P-06-274

Oskarshamn site investigation

Borehole KLX13A

Determination of porosity by water saturation and density by buoyancy technique

Lotta Liedberg
Swedish National Testing and Research Institute, SP

December 2007

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 250, SE-101 24 Stockholm
Tel +46 8 459 84 00

ISSN 1651-4416
SKB P-06-274

Oskarshamn site investigation

Borehole KLX13A

Determination of porosity by water saturation and density by buoyancy technique

Lotta Liedberg
Swedish National Testing and Research Institute, SP

December 2007

Keywords: Rock mechanics, Petro-physics, Density, Porosity, AP PS 400-06-107.

Abstract

The density and porosity was determined on 8 specimens (each divided into two pieces) from borehole KLX13A, Oskarshamn, Sweden. The specimens were sampled at borehole lengths measuring between 250–480 m. The investigated rock types are mapped as metamorphic varieties of Ävrö granite (SKB rock code 501044) and diorite/gabbro (SKB rock code 501033). The results for the dry density varied between 2,680 and 2,930 kg/m^3, and for the wet density likewise between 2,680 and 2,940 kg/m^3. Finally, the porosity results varied between 0.3 and 0.6%.

Sammanfattning

Densiteten och porositeten bestämdes på 8 provkroppar (varje provkropp delad i två delar) från borrhål KLX13A i Oskarshamn. Proverna togs mellan borrhålslängden 250–480 m. De undersökta bergarterna är karterade som Ävrögranit (SKB bergartskod 501044 och diorit/gabbro (SKB bergartskod 501033). Resultaten för torrdensiteten varierade mellan 2 680 och 2 930 kg/m^3 och för våtdensiteten likaså mellan 2 680 och 2 940 kg/m^3. För porositeten, slutligen, varierade resultaten mellan 0,3 och 0,6 %.

Contents

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 att 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, whereas the Quality Plan referred to in the table is an SP internal controlling document. The thermal properties conductivity and diffusivity of the specimens were determined within the scope of a parallel activity /2/.

Samples were collected from the drill core of borehole KLX13A located north-west within the site investigation area at Oskarshamn, Sweden, see Figure 1-1. Borehole KLX13A is a conventional core drilled borehole with a total length of 600 m.

The samples were selected based on the preliminary core logging, and with the strategy to primarily investigate the properties of the rock types Ävrögranite (501044) and diorite/gabbro (501033). The samples, which were collected in September 27, 2006, were transported to SP (Swedish National Testing and Research institute), department of Building and Mechanics, where they arrived in October 26, 2006. Testing commenced in November 2006 and was completed in November 2006.

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

Activity Plan	**Number**	**Version**
KLX13A. Bergmekaniska och termiska laboratoriebestämningar	AP PS 400-06-107	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		

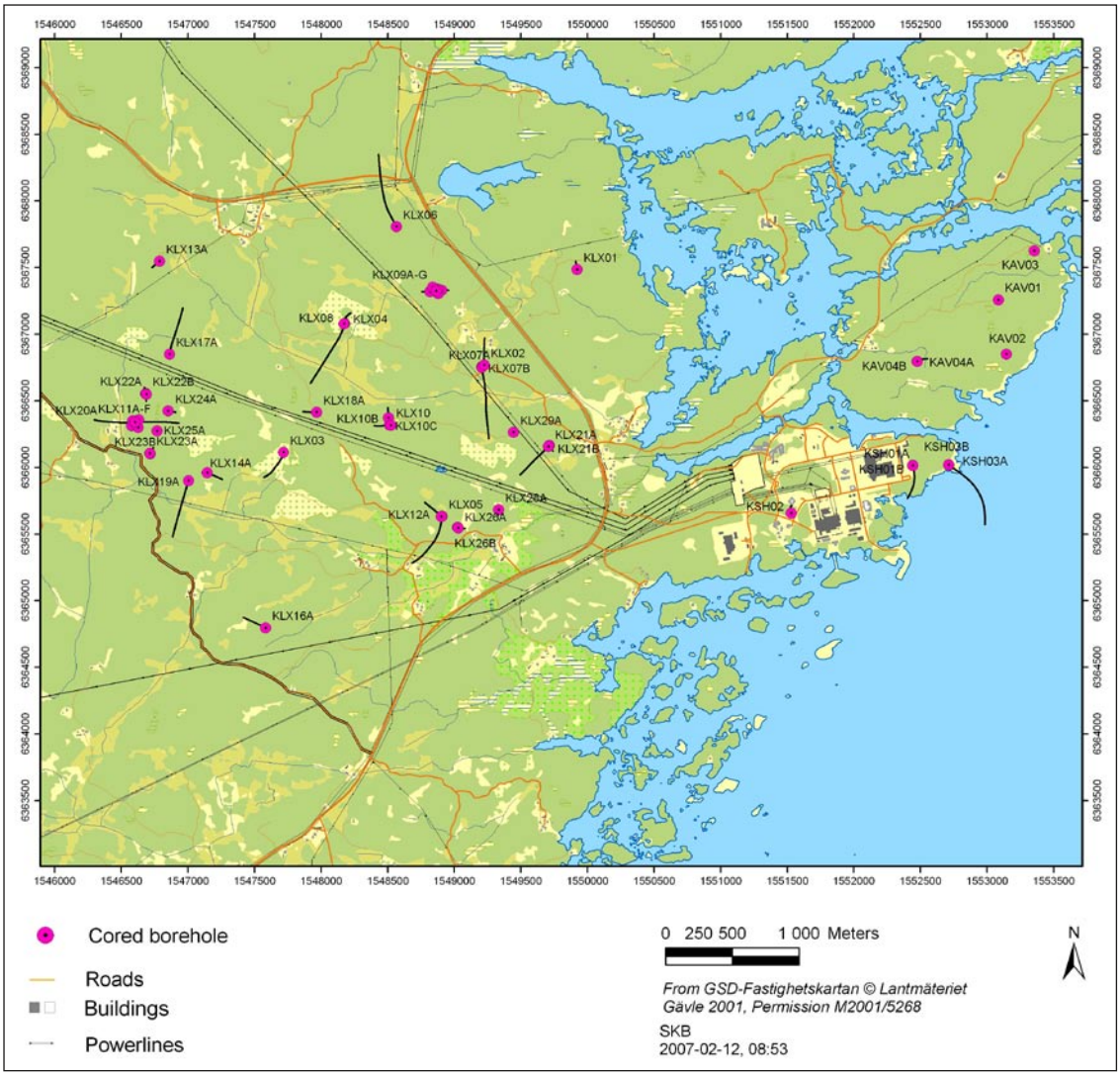

Figure 1-1. *Location of boreholes and drilled up to February 2007.*

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 8 rock samples from borehole KLX13A collected within the borehole interval 250–480 m.

3 Equipment

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

- Thermometer (inv no 102185) for measurement of water temperature. Calibrated 2006-01-17. Measurement accuracy ± 0.4°C.
- Scale (inv no 102291) for weight measurement. Calibrated in 2006-03-10. 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 /3/ and water saturation by EN 13755 /4/ and in compliance with Activity Plan AP PS 400-06-107 (internal controlling document of SKB). The department of Building Technology and Mechanics (BM) at SP performed the tests.

4.1 Description of the specimens

The specimens from borehole KLX13A were sampled at levels ranging between 250 and 480 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 19°C and the density was 998 kg/m^3.The specimens were dried in 105°C for eight days after water saturation. The execution procedure followed the prescription in SKB MD 160.002, see Table 4-2.

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

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

Identification	Sampling level (m, Adj seclow)	Rock type
KLX13A-90V-1	298.46	Ävrögranite (501044)
KLX13A-90V-2	418.09	Ävrögranite (501044)
KLX13A-90V-3	478.52	Ävrögranite (501044)
KLX13A-90V-4	478.58	Ävrögranite (501044)
KLX13A-90V-5	395.42	Diorite/gabbro (501033)
KLX13A-90V-6	395.48	Diorite/gabbro (501033)
KLX13A-90V-7	249.65	Diorite/gabbro (501033)
KLX13A-90V-8	249.71	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 and the calorimetric 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^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 Measurement technology to SP Fire Technology for measurement of thermal properties, TPS method /2/.
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 for six 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.
12	The specimens were water saturated in normal air pressure for at least seven days.
13	The samples were sent from SP Building Technology and Mechanics to SP Measurement technology for measurement of thermal properties, calorimetric method /2/.

4.3 Nonconformities

The Activity Plan was followed without deviations.

The tests were performed in accordance with the Method Description, however with the exception of the statement of significant numbers in Appendix 1. The precision in the method for density gives only three significant digits. The fourth digit given in Appendix 1 is thus not significant. The precision in the method for porosity provides only one significant digit and the second digit given in Appendix 1 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 KLX13A 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 and 5-2 summarize the results of the porosity and density determinations divided according to rock type of the specimens.

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 of Ävrö granite. The result for each specimen is a mean value of subsamples A and B.

Specimen	Sampling level (m, Adj seclow)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KLX13A-90V-1	298.46	0.6	2,740	2,740
KLX13A-90V-2	418.09	0.5	2,750	2,750
KLX13A-90V-3	478.52	0.5	2,680	2,680
KLX13A-90V-4	478.58	0.5	2,690	2,690
Mean value		0.5	2,710	2,720

Table 5-2. Summary of the results for porosity, dry density and wet density of diorite/ gabbro. The result for each specimen is a mean value of subsamples A and B.

Specimen	Sampling level (m, Adj seclow)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KLX13A-90V-5	395.42	0.3	2,930	2,930
KLX13A-90V-6	395.48	0.3	2,930	2,940
KLX13A-90V-7	249.65	0.3	2,900	2,900
KLX13A-90V-8	249.71	0.3	2,890	2,890
Mean value		0.3	2,910	2,920

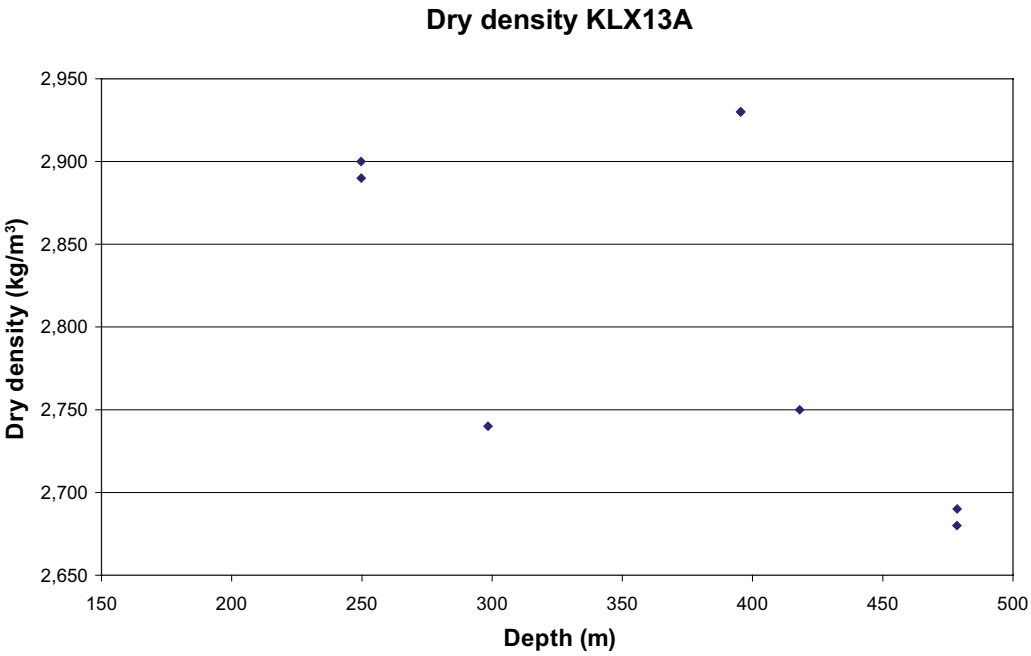

Figure 5-1. *Density (dry) versus sampling level (borehole length).*

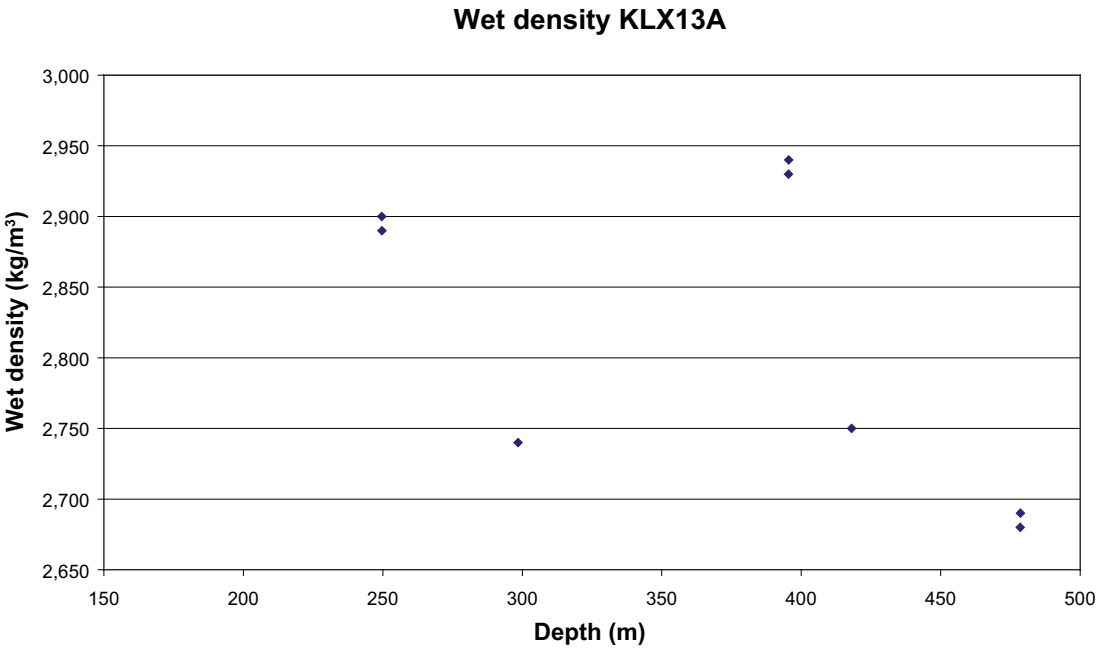

Figure 5-2. *Density (wet) versus sampling level (borehole length).*

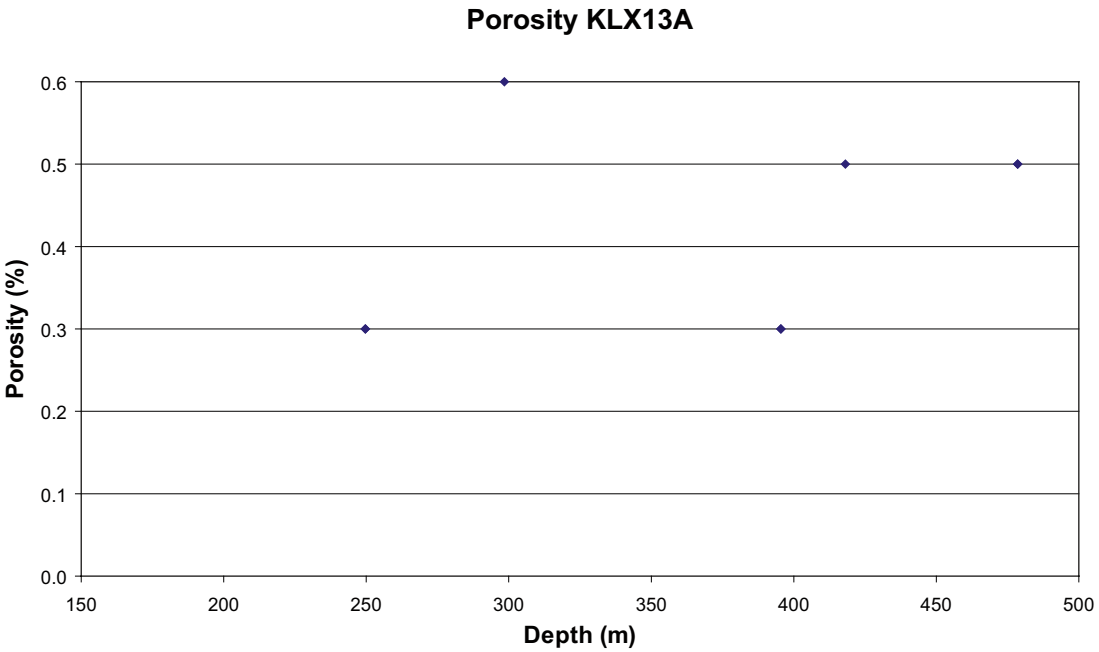

Figure 5-3. *Porosity versus sampling level (borehole length).*

References

/1/ **SKB, 2001.** Site investigations. Investigation methods and general execution programme. SKB TR-01-29, Svensk Kärnbränslehantering AB.

/2/ **Adl-Zarrabi, B, 2006.** Borehole KLX13A. Thermal properties of rock using calirometer and TPS method. SKB P-06-275, Svensk Kärnbränslehantering AB.

/3/ **ISRM, 1979.** Volume 16, Number 2.

/4/ **EN 13755.** Natural stone test methods – Determination of water absorption at atmospheric pressure.

Appendix 1

Result minutes and photos

Table A-1. KLX13A, level 100–480 m. Specimens KLX13A-90V-1 to KLX13A-90V-8.

KLX13A-90V-1 (298.46 m)

Dry density of specimen KLX13A-90V-1A 2,731 kg/m^3 and porosity 0.61%.

Dry density of specimen KLX13A-90V-1B 2,742 kg/m^3 and porosity 0.66%

Figure A-1. *Specimens KLX13A-90V-1 A and B.*

KLX13A-90V-2 (418.09 m)

Dry density of specimen KLX13A-90V-2A 2,753 kg/m^3 and porosity 0.53%.

Dry density of specimen KLX13A-90V-2B 2,746 kg/m^3 and porosity 0.51%.

Figure A-2. *Specimens KLX13A-90V-2 A and B.*

KLX13A-90V-3 (478.52 m)

Dry density of specimen KLX13A-90V-3A 2,676 kg/m^3 and porosity 0.60%.

Dry density of specimen KLX13A-90V-3B 2,681 kg/m^3 and porosity 0.49%.

Figure A-3. *Specimens KLX13A-90V-3 A and B.*

KLX13A-90V-4 (478.58 m)

Dry density of specimen KLX13A-90V-4A 2,690 kg/m^3 and porosity 0.47%.

Dry density of specimen KLX13A-90V-4B 2,686 kg/m^3 and porosity 0.47%.

Figure A-4. *Specimens KLX13A-90V-4 A and B.*

KLX13A-90V-5 (395.42 m)

Dry density of specimen KLX13A-90V-5A 2,933 kg/m^3 and porosity 0.31%.

Dry density of specimen KLX13A-90V-5B 2,929 kg/m^3 and porosity 0.37%.

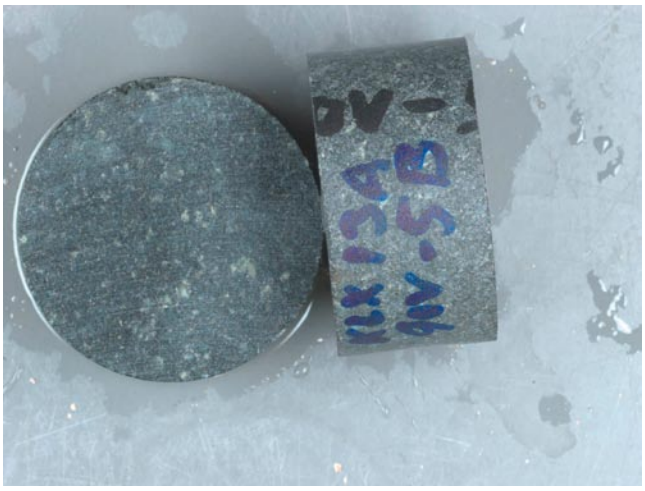

Figure A-5. *Specimens KLX13A-90V-5 A and B.*

KLX13A-90V-6 (395.48 m)

Dry density of specimen KLX13A-90V-6A 2,935 kg/m^3 and porosity 0.31%.

Dry density of specimen KLX13A-90V-6B 2,934 kg/m^3 and porosity 0.33%.

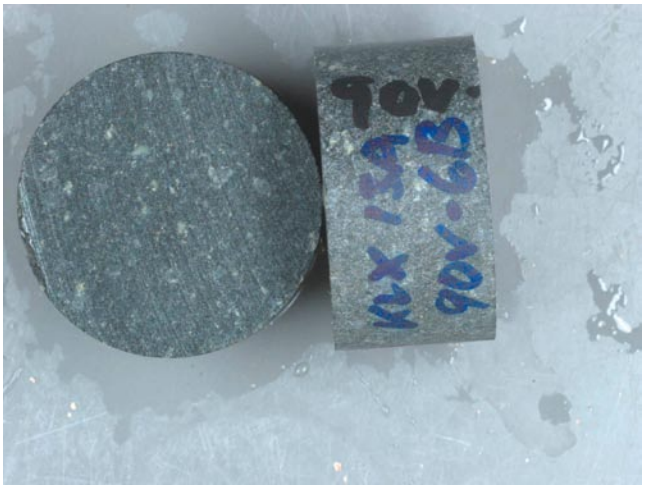

Figure A-6. *Specimens KLX13A-90V-6 A and B.*

KLX13A-90V-7 (249.65 m)

Dry density of specimen KLX13A-90V-7A 2,897 kg/m^3 and porosity 0.33%.

Dry density of specimen KLX13A-90V-7B 2,903 kg/m^3 and porosity 0.29%.

Figure A-7. *Specimens KLX13A-90V-7 A and B.*

KLX13A-90V-8 (249.71 m)

Dry density of specimen KLX13A-90V-8A 2,890 kg/m^3 and porosity 0.29%.

Dry density of specimen KLX13A-90V-8B 2,887 kg/m^3 and porosity 0.29%.

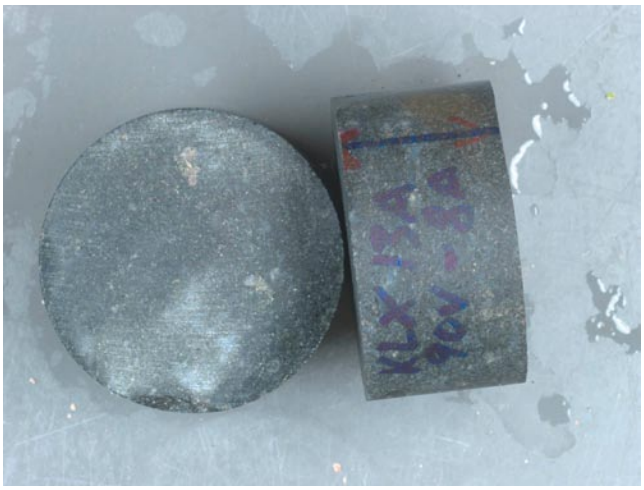

Figure A-8. *Specimens KLX13A-90V-8 A and B.*