

## **Oskarshamn site investigation**

### **Borehole: KSH01A**

### **Results of tilt testing**

Panayiotis Chryssanthakis  
Norwegian Geotechnical Institute

November 2003

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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.

A pdf version of this document can be downloaded from [www.skb.se](http://www.skb.se)

## Summary

Norwegian Geotechnical Institute (NGI) has carried out tilt testing on joint surfaces of drill cores from the borehole KSH01A. From a total 903 m of cores, 51 tilt tests have been carried out on three sets of joints.

The main results from the tilt tests are rather uniform throughout the joint surfaces and they do not show strong variations. The mean value of the joint roughness coefficient ( $JRC_o$ ) obtained from tilt testing of all the joint samples is 6.3. The mean value of the joint wall compressive strength ( $JCS_o$ ) from Schmidt hammer testing of all the joint samples is 84.7 MPa. The mean values of the basic ( $\Phi_b$ ) and residual ( $\Phi_r$ ) friction angles of all the tested samples are 31.3 and 26.8 degrees respectively.

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# 1 Introduction

Norwegian Geotechnical Institute (NGI) has carried out tilt testing on joint surfaces of drill cores from borehole KSH01A at Simpevarp in Sweden according to SKB Aktivitetsplan AP 400-03-23 (SKB internal controlling document). The work has been carried out by Panayiotis Chryssanthakis and Pawel Jankowski during the period 5–15 May 2003 in accordance with SKB's method description MD 190.006 ver 1.0 (SKB internal controlling document). The following tests have been carried out:

**Table 1-1. Total number of tilt tests.**

<b>Borehole</b>	<b>Tilt tests</b>	<b>No of joint sets</b>
KSH01A	51	3

The results from the tilt tests are presented in this report by means of tables, figures and spreadsheets. The results are also reported to SICADA (FN 175).

## 2 General information about tilt testing

### 2.1 The samples

The samples were taken from drill cores with a diameter of 50 mm in that way that each sample contained both faces of a joint, see Figure 2-1. To prepare the sample, sawing is usually necessary.



*Figure 2-1. Sample for tilt testing in the tilt apparatus.*

The frequency of the tilt test samples was determined by choosing one specimen for approximately 18 to 20 meters. A total of 51 tilt samples were chosen in co-operation with SKB. The depths quoted in the tables, can be directly correlated with the SKB database SICADA. During the tilt tests, the real orientation of fractures was not known, and therefore the various joints, fractures were classified according to their angle of intersection with the core in the following way:

Joint set number	Angle of intersection in degrees	Number of tilt tests
Set 1 (steep joints)	0–30°	18
Set 2 (ca 45 degrees joints)	30–60°	17
Set 3 (sub-horizontal joints)	60–90°	16

Because of the small core diameter, it was rather difficult to find good samples for tilt testing. This is specifically valid for joint set 1.

Three profiles on each tilt joint surface have been also carried out. The rocks can be classified as mainly monsoiorite, vulcanite, granodiorite, granite with same veins of amphibolite, pegmatite, but since geological logging of the core has been carried out by SKB, no detailed geological description has been attempted by NGI. Most common minerals on the joint surfaces are chlorite, calcite, pyrite, epidotite and laumontitt. All 51 tilt joint surfaces can be directly identified within the database Sicada at 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.

## 2.2 Equipment

The tilt angles ( $\alpha$  and  $\Phi_b$ ) are measured by a simple tilt apparatus, see Figure 2-2.

For measurements of JCS,  $r$  and  $R$  a Schmidt hammer with a clamp to fasten the samples is used see Figure 2-3.

The profiling is carried out by means of a profilometer, see Figure 2-4. In addition a planimeter is necessary to measure the area of the fracture face.



*Figure 2-2. Tilt apparatus.*



*Figure 2-3. Clamp for Schmidt hammer tests.*



*Figure 2-4. Profilometer.*



## 2.3 Testing

The tilt test consists of the tilting, Schmidt hammer measurements and profiling of the joint faces.

The measuring of the tilt angle  $\alpha$  is performed on wet (humid) joint surfaces. The sample is then fixed to the tilt apparatus and tilted. At least three tilts are carried out on each sample, the tilt angle should not vary more than  $3^\circ$  in these tests. However, in some cases the characteristics of the sample changes during the testing, for example fracture coating may be removed, and therefore variation of more than  $3^\circ$  may (in some cases) be accepted.

The same procedure is used for determining  $\Phi_b$  which is the tilt angle core to core, but here the cores shall be dry.

The Schmidt hammer measurements for JCS were performed on wet (humid) joint surfaces (r value) with 10 blows on each test. The lower five blow values were then eliminated.

For measuring of R-value Schmidt hammer readings on fresh, dry cores near the joint for tilting were performed on dry cores with 10 blows. The lower five blow values were again eliminated.

The weight of the tilting block and the rock density are measured, and the fracture surface area is measured with a planimeter.

Profiling of the tilt tested fractures is carried out by means of a profilometer, and the profiles are drawn on a paper by pulling a pencil along the edge of the profilometer. For each fracture three parallel profiles are drawn; one along the centre of the sample and, one to the left and one to the right of the centre line. From the profile the roughness amplitude (a) and the profile length (L) are measured.

A few density measurements of the rock were carried out during tilt testing, and the results were in the range  $2.80\text{--}2.90\text{ g/cm}^3$ . In the calculations  $2.80\text{ g/cm}^3$  has been used up to 500 m depth,  $2.87\text{ g/cm}^3$  from 500 m to 870 m while  $2.90\text{ g/cm}^3$  from 870 m to 1003 m.

## 3 Results from the tilt testing

### 3.1 General

The results from the different measurements are put into an Excel spreadsheet (Input data). Excel then calculates the different parameters which are shown in another sheet (Output data).

Tables showing all the input and output data are shown in Appendix A. Separate tables are presented for each of the three joint sets. A table showing all the joint sets is also presented in the Appendix A.

Complete input and output data from the tilt tests such as JRC, JCS, Schmidt hammer readings, and roughness amplitudes are shown in the tables in Appendix A.

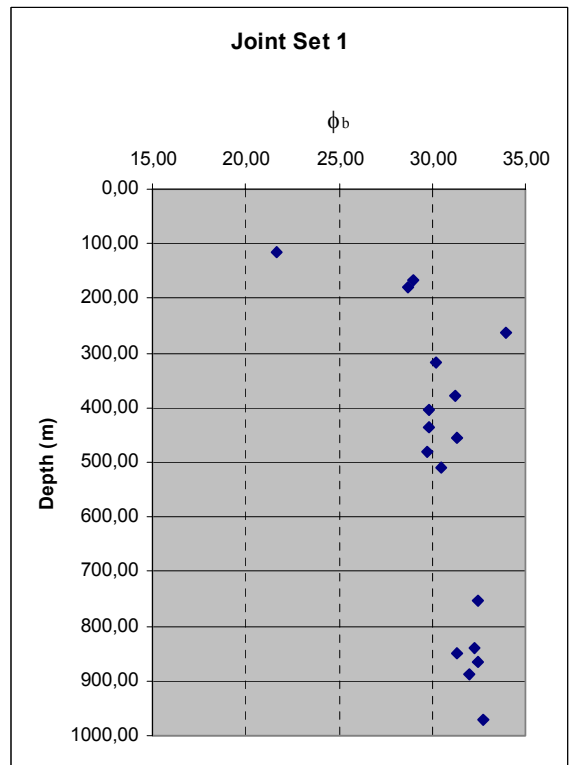
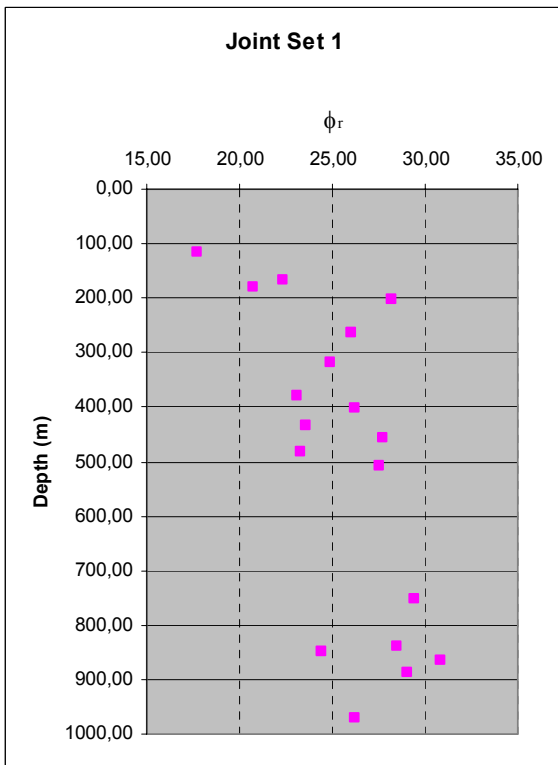
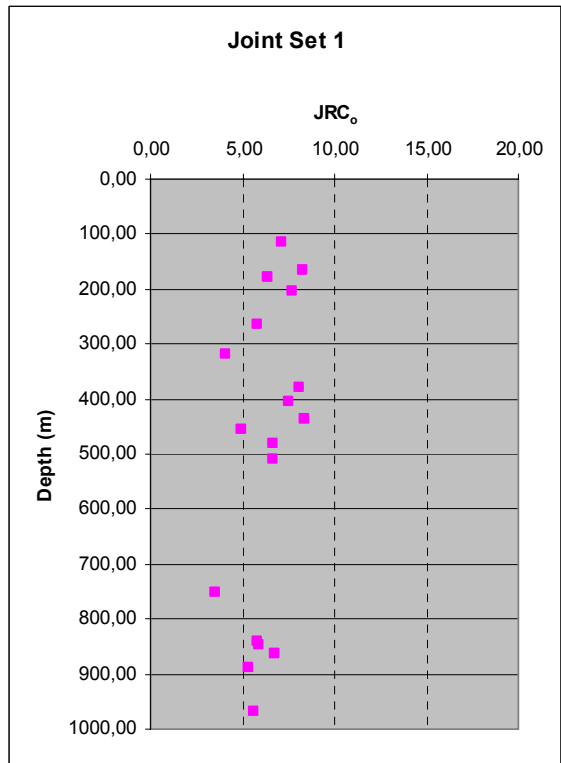
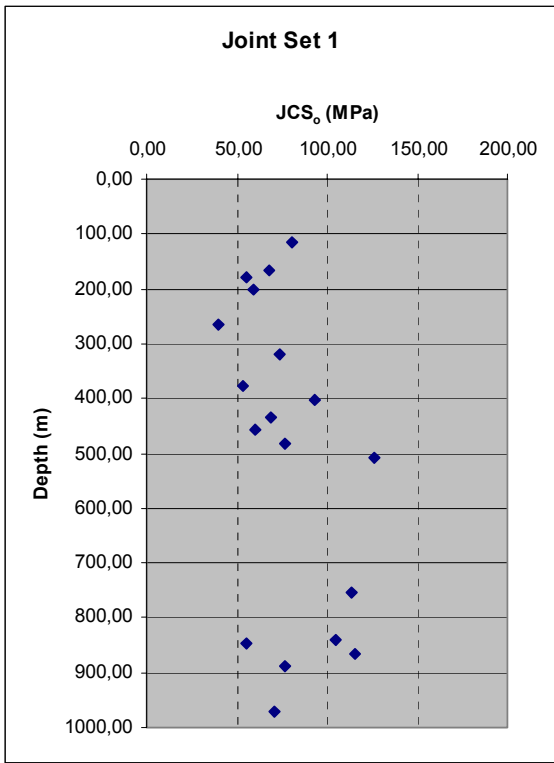
The 51 tilt test specimens have been chosen from the 908 m of core material of borehole KSH01A. As mentioned earlier, the fractures have been classified in three sets according to the angle of intersection with the core. Each set may, however, consist of fractures with different dip directions.

### 3.2 Results from borehole KSH01A

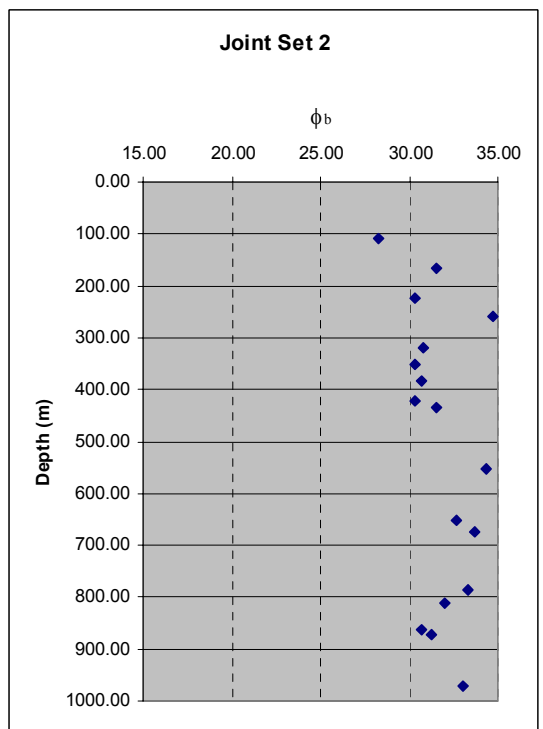
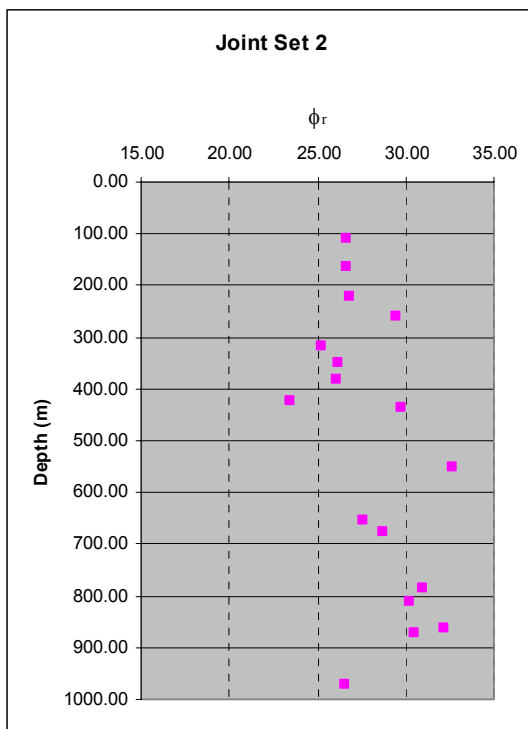
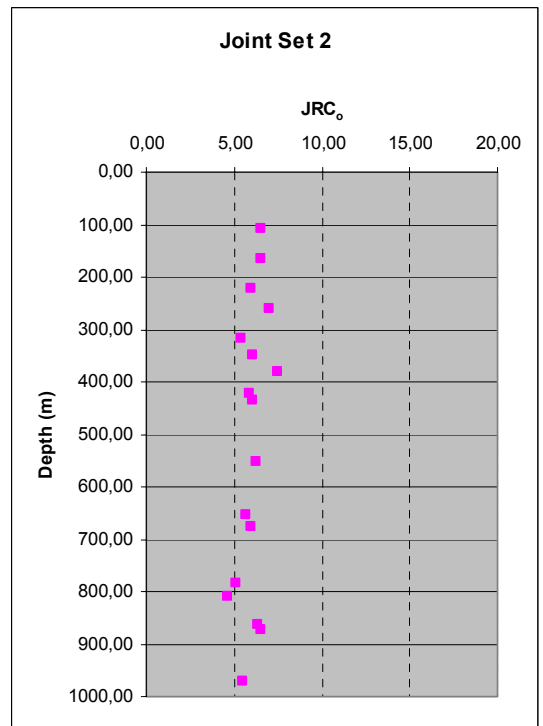
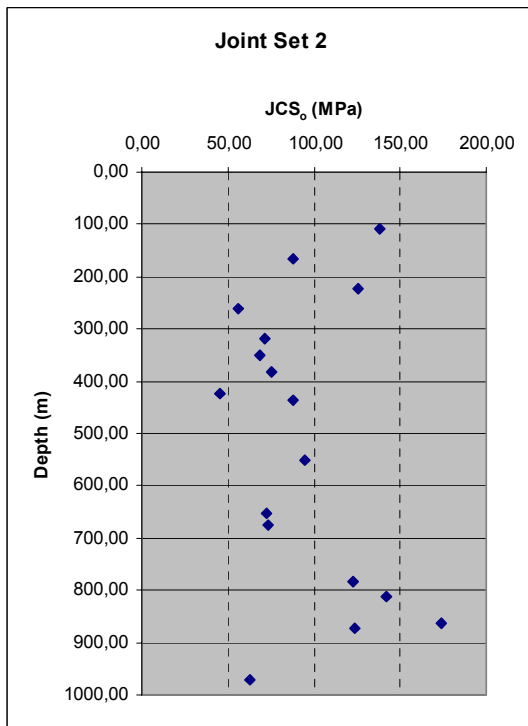
In the section 100–1003 m from this borehole, 51 tilt tests and 51 x 3 profilings on joints have been performed. Complete input data and output data from tilt tests and profiling are found in Appendix A. Figures 3-1, 3-2 and 3-3 show the variation of the parameters  $JCS_o$ ,  $JRC_o$ ,  $\Phi_r$  and  $\Phi_b$  with depth for each of the three joint sets respectively. Table 3-1 shows the arithmetic mean values of these parameters. A summary of the tilt tests and profiling is also given in Table 3-1.

**Table 3-1. Arithmetic mean  $JCS_o$ ,  $JRC_o$ ,  $\Phi_r$  and  $\Phi_b$  -values, borehole KSH01A.**

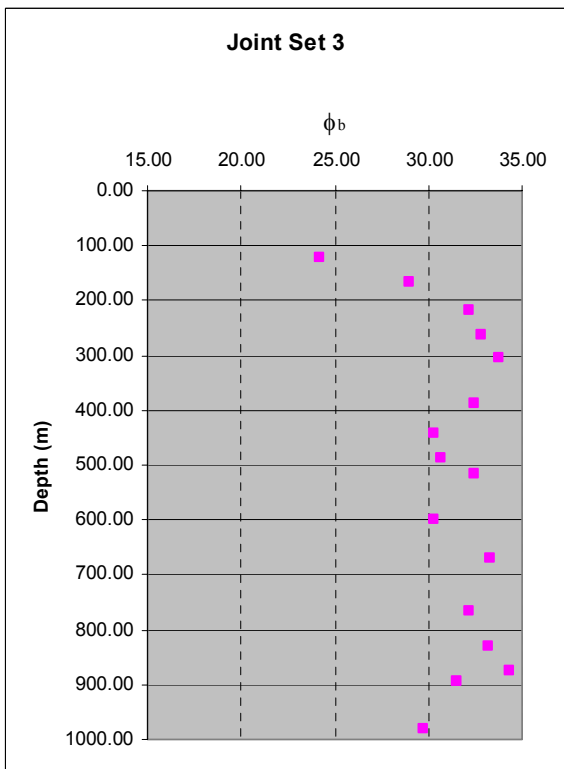
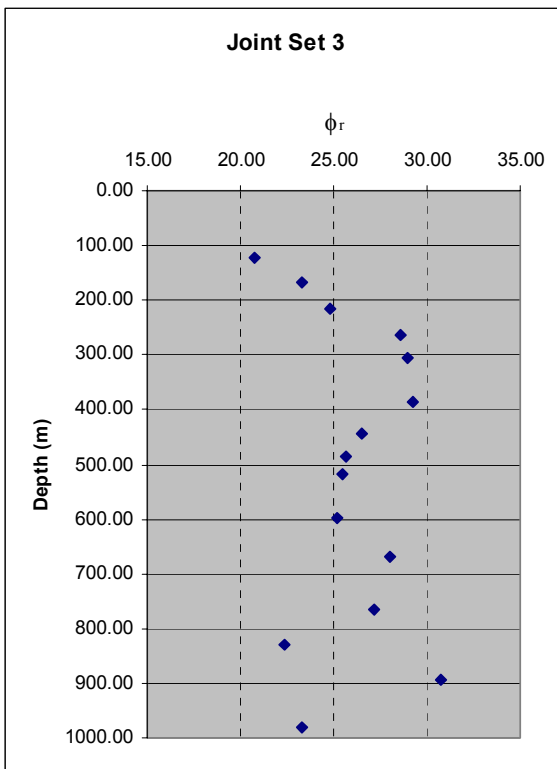
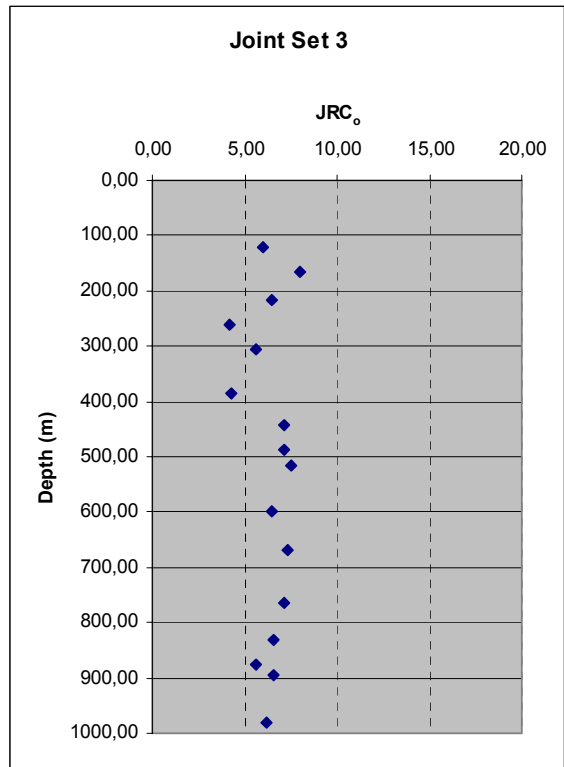
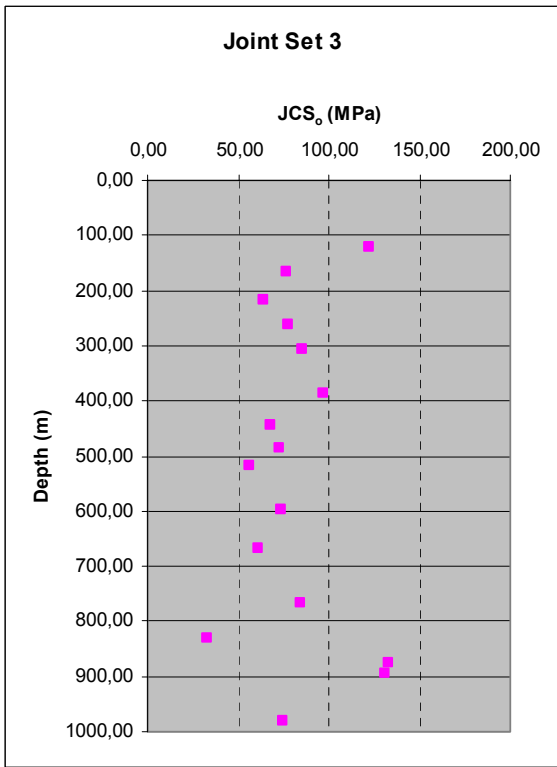
Fracture set	$JRC_o$ (tilt)	$JCS_o$ MPa	$\Phi_b$ (°)	$\Phi_r$ (°)	Number (tilt)	Number (profiles)
Set 1	6.4	77.3	30.8	25.6	18	18
Set 2	6.1	95.4	31.7	28.2	17	17
Set 3	6.4	81.8	31.4	26.6	16	16
<b>Mean/Total</b>	<b>6.3</b>	<b>84.7</b>	<b>31.3</b>	<b>26.8</b>	<b>51</b>	<b>51</b>



**Figure 3-1.** Variation of joint parameters with depth for Set 1.



**Figure 3-2.** Variation of joint parameters with depth for Set 2.



**Figure 3-3.** Variation of joint parameters with depth for Set 3.

### **3.3 Evaluation of the results**

The joint faces are rather similar concerning mineralisation, and the tilt tests show rather uniform JRC – and JCS values. Because of the small core diameter the results are associated with some uncertainty since the standard length for such tests is 100 mm i.e. L<sub>100</sub>. Tilting of samples with relatively high JRC-values is sometimes impossible because toppling takes place before sliding. However the selection of the tilt test samples did not take into account the possible toppling before the sliding. In case of toppling only profiling would have been carried out, but it did not proved to be necessary. All profiling is therefore taken in order to compare them with the tilt test results. If joints are too rough to reach shear failure by tilting “pull test” should be performed using a calibrated equipment attached to the tilt table. The pull test is performed on a horizontally-placed joint sample.

In general, the joint roughness on all three joint sets varied between 3.5 and 8.4. This means that the sample selection for tilt testing is representative for the borehole KSH01A.

**The main results from tilt testing**

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1

Operator: PC

Date: 20.05.2003

## INPUT DATA

Depth zone: 100-1003 m

Borehole: KSH01A

F:\P\2003\10\20031089\Rap KSH01A\set1.xls\INPUT DATA 1

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT		MASS m (g)	AREA A (cm <sup>2</sup> )	MEAN TILT ANGLE (°)	JOINT REBOUN NUMBER (r)	ROCK REBOUN NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m <sup>3</sup> )	
				AMP. a (mm)	LENG. L (mm)								
1	set 1	115.613	Sicada	3.3	147.0	295.30	67.7	59.5	36.4	45.4	21.7	28.04	
2	set 1	165.638	Sicada	3.5	120.3	245.70	54.3	74.7	33.2	49.6	29.0	28.04	
3	set 1	178.900	Sicada	2.7	116.7	250.77	46.6	56.2	29.6	49.0	28.7	28.04	
4	set 1	202.362	Sicada	1.1	121.1	199.22	56.4	82.5	31.0	47.6	35.2	28.04	
5	set 1	263.759	Sicada	1.8	137.7	367.67	59.8	57.0	23.8	39.6	34.0	28.04	
6	set 1	318.800	Sicada	2.0	180.3	638.50	78.6	46.5	34.8	47.4	30.2	28.04	
7	set 1	377.926	Sicada	4.7	152.3	235.70	72.1	87.7	29.2	49.0	31.2	28.04	
8	set 1	403.056	Sicada	2.9	104.7	243.00	45.03	73.8	38.8	47.2	29.8	28.04	
9	set 1	435.073	Sicada	3.6	147.3	319.40	71.8	79.7	33.6	48.6	29.8	28.04	
10	set 1	456.395	Sicada	2.0	102.3	244.70	48.6	55.5	31.2	38.0	31.3	27.93	
11	set 1	481.808	Sicada	7.1	126.0	188.80	52	63.7	35.6	52.2	29.7	27.93	
12	set 1	509.483	Sicada	2.7	113.3	250.80	52.9	70.3	44.4	52.0	30.5	27.93	
13	set 1	752.680	Sicada	4.4	83.3	166.40	35.5	50.0	41.4	48.8	32.5	28.74	
14	set 1	840.119	Sicada	2.0	80.7	202.00	34.9	63.3	40.0	49.4	32.3	28.74	
15	set 1	847.896	Sicada	2.7	130.7	331.20	53.6	57.0	29.0	44.2	31.3	28.74	
16	set 1	864.646	Sicada	2.4	72.3	178.80	34.7	75.3	41.2	45.0	32.5	29.03	
17	set 1	887.266	Sicada	2.5	96.0	232.60	41.5	59.7	34.2	40.2	32.0	29.03	
18	set 1	969.700	Sicada	1.3	82.7	252.71	37.5	57.3	32.8	48.6	32.7	29.03	
				Arithmetic a	2.9	117.5	269.1	52.4	65.0	34.5	46.8	30.8	28.3
				maximum val	1.1	72.3	166.4	34.7	46.5	23.8	38.0	28.7	27.9
				minimum val	7.1	180.3	638.5	78.6	87.7	44.4	52.2	35.2	29.0

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3

Operator: PC

Date: 20.05.2003

## OUTPUT DATA

Depth zone: 100-1003 m

Borehole: KSH01A

F:\P\2003\10\20031089\Rap KSH01A\set1.xls\OUTPUT DATA

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS <sub>0</sub> (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC <sub>0</sub> AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC <sub>100</sub> VALUES 100 mm	EXTRPL'D JCS <sub>100</sub> VALUES 100 mm (MPa)	
										1
2	set 1	165.638	67.49	3.09E-05	22.4	8.25	0.83	8.51	70.65	
3	set 1	178.900	55.00	1.63E-04	20.8	6.41	0.86	6.54	56.66	
4	set 1	202.362	59.56	5.90E-06	28.2	7.75	0.83	7.98	62.27	
5	set 1	263.759	39.56	1.79E-04	26.0	5.80	0.73	6.02	41.82	
6	set 1	318.800	73.91	3.77E-04	24.9	4.08	0.55	4.29	79.45	
7	set 1	377.926	53.77	5.16E-07	23.1	8.05	0.66	8.62	59.52	
8	set 1	403.056	92.77	4.12E-05	26.2	7.49	0.96	7.54	93.73	
9	set 1	435.073	69.04	1.39E-05	23.6	8.38	0.68	8.94	76.09	
10	set 1	456.395	59.82	1.58E-04	27.7	4.98	0.98	4.99	60.02	
11	set 1	481.808	76.73	6.99E-05	23.3	6.68	0.79	6.89	80.37	
12	set 1	509.483	126.26	5.28E-05	27.6	6.70	0.88	6.81	129.47	
13	set 1	752.680	114.04	1.90E-04	29.5	3.55	1.20	3.51	111.84	
14	set 1	840.119	105.11	1.15E-04	28.5	5.84	1.24	5.69	101.24	
15	set 1	847.896	55.39	1.80E-04	24.4	5.94	0.77	6.13	58.10	
16	set 1	864.646	115.48	3.25E-05	30.8	6.79	1.38	6.50	108.10	
17	set 1	887.266	76.50	1.40E-04	29.0	5.35	1.04	5.32	76.01	
18	set 1	969.700	70.46	1.93E-04	26.2	5.59	1.21	5.47	68.25	
			Arithmetic av.	77.32	1.14E-04	25.56	6.37	0.90	6.51	78.97
			maximum val.	126.26	3.77E-04	30.81	8.38	1.38	8.94	129.47
			minimum val.	39.56	5.16E-07	17.74	3.55	0.55	3.51	41.82



# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	20.05.2003
Borehole:	KSH01A

INPUT DATA      Depth zone:      100-1003 m

F:\P\2003\10\20031089\Rap KSH01A\set2.xls\INPUT DATA 1

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT		MASS m (g)	AREA A (cm <sup>2</sup> )	MEAN TILT ANGLE (°)	JOINT REBOUN NUMBER (r)	ROCK REBOUN NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m <sup>3</sup> )
				AMP. a (mm)	LENG. L (mm)							
1	set 2	107.950	Sicada	2.0	86.0	216.62	38.5	67.7	45.8	50.0	28.3	28.04
2	set 2	165.061	Sicada	2.0	55.7	123.10	23.6	65.8	37.9	50.0	31.5	28.04
3	set 2	222.132	Sicada	2.4	70.3	155.23	29.6	63.0	44.2	53.6	30.3	28.04
4	set 2	260.211	Sicada	3.1	88.0	202.88	36.4	71.7	29.8	40.4	34.7	28.04
5	set 2	318.710	Sicada	2.9	61.0	145.90	26.8	55.5	34.1	47.4	30.8	28.04
6	set 2	350.613	Sicada	1.0	50.3	118.50	23.1	61.2	33.5	42.2	30.3	28.04
7	set 2	381.891	Sicada	1.2	48.0	110.40	21.9	73.3	35.1	45.6	30.7	28.04
8	set 2	422.981	Sicada	1.5	50.3	112.30	21.9	55.3	26.4	40.2	30.3	28.04
9	set 2	434.727	Sicada	2.2	53.3	136.15	25.5	66.3	37.9	41.6	31.5	28.04
10	set 2	551.866	Sicada	2.9	85.0	187.00	36.3	71.8	39.3	42.8	34.3	27.93
11	set 2	652.828	Sicada	2.9	81.0	198.30	33.4	59.8	34.5	46.4	32.7	27.93
12	set 2	675.329	Sicada	1.1	70.3	183.80	33.5	63.7	34.9	46.4	33.7	27.93
13	set 2	784.690	Sicada	2.0	76.0	189.70	33.5	61.8	42.7	48.4	33.3	28.74
14	set 2	810.979	Sicada	1.6	55.0	130.80	22.6	57.7	45.2	49.6	32.0	28.74
15	set 2	862.395	Sicada	1.3	47.3	107.50	22.8	75.0	48.6	45.2	30.7	28.74
16	set 2	873.151	Sicada	1.8	62.3	142.90	28.3	72.7	42.3	44.0	31.3	29.03
17	set 2	972.326	Sicada	1.5	77.7	211.40	38.7	57.6	30.8	45.6	33.0	29.03
Arithmetic a				2.0	65.7	157.2	29.2	64.7	37.8	45.8	31.7	28.3
maximum v				1.0	47.3	107.5	21.9	55.3	26.4	40.2	28.3	27.9
minimum v				3.1	88.0	211.4	38.7	75.0	48.6	53.6	34.7	29.0

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3	
Operator:	PC
Date:	20.05.2003
Borehole:	KSH01A

OUTPUT DATA      Depth zone:      100-1003 m

F:\P\2003\10\20031089\Rap KSH01A\set2.xls\OUTPUT DATA

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS <sub>0</sub> (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC <sub>0</sub> AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC <sub>100°</sub> VALUES 100 mm	EXTRPL'D JCS <sub>100°</sub> VALUES 100 mm (MPa)
2	set 2	165.061	88.14	8.60E-05	26.7	6.51	1.80	6.03	78.62
3	set 2	222.132	126.08	1.06E-04	26.8	5.96	1.42	5.71	118.38
4	set 2	260.211	55.63	5.39E-05	29.5	7.03	1.14	6.90	54.15
5	set 2	318.710	71.03	1.71E-04	25.2	5.40	1.64	5.12	65.57
6	set 2	350.613	68.65	1.17E-04	26.2	6.07	1.99	5.58	60.57
7	set 2	381.891	75.18	4.08E-05	26.1	7.53	2.08	6.75	63.69
8	set 2	422.981	45.86	1.63E-04	23.4	5.85	1.99	5.40	40.65
9	set 2	434.727	88.14	8.46E-05	29.7	6.08	1.88	5.63	78.59
10	set 2	551.866	94.61	4.93E-05	32.7	6.23	1.18	6.10	91.78
11	set 2	652.828	72.10	1.47E-04	27.6	5.66	1.23	5.53	69.57
12	set 2	675.329	73.75	1.06E-04	28.7	5.98	1.42	5.73	69.23
13	set 2	784.690	123.01	1.24E-04	30.9	5.15	1.32	5.00	117.91
14	set 2	810.979	142.29	1.62E-04	30.2	4.62	1.82	4.37	130.97
15	set 2	862.395	173.44	3.10E-05	32.2	6.34	2.11	5.77	150.42
16	set 2	873.151	123.20	4.38E-05	30.5	6.54	1.61	6.15	112.28
17	set 2	972.326	62.64	1.54E-04	26.5	5.54	1.29	5.39	60.06
Arithmetic av			95.40	1.01E-04	28.21	6.06	1.59	5.74	88.03
maximum val			173.44	1.71E-04	32.66	7.53	2.11	6.90	150.42
minimum val.			45.86	3.10E-05	23.43	4.62	1.14	4.37	40.65

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	20.05.2003
Borehole:	KSH01A

INPUT DATA Depth zone: 100-1003 m

F:\P\2003\10\20031089\Rap KSH01A\set3.xls\INPUT DATA 1

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT		MASS m (g)	AREA A (cm <sup>2</sup> )	MEAN TILT ANGLE (°)	JOINT REBOUN NUMBER (r)	ROCK REBOUN NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m <sup>3</sup> )
				AMP. a (mm)	LENG. L (mm)							
1	set 3	122.227	Sicada	1.3	52.3	120.24	22.3	55.7	43.6	52.8	24.2	28.04
2	set 3	165.740	Sicada	1.4	49.7	135.20	22.4	72.3	35.4	49.6	29.0	28.04
3	set 3	216.632	Sicada	1.2	46.7	91.77	19.9	62.8	32.3	51.2	32.2	28.04
4	set 3	262.481	Sicada	1.6	49.3	97.96	21.4	52.5	35.7	45.2	32.8	28.04
5	set 3	305.690	Sicada	1.6	48.2	104.55	20	62.3	37.3	49.2	33.8	28.04
6	set 3	386.877	Sicada	0.5	47.3	110.10	20.5	54.0	39.6	47.4	32.5	28.04
7	set 3	443.299	Sicada	1.2	45.3	109.70	20.6	69.7	33.3	41.2	30.3	28.04
8	set 3	486.900	Sicada	0.9	41.3	111.10	20.7	68.7	34.6	46.4	30.7	28.04
9	set 3	517.204	Sicada	1.3	44.7	107.10	19.9	70.3	30.0	46.2	32.5	27.93
10	set 3	598.300	Sicada	2.3	45.3	100.30	20.1	63.2	34.8	46.8	30.3	27.93
11	set 3	668.554	Sicada	1.6	44.6	98.90	19.5	73.7	31.5	42.8	33.3	27.93
12	set 3	765.206	Sicada	0.6	44.3	109.90	21.5	71.3	36.3	48.6	32.2	28.74
13	set 3	831.023	Sicada	1.0	45.0	110.70	19.9	57.2	19.9	43.6	33.2	28.74
14	set 3	876.324	Sicada	1.3	45.0	100.30	21.1	73.5	44.0	39.6	34.3	28.74
15	set 3	894.013	Sicada	1.6	47.3	109.40	20.4	73.3	43.3	45.0	31.5	29.03
16	set 3	979.474	Sicada	0.6	45.6	121.60	21.6	58.5	33.7	49.4	29.7	29.03
Arithmetic av.				1.3	46.4	108.7	20.7	64.9	35.3	46.6	31.4	28.3
maximum val.				0.5	41.3	91.8	19.5	52.5	19.9	39.6	24.2	27.9
minimum val.				2.3	52.3	135.2	22.4	73.7	44.0	52.8	34.3	29.0

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3	
Operator:	PC
Date:	20.05.2003
Borehole:	KSH01A

OUTPUT DATA Depth zone: 100-1003 m

F:\P\2003\10\20031089\Rap KSH01A\set3.xls\OUTPUT DATA

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS <sub>0</sub> (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC <sub>0</sub> AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC <sub>100</sub> VALUES 100 mm	EXTRPL'D JCS <sub>100</sub> VALUES 100 mm (MPa)
2	set 3	165.740	76.47	5.47E-05	23.3	7.98	2.01	7.14	64.69
3	set 3	216.632	64.12	9.45E-05	24.8	6.51	2.14	5.90	55.26
4	set 3	262.481	77.79	1.66E-04	28.6	4.22	2.03	3.97	71.13
5	set 3	305.690	85.19	1.11E-04	29.0	5.66	2.07	5.21	75.25
6	set 3	386.877	97.08	1.82E-04	29.2	4.33	2.11	4.06	88.09
7	set 3	443.299	67.87	6.29E-05	26.5	7.17	2.21	6.40	57.25
8	set 3	486.900	73.07	6.95E-05	25.6	7.15	2.42	6.30	60.44
9	set 3	517.204	55.89	6.00E-05	25.5	7.51	2.24	6.65	46.62
10	set 3	598.300	73.34	9.95E-05	25.2	6.48	2.21	5.85	62.87
11	set 3	668.554	60.84	3.92E-05	28.0	7.38	2.24	6.55	50.89
12	set 3	765.206	84.74	5.15E-05	27.1	7.10	2.26	6.33	71.24
13	set 3	831.023	32.61	1.60E-04	22.3	6.57	2.22	5.91	27.86
14	set 3	876.324	132.68	3.76E-05	36.5	5.65	2.22	5.16	115.89
15	set 3	894.013	130.66	4.34E-05	30.7	6.57	2.11	5.95	112.74
16	set 3	979.474	74.29	1.51E-04	23.3	6.18	2.19	5.60	64.23
Arithmetic av.			81.78	9.69E-05	26.65	6.40	2.16	5.78	70.81
maximum val.			132.68	1.82E-04	36.52	7.98	2.42	7.14	115.89
minimum val.			32.61	3.76E-05	20.72	4.22	1.91	3.97	27.86

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1

Operator: PC

Date: 2003-05-20

Borehole: KSH01A

## INPUT DATA

Depth zone: 100-1003 m

#Saknas!

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT		MASS m (g)	AREA A (cm <sup>2</sup> )	MEAN TILT ANGLE (°)	JOINT REBOUN NUMBER (r)	ROCK REBOUN NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m <sup>3</sup> )
				AMP. a (mm)	LENG. L (mm)							
1	set 1	115,613	Sicada	3,3	147,0	295,30	67,7	59,5	36,4	45,4	21,7	28,04
2	set 2	107,950	Sicada	2,0	86,0	216,62	38,5	67,7	45,8	50,0	28,3	28,04
3	set 3	122,227	Sicada	1,3	52,3	120,24	22,3	55,7	43,6	52,8	24,2	28,04
4	set 1	165,638	Sicada	3,5	120,3	245,70	54,3	74,7	33,2	49,6	29,0	28,04
5	set 2	165,061	Sicada	2,0	55,7	123,10	23,6	65,8	37,9	50,0	31,5	28,04
6	set 3	165,740	Sicada	1,4	49,7	135,20	22,4	72,3	35,4	49,6	29,0	28,04
7	set 1	178,900	Sicada	2,7	116,7	250,77	46,6	56,2	29,6	49,0	28,7	28,04
8	set 2	222,132	Sicada	2,4	70,3	155,23	29,6	63,0	44,2	53,6	30,3	28,04
9	set 3	216,632	Sicada	1,2	46,7	91,77	19,9	62,8	32,3	51,2	32,2	28,04
10	set 1	202,362	Sicada	1,1	121,1	199,22	56,4	82,5	31,0	47,6	35,2	28,04
11	set 2	260,211	Sicada	3,1	88,0	202,88	36,4	71,7	29,8	40,4	34,7	28,04
12	set 3	262,481	Sicada	1,6	49,3	97,96	21,4	52,5	35,7	45,2	32,8	28,04
13	set 1	263,759	Sicada	1,8	137,7	367,67	59,8	57,0	23,8	39,6	34,0	28,04
14	set 2	318,710	Sicada	2,9	61,0	145,90	26,8	55,5	34,1	47,4	30,8	28,04
15	set 3	305,690	Sicada	1,6	48,2	104,55	20	62,3	37,3	49,2	33,8	28,04
16	set 1	318,800	Sicada	2,0	180,3	638,50	78,6	46,5	34,8	47,4	30,2	28,04
17	set 2	350,613	Sicada	1,0	50,3	118,50	23,1	61,2	33,5	42,2	30,3	28,04
18	set 3	386,877	Sicada	0,5	47,3	110,10	20,5	54,0	39,6	47,4	32,5	28,04
19	set 1	377,926	Sicada	4,7	152,3	235,70	72,1	87,7	29,2	49,0	31,2	28,04
20	set 2	381,891	Sicada	1,2	48,0	110,40	21,9	73,3	35,1	45,6	30,7	28,04
21	set 3	443,299	Sicada	1,2	45,3	109,70	20,6	69,7	33,3	41,2	30,3	28,04
22	set 2	422,981	Sicada	1,5	50,3	112,30	21,9	55,3	26,4	40,2	30,3	28,04
23	set 1	403,056	Sicada	2,9	104,7	243,00	45,03	73,8	38,8	47,2	29,8	28,04
24	set 2	434,727	Sicada	2,2	53,3	136,15	25,5	66,3	37,9	41,6	31,5	28,04
25	set 3	486,900	Sicada	0,9	41,3	111,10	20,7	68,7	34,6	46,4	30,7	28,04
26	set 1	435,073	Sicada	3,6	147,3	319,40	71,8	79,7	33,6	48,6	29,8	28,04
27	set 2	551,866	Sicada	2,9	85,0	187,00	36,3	71,8	39,3	42,8	34,3	27,93
28	set 3	517,204	Sicada	1,3	44,7	107,10	19,9	70,3	30,0	46,2	32,5	27,93
29	set 1	456,395	Sicada	2,0	102,3	244,70	48,6	55,5	31,2	38,0	31,3	27,93
30	set 2	652,828	Sicada	2,9	81,0	198,30	33,4	59,8	34,5	46,4	32,7	27,93
31	set 3	598,300	Sicada	2,3	45,3	100,30	20,1	63,2	34,8	46,8	30,3	27,93
32	set 1	481,808	Sicada	7,1	126,0	188,80	52	63,7	35,6	52,2	29,7	27,93
33	set 2	675,329	Sicada	1,1	70,3	183,80	33,5	63,7	34,9	46,4	33,7	27,93
34	set 3	668,554	Sicada	1,6	44,6	98,90	19,5	73,7	31,5	42,8	33,3	27,93
35	set 1	509,483	Sicada	2,7	113,3	250,80	52,9	70,3	44,4	52,0	30,5	27,93
36	set 2	784,690	Sicada	2,0	76,0	189,70	33,5	61,8	42,7	48,4	33,3	28,74
37	set 3	765,206	Sicada	0,6	44,3	109,90	21,5	71,3	36,3	48,6	32,2	28,74

ROCK JOINT CHARACTERISATION								PAGE 3	
CLIENT: SKB- Tilt tests								Operator:	PC
OUTPUT DATA								Date:	20.05.2003
								Depth zone:	
								Borehole:	KSH01A
F:\P\2003\10\20031089\Rap KSH01A\alljoints.xls\OUTPUT DATA									
SAMPLE No	JOINT SET NO	DEPTH (m)	JCS <sub>0</sub> (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC <sub>0</sub> AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC <sub>100</sub> VALUES 100 mm	EXTRPL'D JCS <sub>100</sub> VALUES 100 mm (MPa)
1	set 1	115.613	80.94	1.10E-04	17.7	7.12	0.68	7.52	87.89
2	set 2	107.950	138.08	7.94E-05	26.6	6.58	1.16	6.45	134.03
3	set 3	122.227	121.85	1.68E-04	20.7	5.97	1.91	5.52	108.50
4	set 1	165.638	67.49	3.09E-05	22.4	8.25	0.83	8.51	70.65
5	set 2	165.061	88.14	8.60E-05	26.7	6.51	1.80	6.03	78.62
6	set 3	165.740	76.47	5.47E-05	23.3	7.98	2.01	7.14	64.69
7	set 1	178.900	55.00	1.63E-04	20.8	6.41	0.86	6.54	56.66
8	set 2	222.132	126.08	1.06E-04	26.8	5.96	1.42	5.71	118.38
9	set 3	216.632	64.12	9.45E-05	24.8	6.51	2.14	5.90	55.26
10	set 1	202.362	59.56	5.90E-06	28.2	7.75	0.83	7.98	62.27
11	set 2	260.211	55.63	5.39E-05	29.5	7.03	1.14	6.90	54.15
12	set 3	262.481	77.79	1.66E-04	28.6	4.22	2.03	3.97	71.13
13	set 1	263.759	39.56	1.79E-04	26.0	5.80	0.73	6.02	41.82
14	set 2	318.710	71.03	1.71E-04	25.2	5.40	1.64	5.12	65.57
15	set 3	305.690	85.19	1.11E-04	29.0	5.66	2.07	5.21	75.25
16	set 1	318.800	73.91	3.77E-04	24.9	4.08	0.55	4.29	79.45
17	set 2	350.613	68.65	1.17E-04	26.2	6.07	1.99	5.58	60.57
18	set 3	386.877	97.08	1.82E-04	29.2	4.33	2.11	4.06	88.09
19	set 1	377.926	53.77	5.16E-07	23.1	8.05	0.66	8.62	59.52
20	set 2	381.891	75.18	4.08E-05	26.1	7.53	2.08	6.75	63.69
21	set 3	443.299	67.87	6.29E-05	26.5	7.17	2.21	6.40	57.25
22	set 2	422.981	45.86	1.63E-04	23.4	5.85	1.99	5.40	40.65
23	set 1	403.056	92.77	4.12E-05	26.2	7.49	0.96	7.54	93.73
24	set 2	434.727	88.14	8.46E-05	29.7	6.08	1.88	5.63	78.59
25	set 3	486.900	73.07	6.95E-05	25.6	7.15	2.42	6.30	60.44
26	set 1	435.073	69.04	1.39E-05	23.6	8.38	0.68	8.94	76.09
27	set 2	551.866	94.61	4.93E-05	32.7	6.23	1.18	6.10	91.78
28	set 3	517.204	55.89	6.00E-05	25.5	7.51	2.24	6.65	46.62
29	set 1	456.395	59.82	1.58E-04	27.7	4.98	0.98	4.99	60.02
30	set 2	652.828	72.10	1.47E-04	27.6	5.66	1.23	5.53	69.57
31	set 3	598.300	73.34	9.95E-05	25.2	6.48	2.21	5.85	62.87
32	set 1	481.808	76.73	6.99E-05	23.3	6.68	0.79	6.89	80.37
33	set 2	675.329	73.75	1.06E-04	28.7	5.98	1.42	5.73	69.23
34	set 3	668.554	60.84	3.92E-05	28.0	7.38	2.24	6.55	50.89
35	set 1	509.483	126.26	5.28E-05	27.6	6.70	0.88	6.81	129.47
36	set 2	784.690	123.01	1.24E-04	30.9	5.15	1.32	5.00	117.91
37	set 3	765.206	84.74	5.15E-05	27.1	7.10	2.26	6.33	71.24
38	set 1	752.680	114.04	1.90E-04	29.5	3.55	1.20	3.51	111.84
39	set 2	810.979	142.29	1.62E-04	30.2	4.62	1.82	4.37	130.97
40	set 3	831.023	32.61	1.60E-04	22.3	6.57	2.22	5.91	27.86
41	set 1	840.119	105.11	1.15E-04	28.5	5.84	1.24	5.69	101.24
42	set 2	862.395	173.44	3.10E-05	32.2	6.34	2.11	5.77	150.42
43	set 3	876.324	132.68	3.76E-05	36.5	5.65	2.22	5.16	115.89
44	set 1	847.896	55.39	1.80E-04	24.4	5.94	0.77	6.13	58.10
45	set 2	873.151	123.20	4.38E-05	30.5	6.54	1.61	6.15	112.28
46	set 3	894.013	130.66	4.34E-05	30.7	6.57	2.11	5.95	112.74
47	set 1	864.646	115.48	3.25E-05	30.8	6.79	1.38	6.50	108.10
48	set 2	972.326	62.64	1.54E-04	26.5	5.54	1.29	5.39	60.06
49	set 3	979.474	74.29	1.51E-04	23.3	6.18	2.19	5.60	64.23
50	set 1	887.266	76.50	1.40E-04	29.0	5.35	1.04	5.32	76.01
51	set 1	969.700	70.46	1.93E-04	26.2	5.59	1.21	5.47	68.25
		Arithmetic av.	84.75	1.04E-04	26.78	6.28	1.53	6.03	79.43
		maximum val.	173.44	3.77E-04	36.52	8.38	2.42	8.94	150.42
		minimum val.	32.61	5.16E-07	17.74	3.55	0.55	3.51	27.86