

## **Oskarshamn site investigation**

### **Borehole KLX10**

#### **Determination of porosity by water saturation and density by buoyancy technique**

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December 2007

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author and do not necessarily coincide with those of the client.

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## Abstract

The density and porosity was determined on 9 specimens (each divided into two pieces) from borehole KLX10, Oskarshamn, Sweden. The specimens were sampled at five levels, between 280-900 m (borehole length). The investigated rock types are mapped as Ävrö granite (501044), dioritoid (501033), fine-grained dioritoid (501030) and fine-grained granite (511058). The results for the dry density varied between 2,640 and 2,830 kg/m<sup>3</sup>, and for the wet density between 2,640 and 2,830 kg/m<sup>3</sup>. Finally, the porosity results varied between 0.1 and 0.4%.

## Sammanfattning

Densiteten och porositeten bestämdes på 9 provkroppar (varje provkropp delad i två delar) från borrhål KLX10 i Oskarshamn. Proverna togs från fem nivåer mellan 280-900 m (borrhålsdjup). De undersökta bergarterna är karterade som Ävrögranit (501044), diorit/gabbro (501033), finkornig diorit/gabbro (501030) och finkornig granit (511058). Resultaten för torrdensiteten varierade mellan 2640 och 2830 kg/m<sup>3</sup> och för våtdensiteten mellan 2 640 och 2 830 kg/m<sup>3</sup>. För porositeten, slutligen, varierade resultaten mellan 0,1 och 0,4 %.

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# 1 Introduction

This document reports performance and results of determination of porosity by water saturation and density by buoyancy technique within the site investigation programme at Oskarshamn, Sweden, /1/. The controlling documents for the activity are listed in Table 1-1. Both Activity Plan and Method Description are SKB's internal controlling documents. The thermal properties conductivity and diffusivity of the specimens were determined within the scope of parallel activity /2/.

Specimens were sampled from the drill core of borehole KLX10 at the Oskarshamn site investigation area, Sweden, see Figure 1-1, for determination of the water saturated density, dry density and the porosity. Borehole KLX10 is a telescopic drilled borehole inclined c. 85° from the horizontal plane and with a total length of 1,000 m.

The sampling was based on the preliminary core logging with the strategy to primarily investigate the properties of the dominant rock types as well as of a number of minority rock types. The samples, which were collected in January 10, 2006, were transported to SP (Swedish National Testing and Research institute), department of Building and Mechanics, where they arrived in January 27, 2005. Testing commenced in March 2006 and was completed in May 2006.

**Table 1-1. Controlling documents for performance of the activity.**

<b>Activity Plan</b>	<b>Number</b>	<b>Version</b>
KLX10. Bergmekaniska och termiska laboratoriebestämningar	AP PS 400-05-110	1.0
<b>Method Description</b>	<b>Number</b>	<b>Version</b>
Determining density and porosity of intact rock	SKB MD 160.002	2.0
<b>Quality Plan</b>		
SP-QD 13.1		



**Figure 1-1.** Location of all telescopic boreholes drilled up to November 2005 within and close to the Oskarshamn candidate area.

## **2 Objective and scope**

The purpose of determining density and porosity of intact rock cores is to use these parameters in the rock mechanics and thermal site descriptive model, which will be established for the candidate area selected for site investigations at Oskarshamn.

The testing comprised of 9 rock samples from borehole KLX10 collected within the borehole interval 280-900 m.



### 3 Equipment

The following equipment was used for the density and porosity determinations:

- Thermometer (inv no 102185) for measurement of water temperature. Calibrated 2006-02-17. Measurement accuracy  $\pm 0.4^{\circ}\text{C}$ .
- Scale (inv no 102291) for weight measurement. Calibrated in 2006-03-10. Measurement accuracy  $\pm 0.2$  g.
- Heating chamber (inv no 102284) for drying the specimens. Calibrated 2006-01-17. Measurement accuracy  $\pm 5^{\circ}\text{C}$ .
- A covered plastic box filled with water for water saturation of the samples.
- A desiccator for cooling samples.

Uncertainty of method as expanded uncertainty with covering factor 2 (95% confidence interval):

Density  $\pm 4$  kg/m<sup>3</sup>

Porosity  $\pm 0.09\%$

Water absorption  $\pm 0.05\%$

## 4 Execution

Determination of the porosity and density was made in accordance with SKB's method description SKB MD 160.002, (SKB internal controlling document). This includes determination of density in accordance to ISRM 1979 /3/ and water saturation by EN 13755 /4/ and in compliance with Activity Plan AP PS 400-05-110 (internal controlling document of SKB). The department of Building Technology and Mechanics (BM) at SP performed the test.

### 4.1 Description of the specimens

The specimens from borehole KLX10 were sampled at levels ranging between 280 and 900 m borehole length. Table 4-1 shows the identification mark, sampling level and rock type of each specimen.

### 4.2 Testing

The temperature of the water used for water saturation was 21°C and the density was 998 kg/ m<sup>3</sup>. The specimens were dried in 105°C during four days. The execution procedure followed the prescription in SKB MD 160.002, see Table 4-2.

The present activity was performed parallel to another activities /2/, conducted by the Fire technology at SP, and by whom the thermal properties were determined. The following logistic sequence was applied for the activities.

**Table 4-1. Identification mark, sampling level and rock type of each specimen (rock-type classification according to overview mapping).**

Identification	Sampling level (m borehole length, Adj seclow)	Rock type/occurrence
KLX10-90V-1	280.297	Fine-grained granite (511058)
KLX10-90V-2	280.366	Fine-grained granite (511058)
KLX10-90V-3	399.651	Fine-grained dioritoid (501030)
KLX10-90V-4	400.391	Fine-grained dioritoid (501030)
KLX10-90V-5	501.836	Ävrö granite (501044)
KLX10-90V-6	571.507	Ävrö granite (501044)
KLX10-90V-7	604.697	Ävrö granite (501044)
KLX10-90V-10	902.793	Diorite/Gabbro (501033)
KLX10-90V-11	902.863	Diorite/Gabbro (501033)

**Table 4-2. The sequence of activities applied for execution of the commission.**

Activity no	Activity
1	The specimens were cut according to the marks on the rock cores. Every specimen was cut into two pieces, marked A and B and about 25 mm thick each. The same specimens were used in a parallel activity to determine the thermal properties thermal conductivity and thermal diffusivity by applying the TPS method /2/.
2	The specimens were water saturated in normal air pressure for at least seven days.
3	The specimens were weighed in tapwater. The temperature of the water was 21°C and the density 998 kg/m <sup>3</sup> .
4	The specimens were surface dried with a towel and weighed.
5	The water saturated density was determined.
6	The samples were sent from SP Building Technology and Mechanics to SP Fire Technology for measurement of thermal properties /3/.
7	The samples were sent back from SP Fire Technology to SP Building Technology and Mechanics.
8	The specimens were dried in a heating chamber during four days at 105°C.
9	The specimens were transported to a desiccator for cooling.
10	The dry density and porosity were determined.
11	The specimens were photographed in JPEG-format.

### **4.3 Nonconformities**

The tests were performed in accordance with the Method Description. The Activity Plan was followed without deviations.

An exception from the method was the statement of significant numbers in Appendix 1. The precision in the method for density gives only three significant digits the fourth digit given here is thus not significant. The precision in the method for porosity gives only one significant digit the second digit given here is thus not significant. It is important that this is kept in mind when the results are used for further calculation.

## 5 Results

The results of the porosity and density determinations of core samples from KLX10 are stored in SKB's database SICADA, where they are traceable by the Activity Plan number.

Minutes and photos are presented in Appendix 1.

### 5.1 Results

Tables 5-1 summarize the results of the porosity and density determinations.

### 5.2 Results for the entire test series

Results for the entire test series are shown in the diagrams below. They are divided into three diagrams, see Figures 5-1 to 5-3, illustrating dry density, wet density and porosity.

**Table 5-1. Summary of the results for porosity, dry density and wet density. The result for each specimen is a mean value of sub samples A and B.**

Specimen	Sampling level (m borehole length), according to the marks on the drill-core boxes (Adj seclow)	Porosity (%)	Dry density (kg/m <sup>3</sup> )	Wet density (kg/m <sup>3</sup> )
KLX10-90V-1	280.297	0.3	2,640	2,640
KLX10-90V-2	280.366	0.4	2,640	2,650
KLX10-90V-3	399.651	0.2	2,720	2,720
KLX10-90V-4	400.391	0.1	2,720	2,720
KLX10-90V-5	501.836	0.4	2,680	2,680
KLX10-90V-6	571.507	0.4	2,680	2,680
KLX10-90V-7	604.697	0.4	2,670	2,680
KLX10-90V-10	902.793	0.2	2,830	2,830
KLX10-90V-11	902.863	0.2	2,830	2,830

### Dry density KLX10

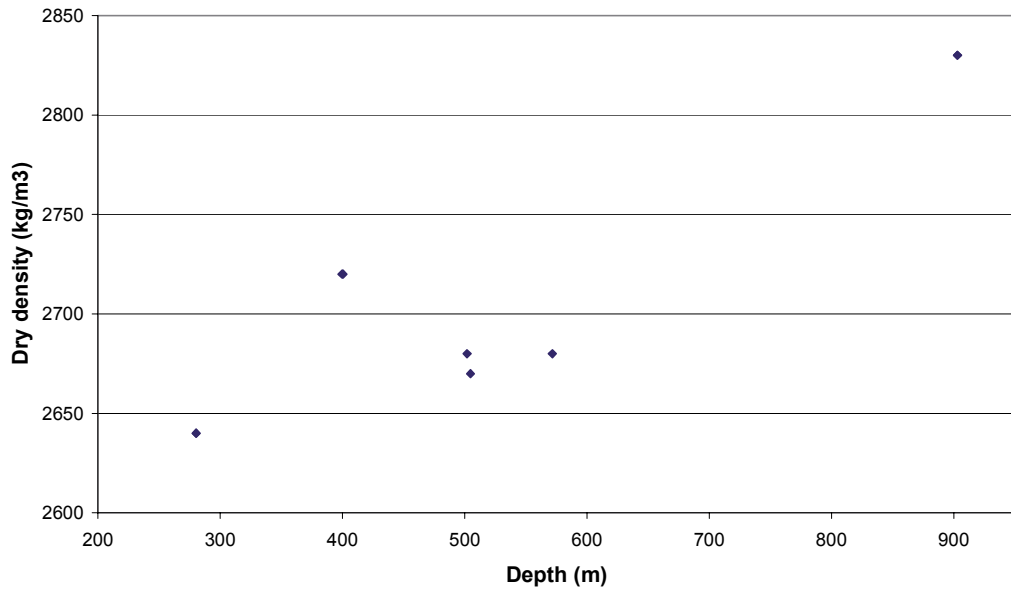


Figure 5-1. Density (dry) versus sampling level (borehole length).

### Wet Density KLX10

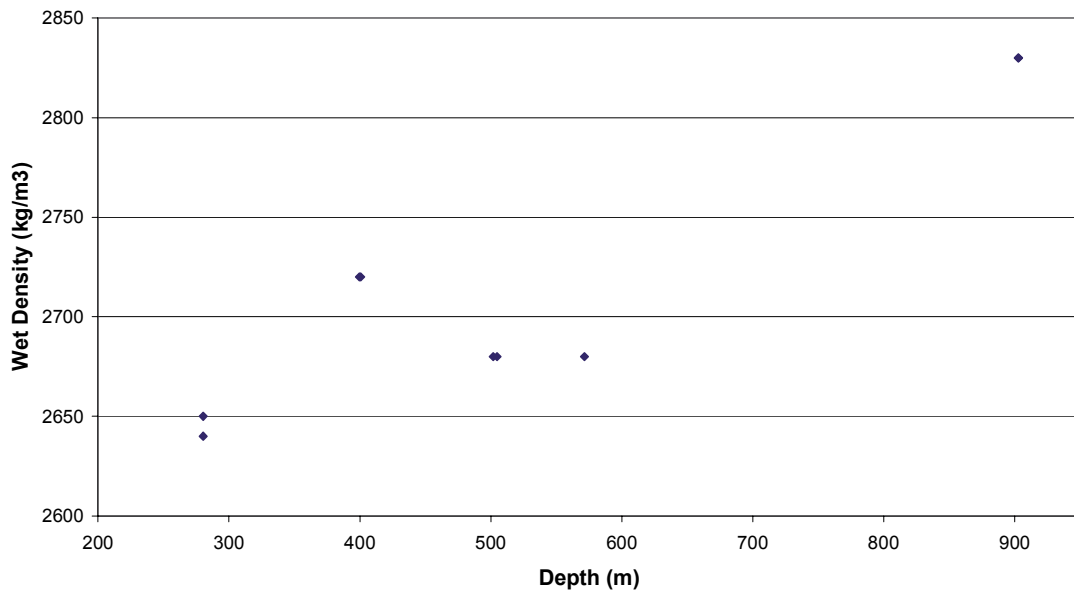
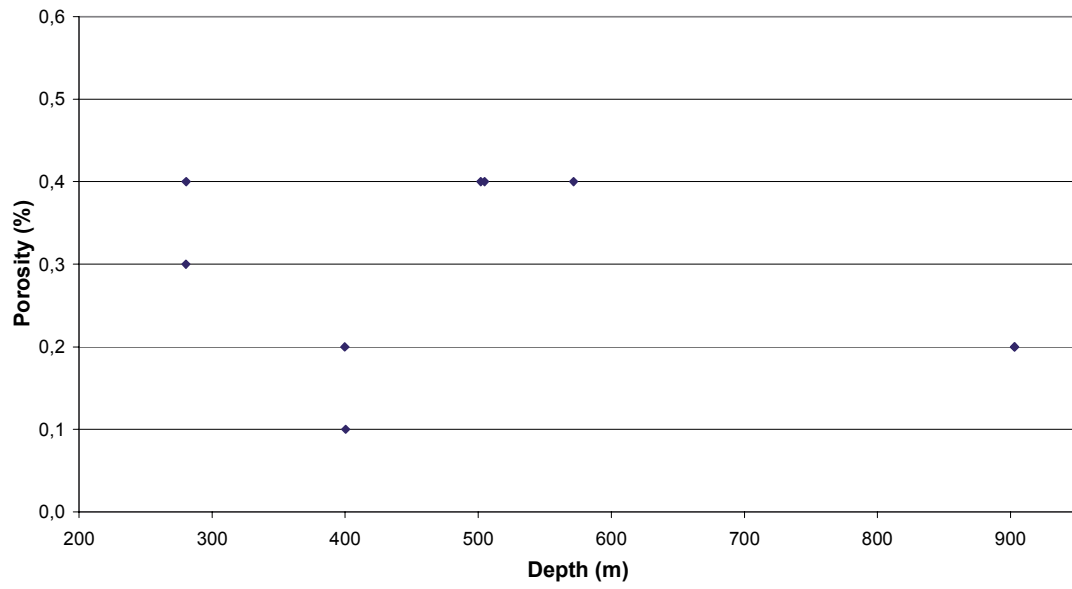


Figure 5-2. Density (wet) versus sampling level (borehole length).

### Porosity KLX10






*Figure 5-3. Porosity versus sampling level (borehole length).*

## References

- /1/ **SKB, 2001.** Site investigations. Investigation methods and general execution programme. SKB TR-01-29, Svensk Kärnbränslehantering AB.
- /2/ **Adl-Zarrabi, B, 2006.** Borehole KLX10. Thermal conductivity and thermal diffusivity determined using the TPS method. SKB P-06-036.
- /3/ **ISRM 1979.** Volume 16, Number 2.
- /4/ **EN 13755.** Natural stone test methods – Determination of water absorption at atmospheric pressure.

Result minutes and photos

Table A-1. KLX10, level 200–800 m. Specimens KLX10-090V-1 to KLX10-090V-11.

<p>KLX10-90V-1 (280.297 m)                  Dry density of specimen KLX10-90V-1A                  2,641 kg/m<sup>3</sup> and porosity 0.33%.                  Dry density of specimen KLX10-90V-1B                  2,642 kg/m<sup>3</sup> and porosity 0.32%</p>	
<p><i>Figure A-1. Specimens KLX10-90V-1 A and B.</i></p>	
<p>KLX10-90V-2 (280.366 m)                  Dry density of specimen KLX10-90V-2A                  2,648 kg/m<sup>3</sup> and porosity 0.39%.                  Dry density of specimen KLX10-90V-2B                  2,635 kg/m<sup>3</sup> and porosity 0.42%.</p>	
<p><i>Figure A-2. Specimens KLX10-90V-2 A and B.</i></p>	
<p>KLX10-90V-3 (399.651 m)                  Dry density of specimen KLX10-90V-3A                  2,712 kg/m<sup>3</sup> and porosity 0.24%.                  Dry density of specimen KLX10 -90V-3B                  2,724 kg/m<sup>3</sup> and porosity 0.22%.</p>	
<p><i>Figure A-3. Specimens KLX10-90V-3 A and B.</i></p>	

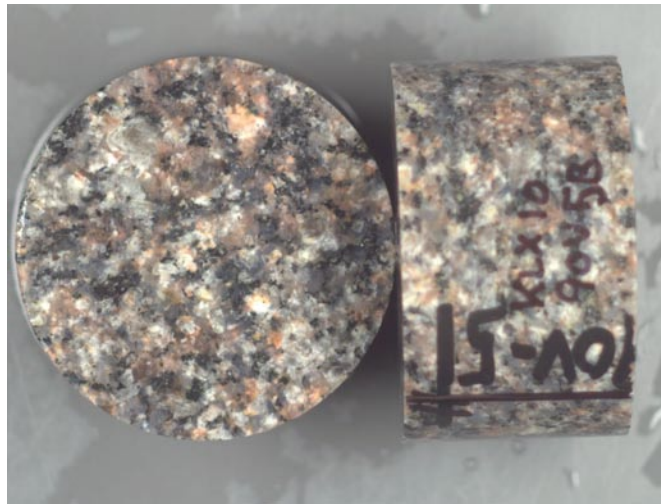


KLX10-90V-4 (400.391 m)  
Dry density of specimen KLX10-90V-4A  
2,720 kg/m<sup>3</sup> and porosity 0.11%.  
Dry density of specimen KLX10-90V-4B  
2,711 kg/m<sup>3</sup> and porosity 0.14%.



**Figure A-4.** Specimens KLX10-90V-4 A and B.

KLX10-90V-5 (501.836 m)  
Dry density of specimen KLX10-90V-5A  
2,681 kg/m<sup>3</sup> and porosity 0.41%.  
Dry density of specimen KLX10 -90V-5B  
2,679 kg/m<sup>3</sup> and porosity 0.44%.



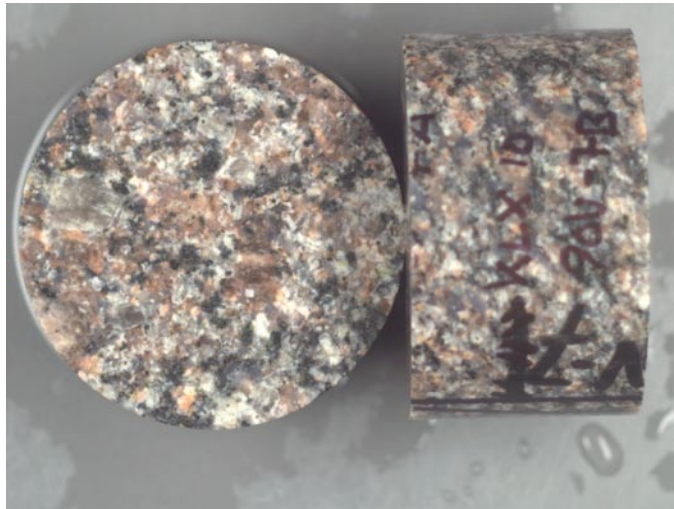
**Figure A-5.** Specimens KLX10-90V-5 A and B.

KLX10-90V-6 (571.507 m)  
Dry density of specimen KLX10-90V-6A  
2,677 kg/m<sup>3</sup> and porosity 0.44%.  
Dry density of specimen KLX10 -90V-6B  
2,674 kg/m<sup>3</sup> and porosity 0.46%.



**Figure A-6.** Specimens KLX10-90V-6 A and B.

KLX10-90V-7 (604.697 m)  
Dry density of specimen KLX10-90V-7A  
2,670 kg/m<sup>3</sup> and porosity 0.39%.  
Dry density of specimen KLX10 -90V-7B  
2,673 kg/m<sup>3</sup> and porosity 0.41%.



**Figure A-7.** Specimens KLX10-90V-7 A and B.

KLX10-90V-10 (902.793 m)  
Dry density of specimen KLX10-90V-10A  
2,830 kg/m<sup>3</sup> and porosity 0.13%.  
Dry density of specimen KLX10 -90V-10B  
2,824 kg/m<sup>3</sup> and porosity 0.20%.



**Figure A-8.** Specimens KLX10-90V-10 A and B.

KLX10-90V-11 (902.863 m)  
Dry density of specimen KLX10-90V-11A  
2,826 kg/m<sup>3</sup> and porosity 0.22%.  
Dry density of specimen KLX10 -90V-11B  
2,826 kg/m<sup>3</sup> and porosity 0.18%.



**Figure A-9.** Specimens KLX10-90V-11 A and B.