P-06-67

Forsmark site investigation

Borehole KFM01C

Determination of porosity by water saturation and density by buoyancy technique

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ISSN 1651-4416
SKB P-06-67

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Keywords: Rock mechanics, Petro-physics, Density, Porosity, AP PF 400-06-024.

Abstract

The density and porosity was determined on 8 specimens (each divided into two pieces) from borehole KFM01C, Forsmark, Sweden. The specimens were sampled at borehole lengths measuring between 200–450 m. The investigated rock types are mapped as metamorphic varieties of granite, granodiorite and tonalite (SKB rock code 101051) and amphibolite (SKB rock code 102017). The results for the dry density varied between 2,660 and 2,960 kg/m^3, and for the wet density likewise between 2,660 and 2,960 kg/m^3. Finally, the porosity results varied between 0.1 and 0.5%.

Sammanfattning

Densiteten och porositeten bestämdes på 8 provkroppar (varje provkropp delad i två delar) från borrhål KFM01C i Forsmark. Proverna togs mellan borrhålslängden 200–450 m. De undersökta bergarterna är karterade som metamorfa varianter av granit, granodiorit och tonalit (SKB bergartskod 101051) och amfibolit (SKB bergartskod 102017). Resultaten för torrdensiteten varierade mellan 2 660 och 2 960 kg/m^3 och för våtdensiteten likaså mellan 2 660 och 2 960 kg/m^3. För porositeten, slutligen, varierade resultaten mellan 0,1 och 0,5 %.

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 Forsmark, 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 KFM01C within the site investigation area at Forsmark, Sweden, see Figure 1-1. Borehole KFM01C is a conventional core drilled borehole inclined c 50° from the horizontal plane and with a total length of 450 m.

The samples were selected based on the preliminary core logging, and with the strategy to primarily investigate the properties of the rock types granit, granodiorite, tonalite (101051) and amphibiolite (102017). The samples, which were collected in March 28, 2006, were transported to SP (Swedish National Testing and Research institute), department of Building and Mechanics, where they arrived in June 26, 2006. Testing commenced in June 2006 and was completed in August 2006.

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

Activity Plan	**Number**	**Version**
KFM01C. Bergmekaniska och termiska laboratoriebestämningar	AP PF 400-06-024	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		

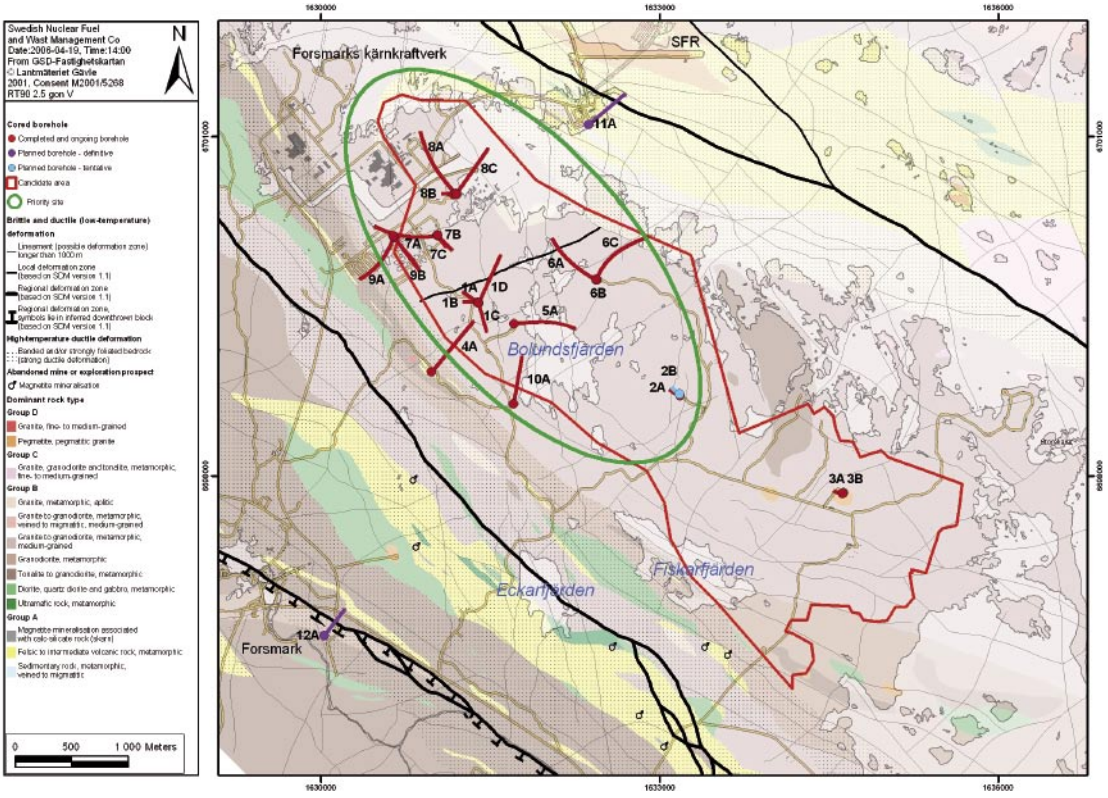


Figure 1-1. *Location of all telescopic boreholes and conventional core drilled boreholes completed (red) or planned (blue and violet) up to April 2006 within and close to the Forsmark candidate area. The projection of each borehole on the horizontal plane at top of casing is also shown in the figure.*

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 Forsmark.

The testing comprised 8 rock samples from borehole KFM01C collected within the borehole interval 200–450 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 102284) 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 PF 400-06-024 (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 KFM01C were sampled at levels ranging between 200 and 450 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^3. The specimens were dried in 105°C for six 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 two other activities /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 borehole length, Adj seclow)	Rock type
KFM01C-90V-1	223.987	Granite, granodiorite, tonalite, metamorphic (101051)
KFM01C-90V-2	224.052	Granite, granodiorite, tonalite, metamorphic (101051)
KFM01C-90V-3	184.219	Granite, granodiorite, tonalite, metamorphic (101051)
KFM01C-90V-4	184.279	Granite, granodiorite, tonalite, metamorphic (101051)
KFM01C-90V-5	448.288	Amphibolite (102017)
KFM01C-90V-6	448.353	Amphibolite (102017)
KFM01C-90V-7	448.418	Amphibolite (102017)
KFM01C-90V-8	448.513	Amphibolite (102017)

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 photographed in JPEG-format.
3	The specimens were water saturated in normal air pressure for at least seven days.
4	The specimens were weighed in tapwater. The temperature of the water was 21°C and the density 998 kg/m^3.
5	The specimens were surface dried with a towel and weighed.
6	The water saturated density was determined.
7	The samples were sent from SP Building Technology and Mechanics to SP Measurement technology for measurement of thermal properties, calorimetric method /2/.
8	The samples were sent from SP Measurement technology to SP Fire Technology for measurement of thermal properties, TPS method /2/.
9	The samples were sent back from SP Fire Technology to SP Building Technology and Mechanics.
10	The specimens were dried in a heating chamber for six days at 105°C.
11	The specimens were transported to a desiccator for cooling.
12	The dry density and porosity were determined.

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. However, in Chapter 5 only significant digits are presented.

5 Results

The results of the porosity and density determinations of core samples from KFM01C 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

Table 5-1 summarizes 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. 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)
KFM01C-90V-1	223.987	0.5	2,660	2,660
KFM01C-90V-2	224.052	0.5	2,660	2,670
KFM01C-90V-3	184.219	0.4	2,720	2,720
KFM01C-90V-4	184.279	0.4	2,720	2,720
KFM01C-90V-5	448.288	0.2	2,960	2,960
KFM01C-90V-6	448.353	0.2	2,950	2,950
KFM01C-90V-7	448.418	0.1	2,960	2,960
KFM01C-90V-8	448.513	0.2	2,960	2,960

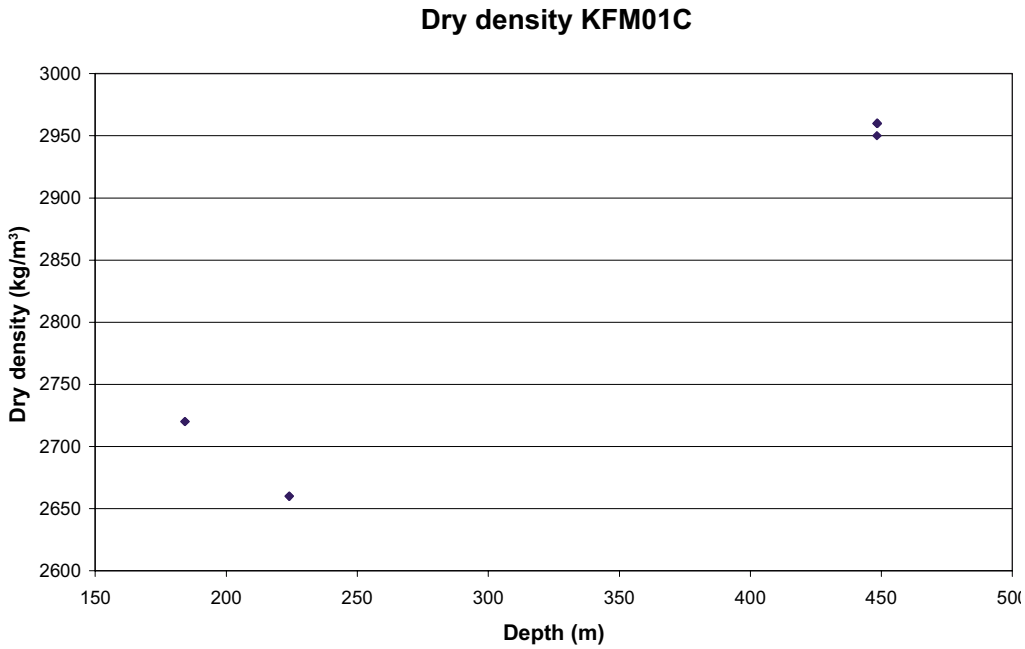


Figure 5-1. *Density (dry) versus sampling level (borehole length).*

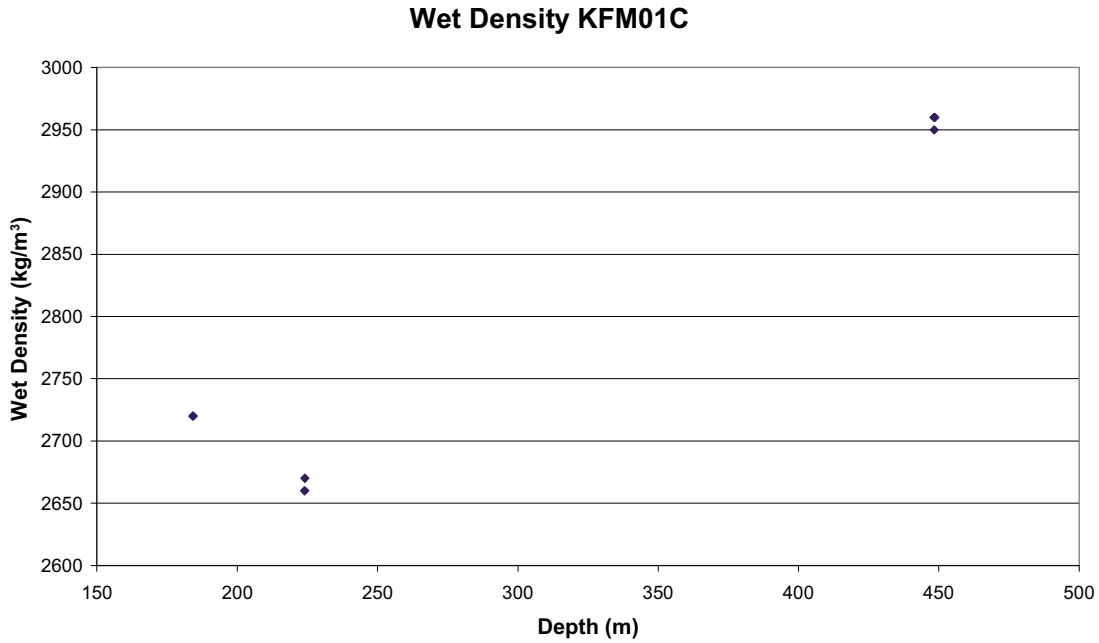


Figure 5-2. *Density (wet) versus sampling level (borehole length).*

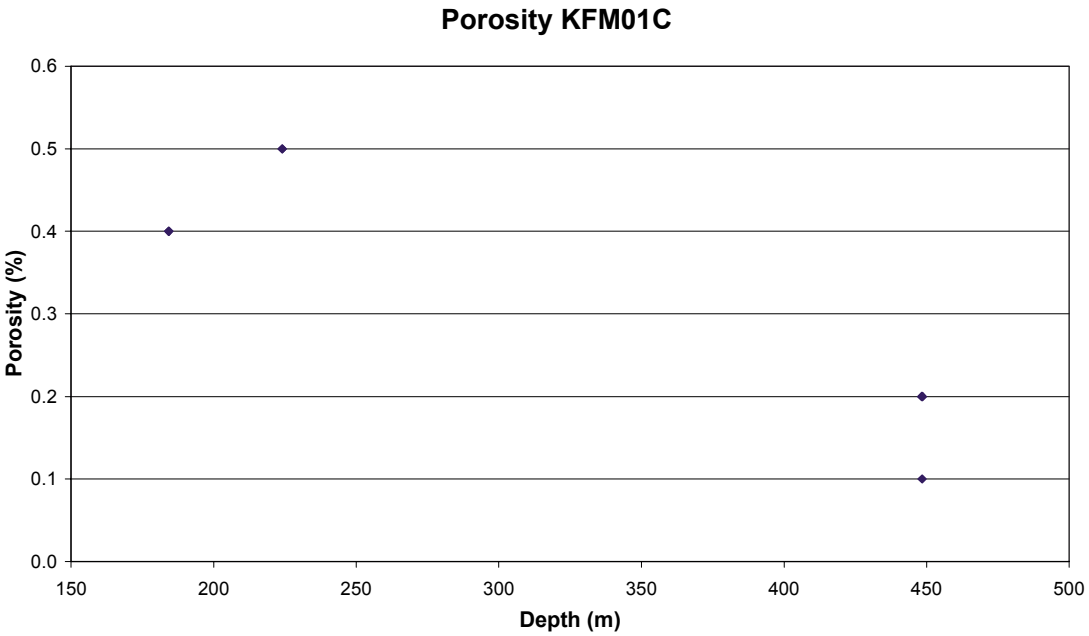


Figure 5-3. *Porosity versus sampling level (borehole length).*

References

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

/2/ **Adl-Zarrabi B, 2005.** Borehole KFM01C. Thermal conductivity and thermal diffusivity determined using the TPS method. SKB P-06-66, Svensk Kärnbränslehantering AB.

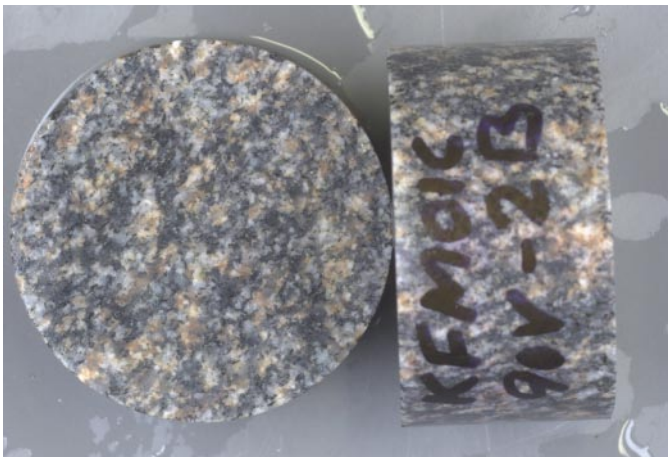
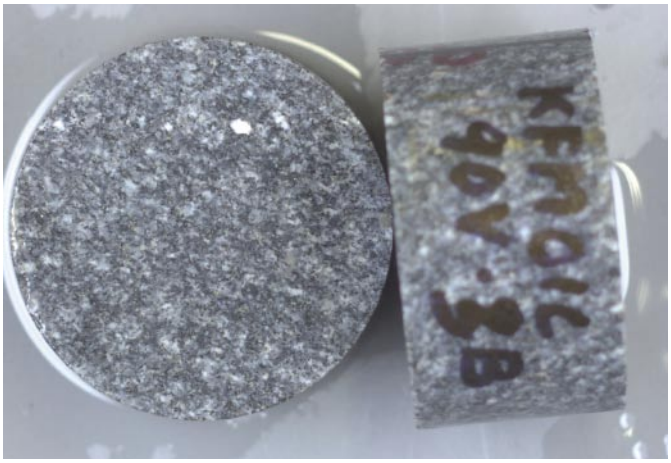
/3/ **ISRM 1979.** Volume 16, Number 2.

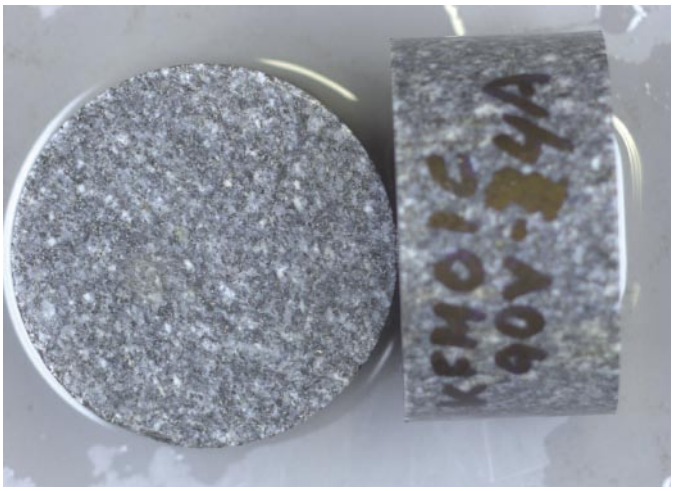
/4/ **EN 13755.** Natural stone test methods – Determination of water absorption at atmospheric pressure.

Appendix

Result minutes and photos

Table A-1. KFM01C, level 184–449 m. Specimens KFM01C-90V-1 to KFM01C-90V-8.

KFM01C-90V-1 (223.99 m) Dry density of specimen KFM01C-90V-1A 2,660 kg/m^3 and porosity 0.50%. Dry density of specimen KFM01C-90V-1B 2,658 kg/m^3 and porosity 0.57%	 ***Figure A-1.*** *Specimens KFM01C-90V-1 A and B.*
KFM01C-90V-2 (224.05 m) Dry density of specimen KFM01C-90V-2A 2,663 kg/m^3 and porosity 0.50%. Dry density of specimen KFM01C-90V-2B 2,666 kg/m^3 and porosity 0.48%.	 ***Figure A-2.*** *Specimens KFM01C-90V-2 A and B.*
KFM01C-90V-3 (184.22 m) Dry density of specimen KFM01C-90V-3A 2,717 kg/m^3 and porosity 0.41%. Dry density of specimen KFM01C-90V-3B 2,718 kg/m^3 and porosity 0.42%.	 ***Figure A-3.*** *Specimens KFM01C-90V-3 A and B.*

KFM01C-90V-4 (184.28 m) Dry density of specimen KFM01C-90V-4A 2,719 kg/m^3 and porosity 0.41%. Dry density of specimen KFM01C-90V-4B 2,719 kg/m^3 and porosity 0.43%.	 ***Figure A-4.*** *Specimens KFM01C-90V-4 A and B.*
KFM01C-90V-5 (448.29 m) Dry density of specimen KFM01C-90V-5A 2,956 kg/m^3 and porosity 0.18%. Dry density of specimen KFM01C-90V-5B 2,956 kg/m^3 and porosity 0.20%.	 ***Figure A-5.*** *Specimens KFM01C-90V-5 A and B.*
KFM01C-90V-6 (448.35 m) Dry density of specimen KFM01C-90V-6A 2,953 kg/m^3 and porosity 0.20%. Dry density of specimen KFM01C-90V-6B 2,951 kg/m^3 and porosity 0.20%.	 ***Figure A-6.*** *Specimens KFM01C-90V-6 A and B.*

KFM01C-90V-7 (448.42 m) Dry density of specimen KFM01C-90V-7A 2,960 kg/m^3 and porosity 0.13%. Dry density of specimen KFM01C-90V-7B 2,962 kg/m^3 and porosity 0.16%.	 ***Figure A-7.*** *Specimens KFM01C-90V-7 A and B.*
KFM01C-90V-8 (448.51 m) Dry density of specimen KFM01C-90V-8A 2,964 kg/m^3 and porosity 0.16%. Dry density of specimen KFM01C-90V-8B 2,961 kg/m^3 and porosity 0.22%.	 ***Figure A-8.*** *Specimens KFM01C-90V-8 A and B.*