0.123			-11.0
0.266	0.266			-11.1
0.381	0.381			-11.1
0.725	0.725			-11.1
1.075	1.075			-9.3
1.380	1.380			-7.6
1.537	1.537			-6.3
1.690	1.690			-5.3
1.839	1.839			-4.3
1.934	1.934			-3.5
1.989	1.989			-2.5
2.034	2.034			-1.4
2.031	2.031			3.9
1.917	1.917			4.6
1.725	1.725			4.6
	1.551	1.551	1.551	1.551
0.036	0.036	1.267 1.655 2.042 2.100 0.036	1.267 1.655 2.042 2.100 0.036	4.8 1.267 1.655 2.042 2.100 0.036
0.072	2.683 0.072	1.902 2.183 2.465 2.683 0.072	1.902 2.183 2.465 2.683 0.072	6.7 1.902 2.183 2.465 2.683 0.072
0.141	3.966 0.141	2.332 2.883 3.434 3.966 0.141	2.332 2.883 3.434 3.966 0.141	5.7 2.332 2.883 3.434 3.966 0.141
0.183	5.963 0.183	3.317 4.366 5.414 5.963 0.183	3.317 4.366 5.414 5.963 0.183	5.1 3.317 4.366 5.414 5.963 0.183
	8.687 0.256	5.942 7.261 8.580 8.687 0.256	5.942 7.261 8.580 8.687 0.256	5.0 5.942 7.261 8.580 8.687 0.256
	8.411	8.411	8.411	5.0 8.411
8.185	8.185			5.1
7.946	7.946			5.1
7.708	7.708			5.1
6.861				5.1

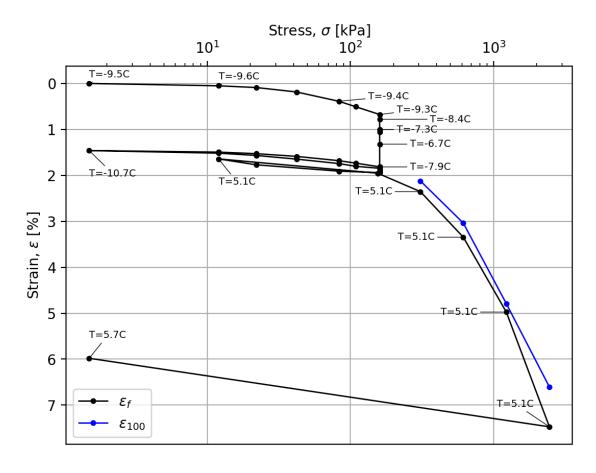
D.2 Overview of load steps and interpreted results





E Sample "QAA2017-14 S09B"

E.1 Consolidation curve



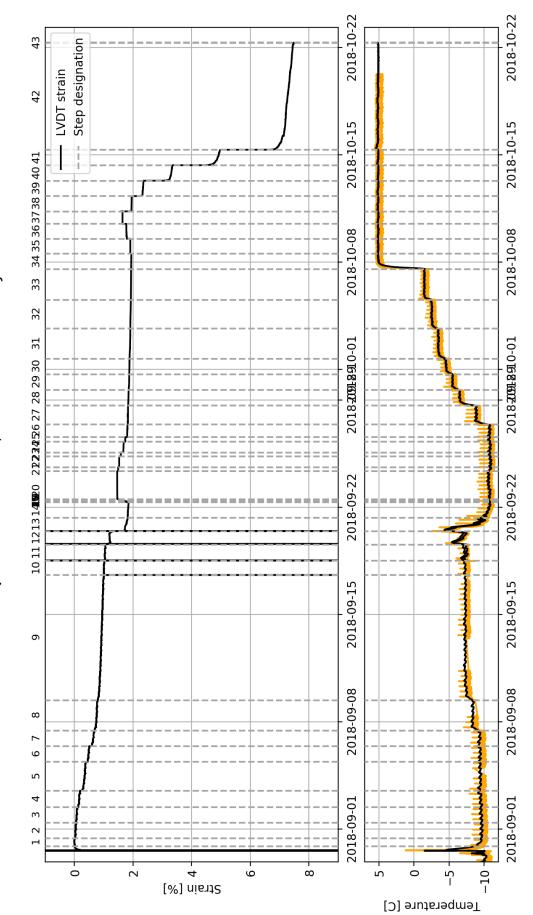
Parameter	Value
Name	QAA2017-14 S09B
Depth	4.73-4.77 m
Start date	2018-08-30
End date	2018-10-22

Step	σ [kPa]	T [°C]	ε_0 [%]	ε_{50} [%]	ε_{100} [%]	ε _f [%]	C_{lpha} [%/lct]	$c_v [{ m m^2/s}]$	K [kPa]	$k_0 [m/s]$
	1.5	-9.5				0.000				
2	12.0	-9.6				0.051				
ო	22.0	-9.5				0.089				
4	42.0					0.186				
5	83.0	-9.4				0.388				
9	109.0	-9.4				0.507				
7	160.0	-9.3				0.676				
8	160.0	-8.4				0.780				
o	160.0	-7.3				1.006				
10	160.0	-7.3				1.018				
£	160.0	-7.1				1.058				
12	160.0	-6.7				1.320				
13	160.0	-7.9				1.817				
4	160.0	-10.5				1.847				
15	109.0	-10.8				1.804				
16	83.0	-10.8				1.744				
17	42.0	-10.7				1.647				
18	22.0	-10.6				1.567				
19	12.0	-10.6				1.518				
20	1.5	-10.7				1.461				
21	12.0	-10.8				1.494				
22	22.0	-10.9				1.528				
23	42.0	-10.8				1.587				
24	83.0	-10.8				1.681				
25	109.0	-10.7				1.735				
26	160.0	-10.8				1.815				

E.2 Overview of load steps and interpreted results

Table continues on next page...

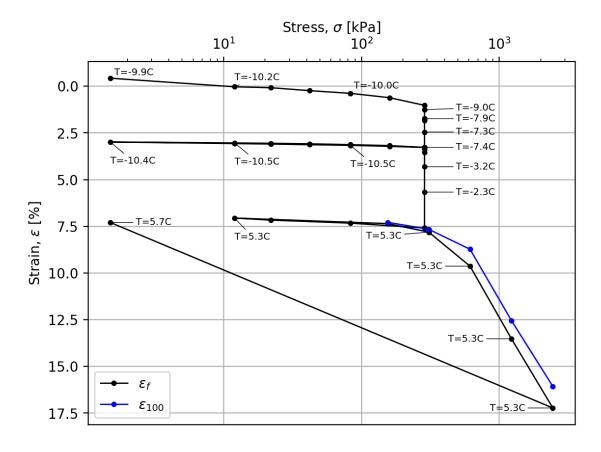
Step	σ [kPa]	T [°C]	ε_0 [%]	ε_{50} [%]	ε_{100} [%]	ε_f [%]	C_{lpha} [%/lct]	$c_v ~[{ m m^2/s}]$	K [kPa]	$k_0 \; [m/s]$
7	160.0	-8.9				1.831				
80	160.0	-6.5				1.850				
o,	160.0	-5.5				1.870				
0	160.0	-4.6				1.881				
-	160.0	-3.5				1.908				
2	160.0	-2.5				1.926				
ო	160.0	-1.5				1.934				
34	160.0	5.1				1.941				
2	83.0	5.1				1.909				
9	22.0	5.1				1.771				
2	12.0	5.1				1.642				
8	155.0	5.1				1.954				
6	308.0	5.1	1.869	1.995	2.121	2.354	0.032	$9.338 imes10^{-6}$		1.535×10^{-1}
0	614.0	5.1	2.131	2.585	3.038	3.345	0.101	$4.562 imes10^{-6}$		1.352×10^{-1}
~	1226.0	5.1	4.426	4.608	4.791	4.975	0.224	$7.022 imes 10^{-9}$	167388	$4.195 imes 10^{-13}$
42	2451.0	5.1	4.564	5.584	6.605	7.472	0.199	$3.977 imes10^{-6}$		6.628×10^{-1}
с С	1.5	5.7				5.981				





F Sample "QAA2017-14 S23A"

F.1 Consolidation curve



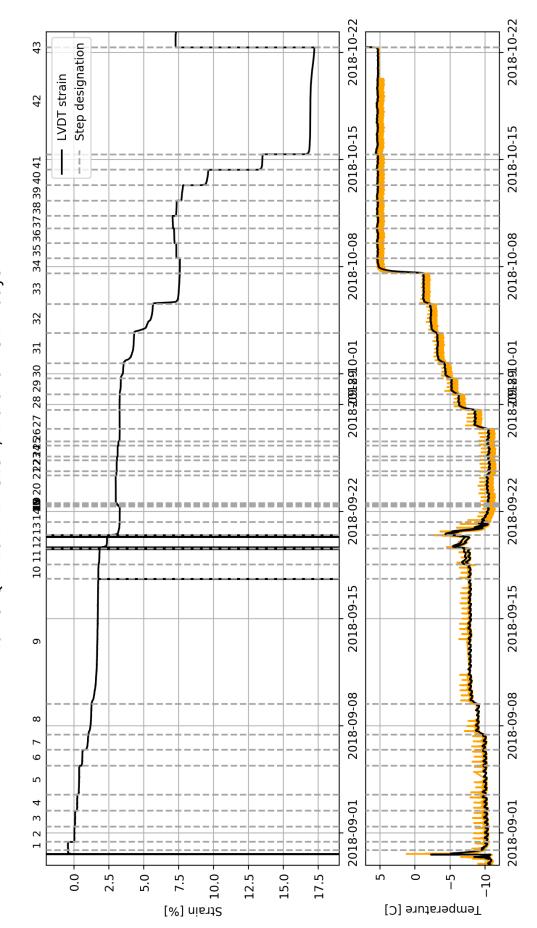
Parameter	Value
Name	QAA2017-14 S23A
Depth	10.97-11.01 m
Start date	2018-08-30
End date	2018-10-22

Step	σ [kPa]	T [°C]	ε_0 [%]	ε_{50} [%]	ε_{100} [%]	ε _f [%]	C_{lpha} [%/lct]	$c_v [{\sf m}^2/{\sf s}]$	K [kPa]	$k_0 [m/s]$
-	1.5	6.6-				-0.430				
2	12.0	-10.2				0.032				
ო	22.0	-10.2				0.080				
4	42.0	-10.1				0.237				
5	83.0	-10.0				0.382				
9	160.0	-10.0				0.615				
7	287.0	-9.9				1.025				
∞	287.0	-9.0				1.258				
б	287.0	-7.9				1.740				
10	287.0	-7.8				1.753				
£	287.0	-7.7-				1.834				
12	287.0	-7.3				2.450				
13	287.0	-7.4				3.271				
4	287.0	-10.1				3.280				
15	160.0	-10.5				3.218				
16	83.0	-10.5				3.166				
17	42.0	-10.4				3.131				
18	22.0	-10.3				3.096				
19	12.0	-10.3				3.071				
20	1.5	-10.4				2.986				
21	12.0	-10.5				3.037				
22	22.0	-10.6				3.057				
23	42.0	-10.5				3.083				
24	83.0	-10.5				3.129				
25	160.0	-10.4				3.180				
26	287.0	-10.4				3.276				

F.2 Overview of load steps and interpreted results

Table continues on next page...

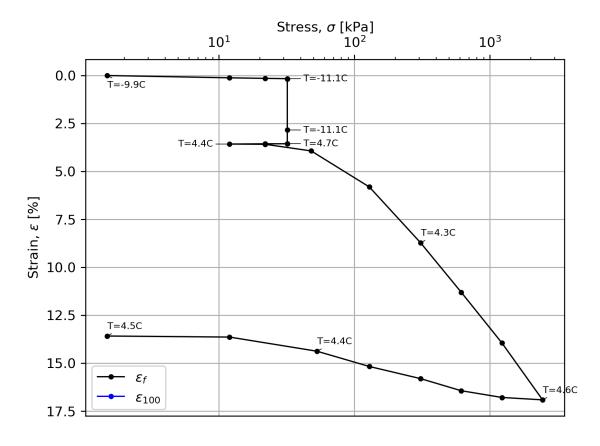
Step	σ [kPa]	T [°C]	ε_0 [%]	ε_{50} [%]	ε_{100} [%]	ε_f [%]	C_{lpha} [%/lct]	$c_v ~[{\sf m}^2/{\sf s}]$	K [kPa]	$k_0 \; [m/s]$
2	287.0	-8.6				3.271				
ø	287.0	-6.3				3.279				
6	287.0	-5.2				3.357				
0	287.0	-4.3				3.549				
~	287.0	-3.2				4.314				
2	287.0	-2.3				5.670				
ო	287.0	-1.2				7.575				
34	287.0	5.3				7.592				
5	83.0	5.4				7.329				
9	22.0	5.3				7.167				
2	12.0	5.3				7.057				
ω	155.0	5.3	7.236	7.260	7.284	7.355	0.033	$1.768 imes 10^{-6}$		5.962×10^{-1}
ი	308.0	5.3	7.326	7.493	7.660	7.811	0.075	$1.240 imes10^{-6}$		2.706×10^{-1}
0	614.0	5.3	6.938	7.833	8.727	9.633	0.173	$1.746 imes 10^{-5}$		1.020×10^{-10}
~	1226.0	5.3	6.944	9.743	12.541	13.518	0.123	$1.630 imes 10^{-5}$	10934	$1.490 imes10^{-8}$
2	2451.0	5.3	12.719	14.394	16.069	17.224	0.123	$1.511 imes 10^{-5}$		4.131×10^{-1}
ო	1.5	5.7				7.290				





G Sample "QAA2017-18 S03C"

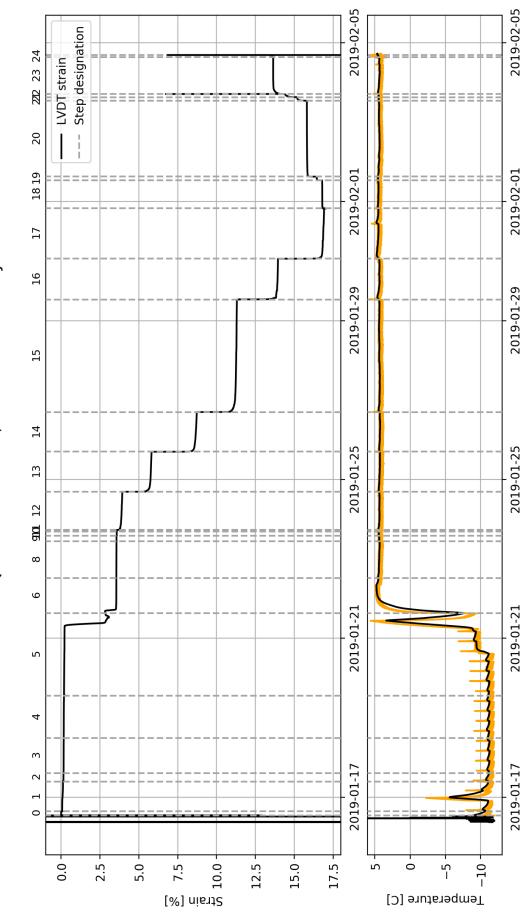
G.1 Consolidation curve



Parameter	Value
Name	QAA2017-18 S03C
Depth	1.25-1.35 m
Start date	2019-01-16
End date	2019-02-04

ر ا%]	5	0.003	0.123	ς.	0.168	0.186	2.844	3.554	3.562	3.565	3.578	3.591	3.936	5.817		11.310	13.955	16.920	16.796	16.445	15.814	15.180	14.384	13.646	13.591
		-9.9	-10.7	-11.0	-11.1	-11.1	-11.1	4.7	4.4	4.4	4.4	4.5	4.4	4.3	4.3	4.3	4.4	4.6	4.5	4.5	4.4	4.4	4.4	4.4	4.5
ر [kPa]		1.5	U	22.0	32.0	32.0	32.0	32.0	32.0	22.0	12.0	22.0	48.0	129.0	308.0	615.0	1228.0	2448.0	1228.0	615.0	308.0	129.0	53.0	12.0	1.5
Sten	2220	0	-	7	ო	4	2	9	∞	6	10	7	12	13	14	15	16	17	18	19	20	21	22	23	24

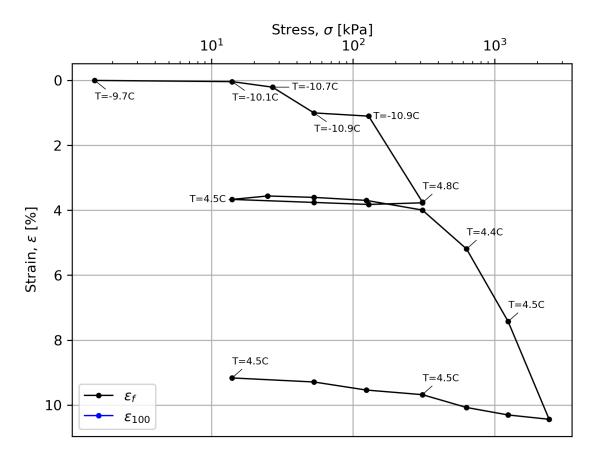
G.2 Overview of load steps and interpreted results





H Sample "QAA2017-22 S27B"

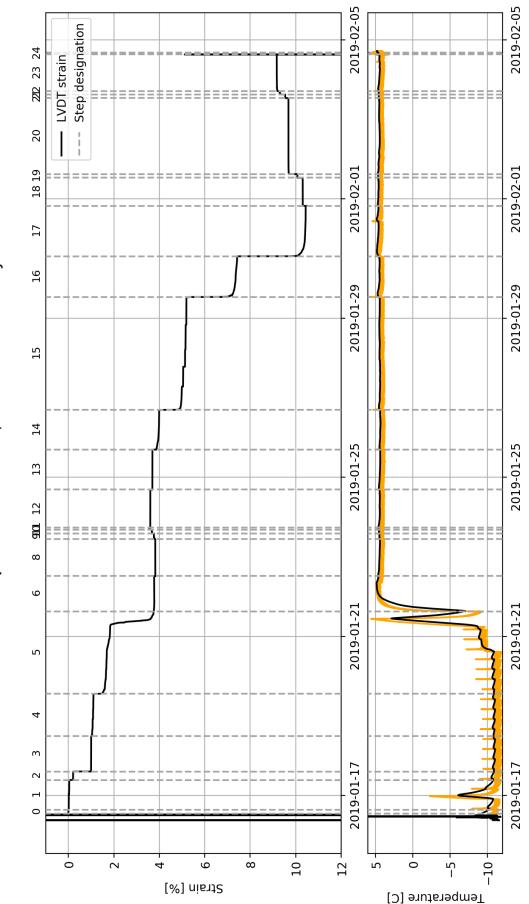
H.1 Consolidation curve



Value
QAA2017-22 S27B
12.57-12.63 m
2019-01-16
2019-02-04

Step	σ [kPa]	T [°C]	ε_0 [%]	ε_{50} [%]	ε_{100} [%]	ε_f [%]	C_{lpha} [%/lct]	$c_v \; [{ m m^2/s}]$	K [kPa]	$k_0 [m/s]$
	1.5	-9.7				0.004				
	14.0	-10.1				0.041				
	27.0	-10.7	0.205	0.206	0.207	0.211	0.005	$2.436 imes10^{-7}$	1203231	$2.025 imes 10^{-12}$
	53.0	-10.9	0.994	0.997	1.001	1.004	0.003	$2.872 imes10^{-8}$	384375	$7.471 imes 10^{-13}$
	129.0	-10.9	1.029	1.029	1.029	1.103	0.043	$9.849 imes 10^{-6}$	-45097863	-2.184×10^{-12}
	309.0	-10.8	1.453	1.453	1.454	3.747	0.121	$1.153 imes 10^{-5}$	26785679	$4.305 imes 10^{-12}$
	309.0	4.8				3.772				
	129.0	4.5				3.823				
	53.0	4.5	3.770	3.770	3.771	3.761	-0.003	$9.726 imes10^{-6}$	-12023911	-8.089×10^{-12}
	14.0	4.5	3.698	3.697	3.695	3.668	-0.024	$2.162 imes10^{-6}$	1364492	$1.585 imes 10^{-11}$
	25.0	4.6	3.557	3.559	3.562	3.562	0.001	$1.575 imes 10^{-7}$	254100	6.197×10^{-12}
	53.0		3.601	3.602	3.602	3.605	0.001	$7.778 imes 10^{-7}$	2876272	$2.704 imes 10^{-12}$
	124.0	4.4	3.696	3.696	3.696	3.698	0.001	$6.103 imes10^{-6}$	68163900	$8.953 imes 10^{-13}$
	309.0	4.4	3.872	3.871	3.870	3.995	0.091	$4.148 imes 10^{-6}$	-10478299	$-3.959 imes 10^{-12}$
	634.0	4.4	4.764	4.883	5.001	5.193	0.059	$3.071 imes10^{-9}$	137159	$2.239 imes 10^{-13}$
	1247.0	4.5	5.874	6.165	6.455	7.428	0.201	$6.955 imes 10^{-6}$	105605	$6.586 imes 10^{-10}$
	2429.0	4.7	9.642	9.643	9.644	10.439	0.198	$1.699 imes 10^{-5}$	74746120	$2.273 imes 10^{-12}$
	1247.0	4.6	10.319	10.314	10.309	10.305	-0.001	$7.714 imes 10^{-7}$	11501232	$6.707 imes 10^{-13}$
	634.0	4.7	10.088	10.087	10.085	10.075	-0.008	$5.024 imes10^{-6}$	21446542	$2.342 imes 10^{-12}$
	309.0	4.5	9.713	9.700	9.687	9.680	-0.007	$2.112 imes10^{-8}$	1223415	$1.726 imes 10^{-13}$
	124.0	4.6	9.540	9.541	9.541	9.538	-0.003	$7.743 imes10^{-6}$	-25557691	-3.029×10^{-12}
	53.0	4.6	9.337	9.332	9.328	9.290	-0.047	$7.696 imes 10^{-8}$	841058	$9.150 imes 10^{-13}$
	14.0	4.5	9.220	9.220	9.220	9.165	-0.015	$2.482 imes 10^{-6}$	-274438102292889600	$-9.045 imes 10^{-23}$

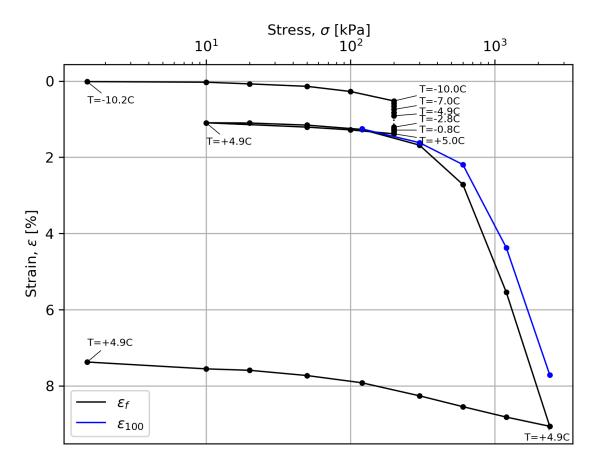
H.2 Overview of load steps and interpreted results





I Sample "QAA2017-22 S27A"

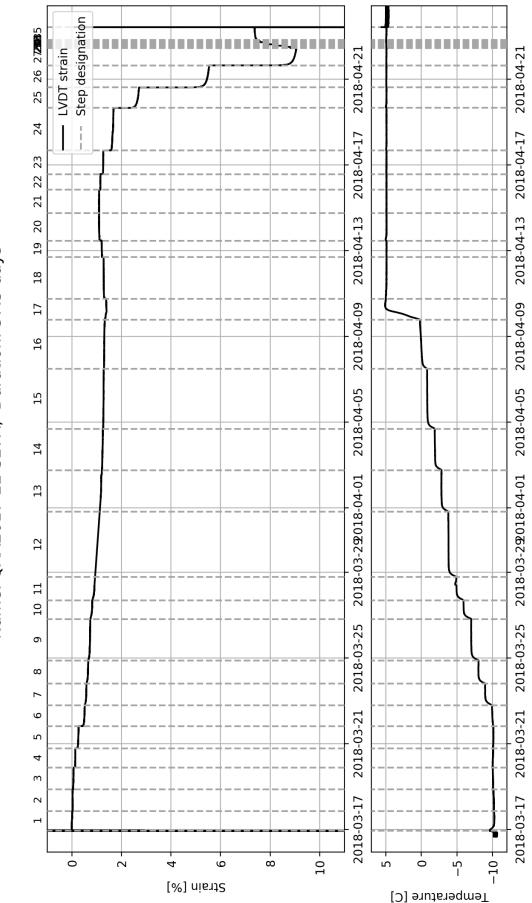
I.1 Consolidation curve



Parameter	Value
Name	QAA2017-22 S27A
Depth	12.63-12.67 m
Start date	2018-03-16
End date	2018-04-23

I	1																																		I
k_0 [m/s]																							$1.756 imes 10^{-11}$	$7.562 imes 10^{-9}$	1.678×10^{-9}	$1.649 imes 10^{-9}$	$1.250 imes 10^{-9}$								
K [kPa]																							1497784	27700	99202	88277	116700								
$c_v ~[{ m m^2/s}]$																							$2.630 imes10^{-6}$	$2.095 imes 10^{-5}$	1.664×10^{-5}	$1.455 imes10^{-5}$	$1.458 imes10^{-5}$								
C_{lpha} [%/lct]																							0.005	0.036	0.151	0.228	0.278								
ε _f [%]	0.014	0.030	0.074	0.139	0.274	0.522	0.591	0.661	0.744	0.826	0.913		1.209	1.251	1.286	1.329	1.384	1.281	1.208	1.094	1.101	1.156	1.269	1.680	2.713	5.540	9.057	8.815	8.542	8.256	7.916	7.726	7.588	7.550	7.371
ε_{100} [%]																							1.255	1.615	2.190	4.372	7.706								
ε_{50} [%]																							1.253	1.290	2.039	4.032	7.192								
ε_0 [%]																							1.250	0.965	1.888	3.692	6.678								
T [°C]	-10.2	-10.2	-10.1	-10.1	-10.1	-10.0	-9.0	-8.0	-7.0	-5.9	-4.9	-3.9	-2.8	-1.9	-0.8	0.2	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
σ [kPa]	1.5	10.0	20.0	50.0	100.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	100.0	50.0	10.0	20.0	50.0	120.0	300.0	600.0	1200.0	2400.0	1200.0	600.0	300.0	120.0	50.0	20.0	10.0	1.5
Step	-	2	ო	4	5	9	7	8	6	10	5	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35

I.2 Overview of load steps and interpreted results



Name: QAA2017-22 S27A, Duration: 37.5 days



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