

Anholt/Djursland Offshore Wind Farm  
Geotechnical Investigations  
Wind Farm Area  
Geotechnical Report – Consolidation Tests

GEO project no 32490  
Report 3, 2009-10-06

## Summary

Ramboll Wind has on behalf of Energinet.dk contracted GEO (Danish Geotechnical Institute) to conduct the geotechnical site investigations at the planned offshore wind farm between Anholt and Djursland.

The Anholt/Djursland Offshore Wind Farm worksite is located approximately 20 km off the coast of Djursland, north-east of the town Grenaa. The exact location of the farm is not yet established and several options are being assessed. The Anholt/Djursland Offshore Wind farm is planned as a 400 MW farm.

This Report 3 presents the detailed results from consolidation tests (compressibility tests) executed on 4 selected samples from the geotechnical boreholes executed within the wind farm area.

Two reports have previously been prepared for this project. These reports (Report 1 and 2) include the results from the fieldwork and soil classifications tests done in relation to the boreholes executed in the wind farm area and vibrocores executed in the cable corridors, respectively.

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## Enclosures:

3B.01

Summary – Consolidation Tests

3C.01-3C.04

Consolidation Tests

## Appendices:

None

# 1 INTRODUCTION AND SCOPE OF REPORT

## 1.1 Project and site location

On the instruction and under the supervision of Rambøll, acting on behalf of Energinet.dk a geotechnical investigation has been carried out by GEO at the location for the planned Anholt/Djursland Offshore Wind Farm.

The Anholt/Djursland Offshore Wind Farm is planned as a 400 MW farm. The exact location of the farm is not yet established and several options are being assessed. The overall worksite is located approximately 20 km off the coast of Djursland, north-east of the town Grenaa. The worksite is depicted (orange area) in Figure 1.1 and measures approximately 144 km<sup>2</sup>. The water depth across the site generally ranges between 14 and 20 m.

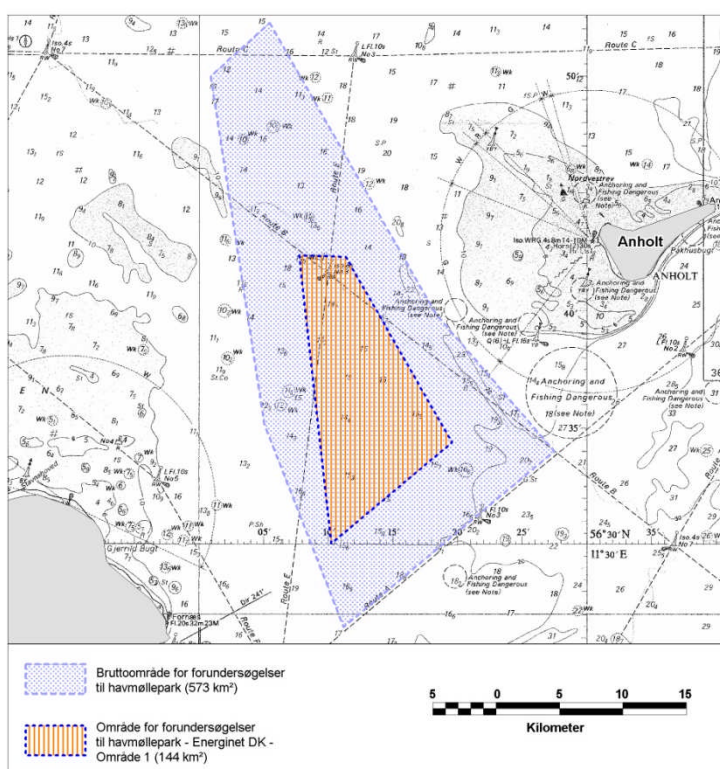


Figure. 1.1 Location of Anholt/Djursland Offshore Wind Farm

Power produced by the Wind Farm will be distributed via an approx. 20 km sea cable going to the shore of Djursland. The exact location of the cable is not yet established and therefore two cable corridors are being assessed, a northern alignment, Gjerrild Strand and a southern alignment, Grenaa Nord.

The purpose of the geotechnical investigation is to gather adequate geological and geotechnical data for a preliminary technical assessment. The geotechnical investigation follows a geophysical campaign and the vibrocore and CPT locations have been selected by the Client based on the results of this survey. The purpose of the laboratory work

under this report is to determine the over consolidation rate (OCR) and the compression index (Q) for 4 selected samples.

## 1.2 Geotechnical reporting under the contract

The performed geotechnical works for the Anholt/Djursland project are presented in totally 3 reports. The overall content of the 3 reports are:

**Report 1:** Wind Farm Area - Geotechnical Report – Boreholes (borehole logs, CPT profiles, laboratory results, soil conditions, summaries of work completed etc.).

**Report 2:** Cable Corridors – Geotechnical Report – CPT tests and vibrocores (vibro-core logs, CPT profiles, laboratory results, soil conditions, summaries of work completed etc.).

**Report 3:** Wind Farm Area – Geotechnical Report – Consolidation tests on 4 selected samples from borehole BH02, BH05, BH09 and BH10.

## 1.3 Content of this report

This Report 3 includes factual data from 4 consolidation tests performed on samples from the boreholes BH02, BH05, BH09 and BH10. All boreholes are located within the wind farm area.

# 2 LABORATORY WORK

## 2.1 Testing program and standards

The samples tested, elevation and classification data in respect of the samples are listed in Summary – Compressibility Tests, Enclosure 3B.01.

Rambøll informed the detailed testing procedure for each sample prior to the test. The tests were executed overall in accordance with DS/CEN ISO/TS 17892-5: 2004.

## 2.2 Test Results

The detailed test results are presented in Enclosure 3C.01 – 3C.04. The overall results are resented in Summary – Compressibility Tests, Enclosure 3B.01

## 2.3 Comments to laboratory work

All tests have been executed as specified in the relevant standard.

Enclosure 3B.01  
Summary – Consolidation Tests

## Summary - Compressibility Tests

	Borehole No	Sample No	Depth below seabed (m)	Level (m)	Soil Description	w (%)	e	Q (%/lcs)	OCR
1	BH02	4	6.0	-23.0	Clay, med. plastic, silty, sandy	13.3	0.384	5.4	1.0
2	BH.05	13	24.0	-42.0	Clay, highly plastic, silty, sl. sandy	35.2	0.919	14.1	1.1
3	BH.09	3	6.0	-22.2	Clay, highly plastic, w. silt streaks	32.9	0.934	13.4	1.9
4	BH.10	3	5.8	-24.6	Clay, highly plastic, sl. sandy	30.5	0.871	12.9	5.5



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Subject: Summary – Consolidation Tests

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Date: 2009-10-06

Page 1/1

Approved : JBC

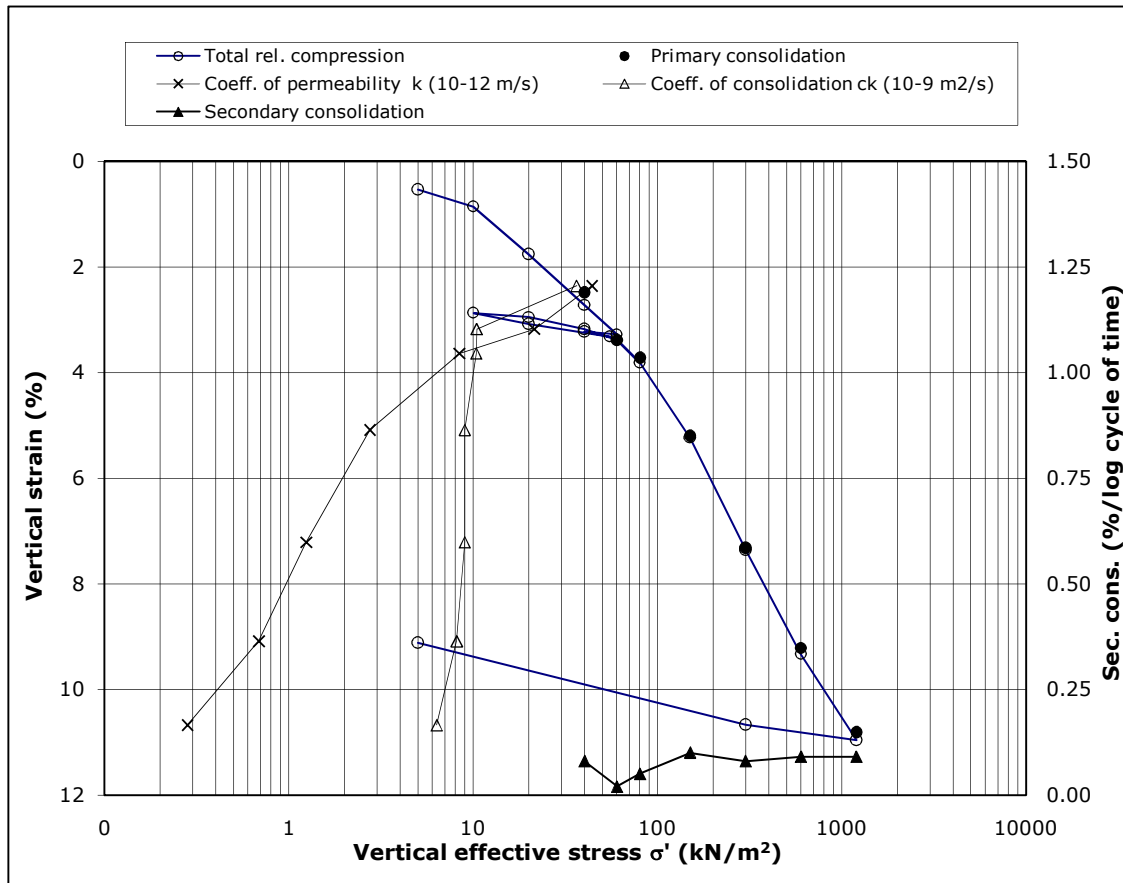
Date: 2009-10-06

Report 3

Enclosure 3B.01

Rev.

Enclosure 3C.01 - 3C.04  
Consolidation Tests



**Description of soil sample:**

Geology: CLAY, medium plastic, silty, sandy, sl. gravelly, calcareous, grey					
Pressure area	28.274	cm <sup>2</sup>	$C_v$	-	kN/m <sup>2</sup>
Height	30	mm	$\sigma'_{O_0}$	70	kN/m <sup>2</sup>
e (initial)	0.384		$\sigma'_{pc}$	~70	kN/m <sup>2</sup>
$\rho$ (initial)	2.20	g/cm <sup>3</sup>	$Q_{(600-1200)}$	5.4	(%/lcs)
w (initial)	13.3	%	$S_0$	93	%
Temperature	24	°C	$\rho_s$	2.68	g/cm <sup>3</sup>

Depth below seabed:	6.00 m	Bor. No.	BH02
		Lab. No.	4

NOTE: The values of k &  $c_k$  correspond to average laboratory temperature as shown above.  
 Test method: Incremental loading  
 Procedure: DS/CEN ISO/TS 17892-5: 2004



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Prepared : KRS      Date : 2009-09-24      Subject: Consolidation test. Lab. No. 4 (BH02)  
 Controlled : LFJ      Date : 2009-09-25  
 Approved : JLC      Date : 2009-09-29      Report 3      Encl. No. 3C.01      Page: 1/2



**Test parametres**

	$\sigma$ (kN/m <sup>2</sup> )	$\epsilon_{final}$ (%)	$\epsilon_{100}$ (%)	$\epsilon_s$ (%/lct)	$\epsilon_{50}$ (%)	$k \times 10^{-12}$ (m/s)	$ck \times 10^{-9}$ (m <sup>2</sup> /s)
SW	5	0.532					
SW	10	0.858					
	20	1.761					
	40	2.720	2.48	0.08	2.36	44.13	36.27
	60	3.278	3.38	0.02	3.18	21.41	10.42
	40	3.223					
	55	3.316					
	20	3.078					
	10	2.867					
	20	2.950					
	40	3.179					
	60	3.382					
	80	3.813	3.72	0.05	3.64	8.42	10.37
	150	5.233	5.19	0.10	5.09	2.75	8.98
	300	7.355	7.32	0.08	7.21	1.24	8.98
	600	9.328	9.21	0.09	9.08	0.69	8.12
	1200	10.959	10.81	0.09	10.67	0.28	6.33
	300	10.665					
	5	9.111					



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Subject: Consolidation test. Lab. No. 4 (BH02)

Controlled : LFJ

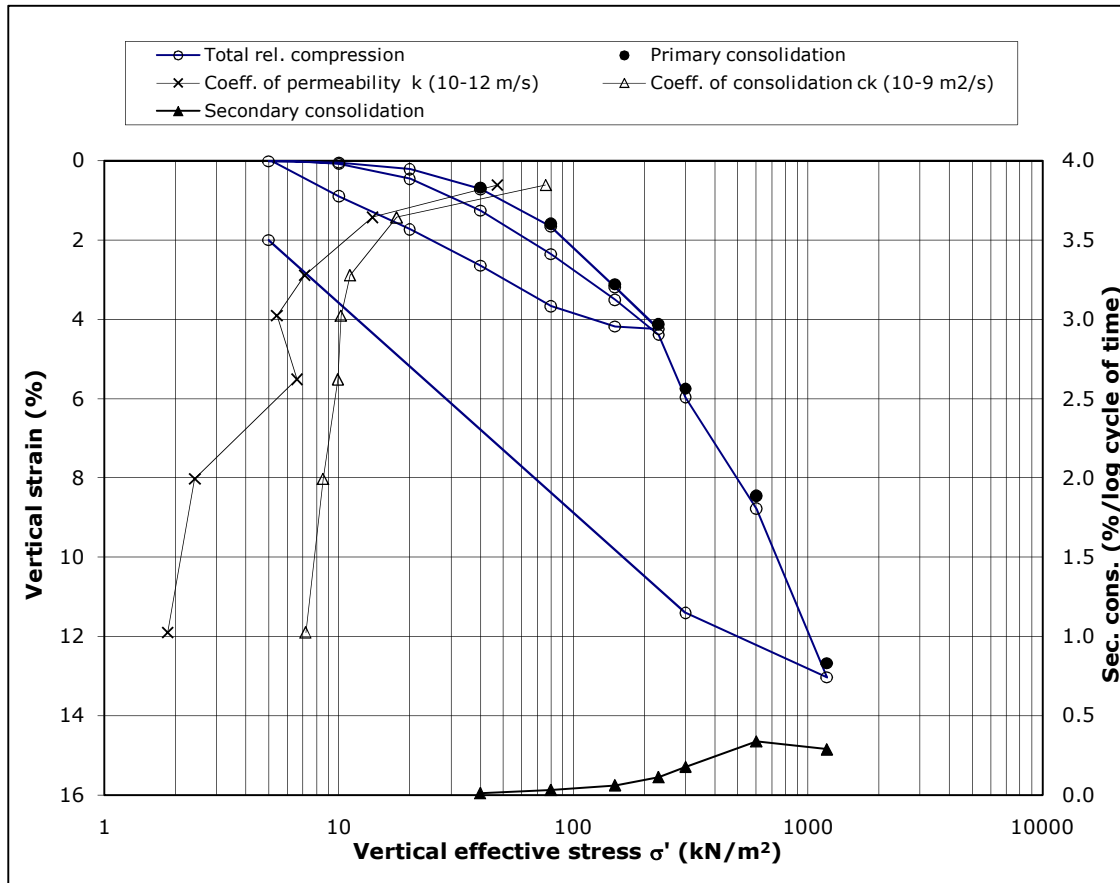
Date : 2009-09-25

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Date : 2009-09-29

Report 3

Encl. No. 3C.01 Page: 2/2



**Description of soil sample:**

Geology: CLAY, highly plastic, silty, sl. sandy, calcareous, w. fine sand streaks, grey				
Pressure area	28.274	cm <sup>2</sup>	C <sub>v</sub>	- kN/m <sup>2</sup>
Height	30	mm	σ' <sub>0</sub>	205 kN/m <sup>2</sup>
e (initial)	0.919		σ' <sub>pc</sub>	~220 kN/m <sup>2</sup>
ρ (initial)	1.89	g/cm <sup>3</sup>	Q <sub>(600-1200)</sub>	14.1 (%/lcs)
w (initial)	35.2	%	S <sub>0</sub>	100 %
Temperature	24	°C	ρ <sub>s</sub>	2.68 g/cm <sup>3</sup>

Depth below seabed:	24.04 m	Bor. No.	BH05
		Lab. No.	13

NOTE: The values of k & c<sub>k</sub> correspond to average laboratory temperature as shown above.

Test method: Incremental loading

Procedure: DS/CEN ISO/TS 17892-5: 2004



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 Controlled : LFJ      Date : 2009-09-22  
 Approved : JLC      Date : 2009-09-29      Report 3      Encl. No. 3C.02      Page: 1/2

**Test parametres**

	$\sigma$ (kN/m <sup>2</sup> )	$\epsilon_{final}$ (%)	$\epsilon_{100}$ (%)	$\epsilon_s$ (%/lct)	$\epsilon_{50}$ (%)	$k \times 10^{-12}$ (m/s)	$ck \times 10^{-9}$ (m <sup>2</sup> /s)
Sw	5	0.012					
Sw	10	0.040					
Sw	20	0.211					
	40	0.710	0.68	0.01	0.62	47.19	75.85
	80	1.653	1.59	0.03	1.43	13.87	17.58
	150	3.182	3.12	0.06	2.89	7.13	11.14
	230	4.246	4.13	0.11	3.91	5.42	10.18
	150	4.181					
	80	3.671					
	40	2.641					
	20	1.727					
	10	0.893					
Sw	5	-0.036					
	10	0.075					
	20	0.450					
	40	1.252					
	80	2.350					
	150	3.505					
	230	4.390					
	300	5.966	5.75	0.18	5.52	6.60	9.90
	600	8.779	8.46	0.34	8.03	2.42	8.56
	1200	13.033	12.68	0.29	11.90	1.86	7.21
	300	11.409					
	5	2.000					



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Subject: Consolidation test. Lab. No. 13 (BH05)

Controlled : LFJ

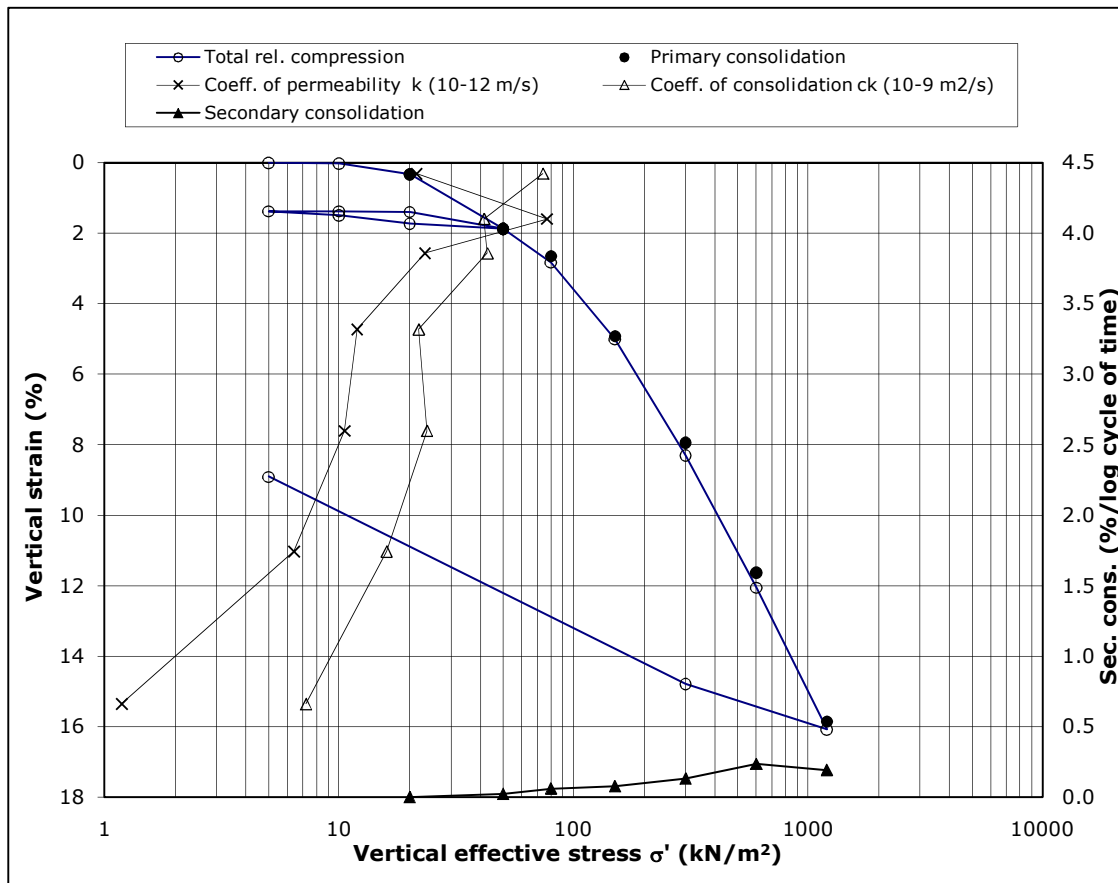
Date : 2009-09-22

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Date : 2009-09-29

Report 3

Encl. No. 3C.02 Page: 2/2



**Description of soil sample:**

Geology: CLAY, highly plastic, w. silt streaks, calcareous, w. iron sulphide streaks, grey					
Pressure area	28.274	cm <sup>2</sup>	$C_v$	-	kN/m <sup>2</sup>
Height	30	mm	$\sigma'_{O_0}$	48	kN/m <sup>2</sup>
e (initial)	0.934		$\sigma'_{pc}$	~90	kN/m <sup>2</sup>
$\rho$ (initial)	1.84	g/cm <sup>3</sup>	$Q_{(600-1200)}$	13.4	(%/lcs)
w (initial)	32.9	%	$S_0$	94	%
Temperature	24	°C	$\rho_s$	2.68	g/cm <sup>3</sup>

Depth below seabed:	5.97 m	Bor. No.	BH09
		Lab. No.	3

NOTE: The values of k &  $c_k$  correspond to average laboratory temperature as shown above.

Test method: Incremental loading

Procedure: DS/CEN ISO/TS 17892-5: 2004



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Controlled : LFJ	Date : 2009-09-22	
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**Test parameters**

$\sigma$ (kN/m <sup>2</sup> )	$\varepsilon_{\text{final}}$ (%)	$\varepsilon_{100}$ (%)	$\varepsilon_s$ (%/lct)	$\varepsilon_{50}$ (%)	$k \times 10^{-12}$ (m/s)	$ck \times 10^{-9}$ (m <sup>2</sup> /s)
5	0.001					
10	0.020					
20	0.331	0.32	0.00	0.31	21.39	74.05
50	1.877	1.87	0.02	1.60	76.97	41.49
20	1.733					
10	1.496					
5	1.375					
10	1.377					
20	1.396					
50	1.873					
80	2.831	2.65	0.06	2.56	23.23	42.95
150	5.011	4.92	0.08	4.73	11.93	21.86
300	8.306	7.94	0.13	7.61	10.54	23.71
600	12.063	11.63	0.23	11.03	6.42	15.95
1200	16.089	15.85	0.19	15.36	1.18	7.24
300	14.795					
5	8.914					



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Subject: Consolidation test. Lab. No. 3 (BH09)

Controlled : LFJ

Date : 2009-09-22

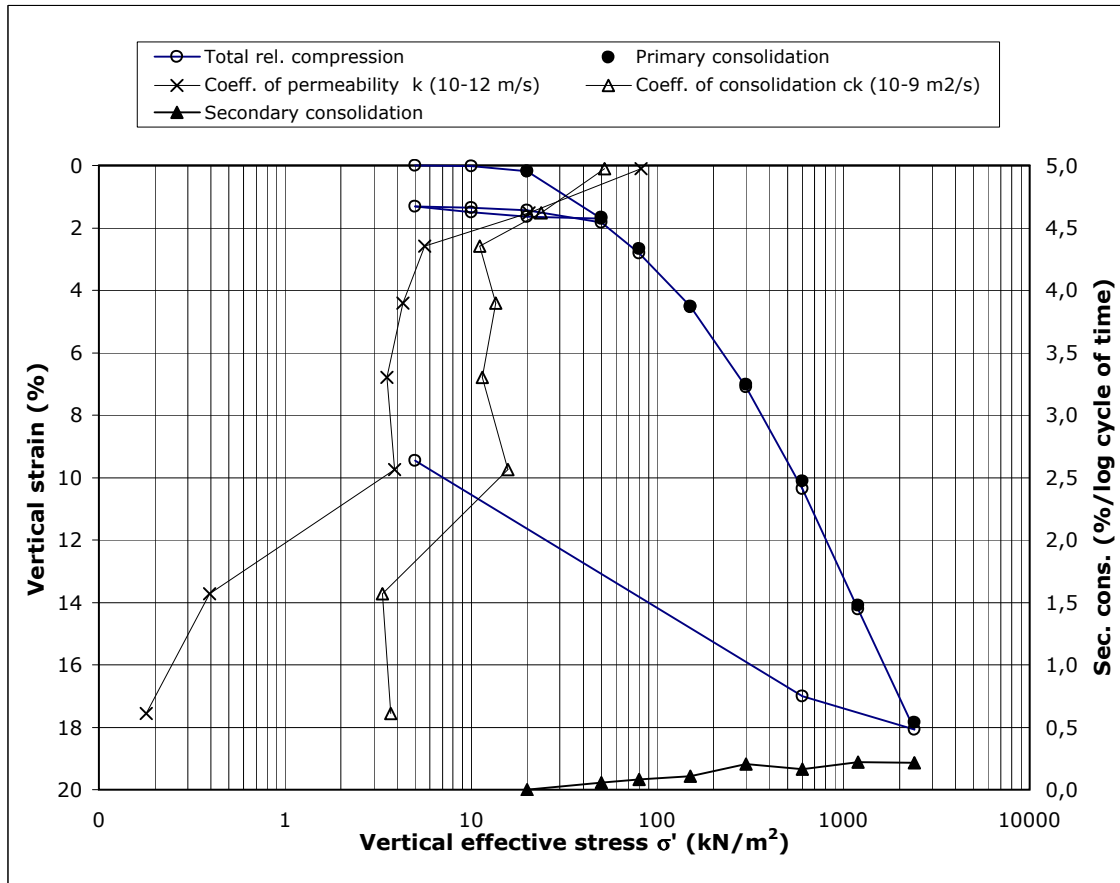
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Report 3

Encl. No. 3C.03

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**Description of soil sample:**

Geology: CLAY, highly plastic, sl. sandy, calcareous, w. sand streaks, grey					
Pressure area	28,274	cm <sup>2</sup>	$C_v$	-	kN/m <sup>2</sup>
Height	30	mm	$\sigma'_{O_0}$	42	kN/m <sup>2</sup>
e (initial)	0,871		$\sigma'_{pc}$	~230	kN/m <sup>2</sup>
$\rho$ (initial)	1,87	g/cm <sup>3</sup>	Q (1200-2400)	12,9	(%/lcs)
w (initial)	30,5	%	$S_0$	94	%
Temperature	24	°C	$\rho_s$	2,68	g/cm <sup>3</sup>

Depth below seabed:	5.80 m	Bor. No.	BH10
		Lab. No.	3

NOTE: The values of k &  $c_k$  correspond to average laboratory temperature as shown above.

Test method: Incremental loading

Procedure: DS/CEN ISO/TS 17892-5: 2004



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Controlled : LFJ      Date : 2009-09-22  
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**Test parametres**

$\sigma$ (kN/m <sup>2</sup> )	$\epsilon_{final}$ (%)	$\epsilon_{100}$ (%)	$\epsilon_s$ (%/lct)	$\epsilon_{50}$ (%)	$k \times 10^{-12}$ (m/s)	$ck \times 10^{-9}$ (m <sup>2</sup> /s)
5	0,001					
10	0,023					
20	0,180	0,19	0,00	0,11	81,69	52,11
50	1,700	1,65	0,06	1,52	20,40	23,76
20	1,634					
10	1,488					
5	1,305					
10	1,361					
20	1,431					
50	1,816					
80	2,807	2,67	0,08	2,59	5,63	11,09
150	4,521	4,53	0,11	4,42	4,31	13,57
300	7,104	7,01	0,20	6,78	3,53	11,46
600	10,350	10,11	0,16	9,74	3,88	15,72
1200	14,206	14,08	0,22	13,73	0,39	3,33
2400	18,077	17,85	0,21	17,56	0,18	3,71
600	16,998					
5	9,458					



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Subject: Consolidation test. Lab. No. 3 (BH10)

Controlled : LFJ

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Report 3

Encl. No. 3C.04

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