P-04-268

Oskarshamn site investigation

Drill hole KLX04A

Determining of porosity by water saturation and density by buoyancy technique

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Swedish National Testing and Research Institute, SP

October 2004

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Keywords: Rock Mechanics, Petro Physics, Density, Porosity.

Abstract

The density and porosity has been determined on 15 specimens (each divided in two pieces) from drill hole KLX04A. The specimens were sampled on three levels in the drill hole: 310, 565 and 740 m. The investigated rock type for level 1, 2 and 3 is mapped as Ävrö granite. The results for dry density varied between 2,640 and 2,750 kg/m^3, for wet density the results varied between 2,650 and 2,760 kg/m^3 and the results for porosity varied between 0.5 and 0.8%.

Sammanfattning

Densiteten och porositeten har bestämts på 15 provkroppar (varje provkropp delad i två delar) från borrhål KLX04A. Proverna togs från tre nivåer i borrhålet: 310, 565 och

740 m. Den undersökta bergartstypen för nivå 1, 2 och 3 är karterad som Ävrögranit. Resultaten för den torra densiteten varierade mellan 2 640 och 2 750 kg/m^3, och för den våta densiteten varierade resultaten mellan 2 650 och 2 760 kg/m^3 och resultaten för porositeten varierade mellan 0,5 och 0,8%.

Contents

1 Introduction

The purpose is to determine the porosity and the wet and dry density of the samples.

The cores are sampled from borehole KLX04A in the Laxemar area. Thomas Janson, Tyréns AB, and Rolf Christiansson, SKB, sampled them 2 July 2004. Specimens were taken from three levels in the rock core at level 1 between 309 and 312 m, level 2 between 562 and 568 m and level 3 between 739 and 747 m. The samples were selected based on the preliminary core logging, and with the strategy to primarily investigate the properties of the dominant rock. The rock cores were transported from Laxemar and arrived to SP in August 2004. The testing was started in September 2004 and ended in October 2004.

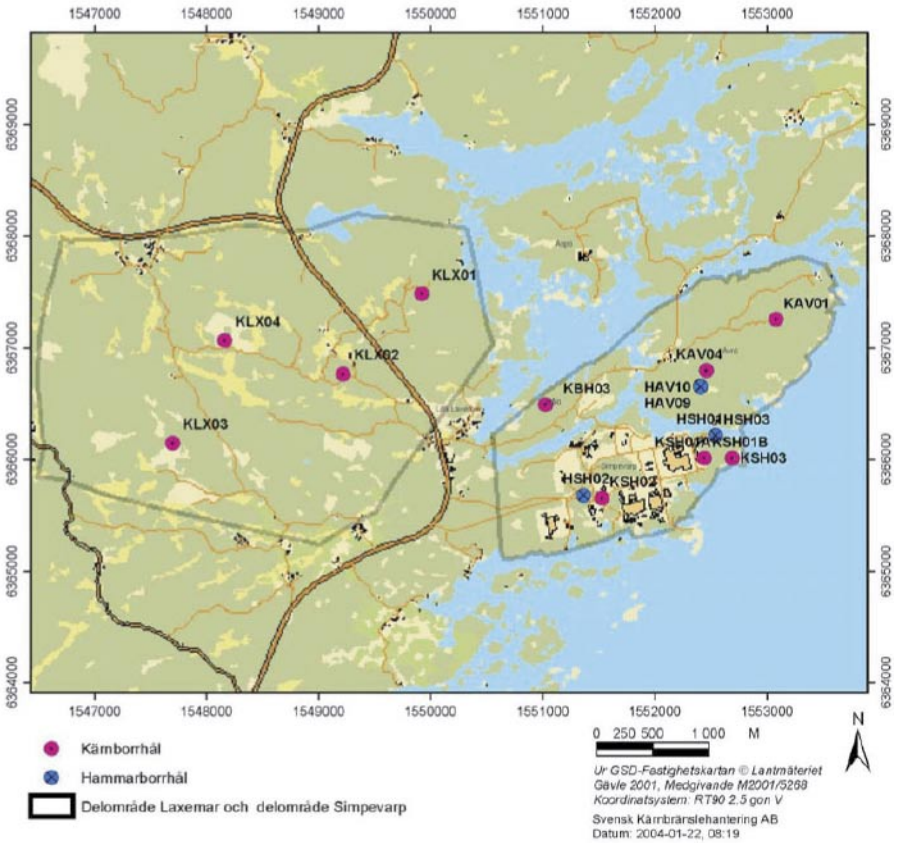


Figure 1-1. *Location of the drill hole KLX04A at the Laxemar site.*

2 Objective and scope

The purpose of the testing is to determine the density and porosity of intact rock core. The parameters are used in the rock mechanics and thermal site descriptive model, which will be established for the candidate area selected for site investigations at Laxemar.

The samples are from the borehole KLX04A in Laxemar, which is a telescope borehole of SKB-standard type with a borehole depth of 1,000 m. The samples in this report are taken at three main levels.

3 Equipment

Following equipment have been used for the analyses:

- Thermometer (inv no 100877) for measurement of water temperature. Calibrated 2004-03-11. Uncertainty of measurement ± 0.4°C.
- Scale (inv no 102291) for weight measurement. Calibrated in March 2004. Uncertainty of measurement ± 0.2 g.
- Heating chamber (inv no 102289) for drying the specimens. Calibrated 2004-08-31.Uncertainty of measurement ± 5°C.
- A covered plastic box filled with water for water saturation of the samples.
- A dessicator for cooling samples in

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

Density	± 4 kg/m^3
Porosity	± 0.09%
Waterabsorption	± 0.05%

4 Execution

Determination of the porosity and density was made in accordance with SKB's method description SKB MD 160.002e -version 2.0 (SKB internal controlling document); This includes determination of density in accordance to ISRM 1979, volume 16, number 2, water saturation by EN 13755 and in accordance to Activity plan AP PS 400-04-073 (internal controlling document of SKB). The Department of Building Technology and Mechanics (BM) at SP performed the test.

4.1 Description of the samples

From the Laxemar area specimens were sampled from three levels in drill hole KLX04A. Level 1 ranged between 309 and 312 m, level 2 between 562 and 568 and level 3 between 739 and 747 m. Table 4-1 show the rock type and identification marks of the specimens.

Table 4-1. Rock type and identification marks (Rock-type classification according to Boremap).

Identification	Sampling depth (Seclow)	Rock type
KLX04A-90V-1	312.4	Ävrö granite
KLX04A-90V-2	312.46	Ävrö granite
KLX04A-90V-3	312.52	Ävrö granite
KLX04A-90V-4	308.2	Ävrö granite
KLX04A-90V-5	308.26	Ävrö granite
KLX04A-90V-7	562.14	Ävrö granite
KLX04A-90V-8	562.2	Ävrö granite
KLX04A-90V-10	567.25	Ävrö granite
KLX04A-90V-11	567.31	Ävrö granite
KLX04A-90V-12	567.37	Ävrö granite
KLX04A-90V-13	739.54	Ävrö granite
KLX04A-90V-14	739.6	Ävrö granite
KLX04A-90V-15	739.66	Ävrö granite
KLX04A-90V-16	746.45	Ävrö granite
KLX04A-90V-17	746.51	Ävrö granite

4.2 Testing

The execution procedure followed the prescription in SKB MD 160.002e-version 2.0 (SKB internal controlling document) and the following steps were performed, see Table 4-2.

Table 4-2. Execution procedure.

Activity no	Activity
1	The specimens were cut according to the marks on the rock cores. Every specimen was cut in two pieces, marked A and B and about 25 mm thick each. The same specimens were used to test Thermal properties: heat conductivity and heat capacity determing using the TPS method.
2	The specimens were water saturated in normal air pressure for at least seven days.
3	The specimens were weighted in tapwater (see Appendix 2).
4	The specimens were surface dried with a towel and weighted.
5	The water saturated density was determined (see Appendix 2).
6	The specimens were photographed in JPEG-format.
7	The samples were sent from SP Building and Mechanics to SP Fire Technology for measurement of thermal properties.
8	The samples were sent back from SP Fire Technology to SP Building and Mechanics.
9	The specimens were dried in a heating chamber at 105°C.
10	The specimens were transported to a dessicator for cooling.
11	The dry density and porosity was determined. (See Appendix 2).

5 Results

The main results of the site investigation of KLX04A could be found in the database SICADA FN428. The data from SICADA should be used for modelling.

Protocols, calculations and pictures can be found in Appendix 1–2.

5.1 Description and presentation of the specimen

The temperature of water for water saturation was 19°C and the density of the water was 998 kg/m^3. The specimens were dried in 105°C for one week after water saturation. Table 5-1, 5-2 and 5-3 shows the results for the different levels.

Table 5-1. Summary of the results for porosity, dry density and wet density of the specimens from level 1, seclow 309 to 312 m. The result for each specimen is a mean value of subsample A and B.

Specimen	Sampling depth, according to the marks on the drill-core boxes (Seclow) (m)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KLX04A-90V-1	312.4	0.6	2,640	2,650
KLX04A-90V-2	312.46	0.6	2,650	2,650
KLX04A-90V-3	312.52	0,7	2,650	2,660
KLX04A-90V-4	308.2	0,6	2,660	2,670
KLX04A-90V-5	308.26	0.6	2,670	2,680
Mean value		0.6	2,650	2,660
Standard deviation		0.1	12	12

Table 5-2. Summary of the results for porosity, dry density and wet density of the specimens from level 2, seclow 562 to 568 m. The result for each specimen is a mean value of subsample A and B.

Specimen	Sampling depth, according to the marks on the drill-core boxes (Seclow) (m)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KLX04A-90V-7	562.14	0.5	2,710	2,720
KLX04A-90V-8	562.2	0.6	2,700	2,710
KLX04A-90V-10	567.25	0.7	2,750	2,760
KLX04A-90V-11	567.31	0.8	2,720	2,730
KLX04A-90V-12	567.37	0.6	2,730	2,730
Mean value		0.6	2,720	2,730
Standard deviation		0.1	20	20

Table 5-3. Summary of the results for porosity, dry density and wet density of the specimens from level 3, seclow 739 to 747 m. The result for each specimen is a mean value of subsample A and B.

Specimen	Sampling depth, according to the marks on the drill-core boxes (Seclow) (m)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KLX04A-90V-13	739.54	0.5	2,680	2,680
KLX04A-90V-14	739.6	0.5	2,670	2,680
KLX04A-90V-15	739.66	0.6	2,670	2,680
KLX04A-90V-16	746.45	0,5	2,680	2,680
KLX04A-90V-17	746.51	0.5	2,670	2,680
Mean value		0.5	2,670	2,680
Standard deviation		0.0	4	4

5.2 Results for the entire test series

Results for the entire test series are shown in the diagrams below. They are divided into 3 diagrams, dry density, wet density and porosity, see Figures 5-1, 5-2 and 5-3.

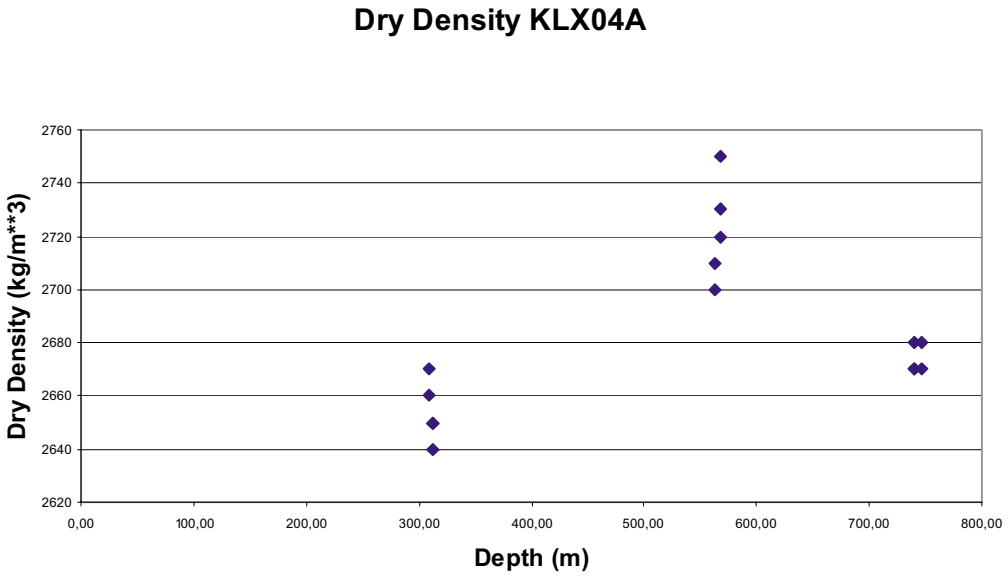


Figure 5-1. *Density (dry) versus depth, depth is where the samples are taken in the borehole.*

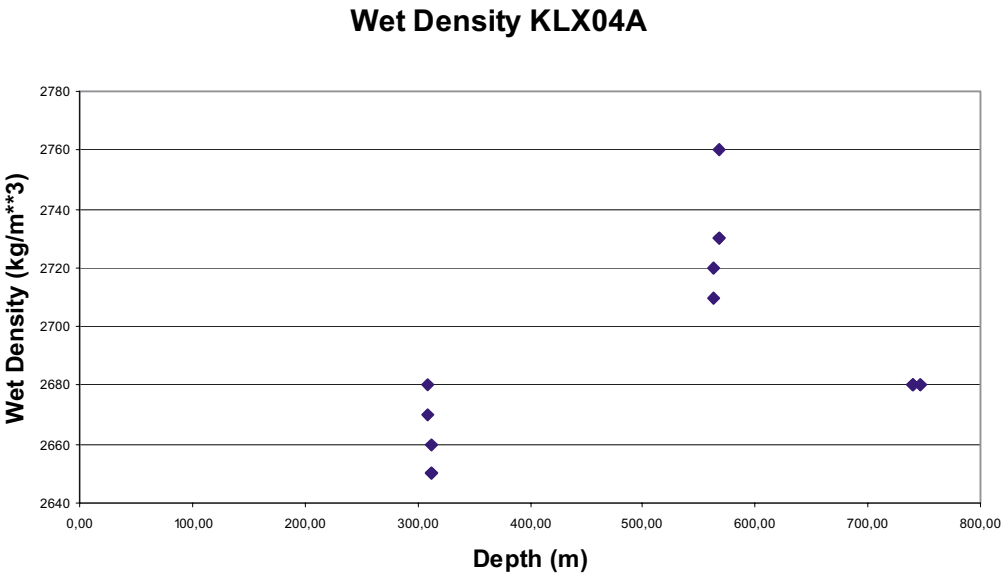


Figure 5-2. *Density (wet) versus depth, depth is where the samples are taken in the borehole.*

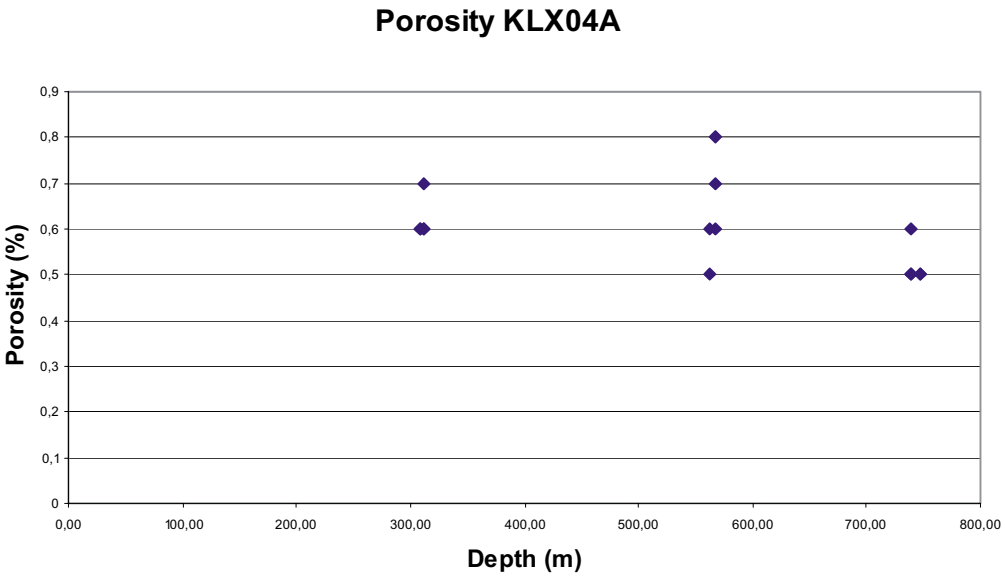


Figure 5-3. *Porosity versus depth, depth is where the samples are taken in the borehole.*

5.3 Discussion

Test specimen KLX04A 90V-9 was not tested because during the sample preparing it was detected that the height of the sample was not high enough. The spare sample KLX04A 90V-12 was used instead.

References

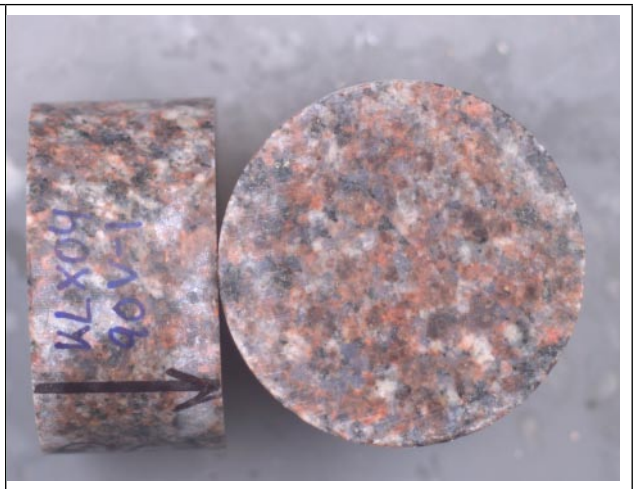
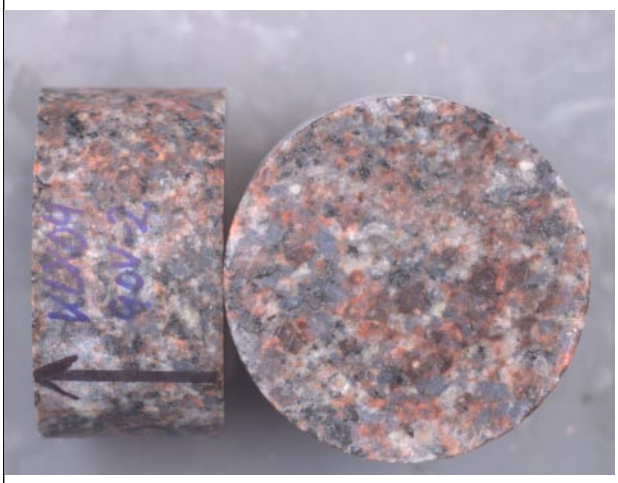
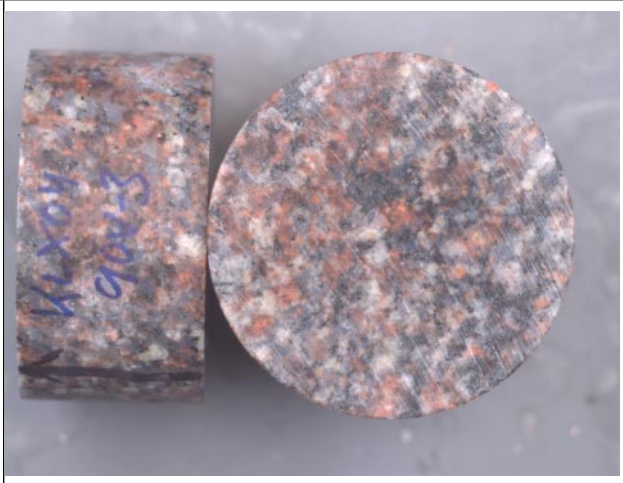
ISRM, 1979. Volume 16, Number 2.

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

Appendix 1

Determination of the linear coefficient of thermal expansion

Table 1. Level 1 309–312 m, Specimen KLX04A-090V-1 to KLX04A-090V-5.

KLX04A-90V-1 (312.40) The dry density for specimen KLX04A-90V-1A was measured to be 2,640 kg/m^3 and the porosity to 0.6% and the dry density for specimen KLX04A-90V-1B was measured to be 2,640 kg/m^3 and the porosity to 0.5%.	 ***Figure 1.*** *Specimen KLX04A-90V-1.*
KLX04A-90V-2 (312.46) The dry density for specimen KLX04A-90V-2A was measured to be 2,650 kg/m^3 and the porosity to 0.6% and the dry density for specimen KLX04A-90V-2B was measured to be 2,650 kg/m^3 and the porosity to 0.6%.	 ***Figure 2.*** *Specimen KLX04A-90V-2*
KLX04A-90V-3 (312.52) The dry density for specimen KLX04A-90V-3A was measured to be 2,650 kg/m^3 and the porosity to 0.8% and the dry density for specimen KLX04A-90V-3B was measured to be 2,650 kg/m^3 and the porosity to 0.6%.	 ***Figure 3.*** *Specimen KLX04A-90V-3.*

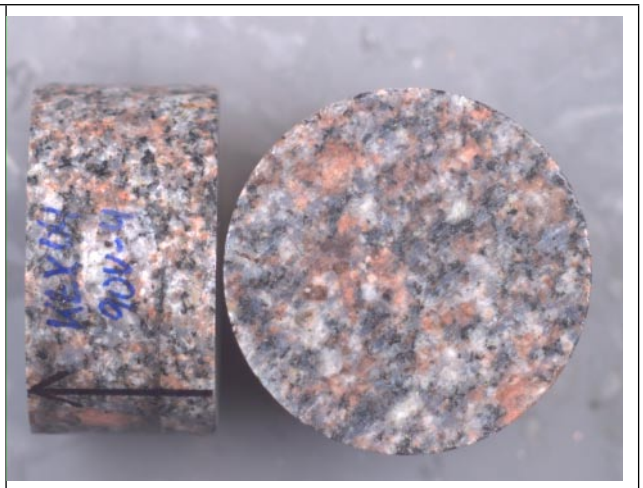
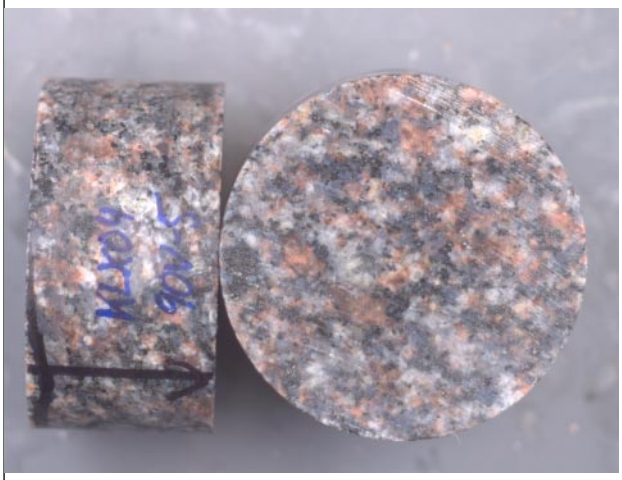
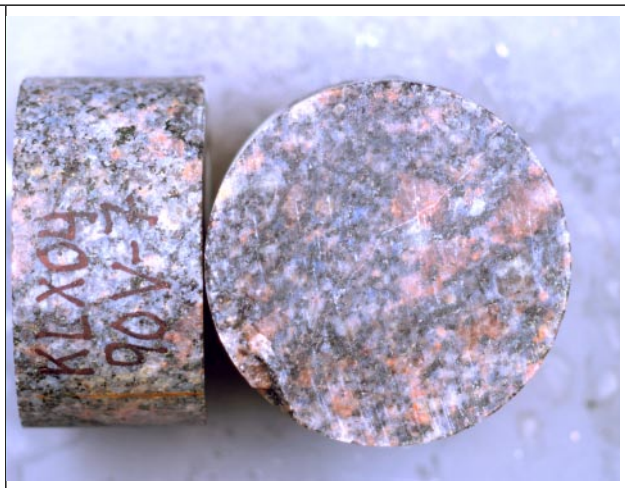
KLX04A-90V-4 (308.20) The dry density for specimen KLX04A-90V-4A was measured to be 2,660 kg/m^3 and the porosity to 0.6% and the dry density for specimen KLX04A-90V-4B was measured to be 2,660 kg/m^3 and the porosity to 0.6%.	 ***Figure 4.*** *Specimen KLX04A-90V-4.*
KLX04A-90V-5 (308.26) The dry density for specimen KLX04A-90V-5A was measured to be 2,670 kg/m^3 and the porosity to 0.6% and the dry density for specimen KLX04A-90V-5B was measured to be 2,670 kg/m^3 and the porosity to 0.6%.	 ***Figure 5.*** *Specimen KLX04A-90V-5.*

Table 2. Level 2 562–568 m, Specimen KLX04A-090V-7 to KLX04A-090V-12.

KLX04A-90V-7 (562.14) The dry density for specimen KLX04A-90V-7A was measured to be 2,720 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX04A-90V-7B was measured to be 2,710 kg/m^3 and the porosity to 0.5%.	 ***Figure 6.*** *Specimen KLX04A-90V-7.*

KLX04A-90V-8 (562.20)

The dry density for specimen KLX04A-90V-8A was measured to be 2,690 kg/m^3 and the porosity to 0.6% and the dry density for specimen KLX04A-90V-8B was measured to be 2,710 kg/m^3 and the porosity to 0.6%.

Figure 7. *Specimen KLX04A-90V-8.*

KLX04A-90V-10 (567.25)

The dry density for specimen KLX04A-90V-10A was measured to be 2,770 kg/m^3 and the porosity to 0.7% and the dry density for specimen KLX04A-90V-10B was measured to be 2,730 kg/m^3 and the porosity to 0.7%.

Figure 8. *Specimen KLX04A-90V-10.*

KLX04A-90V-11 (567.31)

The dry density for specimen KLX04A-90V-11A was measured to be 2,730 kg/m^3 and the porosity to 0.8% and the dry density for specimen KLX04A-90V-11B was measured to be 2,720 kg/m^3 and the porosity to 0.7%.

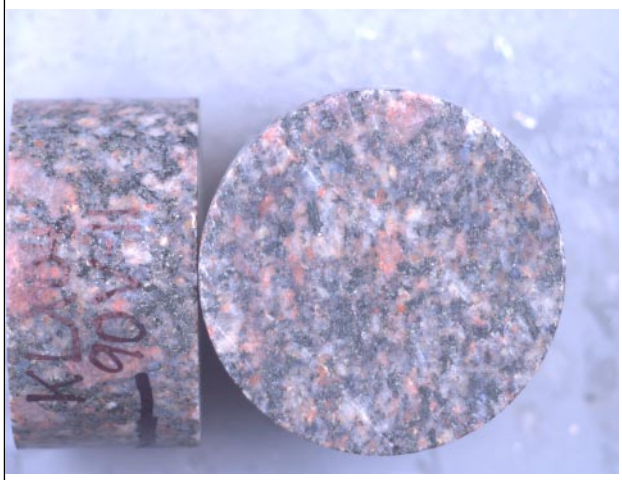
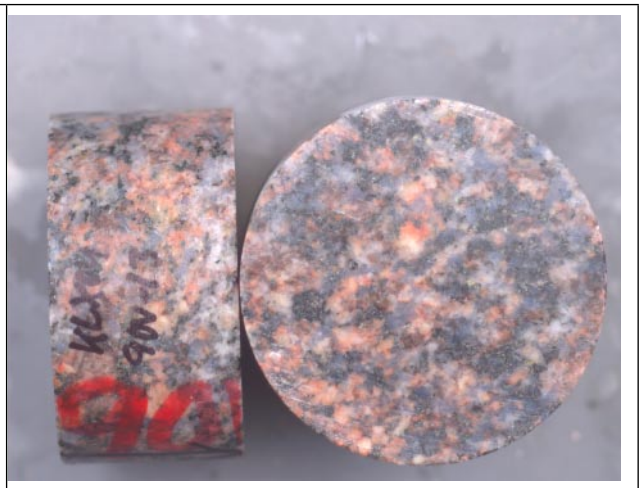
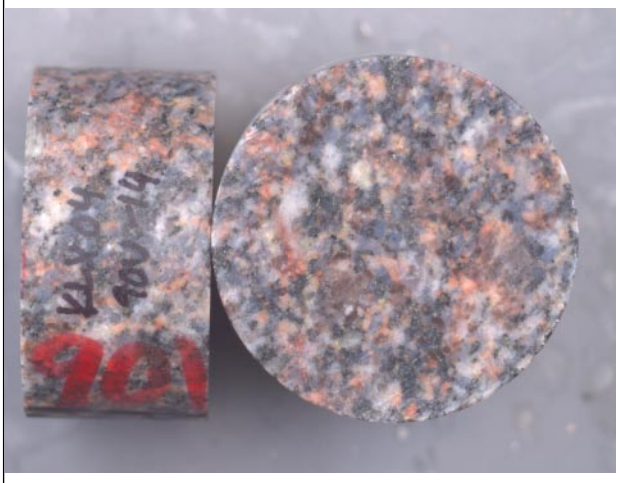


Figure 9. *Specimen KLX04A-90V-11.*

KLX04A-90V-12 (567.37) The dry density for specimen KLX04A-90V-12A was measured to be 2,730 kg/m^3 and the porosity to 0.6% and the dry density for specimen KLX04A-90V-12B was measured to be 2,720 kg/m^3 and the porosity to 0.6%.	 ***Figure 10.*** *Specimen KLX04A-90V-12.*

Table 3. Level 3 739–747 m, Specimen KLX04A-090V-13 to KLX04A-090V-17.

KLX04A-90V-13 (739.54) The dry density for specimen KLX04A-90V-13A was measured to be 2,670 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX04A-90V-13B was measured to be 2,680 kg/m^3 and the porosity to 0.5%.	 ***Figure 11.*** *Specimen KLX04A-90V-13.*
KLX04A-90V-14 (739,60) The dry density for specimen KLX04A-90V-14A was measured to be 2,680 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX04A-90V-14B was measured to be 2,670 kg/m^3 and the porosity to 0.5%.	 ***Figure 12.*** *Specimen KLX04A-90V-14.*

KLX04A-90V-15 (739.66)

The dry density for specimen KLX04A-90V-15A was measured to be 2,680 kg/m^3 and the porosity to 0.6% and the dry density for specimen KLX04A-90V-15B was measured to be 2,670 kg/m^3 and the porosity to 0.6%.

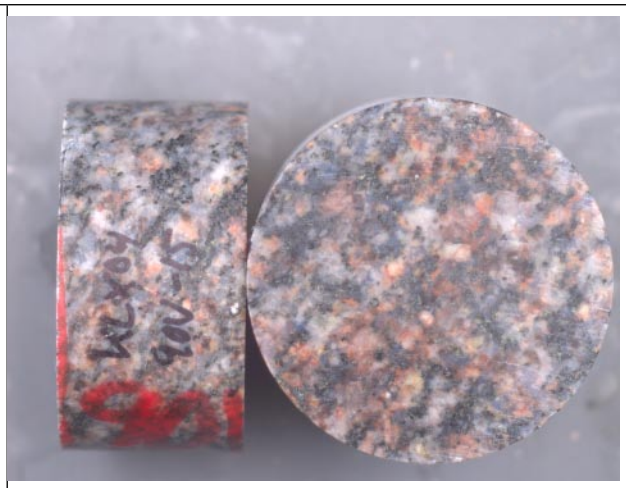


Figure 13. *Specimen KLX04A-90V-15.*

KLX04A-90V-16 (746.45)

The dry density for specimen KLX04A-90V-16A was measured to be 2,680 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX04A-90V-16B was measured to be 2,670 kg/m^3 and the porosity to 0.5%.

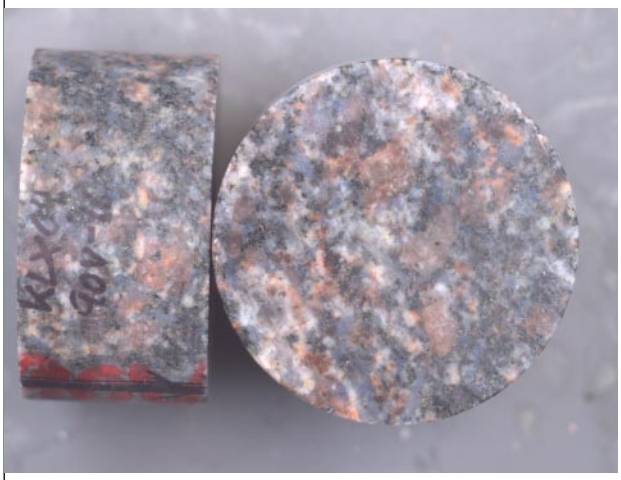


Figure 14. *Specimen KLX04A-90V-16.*

KLX04A-90V-17 (746.51)

The dry density for specimen KLX04A-90V-17A was measured to be 2,670 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX04A-90V-17B was measured to be 2,670 kg/m^3 and the porosity to 0.5%.

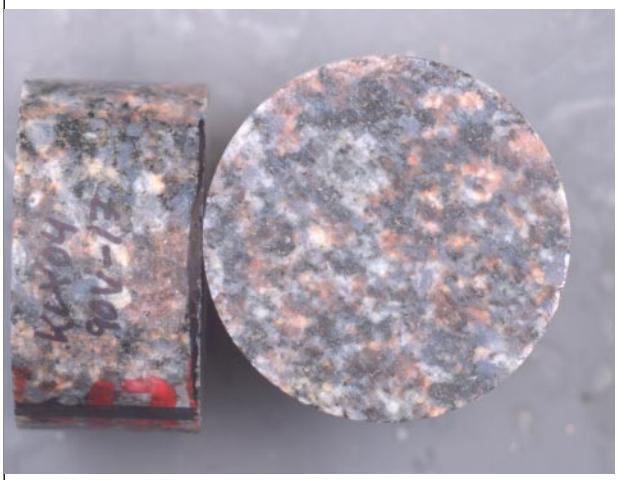


Figure 15. *Specimen KLX04A-90V-17.*

Appendix 2

Determination of wet density

Uppdragsnummer:	P402277
Borrhål:	KLX04A
Metod:	EN 13755, ISRM (1973), avsnitt 3 samt SKB MD 160.002 version 1.0

Provkroppar som provas se nästa blad

Provberedning	**Datum**	**Sign**
Sågning:	8/13/04	Lej
Foto:	9/3/04	JEL
Vattenmättnad start datum:	8/13/04	Lej
Vägning vattenmättat yttorrt tillstånd:	8/20/04	Lej
Provkropparna överlämnade till BRk:	9/13/04	Lej
Provkropparna åter från BRk:	10/1/04	Lej
Torkning:	10/1/04	Lej
Vägning torrt tillstånd:	10/5/04	Lej

Utrustning	**Inventarienummer**	**Kalibrerad datum**
Våg	102291	Mar-04
Torkskåp	102289	8/31/04
Termometer	100877	3/11/04

Övrigt

Eventuella avvikelser under provning:	provkropp 9 för liten
Proverna åter i kärnlådan (datum och sign):	10/5/04

Densitet och porositet, SKB

Metod: EN 13755, ISRM (1979), avsnitt 3 samt SKB MD 160.002 version 2.0

Vattnets temperatur (ºC): 18,8

Borrhål: KLX04A

Vattnets densitet (g/cm³): 0,9985

	Prov-märkning:	Vikt i vatten, Msub (g)	Yttor vikt, Msat (g)	Torr vikt, Ms (g)	Bulk volume, V (cm³)	Pore volume, Vv (cm³)	Porosity, n (%)	Dry density, ρd (g/cm³)	Wet density (g/cm³)
1	KLXO4- 1A	85,17	136,85	136,56	51,76	0,29	0,6	2,64	2,64
2	1B	85,42	137,08	136,8	51,74	0,28	0,5	2,64	2,65
3	2A	86,18	138,2	137,91	52,10	0,29	0,6	2,65	2,65
4	2B	86,31	138,33	138,03	52,10	0,30	0,6	2,65	2,66
5	3A	86,26	138,25	137,86	52,07	0,39	0,8	2,65	2,66
6	3B	85,42	136,91	136,61	51,57	0,30	0,6	2,65	2,66
7	4A	86,37	137,97	137,66	51,68	0,31	0,6	2,66	2,67
8	4B	86,85	138,7	138,38	51,93	0,32	0,6	2,66	2,67
9	5A	87,32	139,29	138,98	52,05	0,31	0,6	2,67	2,68
10	5B	87,29	139,23	138,91	52,02	0,32	0,6	2,67	2,68
11	R6A	87,62	139,63	139,34	52,09	0,29	0,6	2,68	2,68
12	R6B	87,08	139,08	138,8	52,08	0,28	0,5	2,67	2,67
13	7A	89,42	141,16	140,88	51,82	0,28	0,5	2,72	2,72
14	7B	88,7	140,38	140,1	51,76	0,28	0,5	2,71	2,71
15	8A	87,69	139,15	138,86	51,54	0,29	0,6	2,69	2,70
16	8B	89,02	140,85	140,55	51,91	0,30	0,6	2,71	2,71
19	10A	91,47	142,86	142,52	51,47	0,34	0,7	2,77	2,78
20	10B	89,71	141,27	140,9	51,64	0,37	0,7	2,73	2,74
21	11A	90,13	141,94	141,51	51,89	0,43	0,8	2,73	2,74
22	11B	89,95	141,91	141,56	52,04	0,35	0,7	2,72	2,73
23	12A	89,49	141,02	140,7	51,61	0,32	0,6	2,73	2,73
24	12B	89,34	140,83	140,52	51,57	0,31	0,6	2,73	2,73
25	13A	86,8	138,42	138,14	51,70	0,28	0,5	2,67	2,68
26	13B	86,97	138,42	138,16	51,53	0,26	0,5	2,68	2,69
27	14A	86,84	138,29	138,02	51,53	0,27	0,5	2,68	2,68
28	14B	86,39	137,81	137,54	51,50	0,27	0,5	2,67	2,68
29	15A	86,85	138,29	138	51,52	0,29	0,6	2,68	2,68
30	15B	86,3	137,66	137,37	51,44	0,29	0,6	2,67	2,68
31	16A	88,07	140,26	139,98	52,27	0,28	0,5	2,68	2,68
32	16B	84,36	134,51	134,24	50,23	0,27	0,5	2,67	2,68
33	17A	87,47	139,56	139,28	52,17	0,28	0,5	2,67	2,68
34	17B	86,93	138,7	138,43	51,85	0,27	0,5	2,67	2,68
35	R18A	87,79	140	139,73	52,29	0,27	0,5	2,67	2,68
36	R18B	87,66	139,68	139,39	52,10	0,29	0,6	2,68	2,68