P-05-131

Oskarshamn site investigation

Borehole: KLX06A

Determination of P-wave velocity, transverse borehole core

Panayiotis Chryssanthakis, Lloyd Tunbridge
Norwegian Geotechnical Institute, Oslo

September 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-05-131

Oskarshamn site investigation

Borehole: KLX06A

Determination of P-wave velocity, transverse borehole core

Panayiotis Chryssanthakis, Lloyd Tunbridge
Norwegian Geotechnical Institute, Oslo

September 2005

Keywords: Rock mechanics, P wave velocity, Anisotropy.

Summary

The Norwegian Geotechnical Institute has carried out P-wave measurements on drill cores from borehole KLX06A at Laxemar in February 2005. Thirty-three P-wave velocity measurements have been carried out from a total of about 900 m of core.

The results from the P-wave velocity measurements over the whole length of the borehole show maximum principal velocities, V_1, between 5,419–6,100 m/s and a variable anisotropy ratio between 1.01 to 1.15.

The maximum principal velocity, V_1, appears to be constant with depth and lies between 5,618–6,100 m/s, with outlying values of 5,492 m/s at 353.85 m and 5,419 m/s at 628.45 m.

The anisotropy ratio is consistent with depth and lies between 1.01 to 1.05 down to 500 m depth and between 1.01 to 1.09 below that depth, with an outlying high value of 1.15 at 491.60 m.

The foliation is not identifiable over most of the core and the orientation of the principal velocities could not be identified relative to the foliation.

Sammanfattning

Norges Geotekniska Institut (NGI) har i februari 2005 utfört P-vågsmätningar på borrkärnor från borrhål KLX06A i Laxemar. Sammanlagt är det utfört 33 stycken hastighetsbestämningar av P-vågen på kärnprover. Kärnproverna blev utvalda från en borrkärna med en sammanlagd längd av 900 m.

Resultaten längs hela borrkärnelängden uppvisade en maximalhastighet på mellan ca 5 419–6 100 m/s och en varierande anisotropikvot mellan 1,01 och 1,15.

Den maximala hastigheten är relativt konstant, kring 5 618–6 100 m/s med undantag av två lägre hastigheter på 353,85 m och 628,45 m djup där den mätta högsta hastigheten var 5 492 m/s respektive 5 419 m/s.

Anisotropikvot är också relativt konstant, och varierar mellan 1,01–1,05 ned till 500 m djup och mellan 1,01–1,09 under 500 m djup. Det finns dock ett undantag på 491,60 m djup där anisotropikvoten är mätt till 1,15.

Någon tydlig identifierbar foliation längs kärnan har inte kunnat identifieras och därmed har inte hastigheternas orientering till foliation kunnat bestämmas.

Contents

1 Introduction

The Norwegian Geotechnical Institute (NGI) has carried out P-wave velocity measurements on cores from borehole KLX06A at Laxemar in Sweden in accordance with SKB's Activity Plan AP PS 400-05-009 (SKB's internal controlling document).

The work was carried out by Panayiotis Chryssanthakis and Paweł Jankowski during the period 8th–11th February 2005 in accordance with SKB's method description MD 190.002 (SKB internal controlling document).

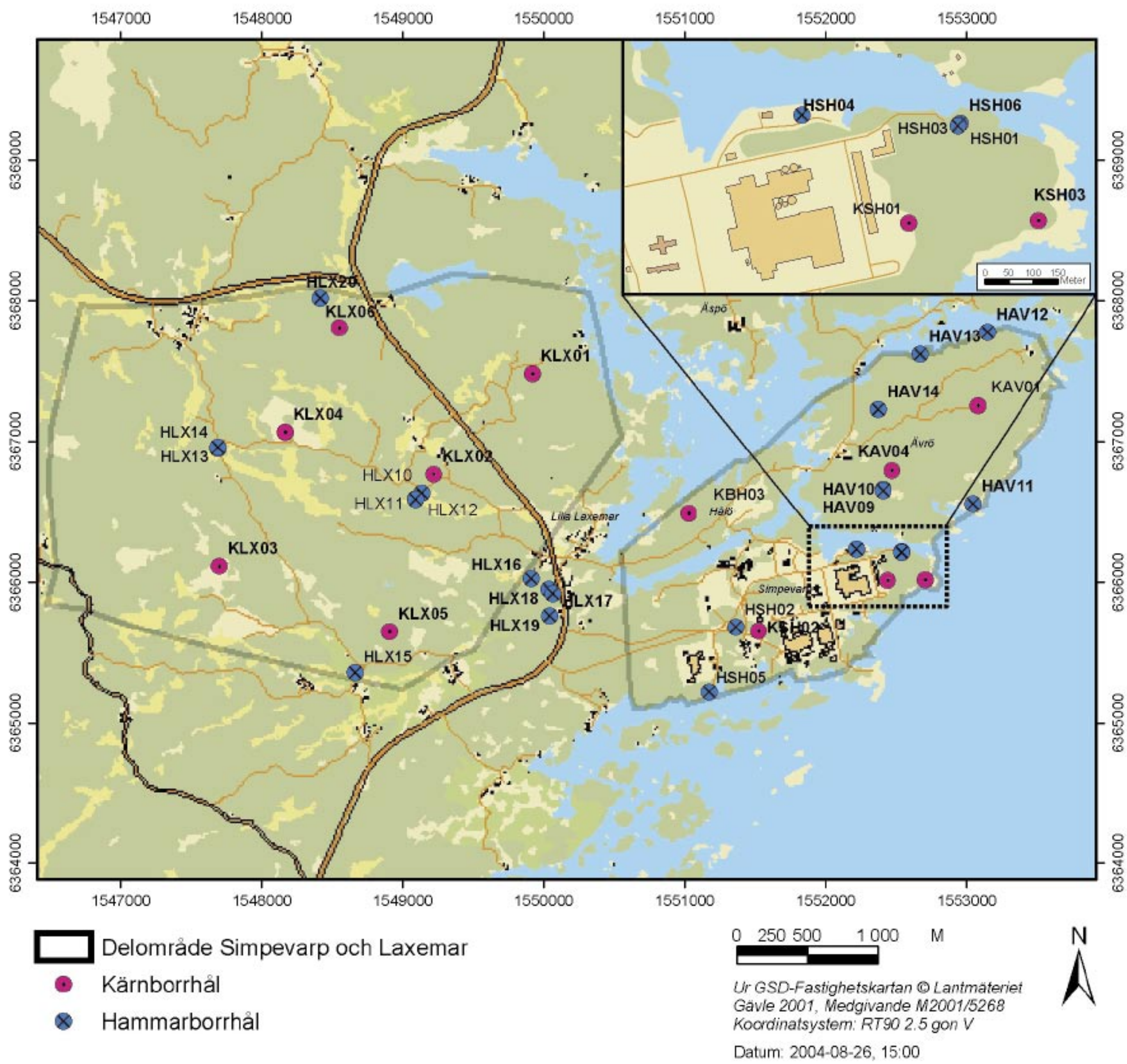


***Figure 1-1.** Location of drill hole KLX06A at the Oskarshamn site investigation area.*

2 Objective and scope

The purpose of the testing is to determine the P wave velocity transverse to the core axis. The P wave velocity is a parameter used in the rock mechanical model which will be established for the candidate area selected for site investigations at Oskarshamn.

The number of core specimens tested and the number of tests performed are given in Table 2-1.

The results from the P-wave velocity measurements are presented in this report by means of tables, figures and spreadsheets.

Table 2-1. Total number of P-wave velocity specimens and measurements.

Borehole	P wave velocity test specimens	P wave velocity measurements
KLX06A	30	33

3 Equipment

The measurements were conducted using Panametrics Videoscan transducers with a natural frequency of 0.5 MHz. These were mounted in a special frame to hold them in contact with the core (see Figure 3-1). Special wave guides, metal shoes with a concave radius similar to the core, were installed between the transducers and the core. The equipment was designed and constructed specially for this contract by NGI, based on the information presented in SKB report entitled "Detection of Anisotropy by Diametral Measurements of Longitudinal Wave Velocities on Rock Cores" /Eitzenberger, 2002/.

A strong sine-wave pulse at the natural frequency of the transducers was used as the acoustic signal source. The arrival of the signals was measured using a PC with a high speed data acquisition board and software to emulate an oscilloscope (see Figures 3-2 and 3-3). The time pick for the first break was taken as the beginning of the first transition, i.e. the point where the received signal first diverges from the zero volts line. In order to provide consistent interpretation of the time pick, one operator (PC) made all the interpretations. The time pick was measured with a precision better than 0.01 µs. The instrumentation was calibrated using a cylinder of aluminium of known acoustic velocity of the same diameter as the core. Several measurements were taken each day on the calibration piece to check operation of the system.

A thin layer of a thick honey was used, as a coupling medium as this proved to be one of the most effective of different media tested and was easily removed by washing without damaging or contaminating the cores.

Figure 3-1. *Detail of NGI's apparatus for measuring acoustic P-wave travel time transverse borehole core. The aluminium cylinder for calibration of the device is on the left.*

__Figure 3-2.__ NGI's equipment set-up for measuring acoustic P-wave travel time transverse borehole core.

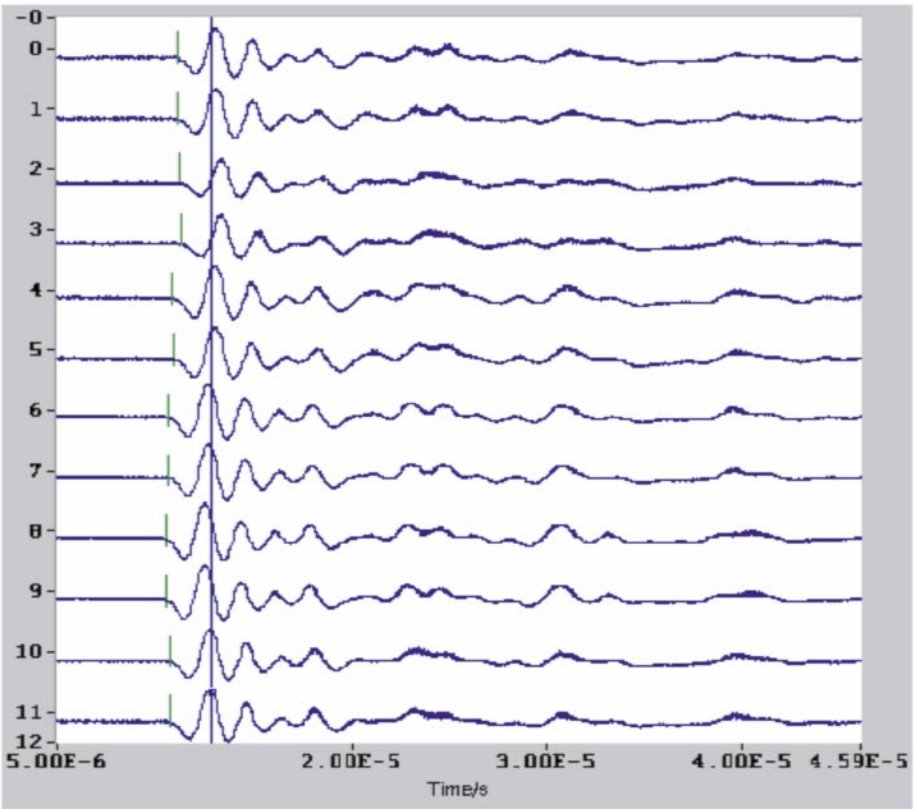


__Figure 3-3.__ Example traces from 12 measurements of P-wave travel time transverse borehole core (two from each orientation). Time picks marked with green lines. Picture captured from NGI's oscilloscope emulation software.

4 Execution

4.1 Sampling

Thirty core specimens of length ca 200–500 mm and diameter about 50 mm were selected from borehole KLX06A while the complete length of the borehole (depth 100.3–999.4 m) was displayed on the racks in the core shed at the Simpevarp peninsula. The specimens were selected together by NGI, Thomas Janson and Björn Ljunggren representing SKB.

These specimens represent mainly the Ävrö granite and in some areas fine grained granite, with some veins of pegmatite and fine grained granodiorite/gabbro found over most of the length of the borehole. Geological logging of core has been carried out by SKB. No detailed geological description has been attempted by NGI.

The depths used to describe the location are those marked on the core and core boxes at the time. Detailed description of the specimens is available from the detailed core log by SKB. At the time of sampling, the core had been exposed to the atmosphere at room temperature for an extended period and may be presumed to be air-dried, though no measurements of the moisture content were made.

4.2 Test method

Tests were made at 30° intervals around the core, starting at 0° parallel with the foliation. However, where the foliation was not identifiable the first test was made at a random orientation. The cores were all oriented such that successive measurements were made clockwise looking down the borehole (see Figure 4-1). The cores were marked by attaching a piece of self-adhesive tape that had been previously cut to the appropriate lengths and marked up with the locations for the tests. These marks were then transferred to the core with a permanent marker. The cores may thus be checked at any time to ascertain the location and orientation of the tests.

Each test sample comprised a minimum of two consecutive determinations of acoustic pulse travel time at each of six locations around the core (at 0°, 30°, 60°, 90°, 120° and 150°) at one cross section. The seating of the transducers and application of the coupling medium was adjusted in cases where there was a significant difference between the time picks, and additional measurements were made until two similar time picks were obtained. The average of the two measured time picks was recorded.

As the travel time includes a number of other factors, such as travel through the wave guides, time pick method, and delay due to the oscilloscope triggering on the rising part of the sine-wave, the determination of the true travel time was calibrated using an aluminium cylinder with known P-wave velocity. The correction factor determined in the calibration tests was subtracted from all the measurements on the rock cores.

The diameter of the core was measured using a calliper with an accuracy of 0.01 mm and the P-wave velocity determined by dividing the diameter (in mm) by the travel time (in µs) and multiplying by 1,000 to obtain the velocity in m/s.

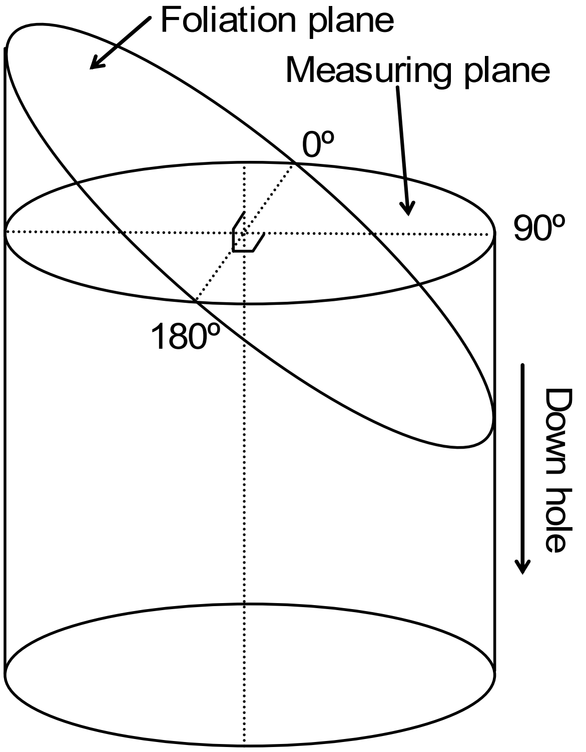


Figure 4-1. *Orientation of measurements.*

Analysis

Since the acoustic velocity is dependent on the elastic properties of the material, the results were analysed similarly to determining the stress or strain tensor in the material. In this case the velocity in the orientation θ is given by:

$$V_\theta = V_x\cos^2\theta + V_y\sin^2\theta + 2\cdot V_{xy}\sin\theta\cos\theta \qquad (1)$$

A simple regression analysis of the six measurements was used to determine the values of V_x, V_y, and V_{xy} (where the X-axis is parallel with the foliation where identifiable).

These values were used to model the complete velocity profile around the core.

The magnitude and orientation of the principal velocities, V_1, V_3, θ_{V1} and θ_{V3}. were determined from the Eigen values and vectors of the 2D tensor matrix:

$$\begin{vmatrix} V_x & V_{xy} \\ V_{xy} & V_y \end{vmatrix} \qquad (2)$$

The results are reported as the maximum principal velocity, V_1, the minimum principal velocity, V_3, the anisotropy ratio, V_1/V_3, and the orientations of the principal velocities with respect to the foliation direction in the plane perpendicular to the core sample, θ_{V1} and θ_{V3}.

4.3 Nonconformities

Tests were made at 30° intervals around the core instead of the 45° intervals suggested in the Method Description. This was the only nonconformity to the controlling documents.

5 Results

5.1 Summary of results

The results of the determinations of the travel time and velocity for all the tests are presented in Table 5-1, and the velocity and anisotropy are shown diagrammatically versus borehole length in Figures 5-1 and 5-2.

The results of calculated principal velocities and the anisotropy ratio are presented in Table 5-2, and shown diagrammatically versus borehole length in Figures 5-3 to 5-4. The foliation was not identifiable over most of the core and therefore the orientation of the maximum velocity could not be determined.

The results of calibration determinations for the system are shown in Appendix A. The results are also reported to SICADA.

5.2 Discussion

Accuracy and Repeatability

Calibration tests on an aluminium cylinder indicated a variation of ± 0.020 μs in determination of the time pick, equivalent to differences in velocity of about ± 10 m/s. Some of this variation may be explained by temperature variations, thickness of coupling medium and seating of the shoes. Similar variations may be expected from the measurements on the cores.

Tests on cores were repeated at three locations, 260.30 m, 491.60 m and 831.12 m, after the first series of tests were completed. These tests were repeated to investigate and determine typical values for repeatability of velocity determinations.

The repeatability of the diameter measurements was about ± 0.02 mm which gives an error of about ± 2 m/s.

At 260.30 m the maximum difference in magnitude of the velocities is 115 m/s, the difference in anisotropy ratio was 0.02 and there is about 5° difference in orientation. At 491.60 m the maximum difference in magnitude of the velocities is 159 m/s, the anisotropy ratios are the same and there is about 5° difference in orientation. At 831.12 m the maximum difference in magnitude of the velocities is 72 m/s, the difference in anisotropy ratio was 0.01 and there is about 5° difference in orientation.

The differences in the measured velocities on the calibration cylinder and rock cores are presumably due to temperature changes, the problems in seating the transducers and obtaining good signal contact with the material and due to the interpretation of the time pick.

Generally there is a good fit between the measurements and the best fit line (model fit) which suggests that random type errors are relatively small. At 260.30 m the maximum difference was 79 m/s, at 491.60 m the maximum difference was 118 m/s, and at 831.12 m the maximum difference was 120 m/s, see Figure 5-5.

Typically in the entire series of tests, the average deviation between the measured value and the model fit is about 0.7% (about 40 m/s), with a maximum error of 4.4% (250 m/s).

The deviation between the model fitted to the data and the measured data reported here is in agreement with the previous work /Chryssanthakis and Tunbridge, 2003a,b,c,d,e,f,g, 2004a,b,c/. The results are also very consistent. It is therefore concluded that the measurement errors are similar to those determined previously.

It is therefore concluded that:

- the repeatability of the reported results for velocities is generally better than ± 100 m/s,
- the error in the orientation of the principal velocities is generally better than ± 10° where the anisotropy ratio is greater than 1.10 with greater errors below this limit (with an anisotropy ratio of less than about 1.03 the determination of the orientation is poorly constrained and has little significance in practice),
- errors in determining the anisotropy ratio and orientation are partly mitigated by the redundant data and regression analysis and it is considered that the error in the anisotropy ratio is generally better than ± 0.02.

Conclusions

The results from the P-wave velocity measurements over the whole length of the borehole show maximum principal velocities, V_1, between 5,419-6,100 m/s and a variable anisotropy ratio between 1.01 to 1.15.

The maximum principal velocity, V_1, appears to be constant with depth and lies between 5,618-6,100 m/s, with outlying values of 5,492 m/s at 353.85 m and 5,419 m/s at 628.45 m.

The anisotropy ratio is consistent with depth and lies between 1.01 to 1.05 down to 500 m depth and between 1.01 to 1.09 below that depth, with an outlying high value of 1.15 at 491.60 m.

The foliation is not identifiable over most of the core and the orientation of the principal velocities could not be identified relative to the foliation.

Table 5-1. Measurements of acoustic velocity, transverse core in borehole KLX06A. (Orientation clockwise looking down hole, 0° is parallel with foliation).

Depth m	Dia-meter mm	Corrected time, mS						Velocity m/S						Aniso-tropy ratio
		Parallel foliation			Perpendicular foliation			Parallel foliation			Perpendicular foliation			
		0°	30°	60°	90°	120°	150°	0°	30°	60°	90°	120°	150°	
199.90	47.48	8.27	8.14	8.22	8.46	8.36	8.30	5,741	5,832	5,776	5,612	5,679	5,720	1.04
220.40	50.49	9.22	9.01	8.84	9.08	9.34	9.22	5,476	5,603	5,711	5,560	5,405	5,476	1.06
242.10	50.51	8.74	8.66	8.64	8.88	8.64	8.74	5,779	5,832	5,846	5,688	5,846	5,779	1.03
260.30	50.09	9.04	9.09	8.98	8.60	8.80	9.07	5,540	5,510	5,577	5,824	5,692	5,522	1.06
280.40	50.20	9.09	9.13	9.11	9.01	8.88	9.04	5,522	5,498	5,510	5,571	5,653	5,553	1.03
299.80	49.97	8.68	8.67	8.71	8.58	8.60	8.53	5,756	5,763	5,737	5,823	5,810	5,858	1.02
322.20	50.20	8.82	8.80	8.74	8.83	9.03	8.83	5,691	5,704	5,743	5,685	5,559	5,685	1.03
340.10	50.10	8.81	8.84	8.81	8.78	8.72	8.68	5,686	5,667	5,686	5,706	5,745	5,771	1.02
353.85	50.15	9.38	9.15	9.09	9.38	9.48	9.38	5,346	5,480	5,517	5,346	5,290	5,346	1.04
379.15	50.17	8.28	8.37	8.59	8.65	8.63	8.46	6,059	5,993	5,840	5,799	5,813	5,930	1.04
398.25	50.17	8.83	8.92	8.63	8.75	8.76	8.57	5,681	5,624	5,813	5,733	5,727	5,854	1.04
426.00	50.09	8.60	8.58	8.69	8.69	8.78	8.67	5,824	5,837	5,764	5,764	5,704	5,777	1.02
451.00	50.16	8.66	8.56	8.69	8.90	8.71	8.65	5,792	5,859	5,772	5,635	5,758	5,798	1.04
472.75	50.22	8.78	8.67	8.61	8.82	8.81	8.08	5,719	5,792	5,832	5,693	5,700	6,215	1.09
491.60	50.12	9.29	9.50	9.74	9.11	8.41	8.70	5,395	5,275	5,145	5,501	5,959	5,760	1.16
520.00	50.13	8.59	8.65	9.32	9.21	9.00	8.74	5,835	5,795	5,378	5,443	5,570	5,735	1.08
544.70	50.12	8.66	8.38	8.89	9.04	8.96	8.86	5,787	5,980	5,637	5,544	5,593	5,656	1.08
565.80	50.15	8.53	8.95	9.03	9.07	8.71	8.65	5,879	5,603	5,553	5,529	5,757	5,797	1.06
472.75	50.22	8.78	8.67	8.61	8.82	8.81	8.08	5,719	5,792	5,832	5,693	5,700	6,215	1.09
491.60	50.12	9.29	9.50	9.74	9.11	8.41	8.70	5,395	5,275	5,145	5,501	5,959	5,760	1.16
520.00	50.13	8.59	8.65	9.32	9.21	9.00	8.74	5,835	5,795	5,378	5,443	5,570	5,735	1.08
544.70	50.12	8.66	8.38	8.89	9.04	8.96	8.86	5,787	5,980	5,637	5,544	5,593	5,656	1.08
565.80	50.15	8.53	8.95	9.03	9.07	8.71	8.65	5,879	5,603	5,553	5,529	5,757	5,797	1.06
585.75	50.15	8.53	8.95	9.03	9.07	8.71	8.65	5,879	5,603	5,553	5,529	5,757	5,797	1.06
607.55	50.15	8.31	8.44	8.48	8.31	8.40	8.34	6,034	5,941	5,913	6,034	5,970	6,013	1.02
628.45	50.09	9.49	9.31	9.28	9.28	9.70	9.53	5,278	5,380	5,397	5,397	5,163	5,256	1.05
661.60	50.13	8.37	8.40	8.48	8.18	8.29	8.24	5,989	5,967	5,911	6,128	6,046	6,083	1.04
684.67	50.15	8.53	8.55	8.70	8.64	8.68	8.67	5,879	5,865	5,764	5,804	5,777	5,784	1.02
706.24	50.18	8.63	8.74	8.48	8.40	8.53	8.71	5,814	5,741	5,917	5,973	5,882	5,761	1.04
729.25	50.01	8.98	9.33	9.54	9.30	9.21	8.82	5,569	5,360	5,242	5,377	5,429	5,670	1.08
748.70	50.02	8.63	8.50	8.29	8.29	8.41	8.63	5,796	5,884	6,033	6,033	5,947	5,796	1.04
771.70	50.10	8.64	8.69	8.75	8.70	8.58	8.72	5,798	5,765	5,725	5,758	5,839	5,745	1.02
794.10	50.11	8.47	8.40	8.47	8.37	8.25	8.46	5,916	5,965	5,916	5,986	6,073	5,923	1.03
813.45	50.13	8.76	8.65	8.51	8.89	8.44	8.49	5,722	5,795	5,890	5,638	5,939	5,904	1.05
831.12	50.13	8.78	9.11	9.05	8.89	8.85	8.40	5,709	5,502	5,539	5,638	5,664	5,967	1.08
260.30	50.12	8.97	8.91	8.84	8.66	8.79	8.92	5,587	5,625	5,669	5,787	5,701	5,618	1.04
491.60	50.10	9.02	9.63	9.82	9.00	8.61	8.67	5,554	5,202	5,101	5,566	5,818	5,778	1.14
831.12	50.11	8.72	9.05	8.93	8.78	8.74	8.44	5,746	5,537	5,611	5,707	5,733	5,937	1.07

Table 5-2. Determinations of principal velocity and orientation, transverse core in borehole KLX06A. (Orientation clockwise looking down hole, 0° is parallel with foliation where identified).

Depth m	Maximum velocity m/s	Orientation	Minimum velocity m/s	Orientation	Anisotropy ratio	Foliation	
199.90	5,811	25°	5,642	115°	1.03	n	f= foliation (clearly identifiable)
220.40	5,668	55°	5,409	145°	1.05	n	n=no identifiable foliation
242.10	5,818	20°	5,772	110°	1.01	n	w=weak f oliation (not good)
260.30	5,750	100°	5,472	10°	1.05	n	s=strong foliation (good)
280.40	5,618	120°	5,484	30°	1.02	n	x=disturbed sample
299.80	5,841	130°	5,742	40°	1.02	n	
322.20	5,739	35°	5,617	125°	1.02	n	
340.10	5,758	130°	5,663	40°	1.02	n	
353.85	5,492	45°	5,283	135°	1.04	n	
379.15	6,040	5°	5,772	95°	1.05	f	
398.25	5,788	120°	5,689	30°	1.02	n	
426.00	5,835	20°	5,722	110°	1.02	n	
451.00	5,845	10°	5,693	100°	1.03	n	
472.75	5,947	160°	5,704	70°	1.04	n	
491.60	5,884	130°	5,128	40°	1.15	n	
520.00	5,857	175°	5,395	85°	1.09	n	
544.70	5,882	20°	5,517	110°	1.07	n	
565.80	5,861	160°	5,512	70°	1.06	x	
585.75	5,861	160°	5,512	70°	1.06	x	
607.55	6,023	145°	5,946	55°	1.01	n	
628.45	5,419	50°	5,205	140°	1.04	n	
661.60	6,100	125°	5,942	35°	1.03	n	
684.67	5,859	10°	5,765	100°	1.02	n	
706.24	5,951	90°	5,745	0°	1.04	n	
729.25	5,630	155°	5,252	65°	1.07	n	
748.70	6,054	80°	5,776	170°	1.05	n	
771.70	5,799	140°	5,744	50°	1.01	n	
794.10	6,015	110°	5,911	20°	1.02	n	
813.45	5,861	140°	5,769	50°	1.02	n	
831.12	5,853	145°	5,486	55°	1.07	n	
260.30	5,753	90°	5,576	0°	1.03	n	Repeat
491.60	5,877	135°	5,130	45°	1.15	n	Repeat
831.12	5,866	140°	5,557	50°	1.06	n	Repeat

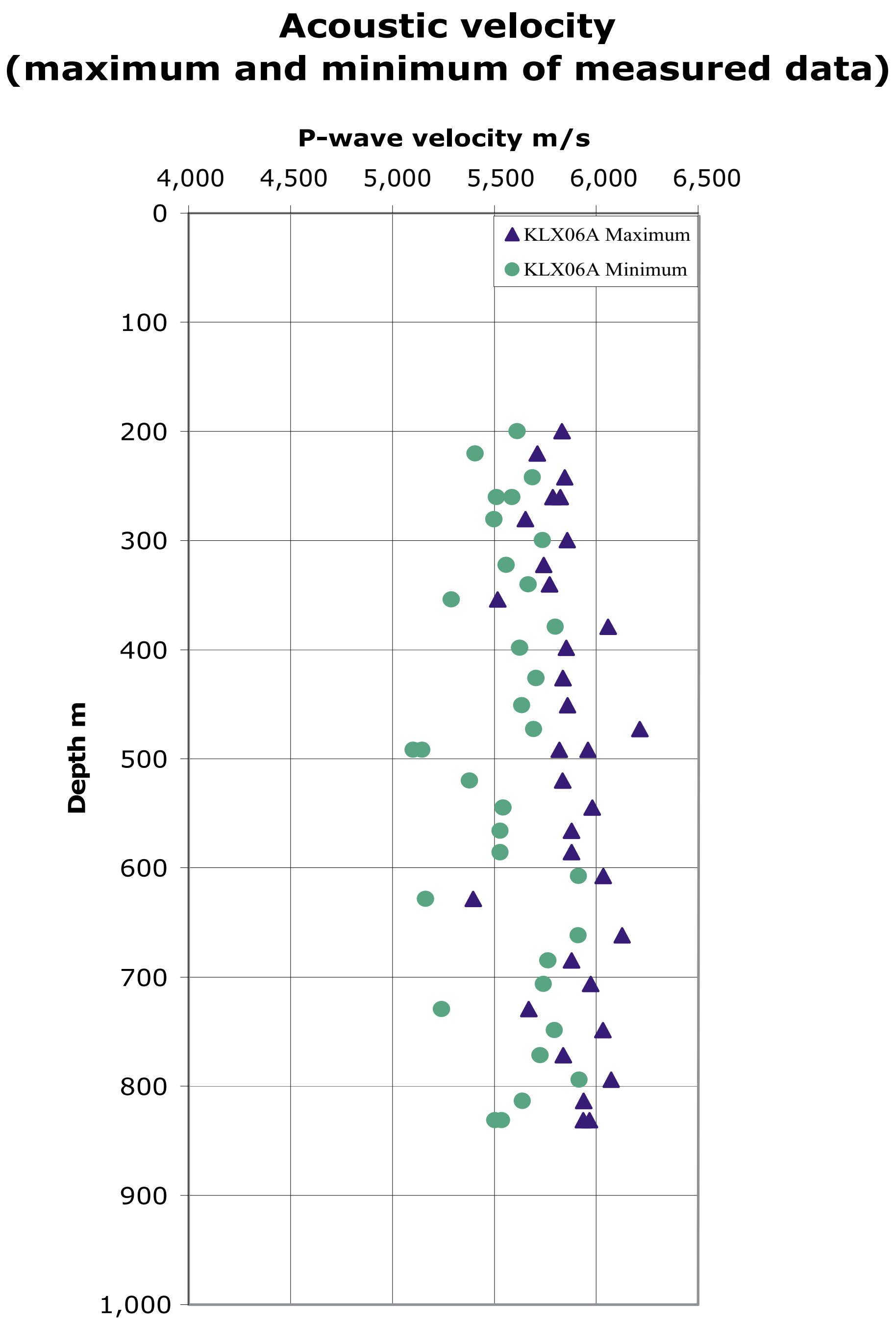


Figure 5-1. *Measured values of maximum and minimum acoustic velocities plotted versus borehole length in KLX06A.*

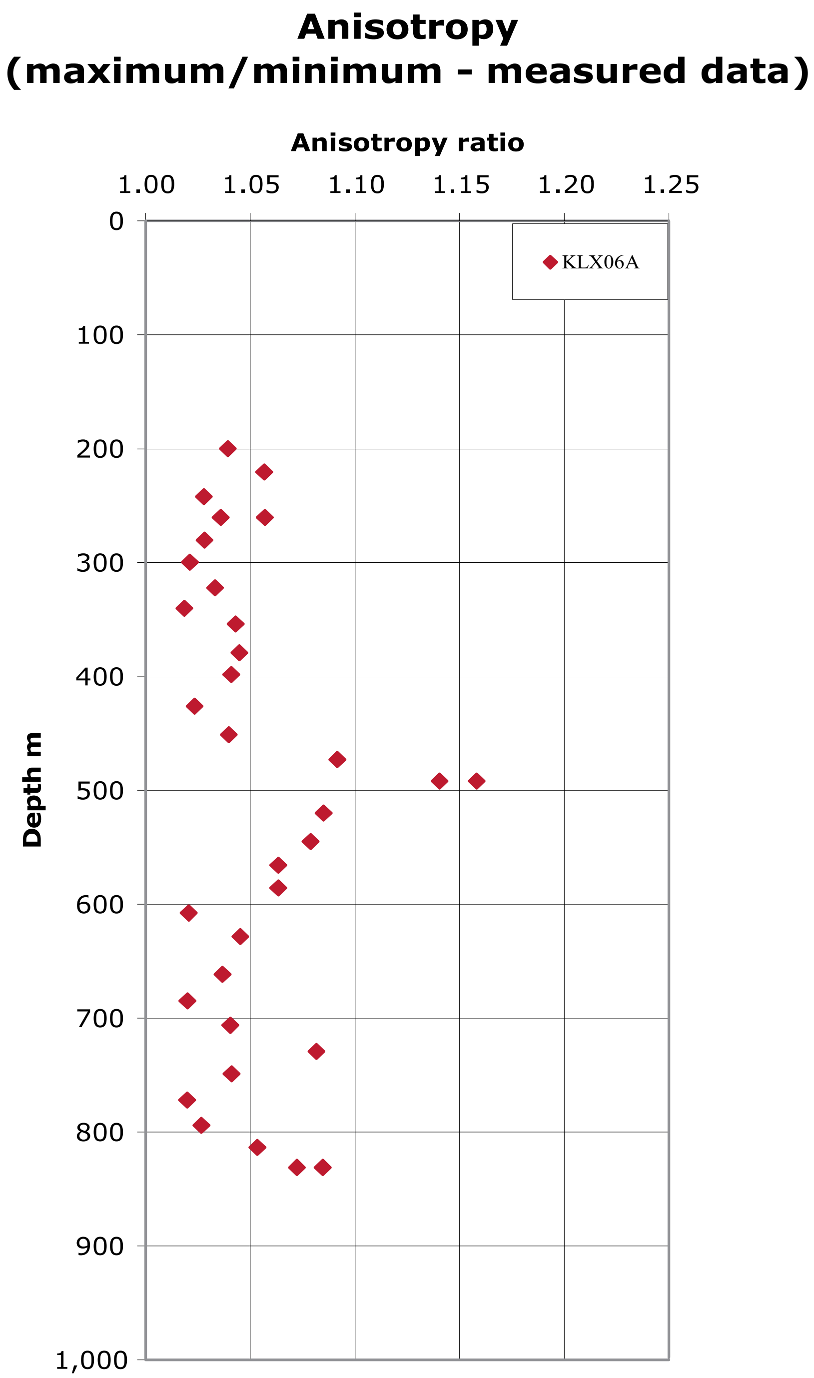


Figure 5-2. *Measured values of acoustic velocities anisotropy plotted versus borehole length in KLX06A.*

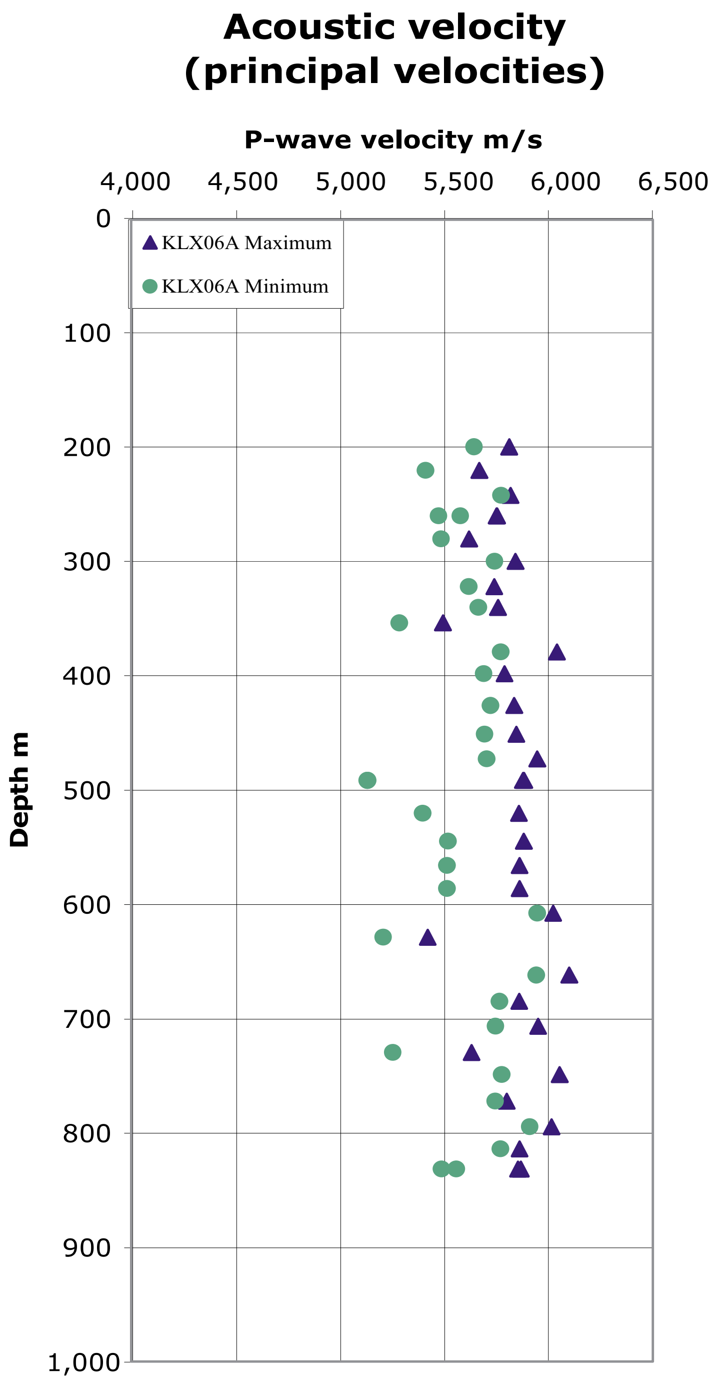


Figure 5-3. Calculated values of maximum and minimum principal acoustic velocities plotted versus borehole length in KLX06A.

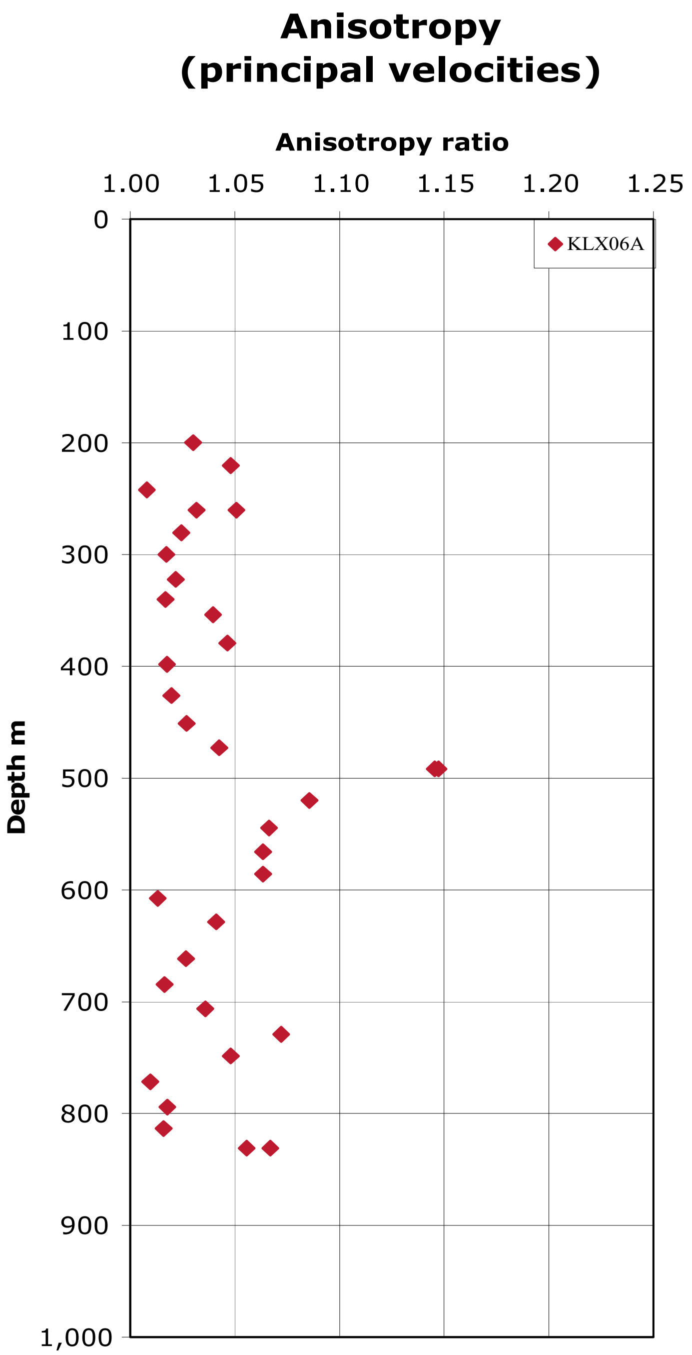
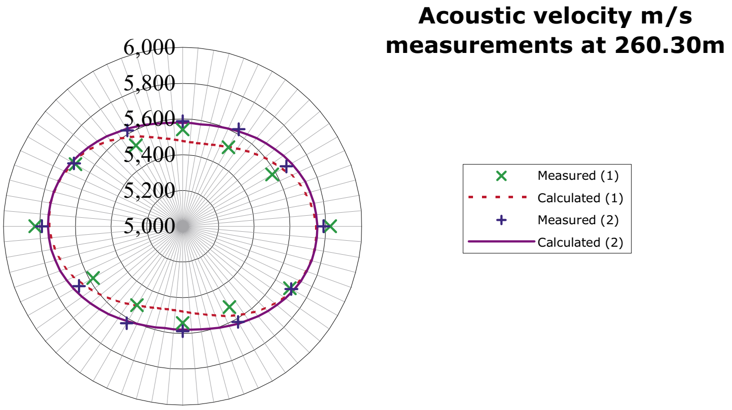
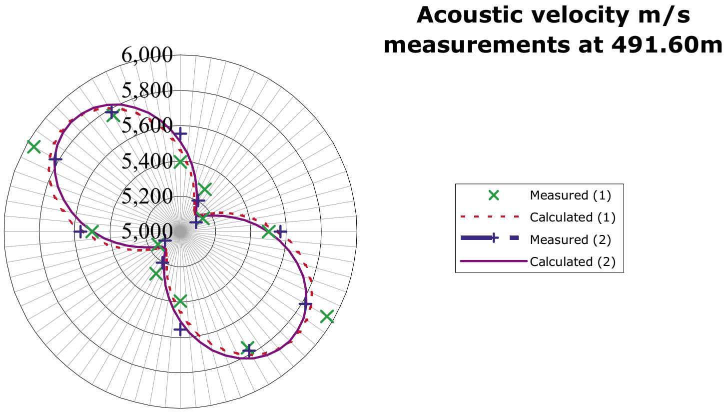


Figure 5-4. *Calculated values of maximum and minimum principal acoustic velocity anisotropy plotted versus borehole length in borehole KLX06A.*





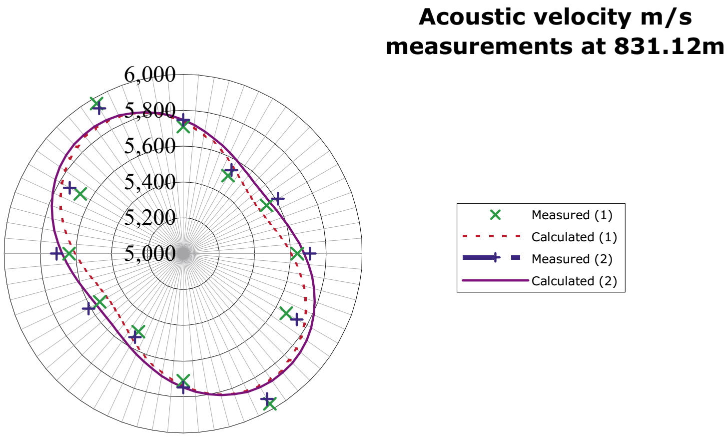


Figure 5-5. *Comparison of measured and calculated values (model fit) of acoustic velocity for each of two determinations at three different depths in borehole KLX06A.*

References

Chryssanthakis P, Tunbridge L, 2003a. Forsmark Site investigation, Borehole: KFM01A. Determination of P-wave velocity, transverse borehole core. SKB P-03-38. Svensk Kärnbränslehantering AB.

Chryssanthakis P, Tunbridge L, 2003b. Oskarshamn Site investigation. Borehole: KSH01A. Determination of P-wave velocity, transverse borehole core. SKB P-03-106. Svensk Kärnbränslehantering AB.

Chryssanthakis P, Tunbridge L, 2003c. Forsmark Site investigation. Borehole: KFM02A. Determination of P-wave velocity, transverse borehole core. SKB P-04-09. Svensk Kärnbränslehantering AB.

Chryssanthakis P, Tunbridge L, 2003d. Oskarshamn Site investigation, Borehole: KSH02A. Determination of P-wave velocity, transverse borehole core. SKB P-04-11. Svensk Kärnbränslehantering AB.

Chryssanthakis P, Tunbridge L, 2003e. Oskarshamn Site investigation. Borehole: KAV01. Determination of P-wave velocity, transverse borehole core. SKB P-04-43. Svensk Kärnbränslehantering AB.

Chryssanthakis P, Tunbridge L, 2003f. Oskarshamn Site investigation. Borehole: KLX02. Determination of P-wave velocity, transverse borehole core. SKB P-04-45. Svensk Kärnbränslehantering AB.

Chryssanthakis P, Tunbridge L, 2003g. Forsmark Site investigation, Borehole: KFM03A. Determination of P-wave velocity, transverse borehole core. SKB P-04-180. Svensk Kärnbränslehantering AB.

Chryssanthakis P, Tunbridge L, 2004a. Forsmark Site investigation, Borehole: KFM04A. Determination of P-wave velocity, transverse borehole core. SKB P-04-181. Svensk Kärnbränslehantering AB.

Chryssanthakis P, Tunbridge L, 2004b. Forsmark Site investigation, Borehole: KFM05A. Determination of P-wave velocity, transverse borehole core. SKB P-04-203. Svensk Kärnbränslehantering AB.

Chryssanthakis P, Tunbridge L, 2004c. Oskarshamn Site investigation. Borehole: KAV04A. Determination of P-wave velocity, transverse borehole core. SKB P-04-206. Svensk Kärnbränslehantering AB.

Eitzenberger A, 2002. Detection of Anisotropy by Diametral Measurements of Longitudinal Wave Velocities on Rock Cores. SKB IPR-03-17. Svensk Kärnbränslehantering AB.

Appendix A

Calibration measurements on aluminium cylinder diameter 50.90 mm with known velocity 6,320 m/s (this page).

Date and time	Known velocity m/S	Diameter mm	Time Measured µS	Calculated µS	Correction µS
20050209 – 0930 hrs	6,320	50.90	9.18	8.05	1.12
20050209 – 1330 hrs	6,320	50.90	9.20	8.05	1.15
20050209 – 1700 hrs	6,320	50.90	9.18	8.05	1.12
20050210 – 0900 hrs	6,320	50.90	9.19	8.05	1.13
20050210 – 1200 hrs	6,320	50.90	9.18	8.05	1.13
Average			9.183		1.129