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Forsmark site investigation

Borehole KFM08D

Indirect tensile strength test

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Abstract

The density and the indirect tensile strength of 10 water saturated specimens of intact rock from borehole KFM08D at Forsmark have been determined. The sampled rock type was albitic granite. The cylindrical specimens were taken from drill cores at two different depth levels ranging between 477–479 m respective 513–515 m borehole length. The specimens were photographed before and after the mechanical test.

The measured densities for the water saturated specimens were in the range 2,640–2,660 kg/m^3, which yield a mean value of 2,649 kg/m^3. The values for indirect tensile strength were in the range 12.8–16.6 MPa with a mean value of 14.8 MPa.

Sammanfattning

Densiteten och den indirekta draghållfastheten hos 10 vattenmättade prover av intakt homogent berg från borrhål KFM08D i Forsmark har bestämts. Bergarten hos dessa var albitisk granit. Proverna har tagits vid två olika djupnivåer som ligger mellan 477–479 m respektive 513–515 m borrhålslängd. Provobjekten fotograferades före och efter de mekaniska proven.

Densiteten hos de vattenmättade proven var mellan 2 640–2 660 kg/m^3 vilket gav ett medelvärde på 2 649 kg/m^3. Värdena på den indirekta draghållfastheten låg mellan 12,8–16,6 MPa med ett medelvärde på 14,8 MPa.

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1 Introduction

This document reports performance and results of indirect tensile strength tests on water-saturated specimens sampled from borehole KFM08D at Forsmark, see map in Figure 1-1. The tests were carried out in the material and rock mechanics laboratories at the Department of Building Technology and Mechanics at the Swedish National Testing and Research Institute (SP). The activity is part of the site investigation programme at Forsmark managed by SKB (The Swedish Nuclear Fuel and Waste Management Co).

The controlling documents for the activity are listed in Table 1-1. Both Activity Plan and Method Descriptions are SKB's internal controlling documents, whereas the Quality Plan referred to in the table is an SP internal controlling document.

Borehole KFM08D, see Figure 1-1, is a core drilled borehole with a total length of c 940 m with an inclination of 55 degrees and with a direction of 100 degrees. The testing has been concentrated to a depth interval between 475–520 m (borehole length) where the rock type is albitic granite (rock type code 101057, with the additional code 104 for albitisation). The granite within this domain has transformed by experiencing a leaching of potassium/calcium and an enrichment of sodium and silicium.

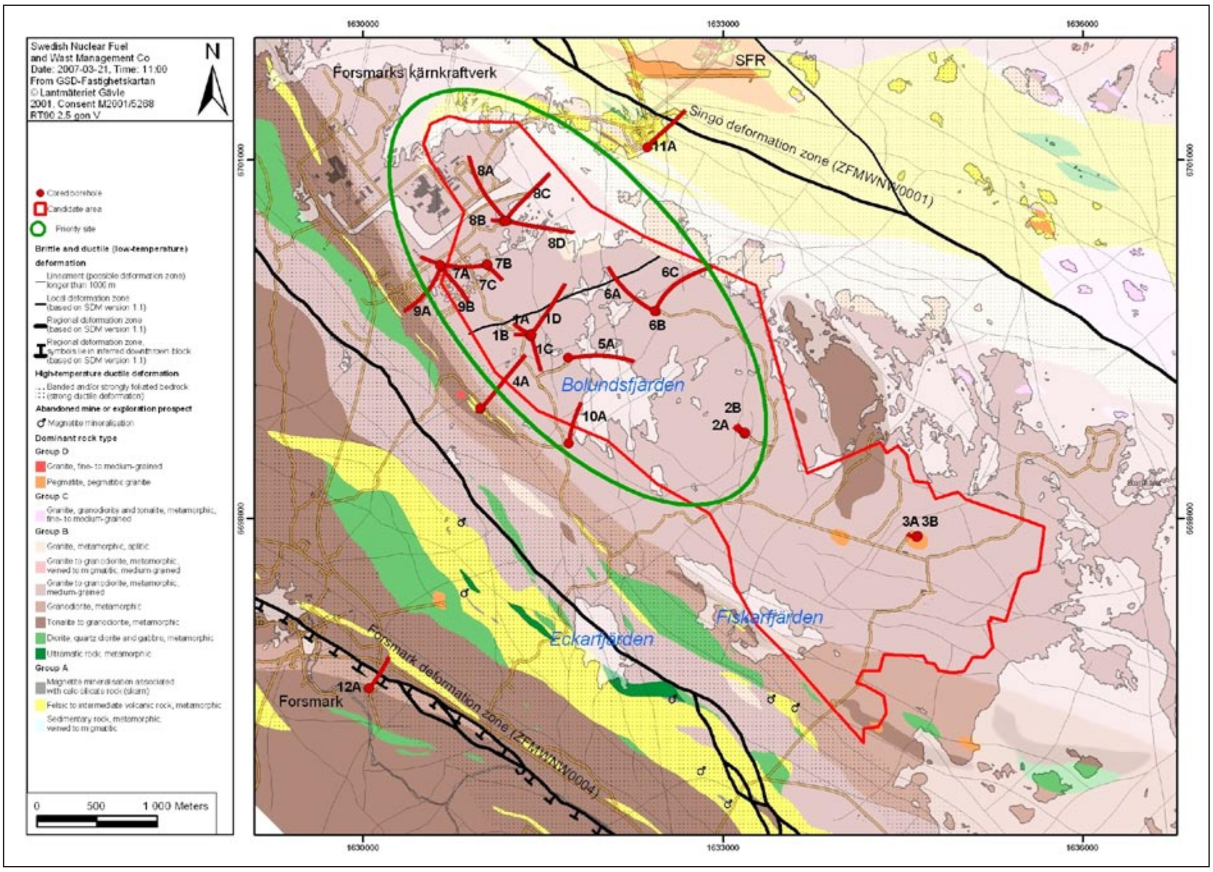

Figure 1-1. Geological map showing the location of all boreholes drilled up to March 2007 within or close to the Forsmark candidate area. The projection of each borehole on the horizontal plane at top of casing is also shown in the figure.

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

Activity Plan	Number	Version
KFM08D. Bergmekaniska laboratoriebestämningar	AP PF 400-07-031	1.0
Method Description	**Number**	**Version**
Indirect test of tensile strength	SKB MD 190.004	3.0
Determining density and porosity of intact rock	SKB MD 160.002	3.0
Quality Plan		
SP-QD 13.1		

SKB supplied SP with rock cores which arrived at SP in May 2007 and were tested during June 2007. Cylindrical specimens were cut from the cores and selected based on the preliminary core logging with the strategy to primarily investigate the properties of the rock type albitic granite (101057, 104). The method description SKB MD 190.004 was followed for the sampling and for the indirect tensile strength tests, whereas the method description SKB MD 160.002, was followed when the density was determined.

The specimens were put into water and stored in water with a minimum of 7 days, up to testing. This yields a water saturation, which is intended to resemble the in-situ moisture condition. The density was determined on each specimen and the indirect tensile tests were carried out at this moisture condition. The rock material had a homogenous structure, which implies that the mechanical response is expected to be approximately isotropic. The direction of loading is displayed on the specimens by a drawn line on each specimen. The specimens were photographed before and after the mechanical testing.

Original data from the reported activities are stored in the primary database Sicada, where data are traceable by the Activity Plan number (AP PF 400-07-031). Only data in SKB's databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major data revisions entail a revision of the P-report. Minor revisions are normally presented as supplements, available at www.skb.se.

2 Objective and scope

The purpose of the testing is to determine the density and the indirect tensile strength of a cylindrical intact rock core.

The results from the tests are going to be used in the site descriptive rock mechanics model, which will be established for the candidate area selected for site investigations at Forsmark.

3 Equipment

A circular saw with a diamond blade was used to cut the specimens to their final lengths. Specimens with a rough cutting surface were levelled in a grinding machine. The measurements of the dimensions were made with a sliding calliper. Furthermore, the tolerances were checked by means of a dial indicator and a stone face plate.

The specimens and the water were weighed using a weighing scale. A thermometer was used for the water temperature measurement. The calculated wet density was determined with an uncertainty of ± 4 kg/m^3.

The mechanical testing was carried out in a load frame where the crossbar is mechanically driven by screws and has a maximum load capacity of 100 kN in compression. The axial compressive load was measured by an external 100 kN load cell. The uncertainty of the load measurement is less than 1%.

The frame was equipped with a pair of curved bearing blocks, radius 39 mm and width 29 mm, with pins for guiding the vertical deformation, see Figure 3-1. The top platen includes a spherical seating in order to have a fully centred loading position. The specimens were photographed with a 4.0 Mega pixel digital camera at highest resolution and the photographs were stored in a jpeg-format.

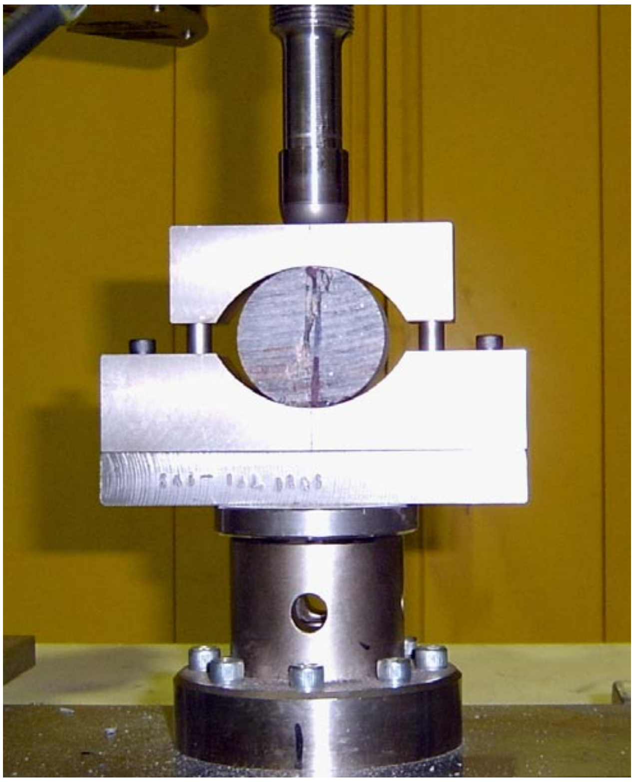

Figure 3-1. *Curved bearing blocks for indirect tensile test.*

4 Execution

The water saturation and determination of the density of the wet specimens were made in accordance with the method description SKB MD 160.002 (SKB internal controlling document). This includes determination of density in accordance to ISRM /1/ and water saturation by SS EN 13755 /2/. The determination of the indirect tensile strength was carried out in compliance with the method description SKB 190.004 (SKB internal controlling document). The test method follows ASTM D3967-95a /3/.

4.1 Description of the specimens

The rock type characterisation was made according to Stråhle /4/ using the SKB mapping system (Boremap). The identification marks, upper and lower sampling depth (Secup and Seclow) and the rock type are shown in Table 4-1.

Table 4-1. Specimen identification, sampling level and rock type/occurrence for all specimens (based on the Boremap mapping).

Identification	Adj Secup (m)	Adj Seclow (m)	Rock type
KFM08D-110-1	477.54	477.59	Albitic granite (101057, 104 for albitisation)
KFM08D-110-2	477.75	477.80	Albitic granite (101057, 104 for albitisation)
KFM08D-110-3	479.01	479.06	Albitic granite (101057, 104 for albitisation)
KFM08D-110-4	479.06	479.11	Albitic granite (101057, 104 for albitisation)
KFM08D-110-5	479.52	479.56	Albitic granite (101057, 104 for albitisation)
KFM08D-110-6	513.58	513.62	Albitic granite (101057, 104 for albitisation)
KFM08D-110-7	513.62	513.67	Albitic granite (101057, 104 for albitisation)
KFM08D-110-8	515.72	515.77	Albitic granite (101057, 104 for albitisation)
KFM08D-110-9	515.77	515.81	Albitic granite (101057, 104 for albitisation)
KFM08D-110-10	515.81	515.86	Albitic granite (101057, 104 for albitisation)

4.2 Testing

The temperature of the water was 23.2°C, which equals to a water density of 997.5 kg/m^3, when the density determination of the rock specimens was carried out. Further, the specimens had been stored 7 days in water when the density was determined and 19 days in water when the indirect tensile strength was determined.

An auto-calibration of the load frame was run prior to the mechanical test in order to check the system. Further, an individual check-list was filled in and checked for every specimen during all the steps in the execution. Moreover, comments were made during the mechanical testing upon observed phenomena that are relevant for the interpretation of the results. The check-list form is an SP internal quality document.

The diameter and thickness were entered into the test software which computed the indirect tensile strength together with the mean value and standard deviation for the whole test series. The results were then exported as text-files and stored in a file server on the SP computer-network. The results were imported to the program MS Excel and rearranged to the Sicada database format. Moreover, the diagrams were produced using MS Excel.

An overview of the activities during the testing is shown in the step-by step description in Table 4-2.

Table 4-2. Activities during the mechanical testing.

Step	Activity
1	The geometrical tolerances were checked: parallel and perpendicular surfaces, smooth and straight circumferential surface.
2	The diameter and thickness were measured three times each. The respective mean value determines the dimensions that are reported.
3	The direction of compressive loading was marked as a line on one of the plane surfaces with a marker pen.
4	The specimens were then put into water and stored in water for minimum 7 days. The weight of water together with one specimen was determined. The specimen was taken out from the water and the weight of the water and rock specimen was determined separately, and by using the known density of the water, the wet density could be computed. This procedure was repeated for each specimen.
5	Digital photos were taken on each specimen.
6	The wet specimens were inserted into the loading device one by one, with the correct orientation given by the marked line. The strain gauges were connected to the sampling device and the signals were checked. The specimens were loaded up to failure during deformation control. The displacement rate was set to 0.3 mm/min during loading. The maximum compressive load, which also defines the failure load, was registered.
7	Digital photos were taken on each specimen after the mechanical testing.

4.3 Nonconformities

The testing was conducted according to the method description. The activity plan was followed without departures.

5 Results

The results of the individual specimens are presented in Section 5.1 and a summary of the results is given in Section 5.2. The original results, unprocessed raw data obtained from the testing, were reported to the Sicada database. These data together with the digital photographs of the individual specimens were handed over to SKB. The handling of the results follows SDP-508 (SKB internal controlling document) in general.

5.1 Description and presentation of the specimens

The results for the individual specimens are as follows:

Specimen ID: KFM08D-110-1

Before mechanical test

After mechanical test

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.9	26.2	2,640	13.9

Comments: None

Specimen ID: KFM08D-110-2

Before mechanical test

After mechanical test

Diameter (mm)	Height (mm)	Density (kg/m^3)	Tensile strength (MPa)
50.9	25.9	2,640	15.3

Comments: None

Specimen ID: KFM08D-110-3

Before mechanical test

After mechanical test

Diameter (mm)	Height (mm)	Density (kg/m^3)	Tensile strength (MPa)
50.8	25.9	2,650	15.3

Comments: None

Specimen ID: KFM08D-110-4

Before mechanical test

After mechanical test

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.8	25.8	2,650	13.1

Comments: None

Specimen ID: KFM08D-110-5

Before mechanical test

After mechanical test

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.9	25.9	2,660	16.6

Comments: None

Specimen ID: KFM08D-110-6

Before mechanical test

After mechanical test

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.8	25.5	2,650	12.8

Comments: None

Specimen ID: KFM08D-110-7

Before mechanical test

After mechanical test

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.8	25.9	2,650	16.5

Comments: None

Specimen ID: KFM08D-110-8

Before mechanical test

After mechanical test

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.8	26.0	2,650	13.9

Comments: None

Specimen ID: KFM08D-110-9

Before mechanical test

After mechanical test

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.8	25.9	2,650	15.0

Comments: None

Specimen ID: KFM08D-110-10

Before mechanical test

After mechanical test

Diameter (mm)	**Height (mm)**	**Density (kg/m³)**	**Tensile strength (MPa)**
50.8	25.9	2,650	15.3

Comments: None

5.2 Results for the entire test series

A summary of the test results is shown in Tables 5-1 and 5-2. The densities and tensile strength versus sampling depth are shown in Figures 5-1 and 5-2.

Table 5-1. Summary of results.

Identification	Density (kg/m³)	Tensile strength (MPa)	Comments
KFM08D-110-1	2,640	13.9	
KFM08D-110-2	2,640	15.3	
KFM08D-110-3	2,650	15.3	
KFM08D-110-4	2,650	13.1	
KFM08D-110-5	2,660	16.6	
KFM08D-110-6	2,650	12.8	
KFM08D-110-7	2,650	16.5	
KFM08D-110-8	2,650	13.9	
KFM08D-110-9	2,650	15.0	
KFM08D-110-10	2,650	15.3	

Table 5-2. Calculated mean values (Mean val) and standard deviation (Std dev) of wet density and tensile strength at the different sampling levels and for all specimens.

	Density (kg/m³)	Tensile strength (MPa)
Mean val (all specimens)	2,649	14.8
Mean val (477–479 m)	2,648	14.9
Mean val (513–515 m)	2,650	14.7
Std dev (all specimens)	6	1.3
Std dev (477–479 m)	8	1.3
Std dev (513–515 m)	0	1.4

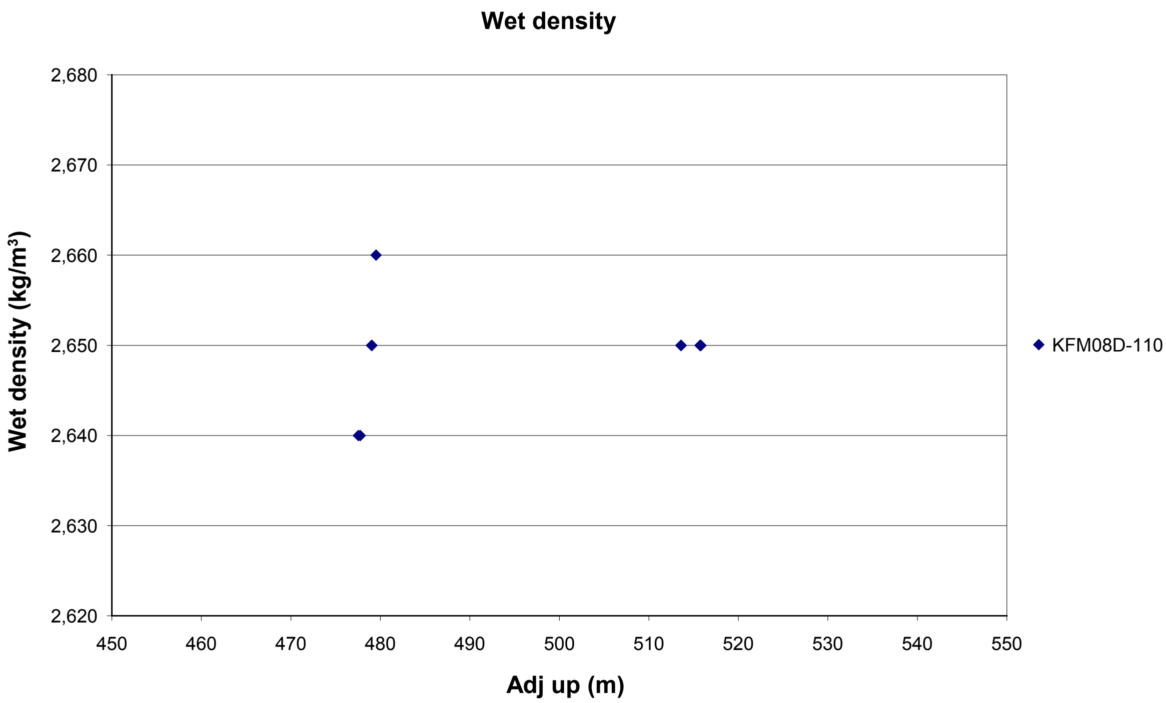

Figure 5-1. Density versus sampling depth in the borehole.

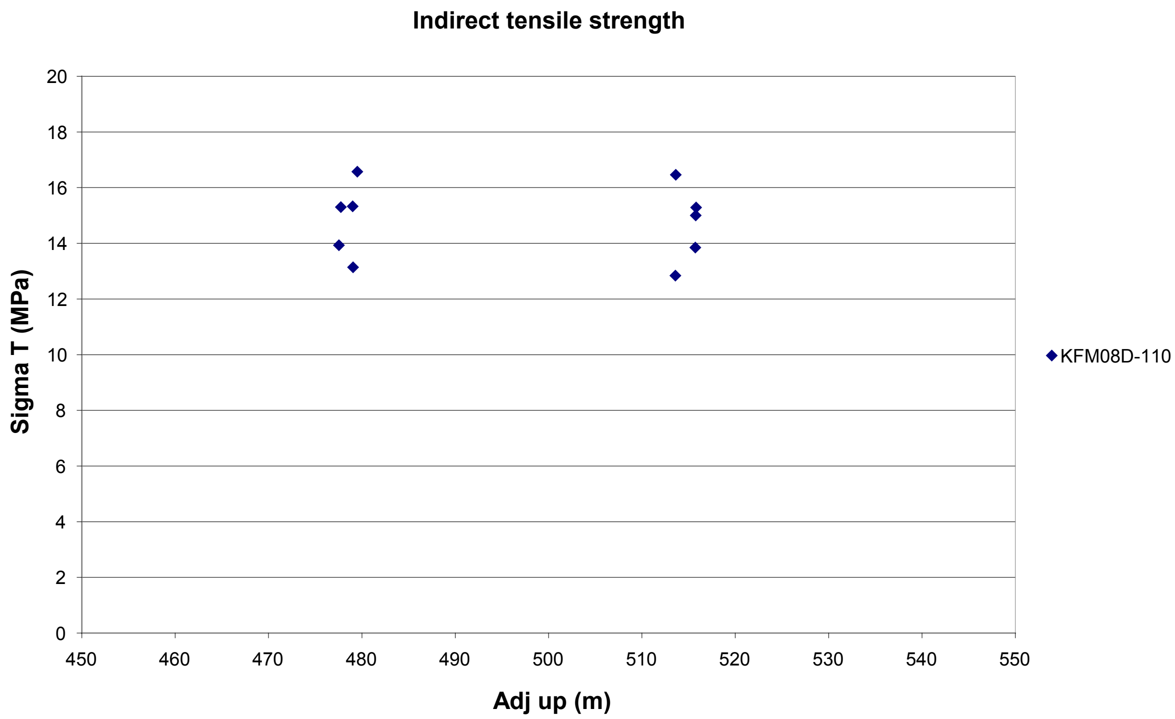

Figure 5-2. Tensile strength versus sampling depth in the borehole.

References

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

/3/ **ASTM D3967-95a, 1996.** Standard test method for splitting tensile strength of intact rock core specimens.

/4/ **Stråhle A, 2001.** Definition och beskrivning av parametrar för geologisk, geofysisk och bergmekanisk kartering av berg. SKB-R-01-19, Svensk Kärnbränslehantering AB. In Swedish.