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Oskarshamn site investigation

Drill hole KSH02

Indirect tensile strength test

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March 2004

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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 indire ct tensile strength of 12 wet specimens of intact rock stored in water during 11 days from borehole KSH02A in Simpevarp have been determined. The samples were taken at one level ranging between 311–325 m. Moreover, the rock type was fine-grained dioritoid. The specimens were photographed before and after the mechanical test.

The measured densities for the water saturated specimens were in the range 2765–2801 kg/m^3, which yield a mean value of 2784 kg/m^3 and the obtained values for the indirect tensile strength were in the range 17.1–24.1 MPa with a mean value of 19.7 MPa.

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1 Introduction

The indirect tensile strength and the density for intact rock have been determined for water-saturated specimens sampled from borehole KSH02A in Simpevarp, see map in Figure 1-1. The specimens, in form of circular discs, were cut from rock cores and selected based on the preliminary core logging with the strategy to primarily investigate the properties of the dominant rock type. The test programme follows the activity plan AP PS 400-03-090 (SKB internal controlling document) and is controlled by SP-QD 13.1 (SP quality document).

According to the used test method, the samples were put in water and stored in water for minimum 7 days. This yields a water saturation, which is intended to resemble the in-situ moisture conditions. The density and the indirect tensile strength were then determined at this moisture condition. The rock material had a homogenous structure, which implies that the mechanical response of is expected to be approximately isotropic. The direction of loading is displayed on the specimens by a drawn line on each specimen. The samples were photographed before and after the mechanical testing.

The Swedish Nuclear Fuel and Waste Management Co (SKB) supplied Swedish National Testing and Research Institute (SP) with rock cores. The rock cores arrived at SP in September 2003 and were tested during February 2004. The method description, SKB MD 190.004, ver 1.9, (SKB internal controlling document), was followed for sampling and for the indirect tensile strength tests and SKB MD 160.002-02, ver 1.9, (SKB internal controlling document) was followed when the density was determined. All work described in this report was carried out by the department of Building Technology and Mechanics at SP.

Figure 1-1. Map of Oskarshamn site.

2 Objective and scope

The purpose of the testing is to determine the density and the tensile strength of a cylindrical intact rock core. The results from the tests are going to be used in the rock mechanical model, which will be established for the candidate area selected for site investigations at Simpevarp.

3 Equipment

A circular saw with a diamond blade was used to cut the specimens to their final lengths. Samples 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 made checked by means of a dial indicator and a stone face plate.

The specimens and the water were weighted using a scale for weight measurement. 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 maximum load capacity is 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. The top platen includes a spherical seating in order to have a fully centred loading position. The samples were photographed with a 4.0 Mega pixel digital camera at highest resolution and the photographs were stored in a jpeg-format.

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, ver 1.9, (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 according to the method description SKB 190.004, ver 1.9, (SKB internal controlling document). The test method follows ASTM D3967-95as /3/.

4.1 Description of the samples

The rock type characterisation was made according to Stråhle /4/ using the SKB mapping (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 and rock type for all specimens.

Identification	Secup (m)	Seclow (m)	Rock type
KSH02A-110-1	311.16	311.20	Fine-grained dioritoid
KSH02A-110-2	311.45	311.49	Fine-grained dioritoid
KSH02A-110-3	311.49	311.54	Fine-grained dioritoid
KSH02A-110-4	311.54	311.58	Fine-grained dioritoid
KSH02A-110-5	311.58	311.62	Fine-grained dioritoid
KSH02A-110-6	318.02	318.06	Fine-grained dioritoid
KSH02A-110-7	318.14	318.18	Fine-grained dioritoid
KSH02A-110-8	318.18	318.23	Fine-grained dioritoid
KSH02A-110-9	322.86	322.90	Fine-grained dioritoid
KSH02A-110-10	324.56	324.60	Fine-grained dioritoid
KSH02A-110-11	324.60	324.64	Fine-grained dioritoid
KSH02A-110-12	325.04	325.08	Fine-grained dioritoid

4.2 Testing

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

Step	Activity
1	The drill cores were marked where the samples are to be taken.
2	The samples 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 respectively 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 samples were then put in water and stored in water for minimum 7 days. The weight of water and one specimen together was determined. The specimen was taken out from the water and the weight of the water and rock specimen was determined separately and by knowing the density of the water the wet density could be computed. This was repeated for each specimen.
7	Digital photos were then taken on each sample.
8	The wet samples were inserted in the loading device one by one, with the correct orientation given by the marked line, and then loaded up to failure in 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 then taken on each sample after the mechanical testing.

The temperature of the water was 19.0°C, which equals to a water density of 998.4 kg/m^3, when the density determinations of the rock specimens were carried out. Further, the specimens had been stored 11 days in water when the density and the indirect tensile strength were determined.

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

The diameter and thickness were entered into the test software whereby the test software 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 program MS Excel and rearranged to the SICADA data base format. Moreover, the diagram was produced using MS Excel.

5 Results

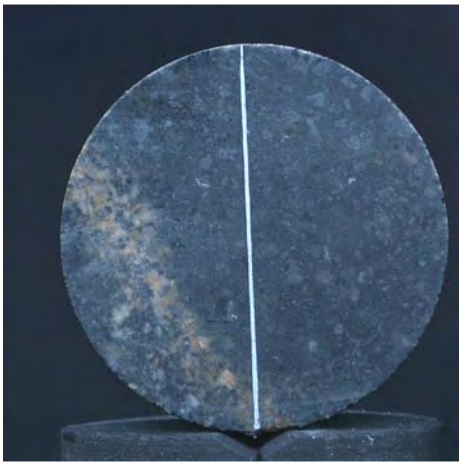
The results of the individual specimens are presented in Section 5.1 and a summary of the results is given in Section 5.2. The original results, unprocessed raw data obtained from the testing, were reported to the SICADA database, FN 161. These data together with the digital photographs of the individual 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

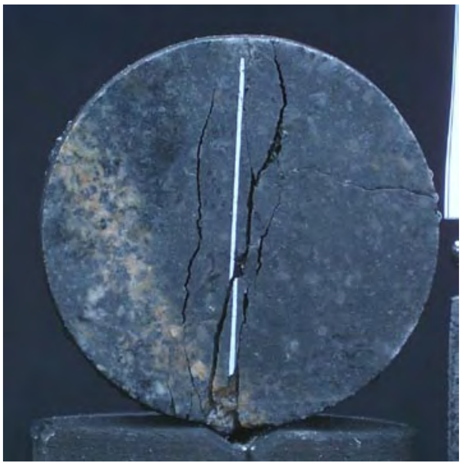
The results for the individual specimens are as follows:

Specimen ID: KSH02A-110-1

Before mechanical test



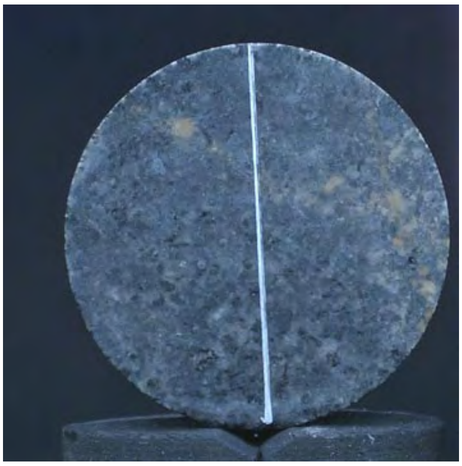
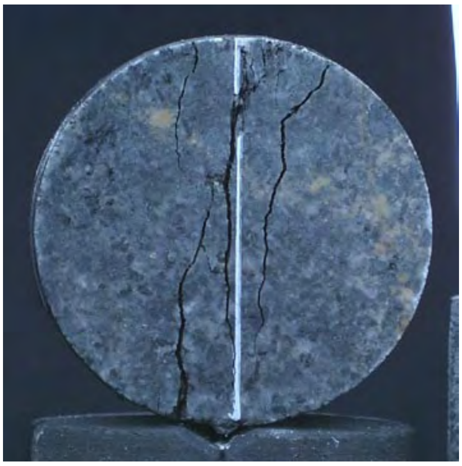
After mechanical test



Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
50.2	25.7	2790	20.2	

Comments: A horizontal crack was developed in addition to the primary vertical crack.

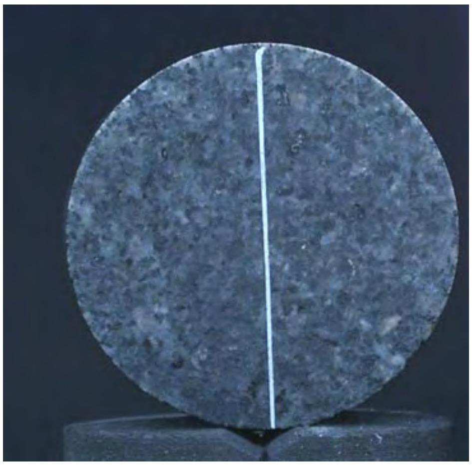
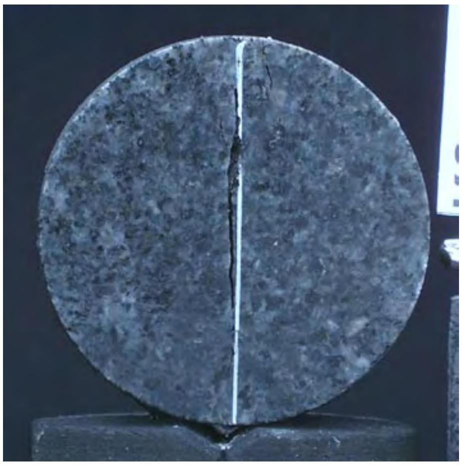
Specimen ID: KSH02A-110-2

Before mechanical test	After mechanical test
	

Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
50.2	26.1	2778	18.9	

Comments: None

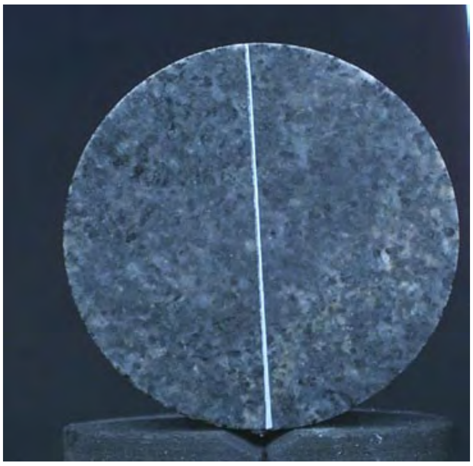
Specimen ID: KSH02A-110-3

Before mechanical test	After mechanical test
	

Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
50.2	26.0	2779	18.5	

Comments: None

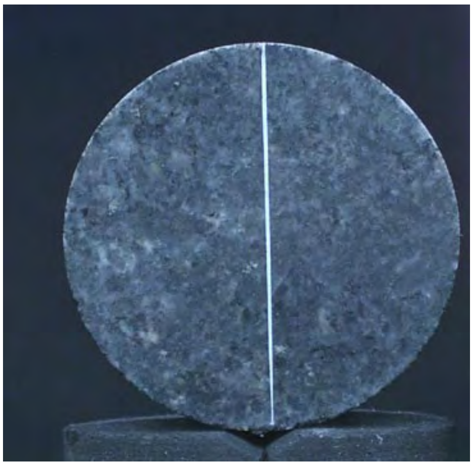
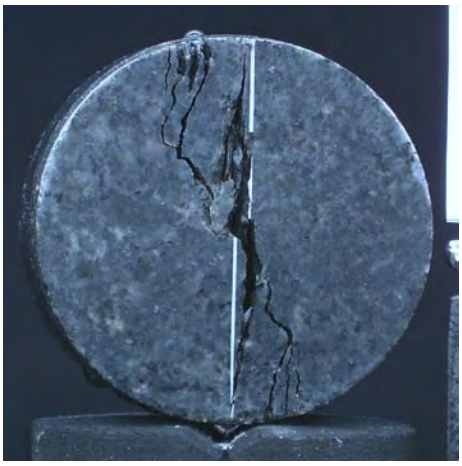
Specimen ID: KSH02A-110-4

Before mechanical test	After mechanical test
	

Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
50.2	26.1	2779	19.3	

Comments: None

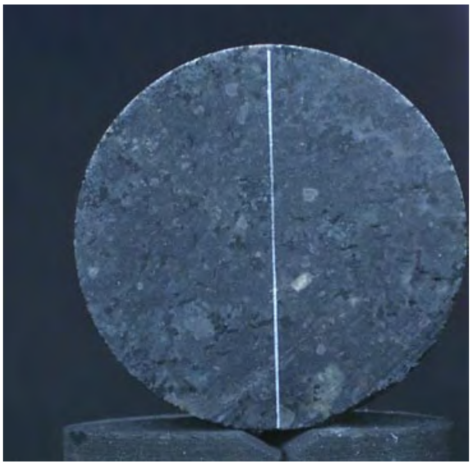
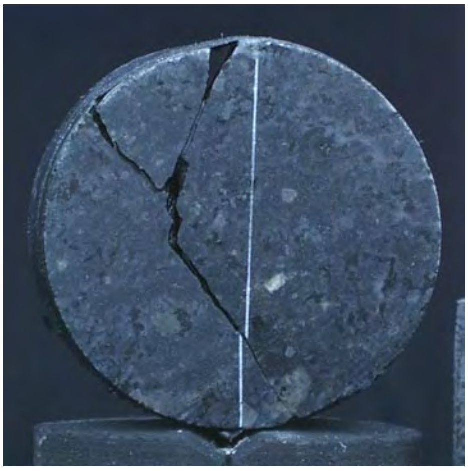
Specimen ID: KSH02A-110-5

Before mechanical test	After mechanical test
	

Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
50.2	26.1	2779	19.9	

Comments: None

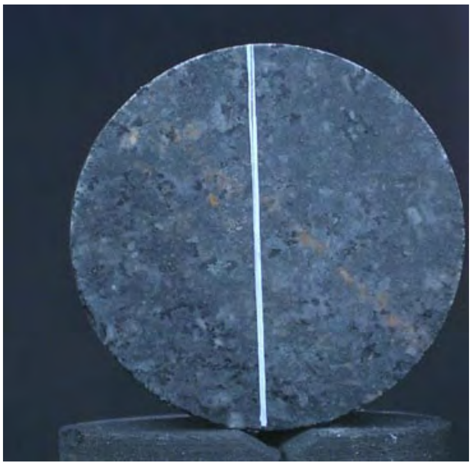
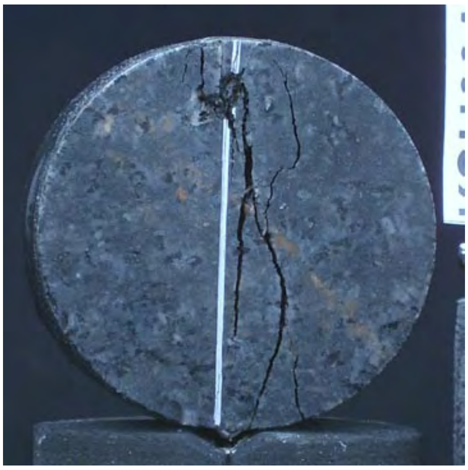
Specimen ID: KSH02A-110-6

Before mechanical test	After mechanical test
	

Diameter [mm]	**Height [mm]**	**Density [kg/m^3]**	**Tensile strength [MPa]**	**Loading direction**
50.2	26.2	2801	17.1	

Comments: The vertical crack is curved

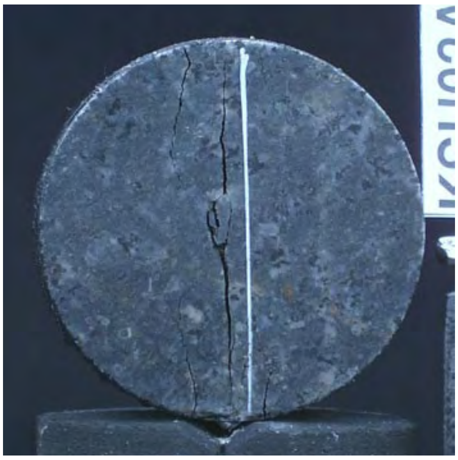
Specimen ID: KSH02A-110-7

Before mechanical test	After mechanical test
	

Diameter [mm]	**Height [mm]**	**Density [kg/m^3]**	**Tensile strength [MPa]**	**Loading direction**
50.0	26.0	2790	18.9	

Comments: None

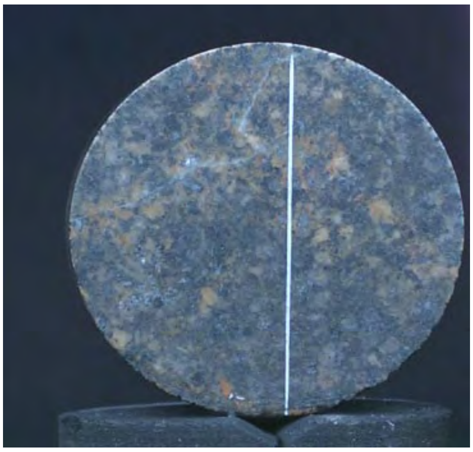
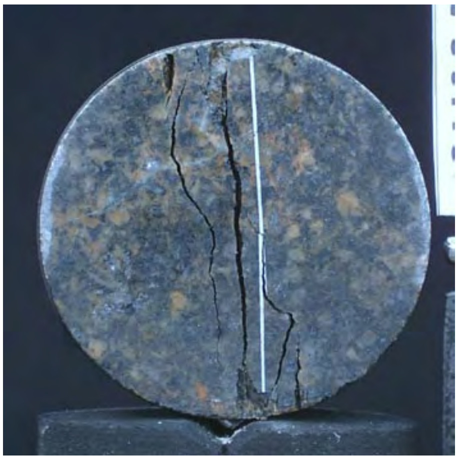
Specimen ID: KSH02A-110-8

Before mechanical test	After mechanical test
	

Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
50.0	26.1	2790	18.8	

Comments: None

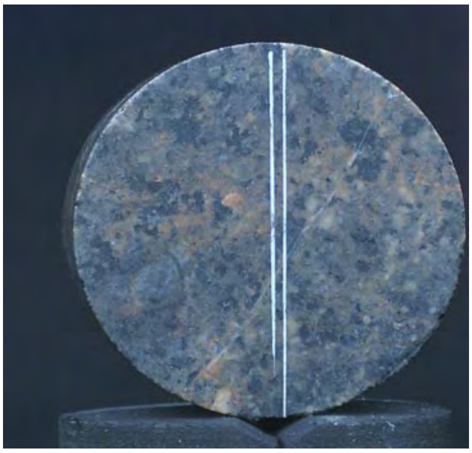
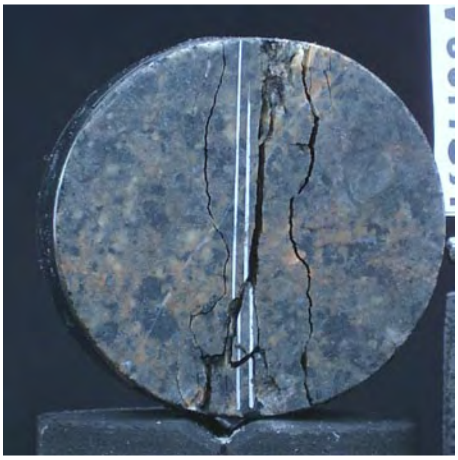
Specimen ID: KSH02A-110-9

Before mechanical test	After mechanical test
	

Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
49.9	26.3	2765	19.7	

Comments: None

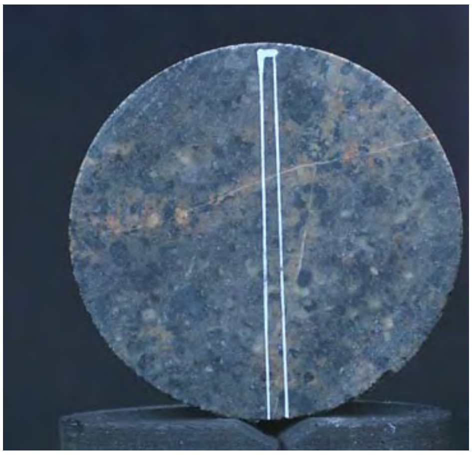
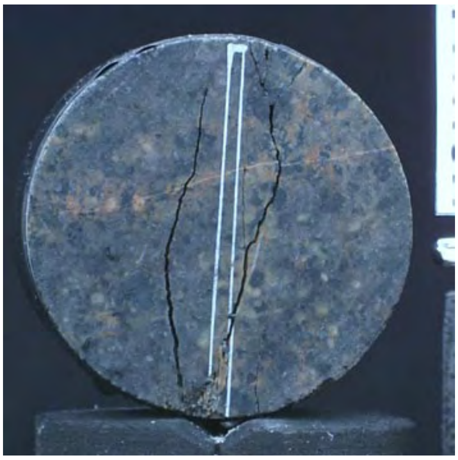
Specimen ID: KSH02A-110-10

Before mechanical test	After mechanical test
	

Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
50.0	26.2	2794	24.1	

Comments: None

Specimen ID: KSH02A-110-11

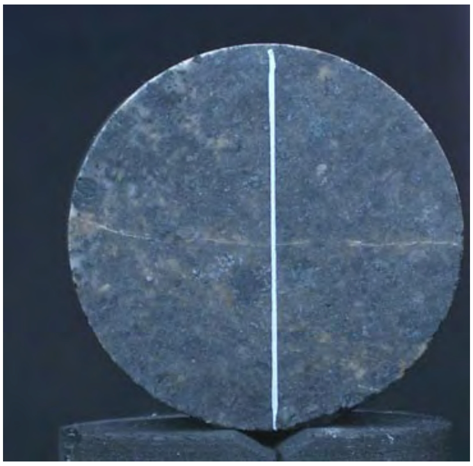
Before mechanical test	After mechanical test
	

Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
49.9	26.1	2792	18.5	

Comments: None

Specimen ID: KSH02A-110-12

Before mechanical test



After mechanical test

Diameter [mm]	Height [mm]	Density [kg/m^3]	Tensile strength [MPa]	Loading direction
50.0	26.3	2776	22.2	

Comments: A horizontal crack was developed in a pre-existent weakness plane in addition to the primary vertical crack.

5.2 Results for the entire test series

A summary of the test results is shown in Table 5-1 and 5-2. The densities and tensile strength versus the depth, at which the samples are taken, are shown in Figures 5-1 and 5-2.

Table 5-1. Summary of results.

Identification	Density [kg/m3]	Tensile strength [MPa]	Comments
KSH02A-110-1	2790	20.2	
KSH02A-110-2	2778	18.9	
KSH02A-110-3	2779	18.5	
KSH02A-110-4	2779	19.3	
KSH02A-110-5	2779	19.9	
KSH02A-110-6	2801	17.1	The vertical crack is curved
KSH02A-110-7	2790	18.9	
KSH02A-110-8	2790	18.8	
KSH02A-110-9	2765	19.7	
KSH02A-110-10	2794	24.1	
KSH02A-110-11	2792	18.5	
KSH02A-110-12	2776	22.2	A horizontal crack was developed in a pre-existent weakness plane in addition to the primary vertical crack.

Table 5-2. Calculated mean values and standard deviation.

	Density [kg/m3]	Tensile strength [MPa]
Mean value	2784	19.7
Standard deviation	10.0	1.9

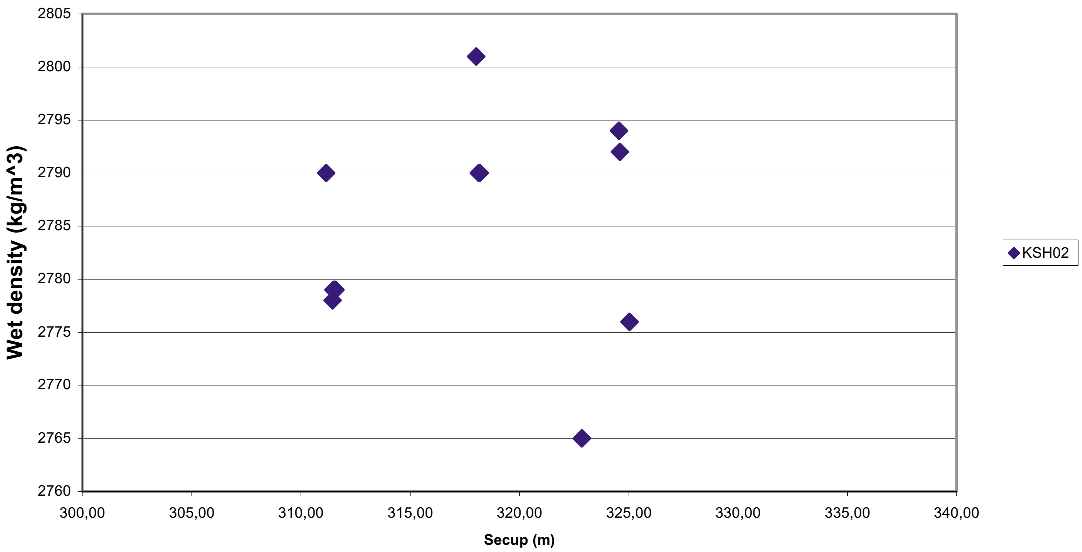


Figure 5-1. Density versus depth at which the samples are taken in the borehole.

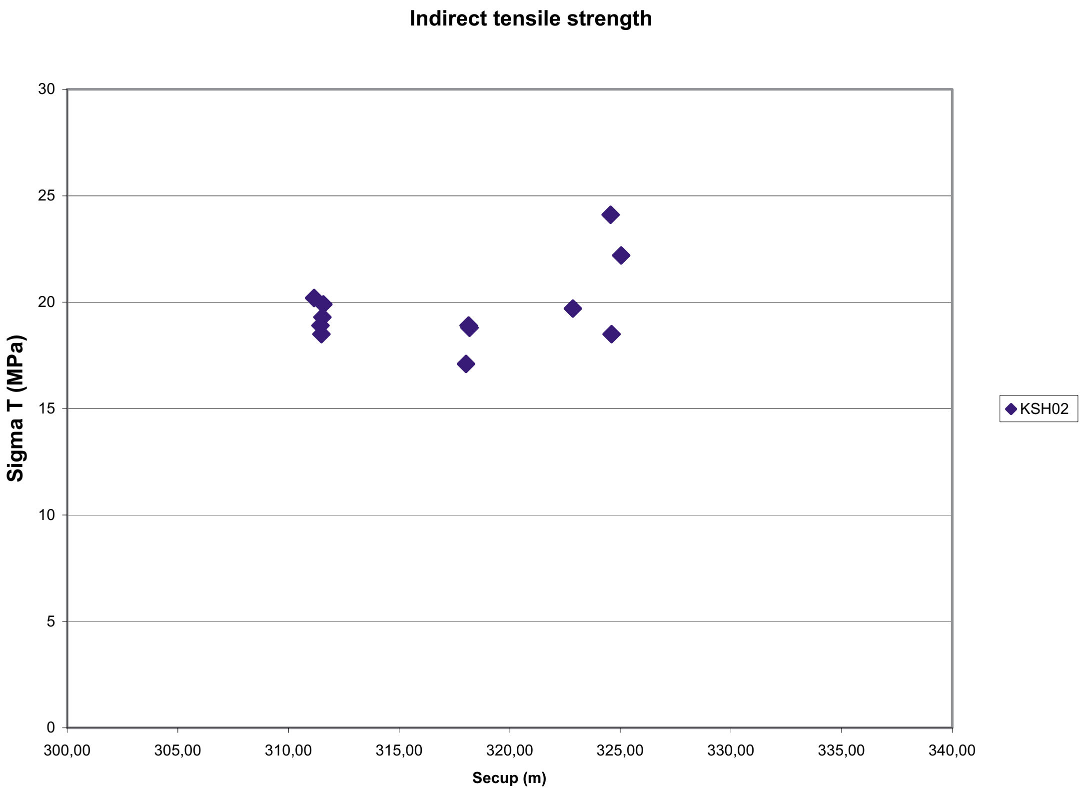


Figure 5-2. Tensile strength versus depth at which the samples are taken in the borehole.

5.3 Discussion

The testing was conducted according to the method description with no departures. All specimens including the two spare specimens, KSH02A-110-11 and KSH02A-110-12, were tested.

References

/1/ ISRM. Suggested Method for Determining Water Content, Porosity, Density, Absorption and Related Properties and Swelling and Slake-durability Index Properties. Int. J. Rock. Mech. Min. Sci. & Geomech. Abstr. 16(2), pp. 141–156, 1979.

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