P-06-30

Oskarshamn site investigation

Borehole KLX08

Determination of porosity by water saturation and density by buoyancy technique

Marjo Savukoski
Swedish National Testing and Research Institute, SP

October 2006

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-06-30

Oskarshamn site investigation

Borehole KLX08

Determination of porosity by water saturation and density by buoyancy technique

Marjo Savukoski
Swedish National Testing and Research Institute, SP

October 2006

Keywords: Rock mechanics, Petro-physics, Density, Porosity, AP PS 400-05-085.

Abstract

The density and porosity was determined on 10 specimens (each divided into two pieces) from borehole KLX08, Oskarshamn, Sweden. The specimens were sampled at one mail level, measuring between 630–845 m in borehole length. The investigated rock types are mapped as Ävrö granite and diorite/gabbro. The results for the dry density varied between 2,670 and 2,960 kg/m^3, and for the wet density between 2,670 and 2,960 kg/m^3. Finally, the porosity results varied between 0.6 and 0.8%.

Sammanfattning

Densiteten och porositeten bestämdes på 10 provkroppar (varje provkropp delad i två delar) från borrhål KLX08 i Oskarshamn. Proverna togs från en nivå i borrhålet mellan 630–845 m borrhålslängd. De undersökta bergarterna är karterade som Ävrö granit och diorit/gabbro. Resultaten för torrdensiteten varierade mellan 2 670 och 2 960 kg/m^3 och för våtdensiteten mellan 2 670 och 2 960 kg/m^3. För porositeten, slutligen, varierade resultaten mellan 0,6 och 0,8 %.

Contents

1 Introduction

Specimens were sampled from the drill core of borehole KLX08 at the Oskarshamn site investigation area, Sweden, see Figure 1-1, for determination of the water saturated respectively dry density as well as of the porosity.

The sampling was based on the preliminary core logging with the strategy to primarily investigate the properties of the dominant rock types. The samples, which were collected by Björn Ljunggren and Thomas Janson in November 9, 2005, were transported to SP (Swedish National Testing and Research institute), department of Building and Mechanics, where they arrived on November 17, 2005. Testing commenced in February 2006 and was completed in March 2006.

The commission was carried out in compliance with the controlling documents presented in Table 1-1. Activity Plan and Method Descriptions are SKB's (The Swedish Nuclear Fuel and waste Management Company) internal controlling documents, whereas SP-QD 13.1 is an SP internal Quality document.

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

Activity Plan	**Number**	**Version**
KLX08. Bergmekaniska och termiska laboratoriebestämningar	AP PS 400-05-058	1.0
Method Description	**Number**	**Version**
Determining density and porosity of intact rock	SKB MD 160.002	2.0
Quality Plan		
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. The projection of each borehole on the horizontal plane at top of casing is also shown in the figure.*

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 10 rock samples from borehole KLX08 collected within the borehole interval 630–845 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 ± 0.4°C.
- Scale (inv no 102291) for weight measurement. Calibrated in 2005-03-10. Measurement accuracy ± 0.2 g.
- Heating chamber (inv no 102289) for drying the specimens. Calibrated 2006-01-17. Measurement accuracy ± 5°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	± 4 kg/m^3
Porosity	± 0.09%
Water absorption	± 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 /1/ and water saturation by EN 13755 /2/ and in compliance with Activity Plan AP PS 400-05-085(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 KLX08 were sampled at levels ranging between 630 and 845 m borehole length. Table 4-1 shows the identification mark, sampling level and rock type of each specimen.

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

Identification	Sampling level (m borehole length, Adj seclow)	Rock type
KLX08-90V-1	630.77	Ävrö granite
KLX08-90V-2	651.36	Diorite/Gabbro
KLX08-90V-3	669.02	Ävrö granite
KLX08-90V-4	692.61	Diorite/Gabbro
KLX08-90V-5	705.71	Diorite/Gabbro
KLX08-90V-6	730.99	Ävrö granite
KLX08-90V-7	740.60	Diorite/Gabbro
KLX08-90V-8	750.43	Ävrö granite
KLX08-90V-9	770.49	Diorite/Gabbro
KLX08-90V-10	845.44	Diorite/Gabbro

4.2 Testing

The execution procedure followed the prescription in SKB MD 160.002, (SKB internal controlling document), see Table 4-2.

4.3 Nonconformities

The tests were performed in accordance with the Method Description. Due to very low porosity results at the first test, the tests were performed twice. Results from the second test were used. The Activity Plan was followed without deviations.

Another 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.

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 /3/.
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 28°C and the density 996 kg/m^3.
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 three 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 water saturated in normal air pressure for at least seven days.
12	The specimens were weighed in tapwater. The temperature of the water was 18°C and the density 999 kg/m^3.
13	The specimens were surface dried with a towel and weighed.
14	The water saturated density was determined.
15	The specimens were dried in a heating chamber during five days at 105°C.
16	The specimens were transported to a desiccator for cooling.
17	The dry density and porosity were determined.
18	The specimens were photographed in JPEG-format.

5 Results

The results of the porosity and density determinations of core samples from KLX08 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 grouped according to rock type of the specimens

Tables 5-1 to 5-2 summarize the results of the porosity and density determinations divided according to rock type of the specimens.

Table 5-1. Summary of the results for porosity, dry density and wet density of the specimens of rock type Ävrö granite, according to the boremap overview. 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^3)	Wet density (kg/m^3)
KLX08-90V-1	630.77	0.8	2,680	2,680
KLX08-90V-3	669.02	0.7	2,670	2,680
KLX08-90V-6	730.99	0.8	2,670	2,670
KLX08-90V-8	750.43	0.7	2,670	2,680
Mean value		0.8	2,670	2,680
Standard deviation		0.04	7	6

Table 5-2. Summary of the results for porosity, dry density and wet density of the specimens of rock type diorite/gabbro, according to the boremap overview. 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^3)	Wet density (kg/m^3)
KLX08-90V-2	651.36	0.7	2,830	2,840
KLX08-90V-4	692.61	0.6	2,880	2,890
KLX08-90V-5	705.71	0.6	2,880	2,890
KLX08-90V-7	740.60	0.6	2,960	2,960
KLX08-90V-9	770.49	0.7	2,890	2,900
KLX08-90V-10	845.44	0.7	2,830	2,830
Mean value		0.6	2,880	2,890
Standard deviation		0.06	45	45

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.

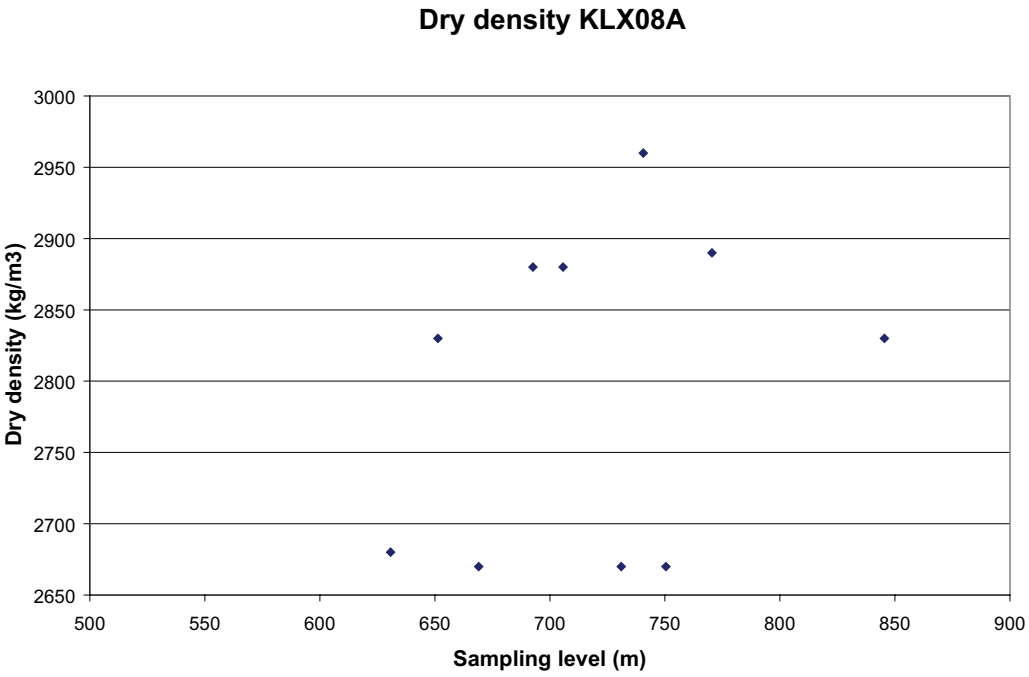

Figure 5-1. *Density (dry) versus sampling level (borehole length).*

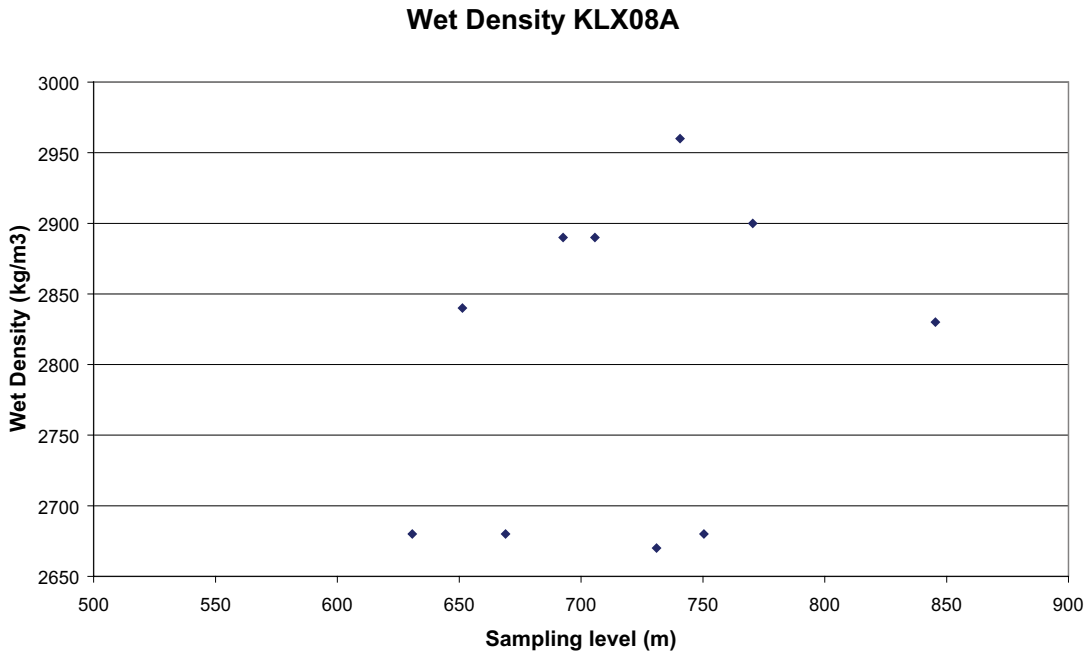

Figure 5-2. *Density (wet) versus sampling level (borehole length).*

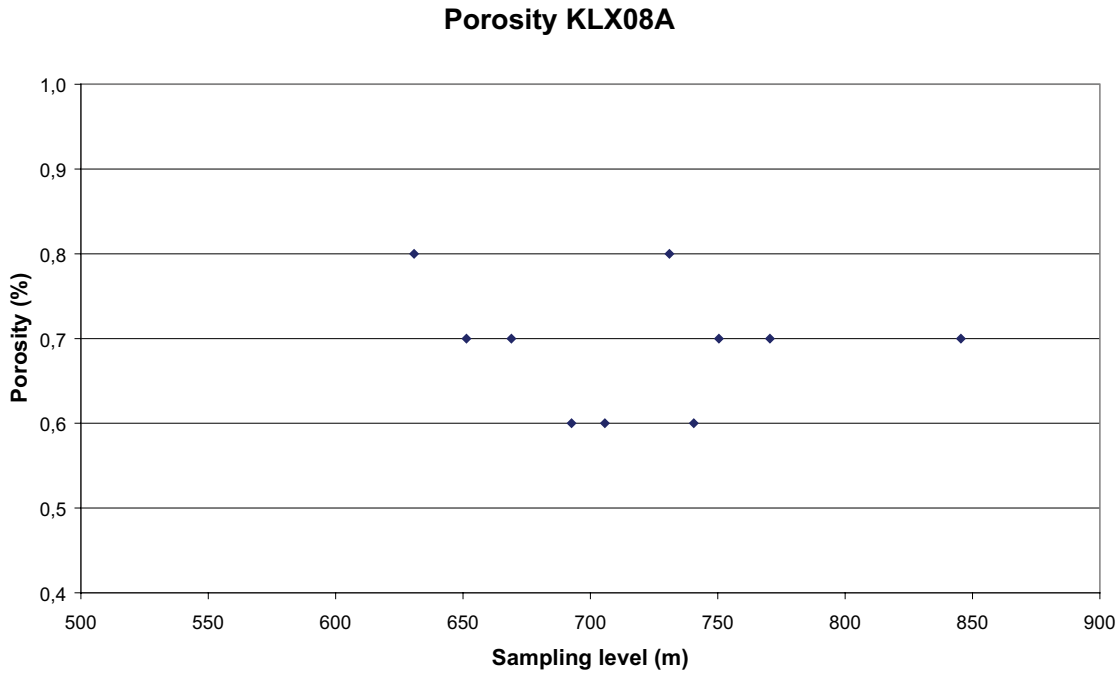

Figure 5-3. *Porosity versus sampling level (borehole length).*

References

/1/ **ISRM, 1979.** Volume 16, Number 2.

/2/ **EN 13755.** Natural stone test methods – Determination of water absorption at atmospheric pressure.

/3/ **Adl-Zarrabi B, 2005.** Borehole KLX08. Thermal conductivity and thermal diffusivity determined using the TPS method. SKB P-06-31. Svensk Kärnbränslehantering AB.

Appendix

Result minutes and photos

Table A-1. KLX08, level 630–845 m. Specimens KLX08-090V-1 to KLX08-090V-10.

KLX08-90V-1 (630.77 m)

Dry density of specimen KLX08-90V-1A 2,677 kg/m^3 and porosity 0.81%.

Dry density of specimen KLX08-90V-1B 2,675 kg/m^3 and porosity 0.77%.

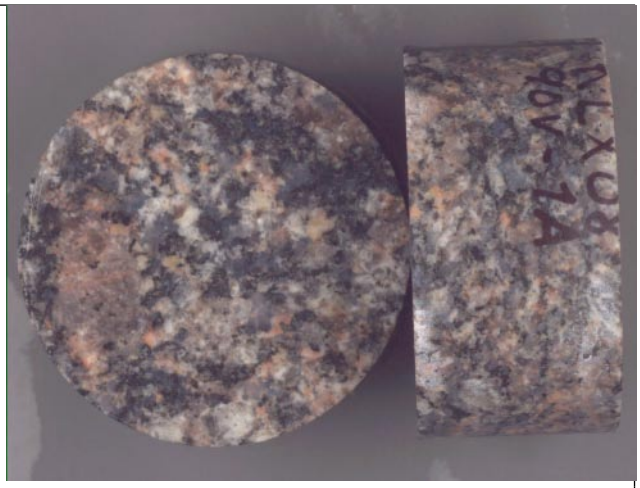

Figure A-1. *Specimens KLX08-90V-1A and B.*

KLX08-90V-2 (651.36 m)

Dry density of specimen KLX08-90V-2A 2,837 kg/m^3 and porosity 0.71%.

Dry density of specimen KLX08-90V-2B 2,831 kg/m^3 and porosity 0.69%.

Figure A-2. *Specimens KLX08-90V-2A and B.*

KLX08-90V-3 (669.02 m)

Dry density of specimen KLX08-90V-3A 2,681 kg/m^3 and porosity 0.72%.

Dry density of specimen KLX08-90V-3B 2,664 kg/m^3 and porosity 0.77%.

Figure A-3. *Specimens KLX08-90V-3A and B.*

KLX08-90V-4 (692.61 m)

Dry density of specimen KLX08-90V-4A 2,879 kg/m^3 and porosity 0.65%.

Dry density of specimen KLX08-90V-4B 2,879 kg/m^3 and porosity 0.63%.

Figure A-4. *Specimens KLX08-90V-4A and B.*

KLX08-90V-5 (705.71 m)

Dry density of specimen KLX08-90V-5A 2,875 kg/m^3 and porosity 0.58%.

Dry density of specimen KLX08-90V-5B 2,887 kg/m^3 and porosity 0.59%.

Figure A-5. *Specimens KLX08-90V-5A and B.*

KLX08-90V-6 (730.99 m)

Dry density of specimen KLX08-90V-6A 2,671 kg/m^3 and porosity 0.82%.

Dry density of specimen KLX08-90V-6B 2,661 kg/m^3 and porosity 0.85%.

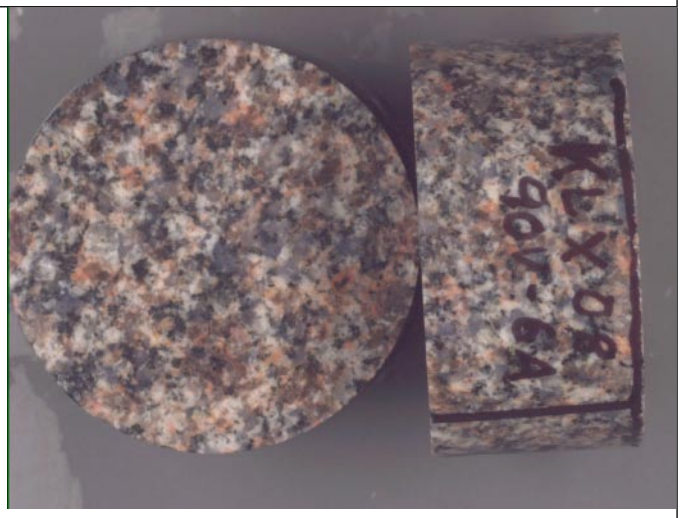

Figure A-6. *Specimens KLX08-90V-6A and B.*

KLX08-90V-7 (740.60 m)

Dry density of specimen KLX08-90V-7A 2,957 kg/m^3 and porosity 0.58%.

Dry density of specimen KLX08-90V-7B 2,959 kg/m^3 and porosity 0.55%.

Figure A-7. *Specimens KLX08-90V-7A and B.*

KLX08-90V-8 (750.43 m)

Dry density of specimen KLX08-90V-8A 2,673 kg/m^3 and porosity 0.73%.

Dry density of specimen KLX08-90V-8B 2,670 kg/m^3 and porosity 0.76%.

Figure A-8. *Specimens KLX08-90V-8A and B.*

KLX08-90V-9 (770.49 m)

Dry density of specimen KLX08-90V-9A 2,894 kg/m^3 and porosity 0.71%.

Dry density of specimen KLX08-90V-9B 2,893 kg/m^3 and porosity 0.69%.

Figure A-9. *Specimens KLX08-90V-9A and B.*

KLX08-90V-10 (845.44 m)

Dry density of specimen KLX08-90V-10A 2,827 kg/m^3 and porosity 0.70%.

Dry density for specimen KLX08-90V-10B 2,826 kg/m^3 and the porosity 0.68%.

Figure A-10. *Specimens KLX08-90V-10A and B.*