P-05-98

Forsmark site investigation

Drill hole KFM05A

Indirect tensile strength test

Lars Jacobsson
SP Swedish National Testing and Research Institute

August 2005

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-05-98

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Keywords: Rock mechanics, Indirect tensile strength, Tension test, AP PF 400-04-80.

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.

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Abstract

The density and the indirect tensile strength of 20 water saturated specimens of intact rock from borehole KFM05A at Forsmark have been determined. The specimens were collected at two depth levels ranging between 330–337 m and 561–575 m borehole length. The rock type was medium-grained granite. The specimens were photographed before and after the mechanical test.

The measured density for the water saturated specimens were in the range 2,650–2,670 kg/m^3, which yields a mean value of 2,657 kg/m^3. The values for indirect tensile strength were in the range 12.4–14.6 MPa (330–337 m) and 10.6–13.9 MPa (561–575 m) respectively.

Sammanfattning

Densiteten och den indirekta draghållfastheten hos 20 vattenmättade prover av intakt homogent berg från borrhål KFM05A i Forsmark har bestämts. Proven har tagits från tre djupnivåer, 330–337 m och 561–575 m borrhålslängd. Bergarten vid dessa nivåer var medelkornig granit. Provobjekten fotograferades före och efter de mekaniska proven.

Densiteten hos de vattenmättade proven var mellan 2 650–2 670 kg/m^3 vilket gav ett medelvärde på 2 657 kg/m^3. Värdena på den indirekta draghållfastheten var 12,4–14,6 MPa (330–337 m) respektive 10,6–13,9 MPa (561–575 m).

Contents

1 Introduction

Indirect tensile strength tests have been conducted on water-saturated specimens sampled from borehole KFM05A at Forsmark, see map in Figure 1-1. These tests belong to one of the activities performed as part of the site investigation in the Forsmark area managed by the Swedish Nuclear Fuel and Waste Management Co (SKB). 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). All work was performed in accordance with the activity plan AP PF 400-04-80 (SKB internal controlling document) and is controlled by SP-QD 13.1 (SP internal quality document).

SKB supplied SP with rock cores, which arrived at SP in September 2004 and were tested during December 2004. The specimens, in form of cylindrical discs, were cut from the cores and selected based on the preliminary core logging with the strategy to primarily investigate

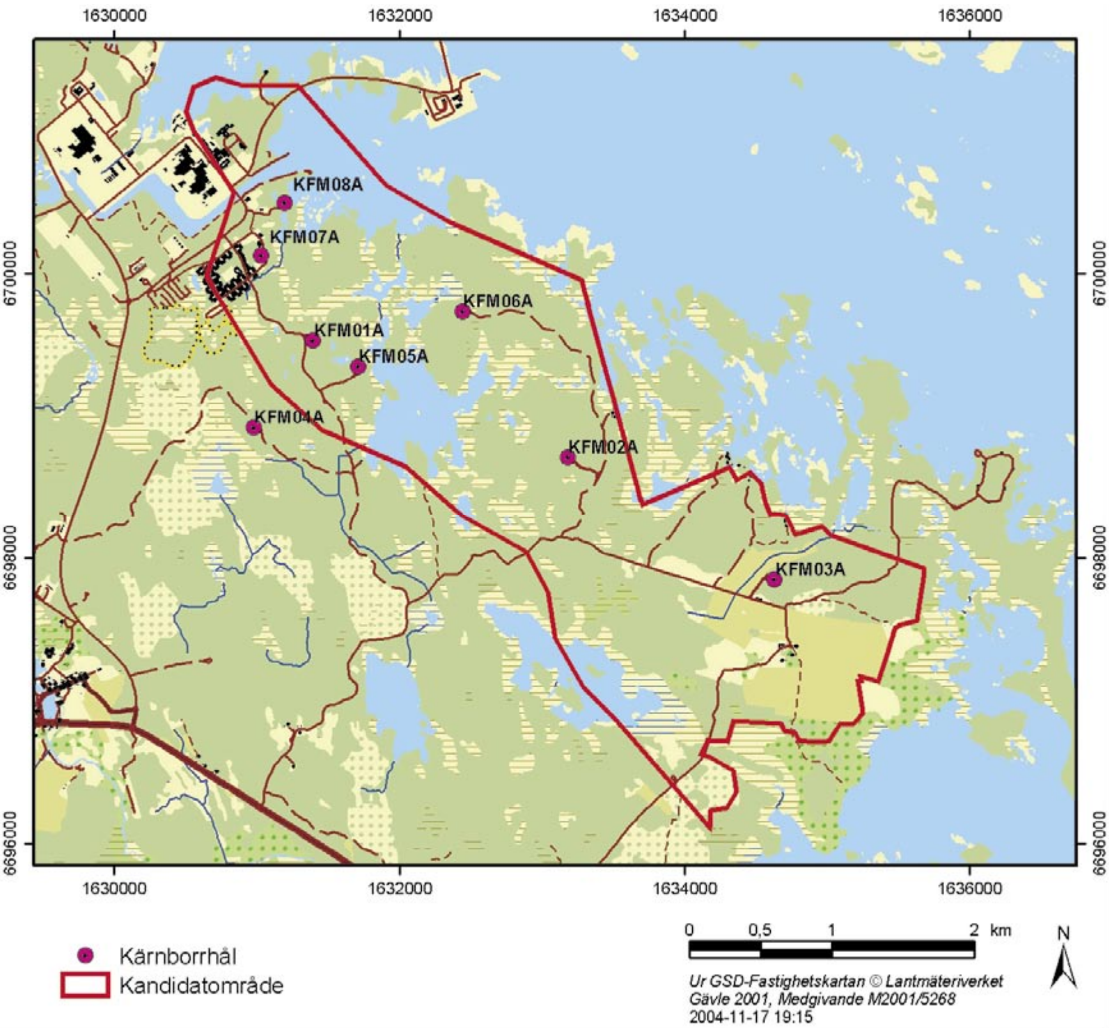


***Figure 1-1.** Location of the drill hole KFM05A at the Forsmark site.*

the properties of the dominant rock type. The specimens were put into water and stored in water for 19 days prior to density determination and during 31 days before the mechanical 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.

Sampling and indirect tensile strength tests were performed according to method description SKB MD 190.004, version 2.0 (SKB internal controlling document), whereas water saturation and density determinations of the wet specimens were made in compliance with method description SKB MD 160.002, version 2.0.

2 Objective and scope

The purpose of the testing was to determine the density and the indirect tensile strength of a cylindrical intact rock core. The specimens were collected from borehole KFM05A, which is a borehole inclined c 60° from the horizontal plane and with a drilling length of c 1,000 m. The borehole section c 100–1,000 m is core drilled.

The results from the tests are 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 obtain 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.

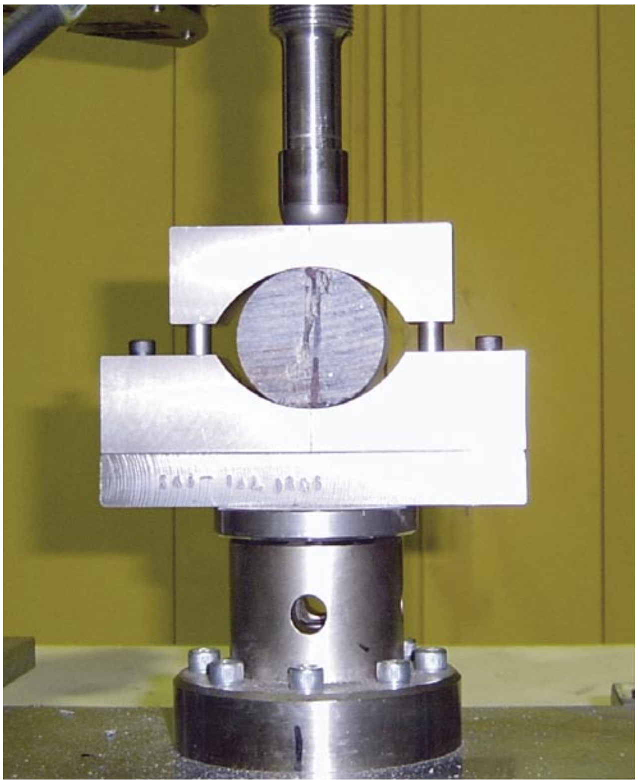


Figure 3-1. *Curved bearing blocks for indirect tensile test. The specimen in the picture does not belong to the tests in this report.*

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, version 2.0, which 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 190.004e, version 2.0. 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 depth (borehole length) and rock type for all specimens.

Identification	Secup (m)	Seclow (m)	Rock type
KFM05A 110-1	330.14	330.17	Medium-grained granite
KFM05A 110-2	330.17	330.19	(All specimens)
KFM05A 110-3	336.85	336.88	
KFM05A 110-4	336.88	336.91	
KFM05A 110-5	336.91	336.93	
KFM05A 110-6	336.94	336.97	
KFM05A 110-7	336.97	336.99	
KFM05A 110-8	337.00	337.03	
KFM05A 110-9	337.03	337.06	
KFM05A 110-10	337.06	337.09	
KFM05A 110-13	561.05	561.08	
KFM05A 110-14	561.08	561.11	
KFM05A 110-15	575.24	575.27	
KFM05A 110-16	575.27	575.30	
KFM05A 110-17	575.31	575.33	
KFM05A 110-18	575.34	575.36	
KFM05A 110-19	575.37	575.39	
KFM05A 110-20	575.40	575.42	
KFM05A 110-21	575.43	575.45	
KFM05A 110-22	575.46	575.48	

4.2 Testing

A general step-by-step description of the full test procedure is as follows.

Table 4-2. Activities during testing.

Step	Activity
1	The drill cores were marked where the specimens are to be collected.
2	The specimens were cut to the specified length according to markings. If the cutting surfaces were rough, they were slightly grinded.
3	The tolerances were checked: parallel and perpendicular surfaces, smooth and straight circumferential surface.
4	The diameter and thickness were measured three times each. The respective mean value determines the dimensions that are reported.
5	The direction of compressive loading was marked as a line on one of the plane surfaces with a marker pen.
6	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.
7	Digital photos were taken on each specimen.
8	The wet specimens were inserted into the loading device one by one, with the correct orientation given by the marked line, and loaded up to failure during deformation control. The load frame crossbar speed was set to 0.3 mm/min, which yielded a loading rate of approximately 9.5 MPa/min. The maximum compressive load, which also defines the failure load, was registered.
9	Digital photos were taken on each specimen after the mechanical testing.

The temperature of the water was 19.7°C, which equals to a water density of 998.2 kg/m^3, when the density determination of the rock specimens was carried out. Further, the specimens had been stored for 19 days in water when the density was determined and 31 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 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.

4.3 Nonconformities

The acitivity was conducted according to the method description and activity plan with no departures.

5 Results

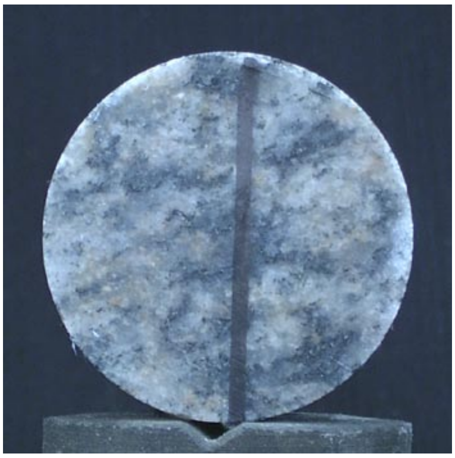
The results of the individual specimens are presented in Section 5.1 and a summary of the results is given in Section 5.2. The original results, unprocessed raw data obtained from the testing, were reported to the SICADA database and are traceable by the activity plan number. These data together with the digital photographs of the individual specimens were stored on a CD and 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 specimen

The results for the individual specimens are as follows:

Specimen ID: KFM05A-110-1

Before mechanical test | After mechanical test




Diameter (mm)	Height (mm)	Density (kg/m^3)	Tensile strength (MPa)
50.4	26.4	2,650	13.7

Comments: None

Specimen ID: KFM05A-110-2

Before mechanical test | After mechanical test


Diameter (mm)	Height (mm)	Density (kg/m^3)	Tensile strength (MPa)
50.4	26.2	2,660	13.8

Comments: None

Specimen ID: KFM05A-110-3

Before mechanical test	After mechanical test
	

Diameter (mm)	Height (mm)	Density (kg/m^3)	Tensile strength (MPa)
50.9	26.2	2,650	14.6

Comments: None

Specimen ID: KFM05A-110-4

Before mechanical test	After mechanical test
	

Diameter (mm)	Height (mm)	Density (kg/m^3)	Tensile strength (MPa)
50.9	26.2	2,650	13.0

Comments: None

Specimen ID: KFM05A-110-5

Before mechanical test

After mechanical test

Diameter (mm)	**Height (mm)**	**Density (kg/m³)**	**Tensile strength (MPa)**
50.9	26.3	2,650	14.0

Comments: None

Specimen ID: KFM05A-110-6

Before mechanical test

After mechanical test

Diameter (mm)	**Height (mm)**	**Density (kg/m³)**	**Tensile strength (MPa)**
50.9	26.3	2,650	14.0

Comments: None

Specimen ID: KFM05A-110-7

Before mechanical test

After mechanical test

Diameter (mm)	**Height (mm)**	**Density (kg/m^3)**	**Tensile strength (MPa)**
50.9	26.2	2,650	14.0

Comments: None

Specimen ID: KFM05A-110-8

Before mechanical test

After mechanical test

Diameter (mm)	**Height (mm)**	**Density (kg/m^3)**	**Tensile strength (MPa)**
50.9	26.2	2,650	13.9

Comments: None

Specimen ID: KFM05A-110-9

Before mechanical test

After mechanical test

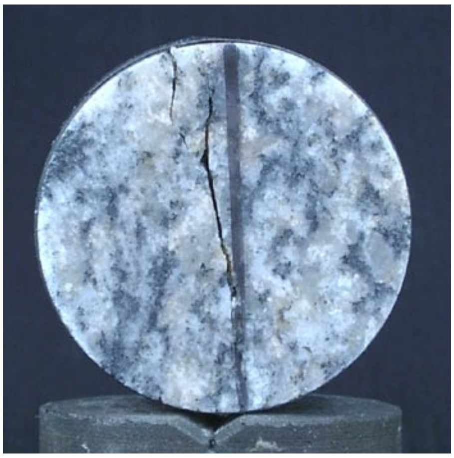
Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.9	26.2	2,650	12.4

Comments: None

Specimen ID: KFM05A-110-10

Before mechanical test

After mechanical test



Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.9	26.1	2,660	13.7

Comments: None

Specimen ID: KFM05A-110-13

Before mechanical test

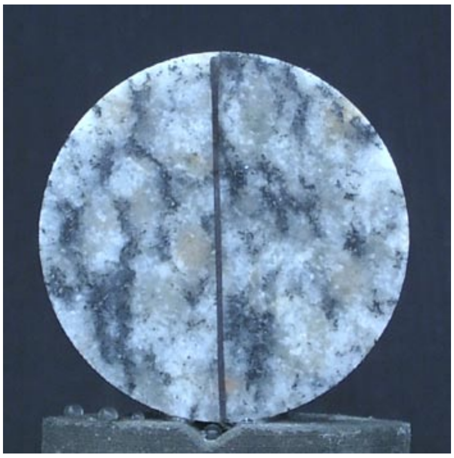
After mechanical test

Diameter (mm)	**Height (mm)**	**Density (kg/m^3)**	**Tensile strength (MPa)**
50.4	26.3	2,660	10.6

Comments: None

Specimen ID: KFM05A-110-14

Before mechanical test

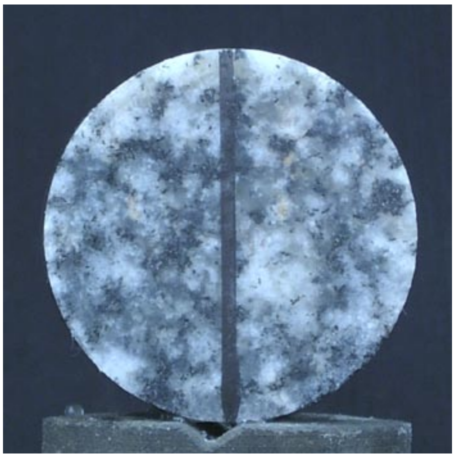
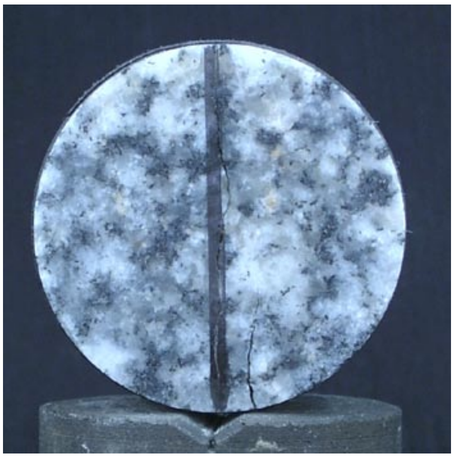


After mechanical test

Diameter (mm)	**Height (mm)**	**Density (kg/m^3)**	**Tensile strength (MPa)**
50.4	26.2	2,660	13.8

Comments: None

Specimen ID: KFM05A-110-15

Before mechanical test	After mechanical test
	

Diameter (mm)	**Height (mm)**	**Density (kg/m³)**	**Tensile strength (MPa)**
50.8	26.1	2,670	10.8

Comments: None

Specimen ID: KFM05A-110-16

Before mechanical test	After mechanical test
	

Diameter (mm)	**Height (mm)**	**Density (kg/m³)**	**Tensile strength (MPa)**
50.8	25.9	2,660	13.1

Comments: None

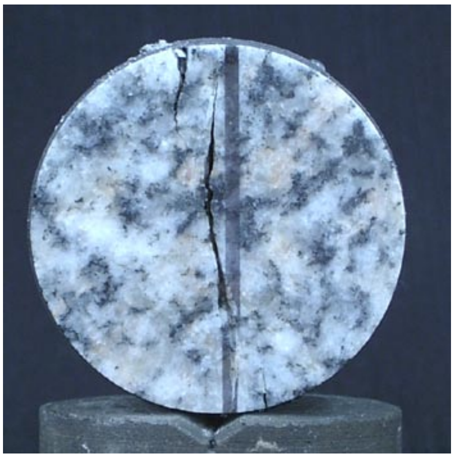
Specimen ID: KFM05A-110-17

Before mechanical test	After mechanical test
	

Diameter (mm)	**Height (mm)**	**Density (kg/m^3)**	**Tensile strength (MPa)**
50.8	26.2	2,650	11.8

Comments: None

Specimen ID: KFM05A-110-18

Before mechanical test	After mechanical test
	

Diameter (mm)	**Height (mm)**	**Density (kg/m^3)**	**Tensile strength (MPa)**
50.8	26.1	2,660	12.4

Comments: None

Specimen ID: KFM05A-110-19

Before mechanical test

After mechanical test

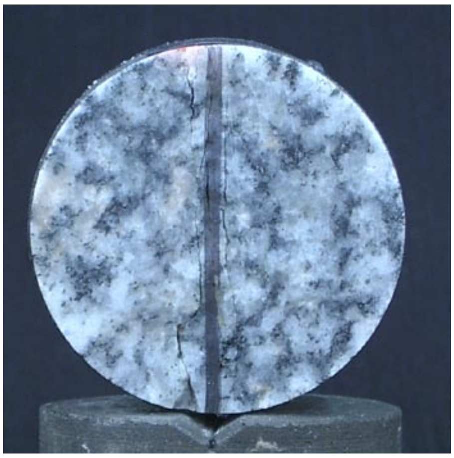
Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.8	25.8	2,660	12.9

Comments: None

Specimen ID: KFM05A-110-20

Before mechanical test

After mechanical test

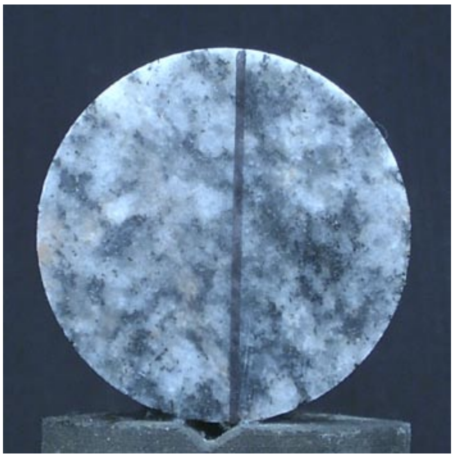


Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.8	25.9	2,670	13.9

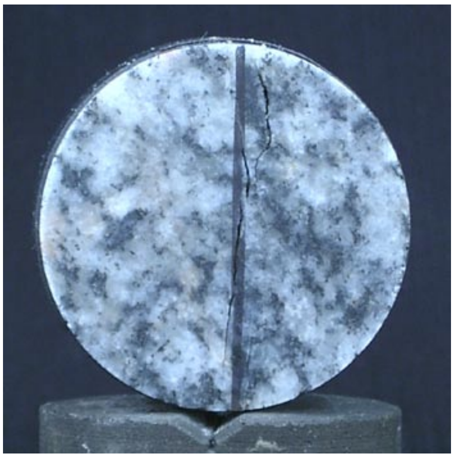
Comments: None

Specimen ID: KFM05A-110-21

Before mechanical test



After mechanical test



Diameter (mm)	**Height (mm)**	**Density (kg/m³)**	**Tensile strength (MPa)**
50.8	25.9	2,670	12.1

Comments: None

Specimen ID: KFM05A-110-22

Before mechanical test

After mechanical test

Diameter (mm)	**Height (mm)**	**Density (kg/m³)**	**Tensile strength (MPa)**
50.8	25.9	2,660	12.6

Comments: None

5.2 Results for the entire test series

A summary of the test results is presented 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
KFM05A 110-1	2,650	13.7	
KFM05A 110-2	2,660	13.8	
KFM05A 110-3	2,650	14.6	
KFM05A 110-4	2,650	13.0	
KFM05A 110-5	2,650	14.0	
KFM05A 110-6	2,650	14.0	
KFM05A 110-7	2,650	14.0	
KFM05A 110-8	2,650	13.9	
KFM05A 110-9	2,650	12.4	
KFM05A 110-10	2,660	13.7	
KFM05A 110-13	2,660	10.6	
KFM05A 110-14	2,660	13.8	
KFM05A 110-15	2,670	10.8	
KFM05A 110-16	2,660	13.1	
KFM05A 110-17	2,650	11.8	
KFM05A 110-18	2,660	12.4	
KFM05A 110-19	2,660	12.9	
KFM05A 110-20	2,670	13.9	
KFM05A 110-21	2,670	12.1	
KFM05A 110-22	2,660	12.6	

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 (330–337 m)	2,652	13.7
Mean val (561–575 m)	2,662	12.4
Mean val (All specimens)	2,657	13.1
Std dev (330–337 m)	4.2	0.6
Std dev (561–575 m)	6.3	1.1
Std dev (All specimens)	7.3	1.1

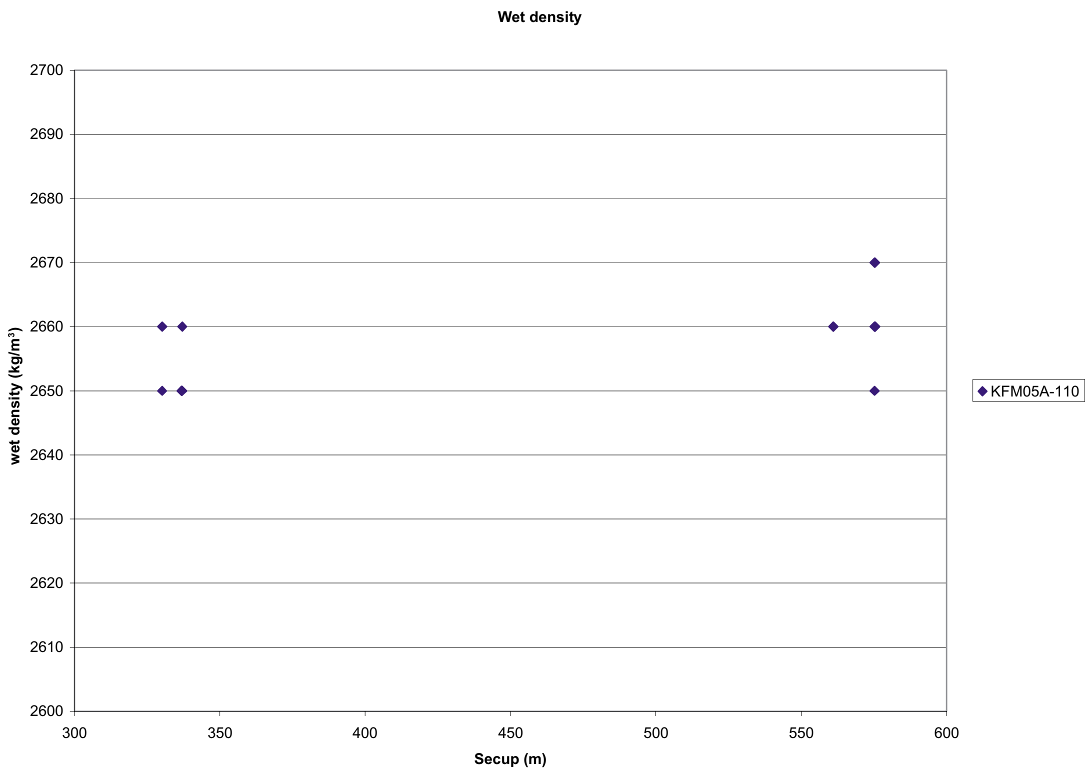


Figure 5-1. Density versus sampling depth in the borehole.

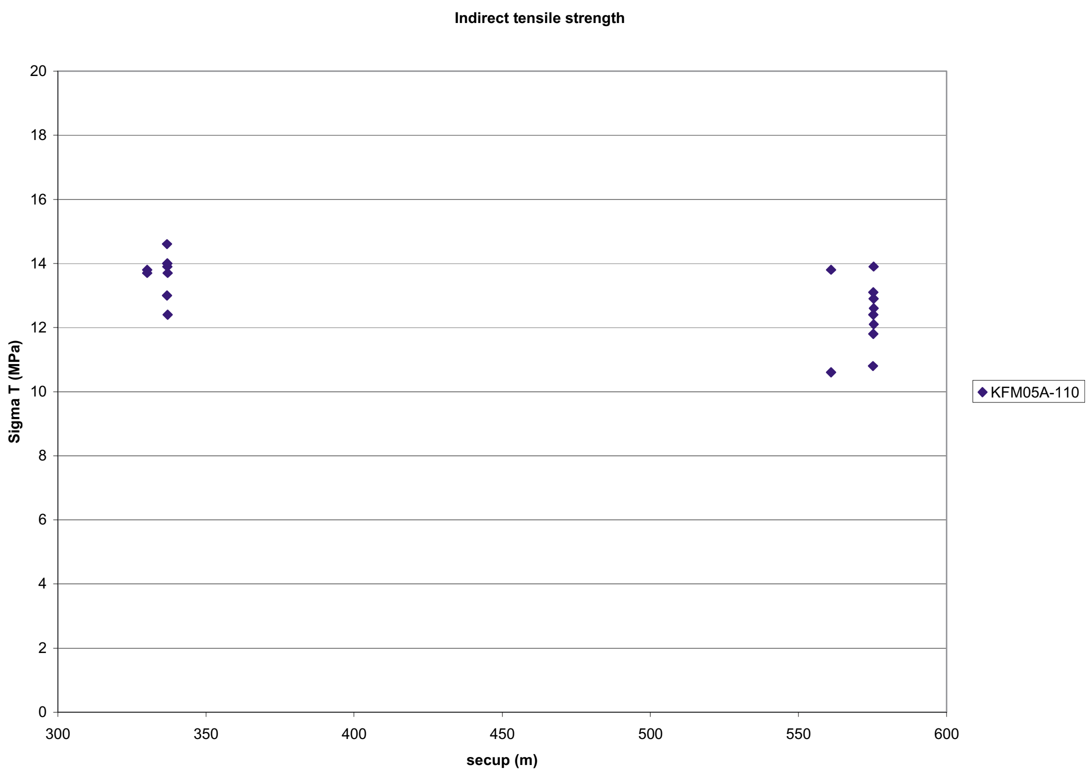


Figure 5-2. Tensile strength versus sampling depth in the borehole.

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