

P-04-168

Forsmark site investigation

Drill hole KFM03A

Determination of porosity by water saturation and density by buoyancy technique

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May 2004

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Keywords: AP PF 400-04-20, Field note no Forsmark 215, Rock mechanics, Petro physics, Density, Porosity.

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.

A pdf version of this document can be downloaded from www.skb.se

Abstract

The density and porosity has been determined on 12 specimens (each divided in two pieces) from drill hole KFM03A, Forsmark, Sweden. The specimens were collected from four levels of the drill hole: c 260, 300, 530 and 680 m. The investigated rock types are mapped as tonalite and medium grained granite for level 1 and 2 (260 and 300 m), whereas level 3 and 4 (530 and 680 m) were mapped as medium-grained granite. The results for dry density varied between 2,640 and 2,810 kg/m³, for wet density between 2,650 and 2,820 kg/m³, and for porosity between 0.2 and 0.5%.

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1 Introduction

This report presents laboratory determinations of porosity and density of drill core samples from Forsmark, Sweden. The test program, which is part of the on-going site investigations for a deep repository, was carried out in compliance with activity plan AP PF 400-04-20 (SKB internal controlling document).

The specimens were sampled from the drill core of borehole KFM03A in the Forsmark area by Thomas Janson, Tyréns AB, and Urban Åkesson, Swedish National Testing and Research Institute (SP), on October 29th 2003. Specimens were taken from 4 levels of the rock core: level 1 between 262 and 263 m, level 2 between 305 and 306 m, level 3 between 527 and 528 m and level 4 between 683 and 685 m. The samples were selected based on the preliminary core logging, and with the strategy to primarily investigate the properties of the dominant rock types. The rock cores were transported by SP from Forsmark and arrived at SP on October 30th 2003. The testing was started in April 2004 and ended in May 2004.

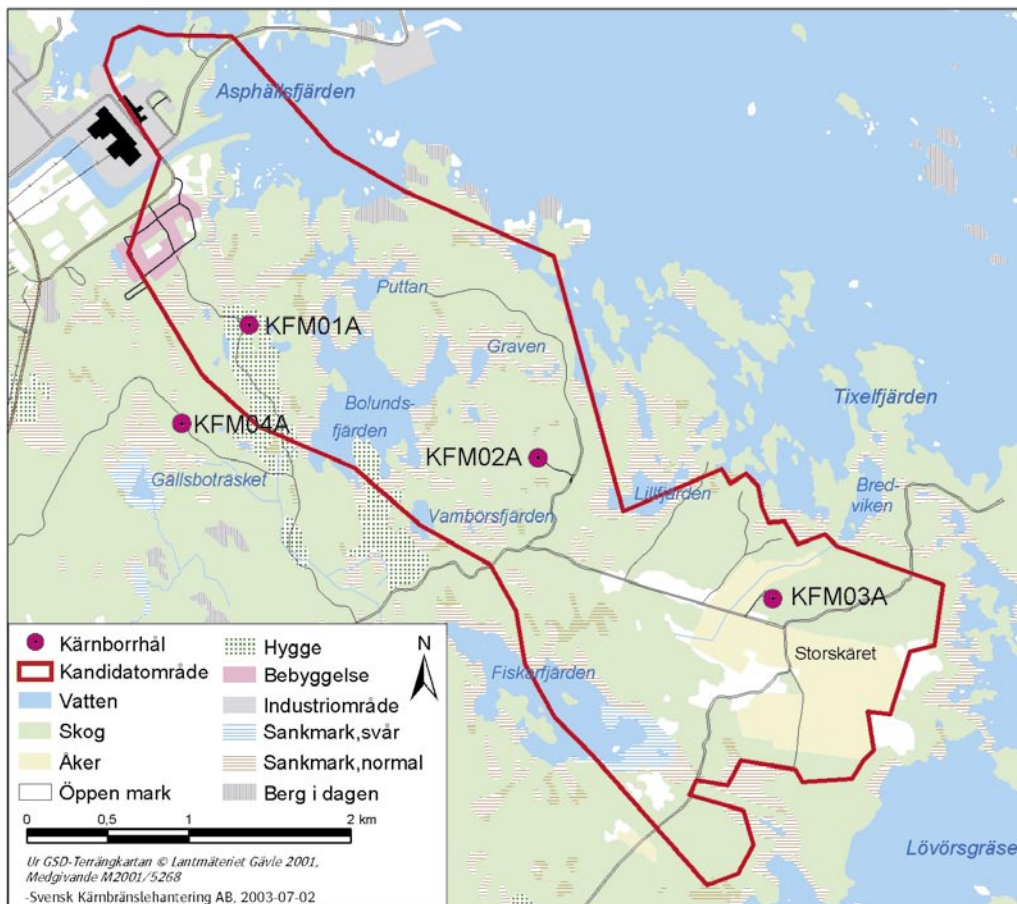


Figure 1-1. Location of drill hole KFM03A at the Forsmark site.

2 Objective and scope

The purpose of the testing is to determine the density and porosity of intact rock core samples. 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 Forsmark.

The samples originate from borehole KFM03A at Forsmark, which is a near-vertical telescopic borehole of SKB-chemistry type with a borehole length of c 1,000 m. The samples in this report are taken at 4 different levels.

3 Equipment

The following equipment was used for the analyses:

- Thermometer (inv no 100877) for measurements of water temperature. Calibrated 2004-03-11. Uncertainty of measurement $\pm 0,4^{\circ}\text{C}$.
- Scale (inv no 102291) for weight measurements. Calibrated 2003-08-12. Uncertainty of measurement ± 0.2 g.
- Heating chamber (inv no 102289) for drying the specimens. Calibrated 2003-08-22. Uncertainty of measurement $\pm 5^{\circ}\text{C}$.
- 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 ± 4 kg/m³

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 160.002e, version 1.9 (SKB internal controlling document). This includes determination of density in accordance with /ISRM, 1979/, volume 16, number 2, water saturation by /EN 13755/ and in compliance with Activity plan AP PF 400-04-20 (internal controlling document of SKB). The department of Building Technology and Mechanics (BM) at SP performed the test.

4.1 Description of the samples

Specimens were sampled from 4 levels in drill hole KFM03A. Core drilling of the borehole started at a depth of c 100 m. Sampling level 1 ranges between 262 and 263 m, level 2 between 305 and 306 m, level 3 between 527 and 528 m and level 4 between 683 and 684 m. Table 4-1 presents the rock type and identification marks of the specimens.

Table 4-1. Rock type and identification marks (rock-type classification according to Boremap, July 2004).

| Identification | Sampling depth (Seclow) | Rock type |
|----------------|-------------------------|-------------------------------------|
| KFM03A-90V-1 | 262.39 | Tonalite and medium-grained granite |
| KFM03A-90V-2 | 262.45 | Tonalite and medium-grained granite |
| KFM03A-90V-3 | 262.51 | Tonalite and medium-grained granite |
| KFM03A-90V-4 | 305.69 | Tonalite and medium-grained granite |
| KFM03A-90V-5 | 305.75 | Tonalite and medium-grained granite |
| KFM03A-90V-6 | 305.82 | Tonalite and medium-grained granite |
| KFM03A-90V-7 | 527.3 | Medium-grained granite |
| KFM03A-90V-8 | 527.36 | Medium-grained granite |
| KFM03A-90V-9 | 527.42 | Medium-grained granite |
| KFM03A-90V-13 | 683.77 | Medium-grained granite |
| KFM03A-90V-14 | 683.84 | Medium-grained granite |
| KFM03A-90V-15 | 683.90 | Medium-grained granite |

4.2 Testing

The execution procedure followed the prescription in SKB MD 160.002e, version 1.9 (SKB internal controlling document) and the activities described in Table 4-2 were performed:

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 in two pieces, marked A and B and about 25 mm thick each. The same specimens were used to test the thermal properties, heat conductivity and heat capacity with the TPS method. |
| 2 | The specimens were photographed in JPEG-format. |
| 3 | The specimens were water saturated in normal air pressure for at least seven days. The temperature of the water used for water saturation was 21.1°C and the density of the water was 998 kg/m ³ . |
| 4 | The specimens were weighed submerged in tapwater (see Appendix 2). |
| 5 | The specimens were surface dried with a towel and weighed. |
| 6 | The water saturated density was determined (see Appendix 2). |
| 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 during one week after water saturation. |
| 10 | The specimens were transported to a desiccator for cooling. |
| 11 | The dry density and porosity were determined. (See Appendix 2). |

4.3 Nonconformities

None.

5 Results

Data resulting from this activity are stored in the SKB database SICADA under field note no Forsmark 142.

Protocols, calculations and photos are presented in Appendix 1–3. A summary of the results of the porosity and density determinations is presented in Tables 5-1, 5-2, 5-3 and 5-4 as well as in the diagrams in Figures 5-1, 5-2 and 5-3 below.

Table 5-1. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 1, secrow 262 to 263 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 (Secrow) (m) | Porosity (%) | Dry density (kg/m ³) | Wet density (kg/m ³) |
|---------------------------|---|--------------|----------------------------------|----------------------------------|
| KFM03A-90V-1 | 262.39 | 0.3 | 2,760 | 2,770 |
| KFM03A-90V-2 | 262.45 | 0.3 | 2,770 | 2,780 |
| KFM03A-90V-3 | 262.51 | 0.3 | 2,750 | 2,760 |
| Mean value | | 0.3 | 2,760 | 2,770 |
| Standard deviation | | 0.1 | 10 | 10 |

Table 5-2. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 2, secrow 305 to 306 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 (Secrow) (m) | Porosity (%) | Dry density (kg/m ³) | Wet density (kg/m ³) |
|---------------------------|---|--------------|----------------------------------|----------------------------------|
| KFM03A-90V-4 | 305.69 | 0.3 | 2,810 | 2,820 |
| KFM03A-90V-5 | 305.75 | 0.2 | 2,810 | 2,810 |
| KFM03A-90V-6 | 305.82 | 0.3 | 2,800 | 2,810 |
| Mean value | | 0.3 | 2,810 | 2,810 |
| Standard deviation | | 0.03 | 7 | 7 |

Table 5-3. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 3, seclow 527 to 528 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) |
|---------------------------|---|--------------|----------------------------------|----------------------------------|
| KFM03A-90V-7 | 527.30 | 0.5 | 2,650 | 2,650 |
| KFM03A-90V-8 | 527.36 | 0.4 | 2,650 | 2,650 |
| KFM03A-90V-9 | 527.42 | 0.4 | 2,640 | 2,650 |
| Mean value | | 0.5 | 2,650 | 2,650 |
| Standard deviation | | 0.05 | 6 | 6 |

Table 5-4. Summary of the results of porosity, dry density and wet density determinations of the specimens from level 4, seclow 683 to 684 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) |
|---------------------------|---|--------------|----------------------------------|----------------------------------|
| KFM03A-90V-13 | 683.77 | 0.3 | 2,650 | 2,650 |
| KFM03A-90V-14 | 683.84 | 0.3 | 2,650 | 2,650 |
| KFM03A-90V-15 | 683.90 | 0.4 | 2,650 | 2,650 |
| Mean value | | 0.3 | 2,650 | 2,650 |
| Standard deviation | | 0.04 | 2 | 2 |

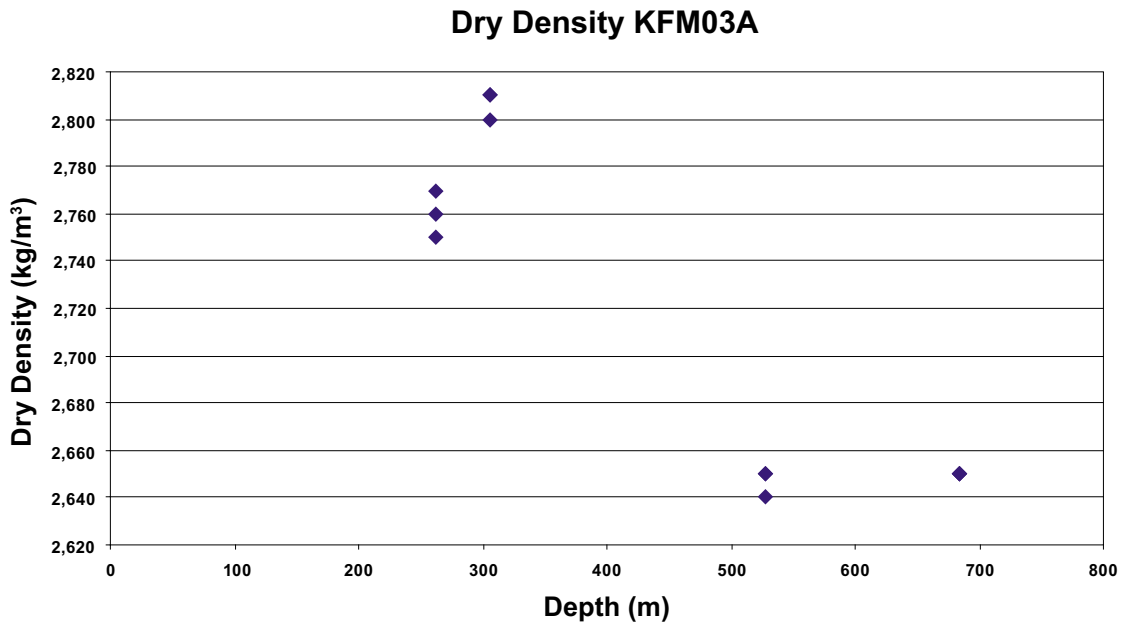


Figure 5-1. Density (dry) versus sampling depth.

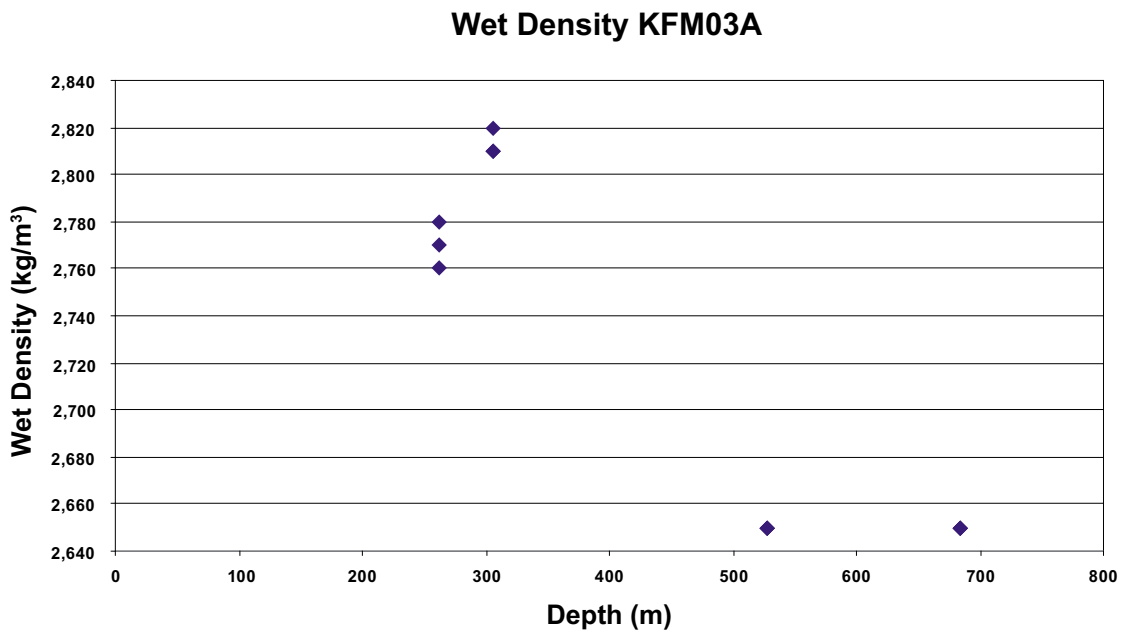


Figure 5-2. Density (wet) versus sampling depth.

Porosity KFM03A

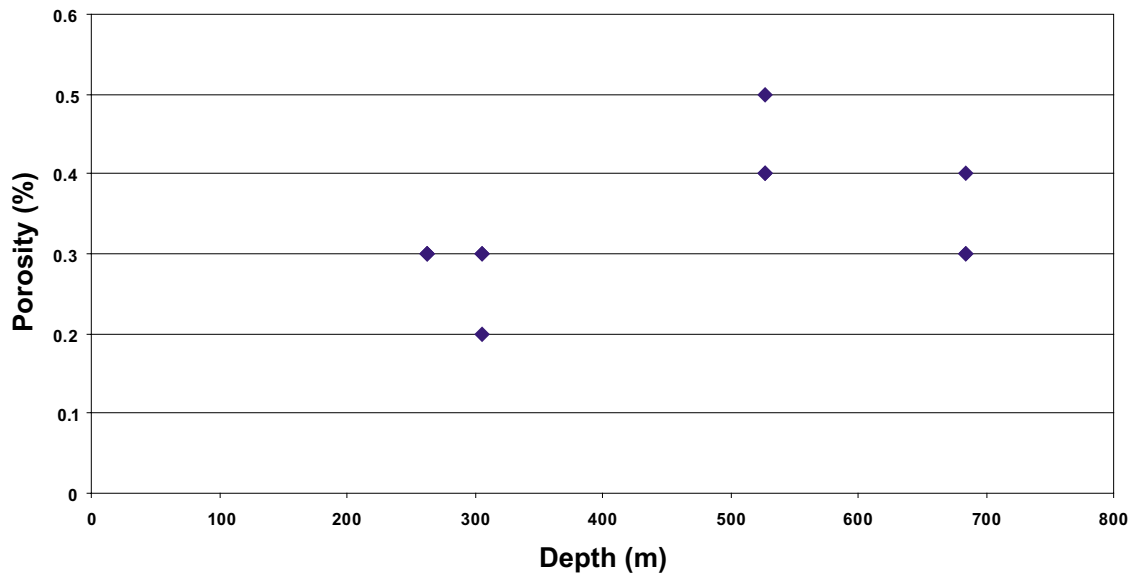


Figure 5-3. Porosity versus sampling depth.

References

ISRM, 1979. Volume 16, Number 2.

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

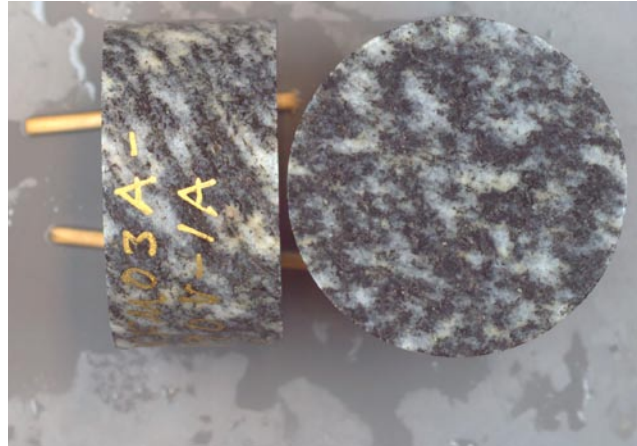
Results and pictures

Table 1. Level 1 262–263 m, specimens KFM03A-090V-1 to KFM03A-090V-3.

KFM03A-90V-1 (262.39)

The dry density for specimen KFM03A-90V-1A was measured to be 2,760 kg/m³ and the porosity to 0.3% and the dry density for specimen KFM03A-90V-1B was measured to be 2,770 kg/m³ and the porosity to 0.3%.

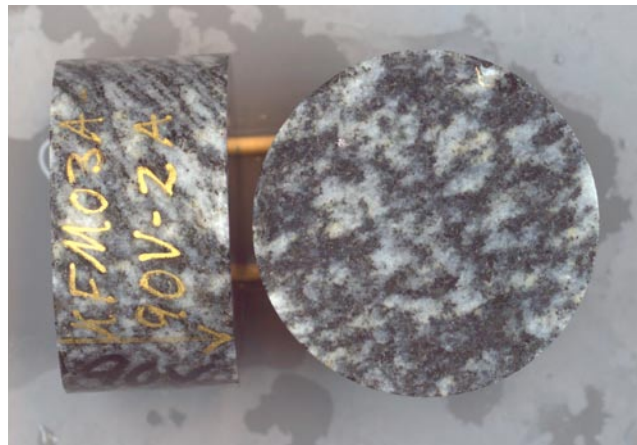
Figure 1. Specimen KFM03A-90V-1.



KFM03A-90V-2 (262.45)

The dry density for specimen KFM03A-90V-2A was measured to be 2,780 kg/m³ and the porosity to 0.3% and the dry density for specimen KFM03A-90V-2B was measured to be 2,770 kg/m³ and the porosity to 0.3%.

Figure 2. Specimen KFM03A-90V-2.



KFM03A-90V-3 (262.51)

The dry density for specimen KFM03A-90V-3A was measured to be 2,760 kg/m³ and the porosity to 0.3% and the dry density for specimen KFM03A-90V-3B was measured to be 2,750 kg/m³ and the porosity to 0.3%.

Figure 3. Specimen KFM03A-90V-3.

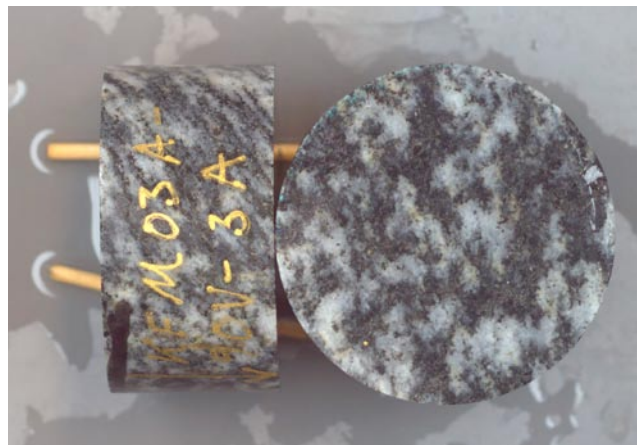
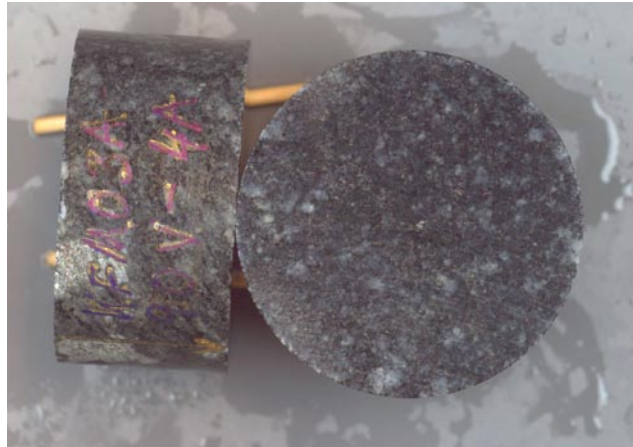


Table 2. Level 2 305–306 m, specimens KFM03A-090V-4 to KFM03A-090V-6.

KFM03A-90V-4 (305.69)

The dry density for specimen KFM03A-90V-4A was measured to be 2,810 kg/m³ and the porosity to 0.3% and the dry density for specimen KFM03A-90V-4B was measured to be 2,810 kg/m³ and the porosity to 0.3%.

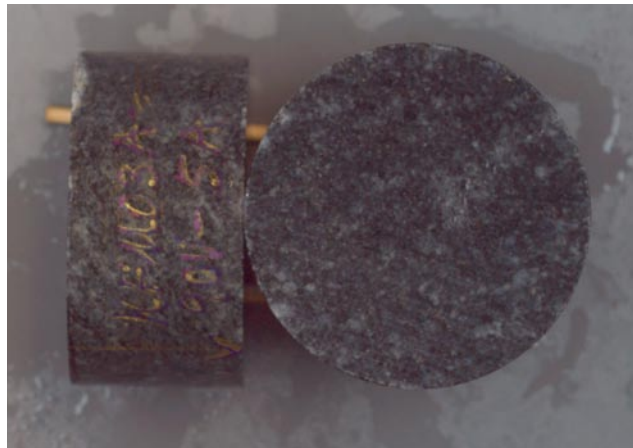
Figure 4. Specimen KFM03A-90V-4.



KFM03A-90V-5 (305.75)

The dry density for specimen KFM03A-90V-5A was measured to be 2,820 kg/m³ and the porosity to 0.2% and the dry density for specimen KFM03A-90V-5B was measured to be 2,810 kg/m³ and the porosity to 0.3%.

Figure 5. Specimen KFM03A-90V-5.



KFM03A-90V-6 (305.82)

The dry density for specimen KFM03A-90V-6A was measured to be 2,800 kg/m³ and the porosity to 0.2% and the dry density for specimen KFM03A-90V-6B was measured to be 2,810 kg/m³ and the porosity to 0.3%.

Figure 6. Specimen KFM03A-90V-6.



Table 2. Level 3 527–528 m, specimens KFM03A-090V-7 to KFM03A-090V-9.

KFM03A-90V-7 (527.30)

The dry density for specimen KFM03A-90V-7A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.6% and the dry density for specimen KFM03A-90V-7B was measured to be $2,640 \text{ kg/m}^3$ and the porosity to 0.4%.

Figure 7. Specimen KFM03A-90V-7.



KFM03A-90V-8 (527.36)

The dry density for specimen KFM03A-90V-8A was measured to be $2,640 \text{ kg/m}^3$ and the porosity to 0.4% and the dry density for specimen KFM03A-90V-8B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.4%.

Figure 8. Specimen KFM03A-90V-8.



KFM03A-90V-9 (527.42)

The dry density for specimen KFM03A-90V-9A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.4% and the dry density for specimen KFM03A-90V-9B was measured to be $2,640 \text{ kg/m}^3$ and the porosity to 0.4%.

Figure 9. Specimen KFM03A-90V-9.

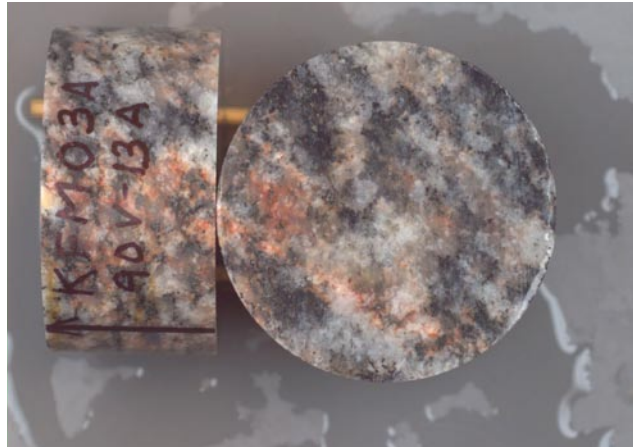


Table 3. Level 4 683–684 m, specimens KFM03A-090V-13 to KFM03A-090V-15.

KFM03A-90V-13 (683.77)

The dry density for specimen KFM03A-90V-13A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM03A-90V-13B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.

Figure 10. Specimen KFM03A-90V-13.



KFM03A-90V-14 (683.84)

The dry density for specimen KFM03A-90V-14A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM03A-90V-14B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3%.

Figure 11. Specimen KFM03A-90V-14.



KFM03A-90V-15 (683.90)

The dry density for specimen KFM03A-90V-15A was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.3% and the dry density for specimen KFM03A-90V-15B was measured to be $2,650 \text{ kg/m}^3$ and the porosity to 0.4%.

Figure 12. Specimen KFM03A-90V-15.



Beräkning densitet och porositet (Calculation density and porosity)

Density and porosity, SKB

Report no: P302791

Method: /EN 13755; ISRM 1973/, chapter 3 and SKB MD 160.002 version 1.0

Water temperature (°C): 21.1 Scale inv.no: 102291

Tested by: Lej

Water density (g/cm³): 0.998 Thermometer inv.no: 100877

Date: 04-04-28 to 05-28

| Sample marking: | Weight in water Msub (g) | Surface dry weight Msat (g) | Dry weight Ms (g) | Bulk volume V (cm ³) | Pore volume Vv (cm ³) | Porosity n (%) | Porosity AB n (%) | Dry density pd (g/cm ³) | Dry Density AB pd (g/cm ³) | Wet density pd (g/cm ³) | Wet density AB pd (g/cm ³) |
|-----------------|-----------------------------|--------------------------------|----------------------|-------------------------------------|--------------------------------------|-------------------|----------------------|--|---|--|---|
| 1 1A | 93.50 | 146.37 | 146.23 | 52.98 | 0.14 | 0.26 | 0.27 | 2.76 | 2.76 | 2.76 | 2.77 |
| 2 1B | 93.64 | 146.40 | 146.25 | 52.87 | 0.15 | 0.28 | | 2.77 | 2.77 | 2.77 | 2.78 |
| 3 2A | 95.07 | 148.24 | 148.10 | 53.28 | 0.14 | 0.26 | 0.27 | 2.78 | 2.77 | 2.78 | 2.78 |
| 4 2B | 94.28 | 147.33 | 147.18 | 53.16 | 0.15 | 0.28 | | 2.77 | 2.77 | 2.77 | 2.77 |
| 5 3A | 93.19 | 145.93 | 145.79 | 52.85 | 0.14 | 0.27 | 0.27 | 2.76 | 2.75 | 2.76 | 2.76 |
| 6 3B | 93.63 | 146.85 | 146.70 | 53.33 | 0.15 | 0.28 | | 2.75 | 2.75 | 2.75 | 2.75 |
| 7 4A | 95.78 | 148.40 | 148.26 | 52.73 | 0.14 | 0.27 | 0.28 | 2.81 | 2.81 | 2.81 | 2.82 |
| 8 4B | 95.89 | 148.52 | 148.37 | 52.74 | 0.15 | 0.29 | | 2.81 | 2.81 | 2.82 | 2.82 |
| 9 5A | 95.81 | 148.31 | 148.19 | 52.61 | 0.12 | 0.23 | 0.24 | 2.82 | 2.81 | 2.82 | 2.82 |
| 10 5B | 95.42 | 147.96 | 147.83 | 52.65 | 0.13 | 0.25 | | 2.81 | 2.81 | 2.81 | 2.81 |
| 11 6A | 94.73 | 147.19 | 147.06 | 52.57 | 0.13 | 0.25 | 0.29 | 2.80 | 2.80 | 2.80 | 2.81 |
| 12 6B | 95.50 | 148.08 | 147.91 | 52.69 | 0.17 | 0.32 | | 2.81 | 2.81 | 2.81 | 2.81 |
| 13 7A | 87.42 | 139.93 | 139.63 | 52.62 | 0.30 | 0.57 | 0.51 | 2.65 | 2.65 | 2.66 | 2.65 |
| 14 7B | 86.68 | 139.06 | 138.83 | 52.49 | 0.23 | 0.44 | | 2.65 | 2.65 | 2.65 | 2.65 |
| 15 8A | 86.87 | 139.41 | 139.18 | 52.65 | 0.23 | 0.44 | 0.44 | 2.64 | 2.64 | 2.65 | 2.65 |
| 16 8B | 87.29 | 139.95 | 139.72 | 52.77 | 0.23 | 0.44 | | 2.65 | 2.65 | 2.65 | 2.65 |
| 17 9A | 87.50 | 140.31 | 140.08 | 52.92 | 0.23 | 0.44 | 0.44 | 2.65 | 2.65 | 2.65 | 2.65 |
| 18 9B | 86.74 | 139.46 | 139.23 | 52.83 | 0.23 | 0.44 | | 2.64 | 2.64 | 2.64 | 2.64 |
| 25 13A | 87.40 | 140.16 | 140.00 | 52.87 | 0.16 | 0.30 | 0.30 | 2.65 | 2.65 | 2.65 | 2.65 |
| 26 13B | 87.55 | 140.21 | 140.05 | 52.77 | 0.16 | 0.30 | | 2.65 | 2.65 | 2.66 | 2.66 |
| 27 14A | 87.17 | 139.70 | 139.55 | 52.64 | 0.15 | 0.29 | 0.30 | 2.65 | 2.65 | 2.65 | 2.65 |
| 28 14B | 87.53 | 140.29 | 140.12 | 52.87 | 0.17 | 0.32 | | 2.65 | 2.65 | 2.65 | 2.65 |
| 29 15A | 87.26 | 139.91 | 139.73 | 52.76 | 0.18 | 0.34 | 0.37 | 2.65 | 2.65 | 2.65 | 2.65 |
| 30 15B | 87.28 | 139.93 | 139.72 | 52.76 | 0.21 | 0.40 | | 2.65 | 2.65 | 2.65 | 2.65 |

Protokoll checklista densitet och porositet (Protocol checklist density and porosity)

Kvalitetsdokument Blankett
Bygg och Mekanik
Checklista densitet och vattenabsorption

BMm-QR 53
Version () (ej publ)
Utfärdat 2004-01-15
Författare Lotta Carlsson
Godkännare Matz Sandström
Sida 1(1)

BMm-QR 53 Checklista densitet och vattenabsorption

Appendix 3

Density porosity

KFM03A

Fyll i datum och signatur:

| Prov id | Prov-beredning/ sågning | Foto | Vattenmätning EN 13755 och SKB MD 160.002 | Densitets- mätning | Till värme- kapacitet, BRk BMm/BRk | | Åter från BRk | Torkning |
|----------|----------------------------|----------|---|-----------------------|---|--|---------------------|----------|
| 1>KFM03A | 04-04-13 | 04-04-22 | 04-04-21 | 04-04-28 | 04-04-28 | | 04-04-27 | 04-06-01 |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
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| | | | | | | | | |

Våg id: 102291.....

Torkskåp id:102289.....

Termometer id:...100877.....