P-05-91

Oskarshamn site investigation

Drill hole KLX03A

Indirect tensile strength test

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August 2005

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Keywords: Rock mechanics, Indirect tensile strength, Tension test.

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.

Abstract

The density and the indirect tensile strength of 20 water saturated specimens of intact rock from borehole KLX03A in Laxemar have been determined. The specimens were collected at two depth levels ranging between 514–515 m, and 711–712 m. Moreover, the rock types were Ävrö granite (514–515 m) and Quartz monzodiorite (711–712 m). The specimens were photographed before and after the mechanical test.

The measured densities for the water saturated specimens were in the range 2,750–2,810 kg/m^3, which yield a mean value of 2,788 kg/m^3. The values for indirect tensile strength were in the range 9.4–14.7 MPa with a mean value of 12.8 MPa (514–515 m) and 14.3–18.0 MPa with a mean value of 16.6 MPa (711–712 m).

Sammanfattning

Densiteten och den indirekta draghållfastheten hos 20 vattenmättade prover av intakt homogent berg från borrhål KLX03A i Laxemar har bestämts. Proven har tagits från två djupnivåer 514–515 m och 711–712 m. Bergtypen vid dessa nivåer var Ävrö granit (514–515 m) och kvartsmonzodiorit (711–712 m). Provobjekten fotograferades före och efter de mekaniska proven.

Densiteten hos de vattenmättade proven var mellan 2 750–2 810 kg/m^3 vilket gav ett medelvärde på 2 788 kg/m^3. Värdena på den indirekta draghållfastheten var 9,4–14,7 MPa med ett medelvärde på 12,8 MPa (515–515 m) och 14.3–18.0 MPa med ett medelvärde på 16,6 MPa (711–712 m).

Contents

1 Introduction

Indirect tensile strength tests have been conducted on water-saturated specimens sampled from borehole KLX03A in Laxemar, see map in Figure 1-1. These tests belong to one of the activities performed as part of the site investigation in the Oskarshamn area conducted 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 is carried out in accordance with the activity plan AP PS 400-04-106 (SKB internal controlling document) and is controlled by SP-QD 13.1 (SP internal quality document).

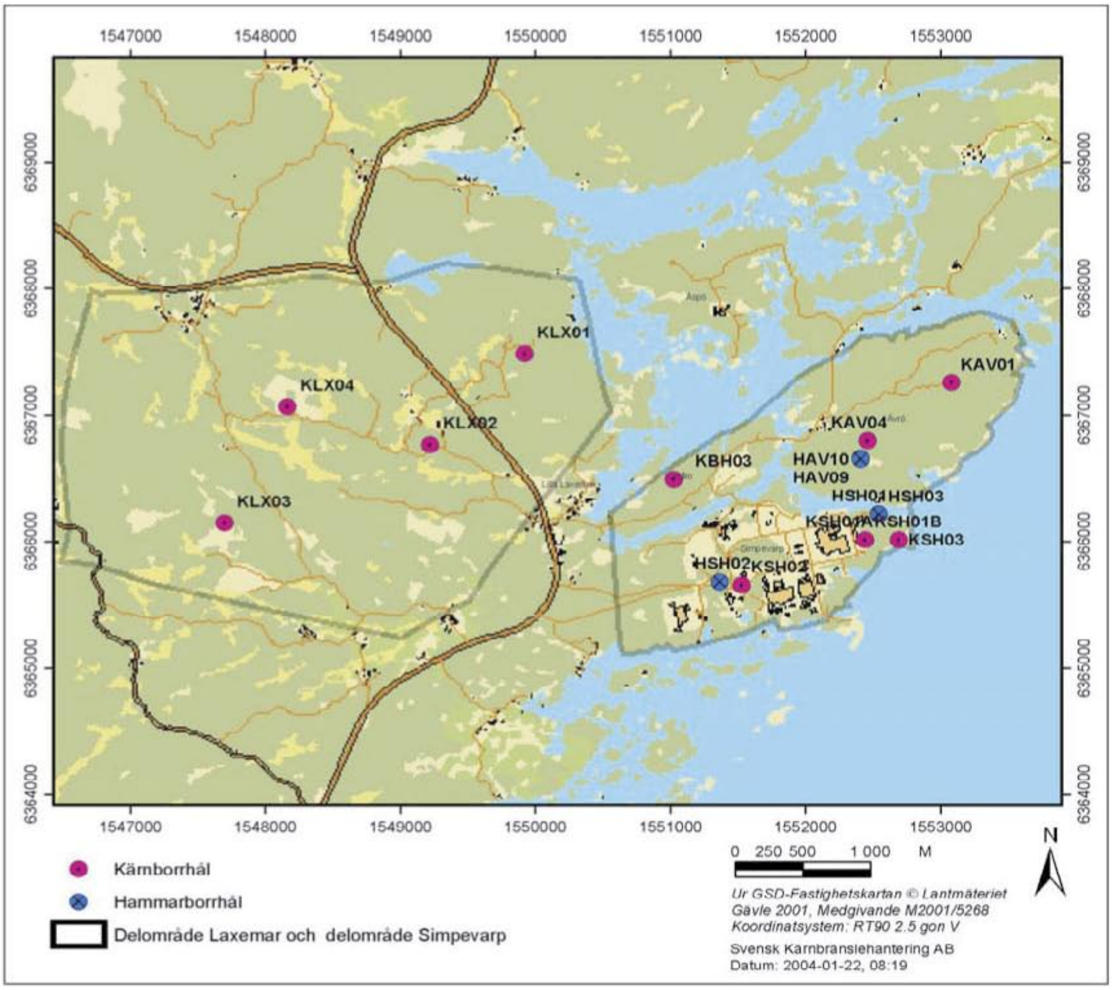


Figure 1-1. Location of the drill hole KLX03A at the Laxemar site.

SKB supplied SP with rock cores and they arrived at SP in December 2004 and were tested during March 2005. 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 the properties of the dominant rock type. 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.

The method description SKB MD 190.004 (SKB internal controlling document), was followed for the sampling and for the indirect tensile strength tests, whereas the method description SKB MD 160.002 (SKB internal controlling document), was followed when the density was determined.

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 specimens are collected from the borehole KLX03A, which is a borehole with a drilling depth of c 1,000 m.

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 Oskarshamn.

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 made 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.

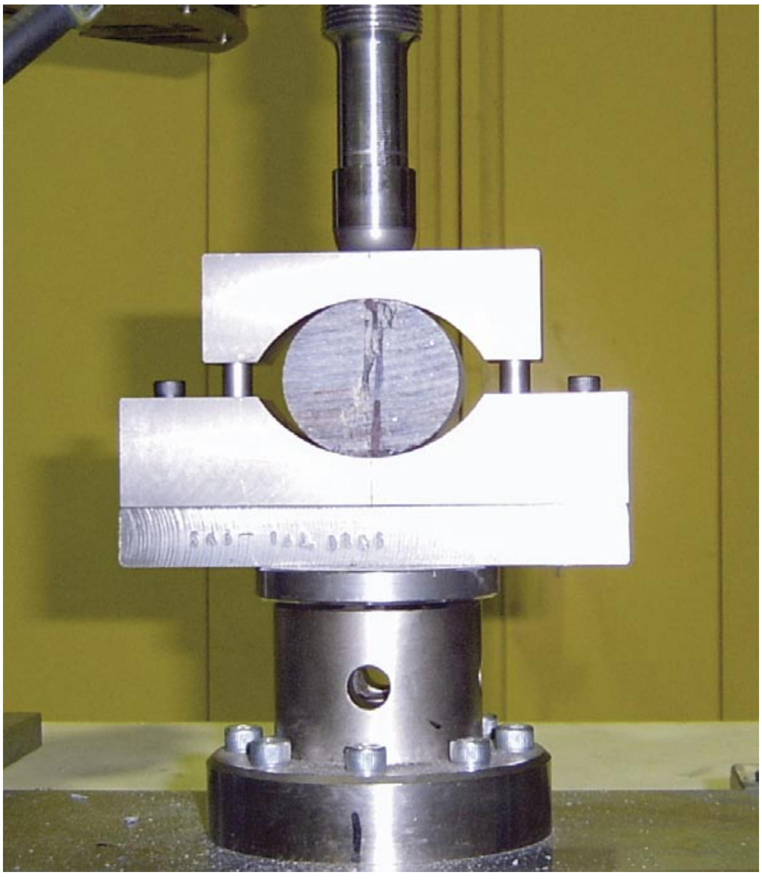


Figure 3-1. *Curved bearing blocks for indirect tensile test. The specimen in the picture does not belong to the tests in this report.*

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 (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 depth and rock type for all specimens (base on the overview mapping).

Identification	Secup (m)	Seclow (m)	Rock type
KLX03A-110-1	514.63	514.66	Ävrö granite
KLX03A-110-2	514.66	514.69	Ävrö granite
KLX03A-110-3	514.69	514.72	Ävrö granite
KLX03A-110-4	514.72	514.75	Ävrö granite
KLX03A-110-5	514.75	514.78	Ävrö granite
KLX03A-110-6	514.78	514.81	Ävrö granite
KLX03A-110-7	514.81	514.84	Ävrö granite
KLX03A-110-8	514.84	514.87	Ävrö granite
KLX03A-110-9	514.87	514.90	Ävrö granite
KLX03A-110-10	514.90	514.93	Ävrö granite
KLX03A-110-13	710.99	711.02	Quartz monzodiorite
KLX03A-110-14	711.02	711.05	Quartz monzodiorite
KLX03A-110-15	711.05	711.08	Quartz monzodiorite
KLX03A-110-16	711.08	711.11	Quartz monzodiorite
KLX03A-110-17	711.76	711.79	Quartz monzodiorite
KLX03A-110-18	711.79	711.82	Quartz monzodiorite
KLX03A-110-19	711.82	711.85	Quartz monzodiorite
KLX03A-110-20	711.85	711.88	Quartz monzodiorite
KLX03A-110-21	711.88	711.91	Quartz monzodiorite
KLX03A-110-22	711.91	711.94	Quartz monzodiorite

4.2 Specimen preparation and testing

The temperature of the water was 18.3°C, which equals to a water density of 998.6 kg/m^3, when the density determination of the rock specimens was carried out. Further, the specimens had been stored 14 days in water when the density was determined and 48 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 a 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 specimen preparation and testing is shown in the step-by step description in Table 4-2.

Table 4-2. Activities during the specimen preparation and 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 geometrical 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 cross-bar 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.

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.

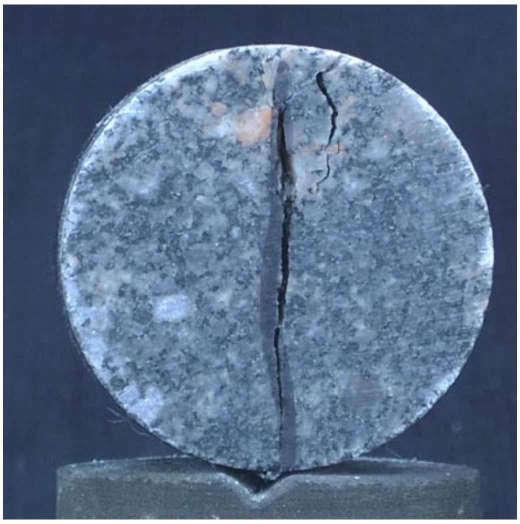
5.1 Description and presentation of the specimen

The results for the individual specimens are as follows:

Specimen ID: KLX03A-110-1

Before mechanical test

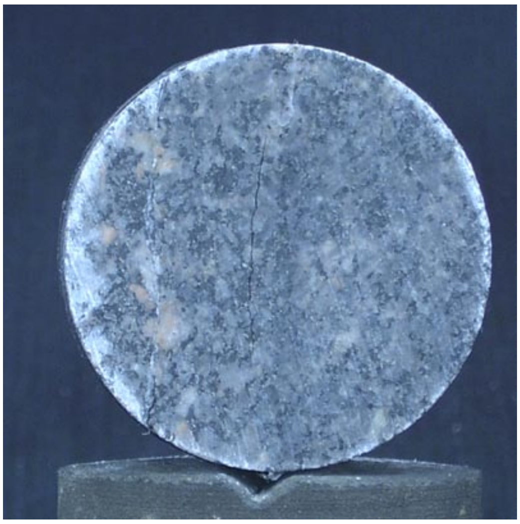
After mechanical test



Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.3	26.4	2,780	14.7
Comments:	None		

Specimen ID: KLX03A-110-2

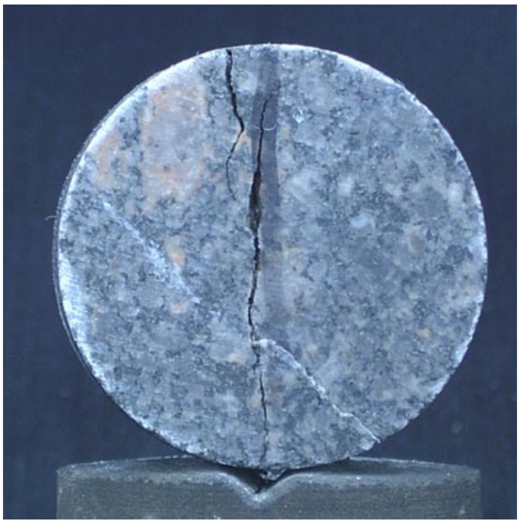
Before mechanical test *After mechanical test*



Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.3	26.2	2,760	9.4
Comments:	None		

Specimen ID: KLX03A-110-3

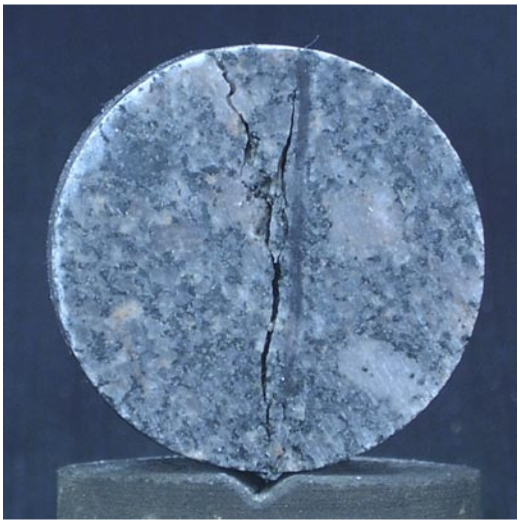
Before mechanical test *After mechanical test*



Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.3	26.3	2,760	13.3
Comments:	None		

Specimen ID: KLX03A-110-4

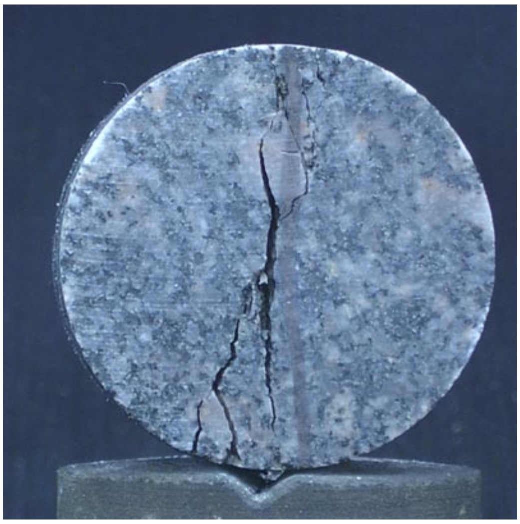
Before mechanical test *After mechanical test*



Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.3	26.3	2,760	13.6
Comments:	None		

Specimen ID: KLX03A-110-5

Before mechanical test *After mechanical test*

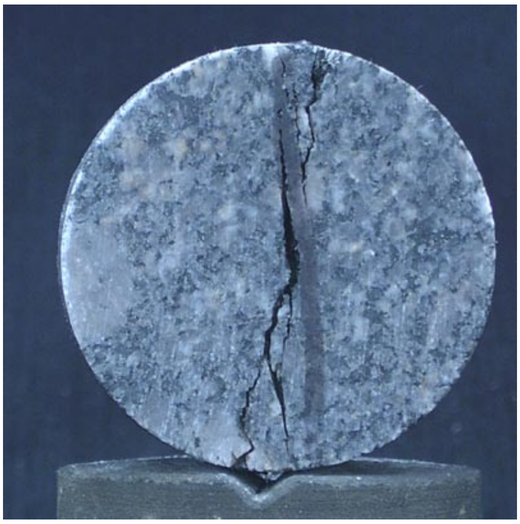


Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.3	26.2	2,770	13.8
Comments:	None		

Specimen ID: KLX03A-110-6

Before mechanical test

After mechanical test

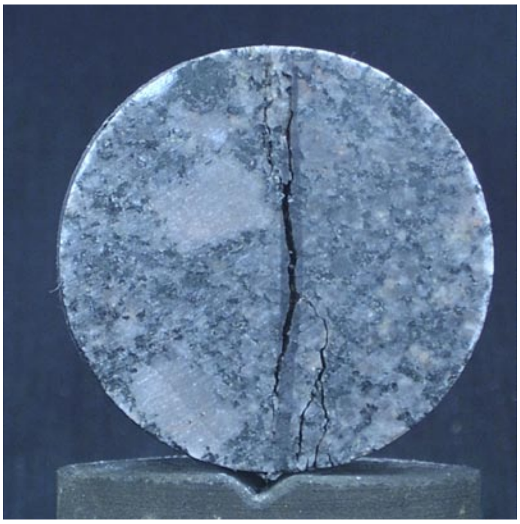


Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.3	26.2	2,770	13.0
Comments:	None		

Specimen ID: KLX03A-110-7

Before mechanical test

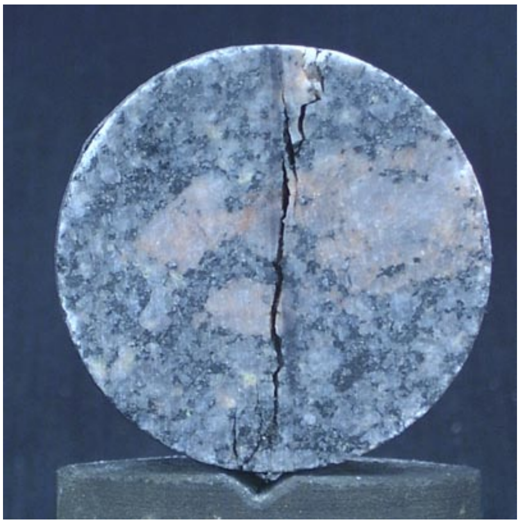
After mechanical test



Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.2	26.2	2,760	13.1
Comments:	None		

Specimen ID: KLX03A-110-8

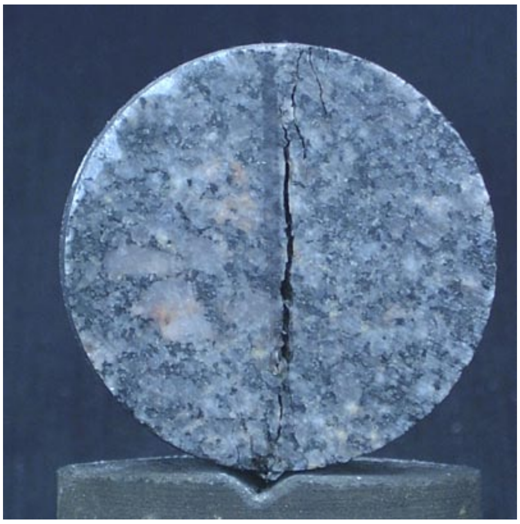
Before mechanical test *After mechanical test*



Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.2	26.2	2,750	10.9
Comments:	None		

Specimen ID: KLX03A-110-9

Before mechanical test *After mechanical test*

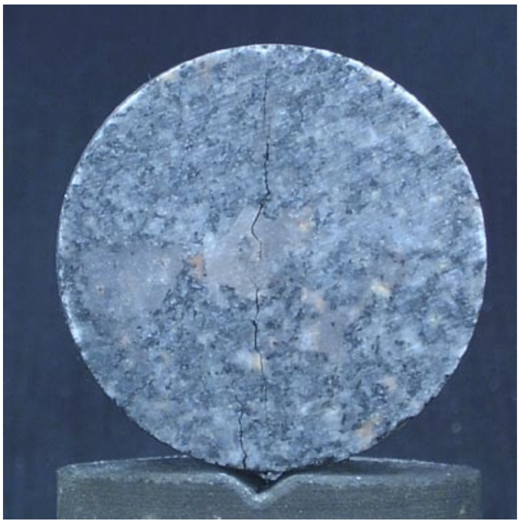


Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.2	26.2	2,780	13.0
Comments:	None		

Specimen ID: KLX03A-110-10

Before mechanical test

After mechanical test

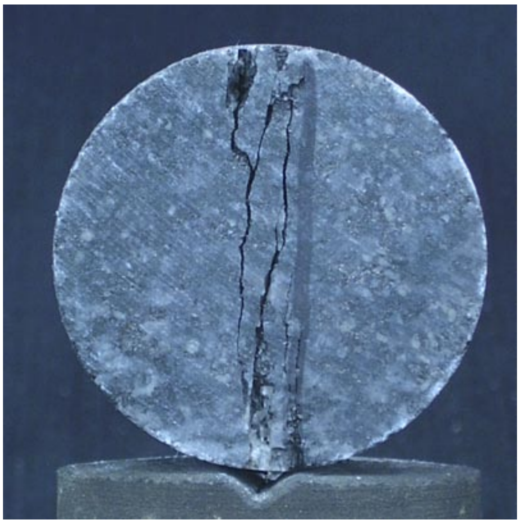


Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.2	25.9	2,770	12.7
Comments:	None		

Specimen ID: KLX03A-110-13

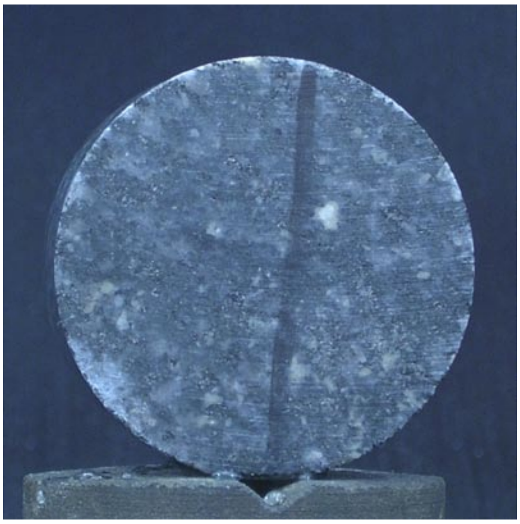
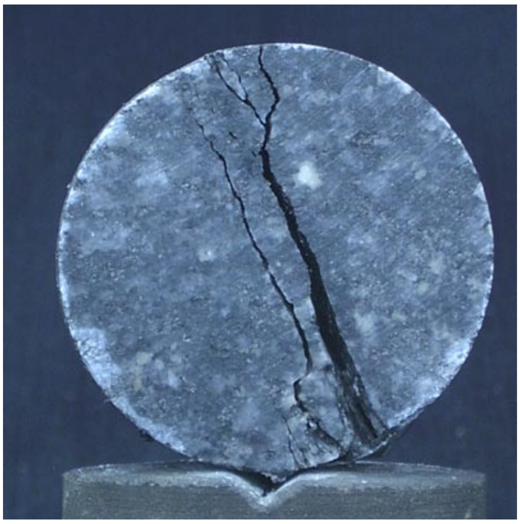
Before mechanical test

After mechanical test



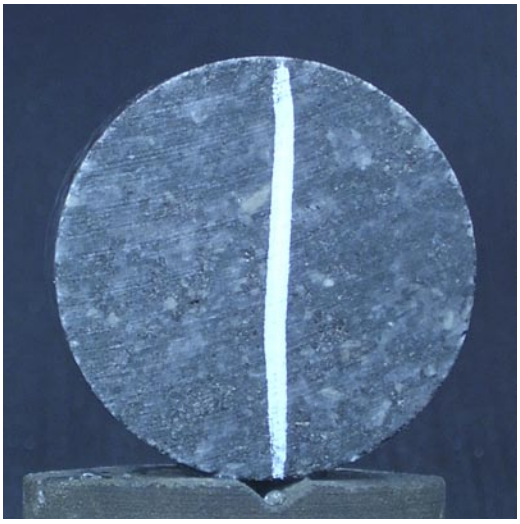
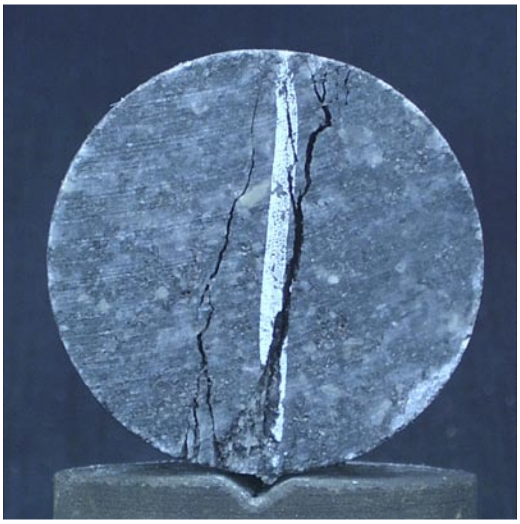
Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.2	2,800	14.3
Comments:	None		

Specimen ID: KLX03A-110-14

Before mechanical test	*After mechanical test*
	

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.1	2,810	17.3
Comments:	None		

Specimen ID: KLX03A-110-15

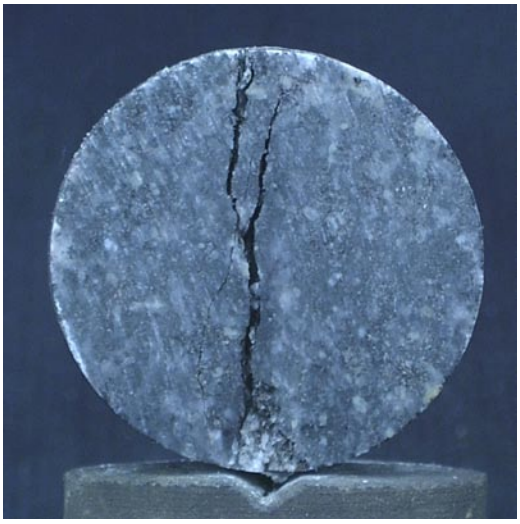
Before mechanical test	*After mechanical test*
	

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.2	2,810	17.6
Comments:	None		

Specimen ID: KLX03A-110-16

Before mechanical test

After mechanical test

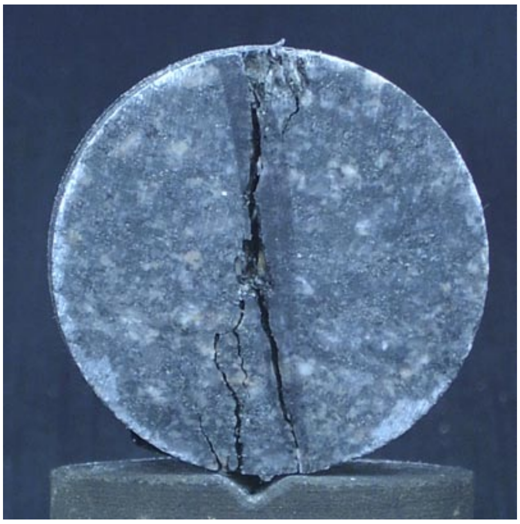


Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.4	2,810	17.1
Comments:	None		

Specimen ID: KLX03A-110-17

Before mechanical test

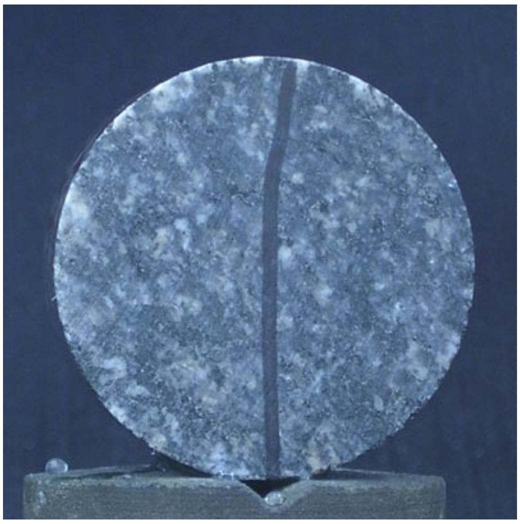
After mechanical test



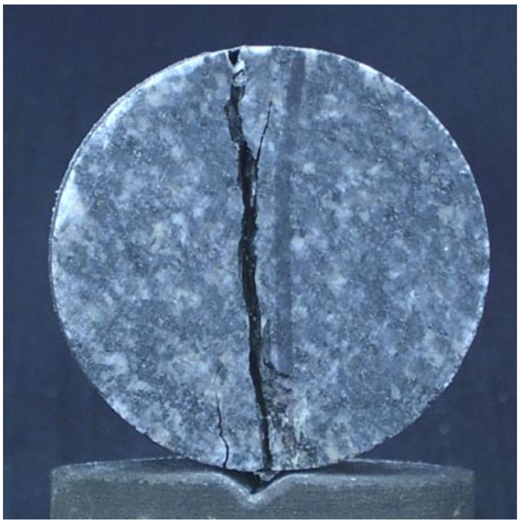
Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.1	2,810	18.0
Comments:	None		

Specimen ID: KLX03A-110-18

Before mechanical test



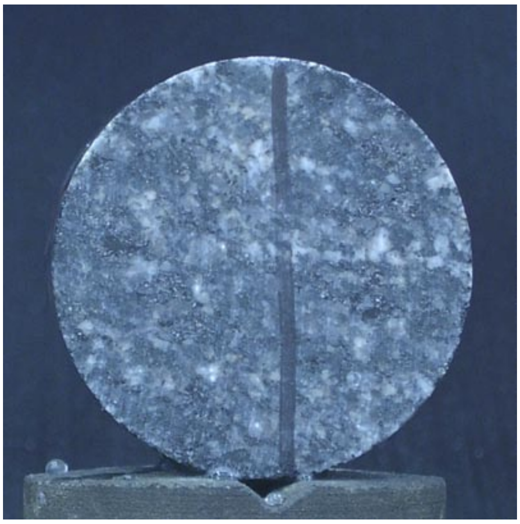
After mechanical test



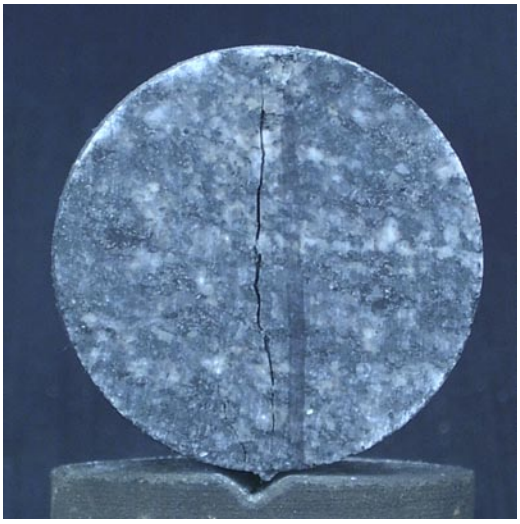
Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.3	2,810	17.2
Comments:	None		

Specimen ID: KLX03A-110-19

Before mechanical test

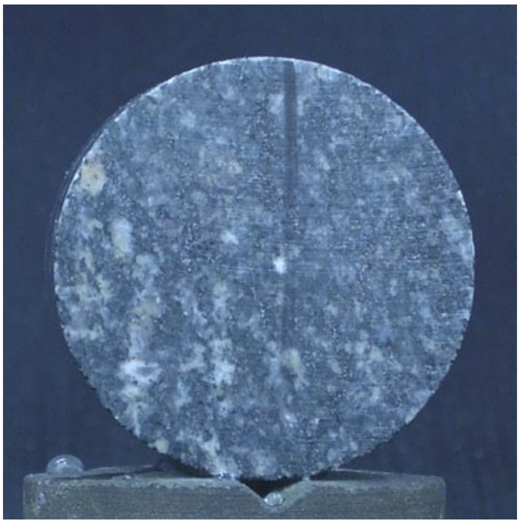
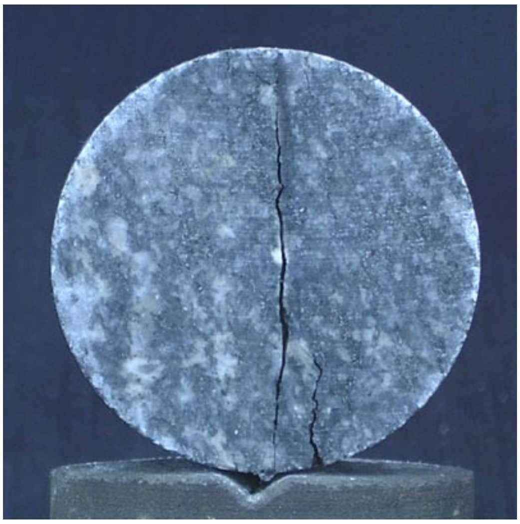


After mechanical test



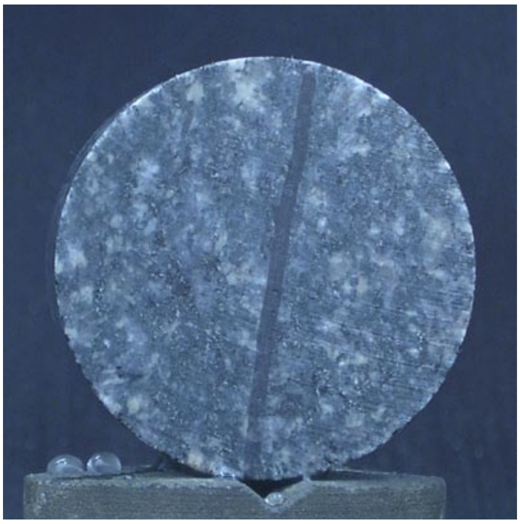
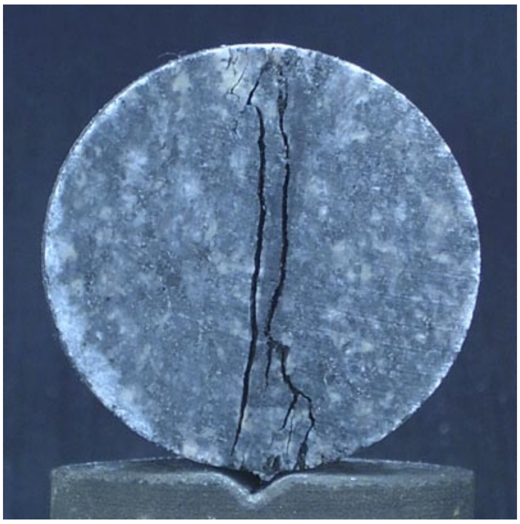
Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.1	2,810	15.8
Comments:	None		

Specimen ID: KLX03A-110-20

Before mechanical test	*After mechanical test*
	

Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.2	2,810	15.6
Comments:	None		

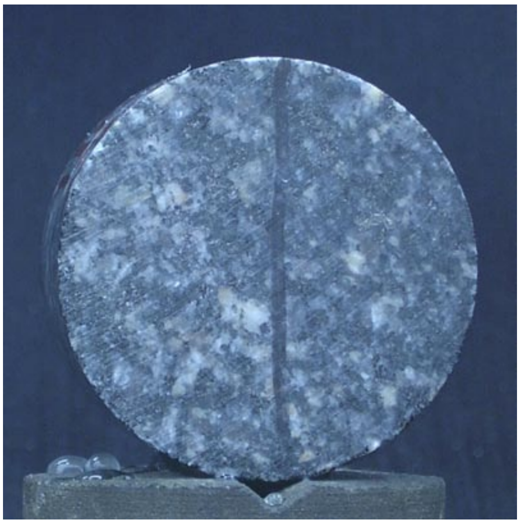
Specimen ID: KLX03A-110-21

Before mechanical test	*After mechanical test*
	

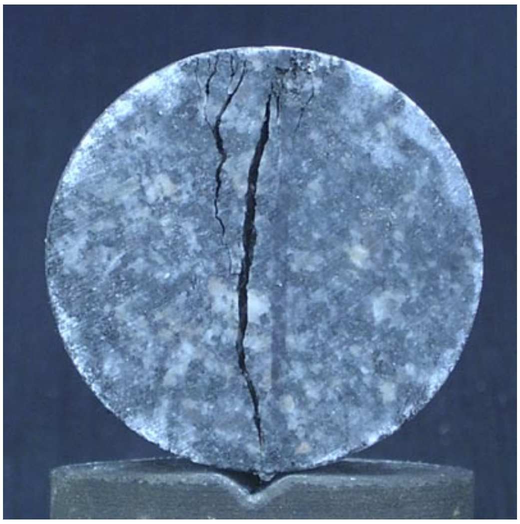
Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.0	2,810	16.3
Comments:	None		

Specimen ID: KLX03A-110-22

Before mechanical test



After mechanical test



Diameter (mm)	Height (mm)	Density (kg/m³)	Tensile strength (MPa)
50.1	26.1	2,810	17.0
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.

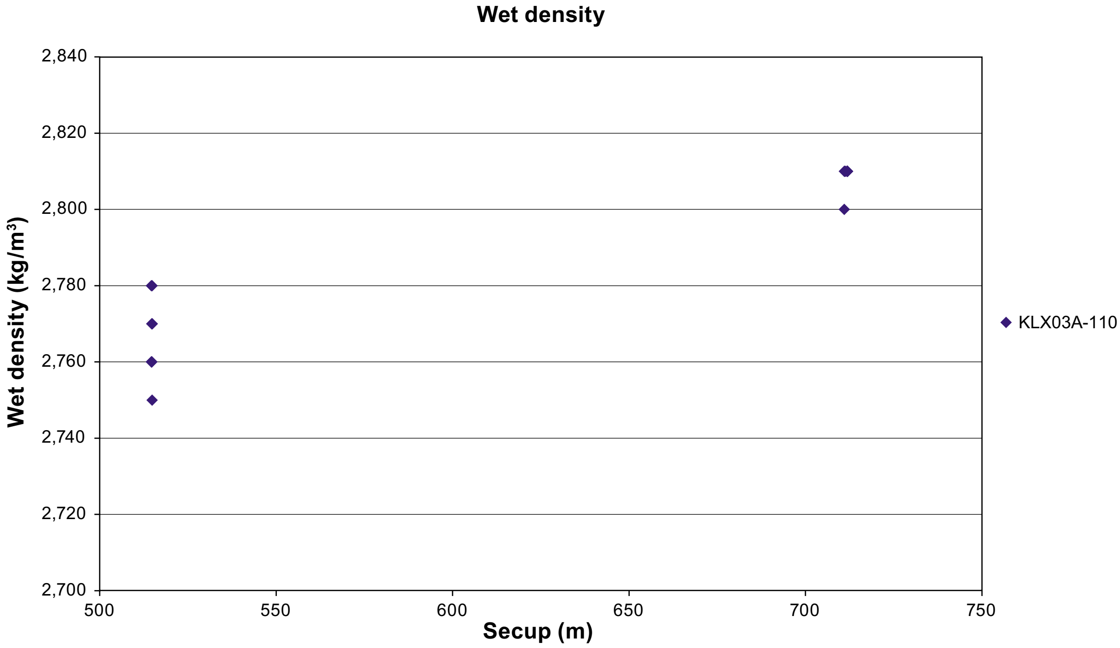


***Figure 5-1.** Density versus sampling depth in the borehole.*

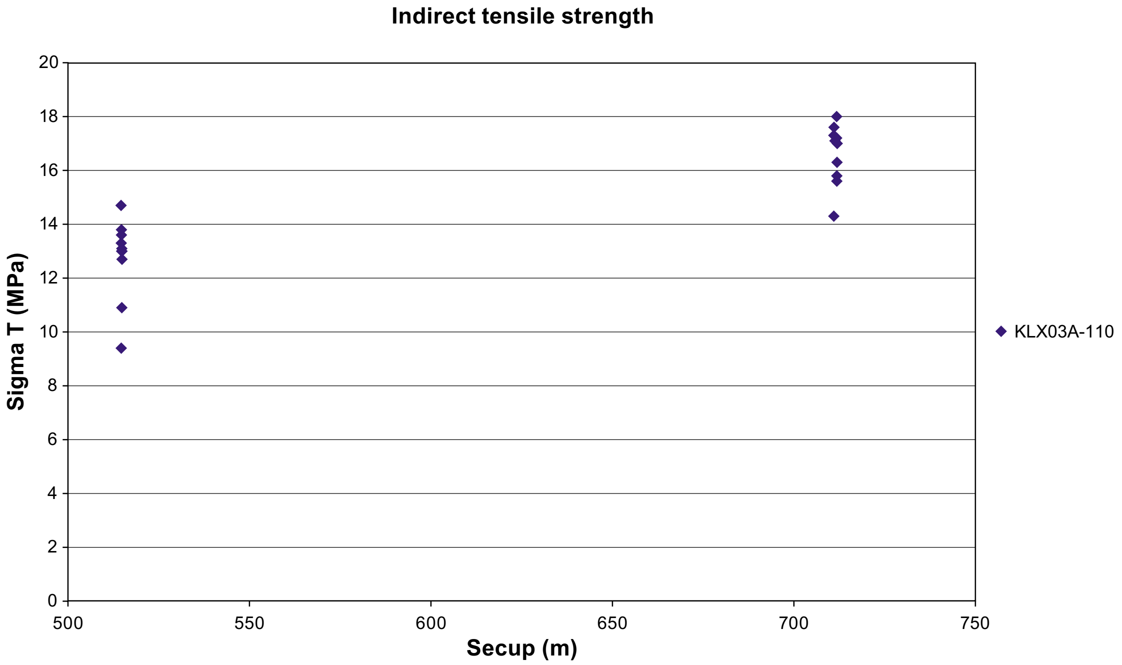


Figure 5-2. *Tensile strength versus sampling depth in the borehole.*

Table 5-1. Summary of results.

Identification	Density (kg/m³)	Tensile strength (MPa)	Comments
KLX03A-110-1	2,780	14.7	
KLX03A-110-2	2,760	9.4	
KLX03A-110-3	2,760	13.3	
KLX03A-110-4	2,760	13.6	
KLX03A-110-5	2,770	13.8	
KLX03A-110-6	2,770	13.0	
KLX03A-110-7	2,760	13.1	
KLX03A-110-8	2,750	10.9	
KLX03A-110-9	2,780	13.0	
KLX03A-110-10	2,770	12.7	
KLX03A-110-13	2,800	14.3	
KLX03A-110-14	2,810	17.3	
KLX03A-110-15	2,810	17.6	
KLX03A-110-16	2,810	17.1	
KLX03A-110-17	2,810	18.0	
KLX03A-110-18	2,810	17.2	
KLX03A-110-19	2,810	15.8	
KLX03A-110-20	2,810	15.6	
KLX03A-110-21	2,810	16.3	
KLX03A-110-22	2,810	17.0	

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 (515–515 m)	2,766	12.8
Mean val (711–712 m)	2,809	16.6
Mean val (All specimens)	2,788	14.7
Std dev (515–515 m)	9.7	1.5
Std dev (711–712 m)	3.2	1.1
Std dev (All specimens)	23.1	2.4

5.3 Discussion

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

Depth level not available, from SKB mapping, for sample KLX03A-110-16.

References

/1/ **ISRM, 1979.** 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.

/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.