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Oskarshamn site investigation

Borehole: KSH02

Results of tilt testing

Panayiotis Chryssanthakis
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May 2004

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Keywords: Rock mechanics, Fracture mechanis, Tilt test, AP 400-03-049.

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

Summary

Norwegian Geotechnical Institute (NGI) has carried out tilt testing on joint surfaces of drill cores from the borehole KSH 02 at Simpevarp. From a total of about 920 m of cores, 48 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 6.0. The mean value of the joint wall compressive strength (JCS_o) from Schmidt hammer testing of all the joint samples is 73.6 MPa. The mean values of the basic (Φ_b) and residual (Φ_r) friction angles of all the tested samples are 31.5 and 26.2 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 KSH 02 at Simpevarp in Sweden according to SKB's Aktivitetsplan AP 400-03-049 (SKB internal controlling document). The work has been carried out by Panayiotis Chryssanthakis and Pawel Jankowski during the period 1–10 September 2003 in accordance with SKB's method description MD 190.006 Version 1.0 (SKB internal controlling document). The following tests have been carried out:

Table 1-1. Total number of tilt tests.

Borehole	Tilt tests	Number of joint sets
KSH 02	48	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 160).

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 15 to 18 m in the depth range between 265.0 m and 985.0 m. A total of 48 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:

Table 2-1. Joint set numbers and orientations.

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

Because of the small core diameter, and many artificial fractures, it was rather difficult to find good samples for tilt testing. This is specifically valid for joint set 3 where not so many horizontal joints were found at depths greater than 750 m.

Three profiles on each tilt joint surface have been also carried out. The rocks can be classified as mainly metamorphic rocks which include mainly fine grain diorite with some areas of coarse to medium grained granite, and some veins of pegmatite and mafic fine grained rock, 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, epidote and laumontite. All 48 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 (α and Φ_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.

Joint 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. NGI's tilt test apparatus.



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

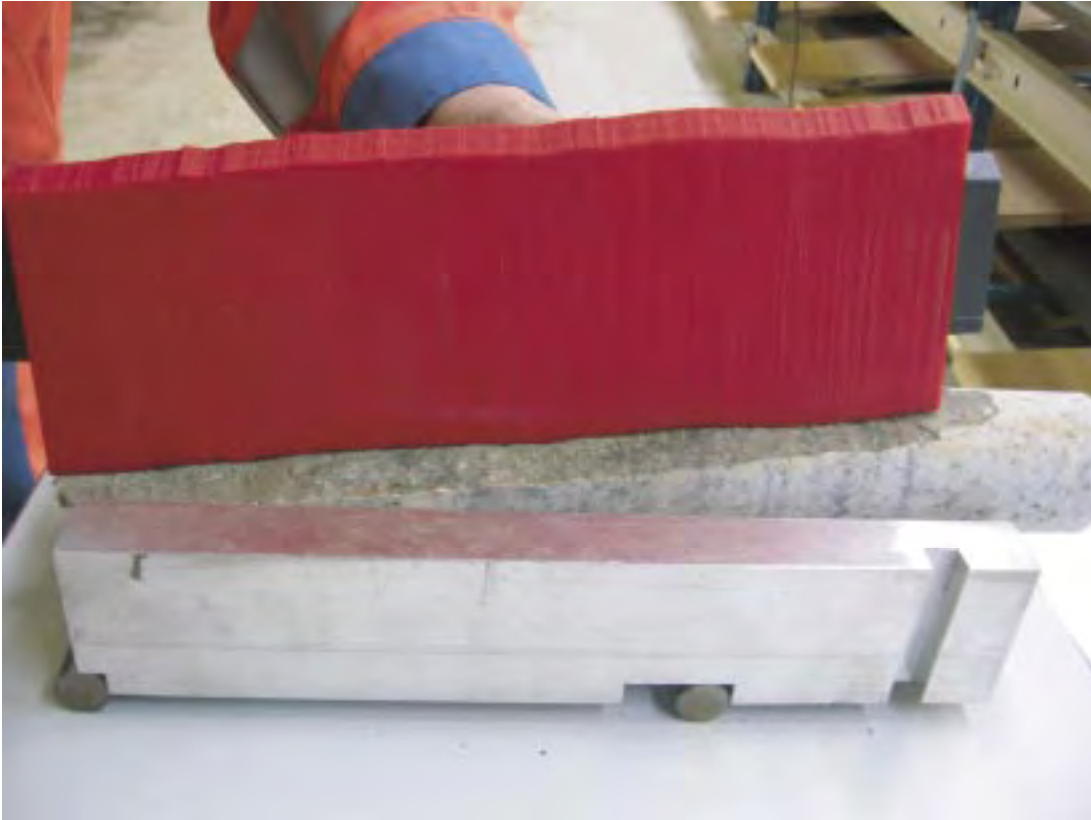


Figure 2-4. Profilometer applied on a joint surface.

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 α 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° 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° may be accepted.

The same procedure is used for determining Φ_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 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.

Several density measurements of the rock were carried out during tilt testing, the results were in the range 2.70–2.84 g/cm³. In the calculations the following densities as listed in Table 2-2 have been used:

Table 2-2. Depth ranges in borehole KSH 02 with the relevant unit weight used.

Depth interval in meters		Unit weight
from	until	kN/m ³
265.00	304.75	27.01
304.75	369.15	27.92
369.15	465.05	27.78
465.05	575.30	27.27
575.30	719.15	27.86
719.15	820.40	28.12
820.40	875.15	27.79
875.15	985.00	28.44

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 48 tilt test specimens have been chosen from the total of 920 m of core material borehole KSH 02 in the depth range between 265 m and 985 m. 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, dip directions and different mineralization.

3.2 Results from borehole KSH 02

In the depth range 265–985 m from borehole KSH 02, 48 tilt tests and 48 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 , Φ_r and Φ_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 , Φ_r and Φ_b -values, Borehole KSH 02.

Fracture set	JRC_o (tilt)	JCS_o MPa	Φ_b (o)	Φ_r (o)	Number (tilt)	Number (profiles)
Set 1	6.25	74.10	31.3	26.11	16	16
Set 2	6.12	72.27	31.8	26.57	16	16
Set 3	5.76	75.36	31.4	25.91	16	16
Mean/Total	6.04	73.59	31.5	26.20	48	48

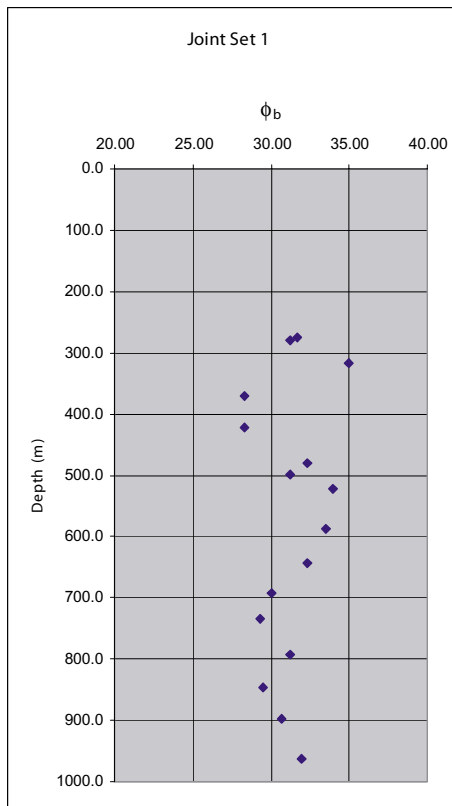
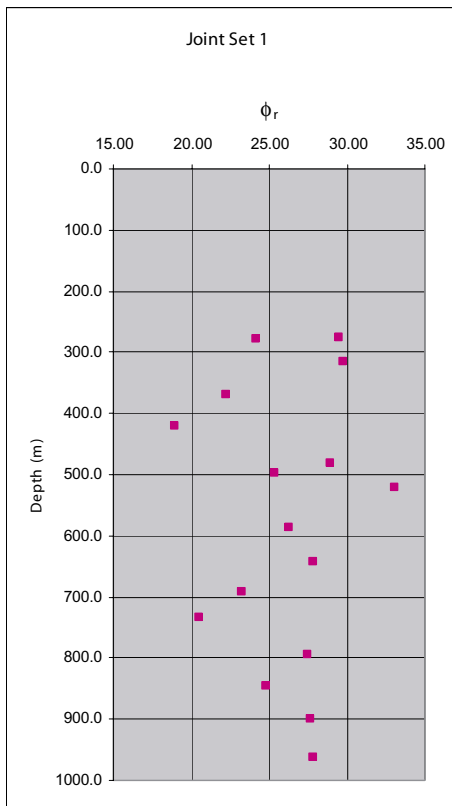
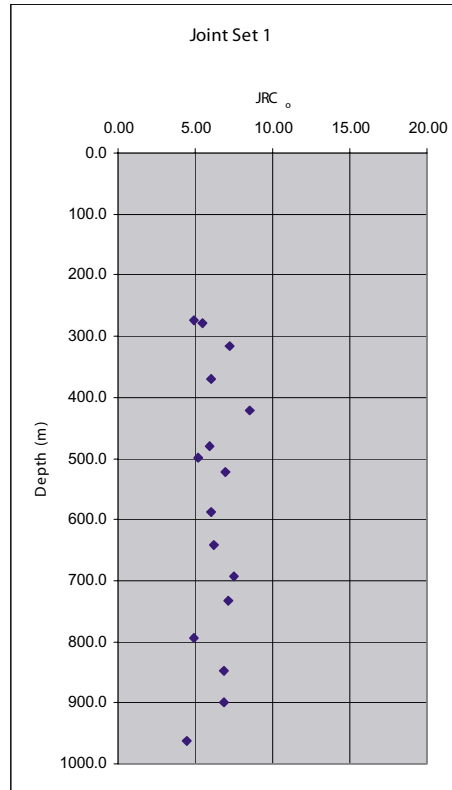
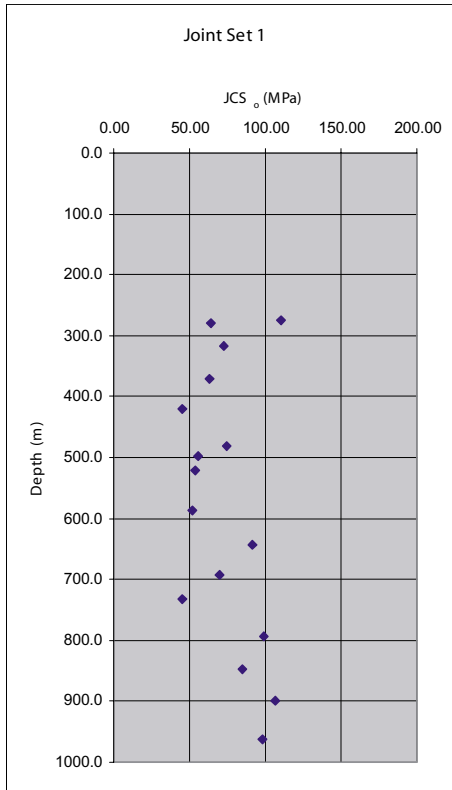


Figure 3-1. Variation of joint parameters with depth for Set 1.

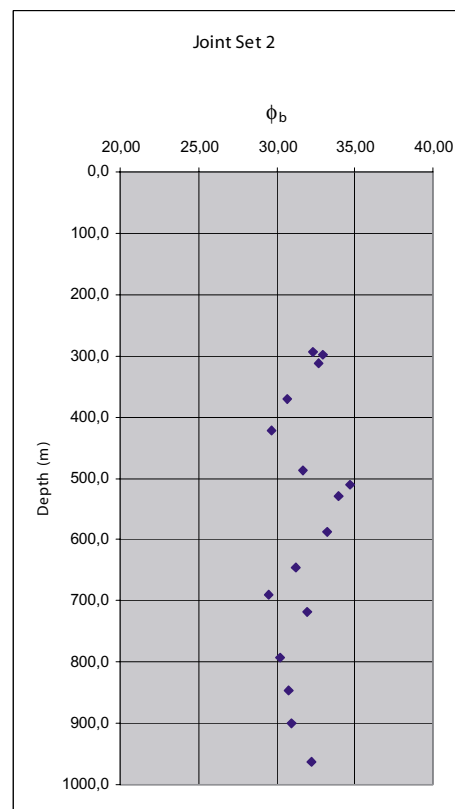
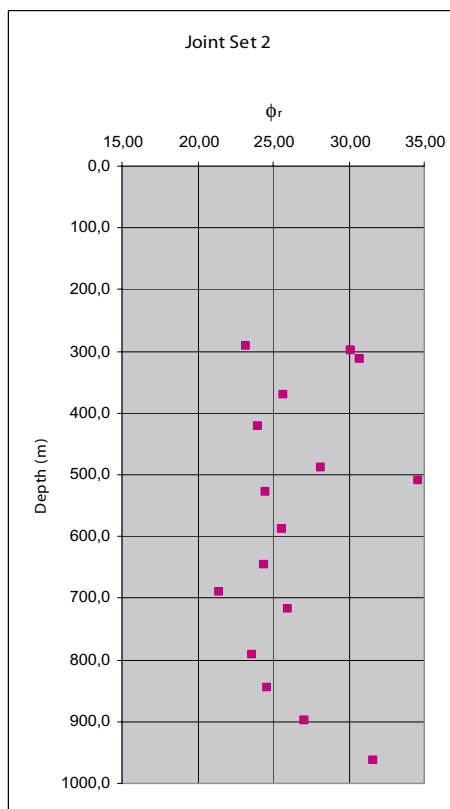
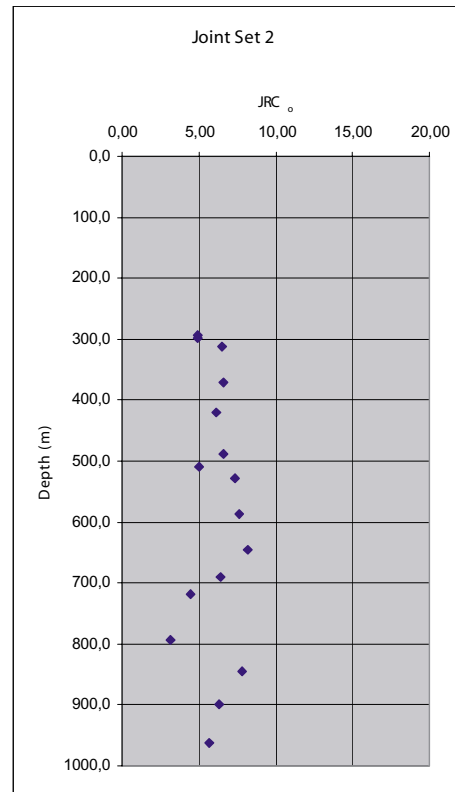
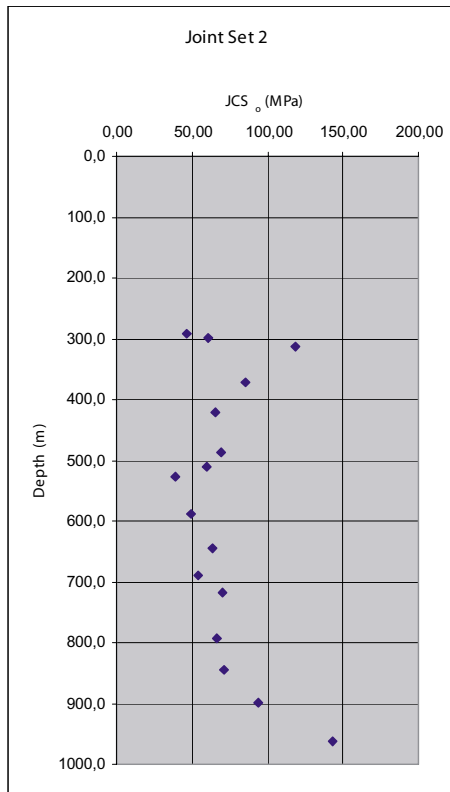


Figure 3-2. Variation of joint parameters with depth for Set 2.

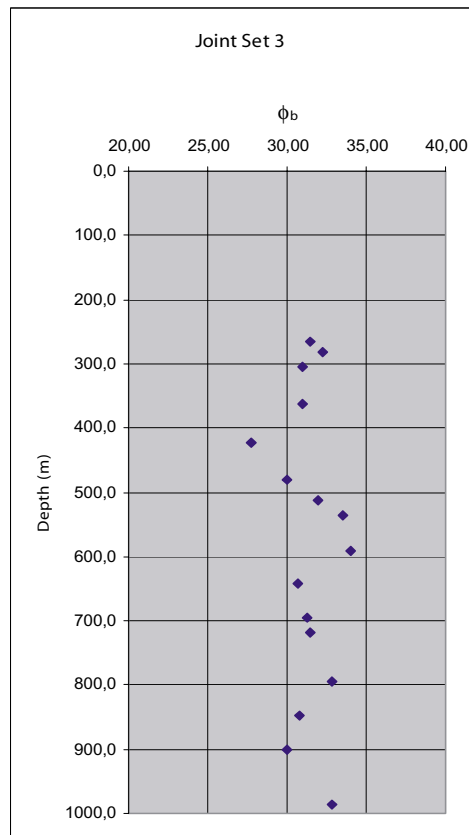
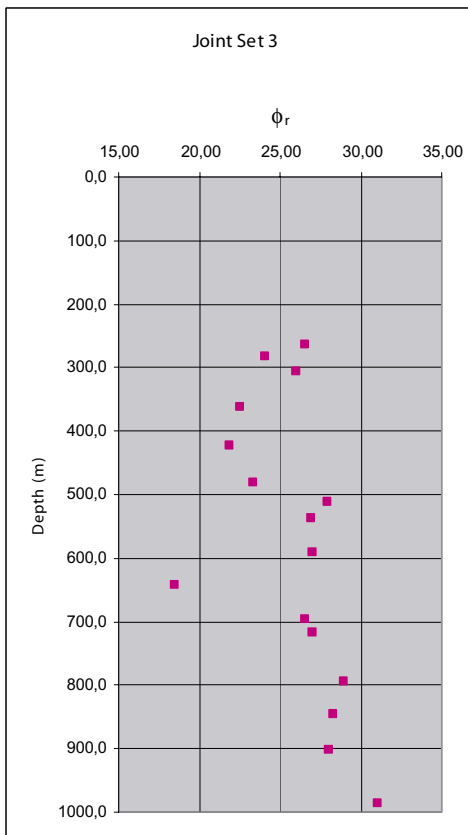
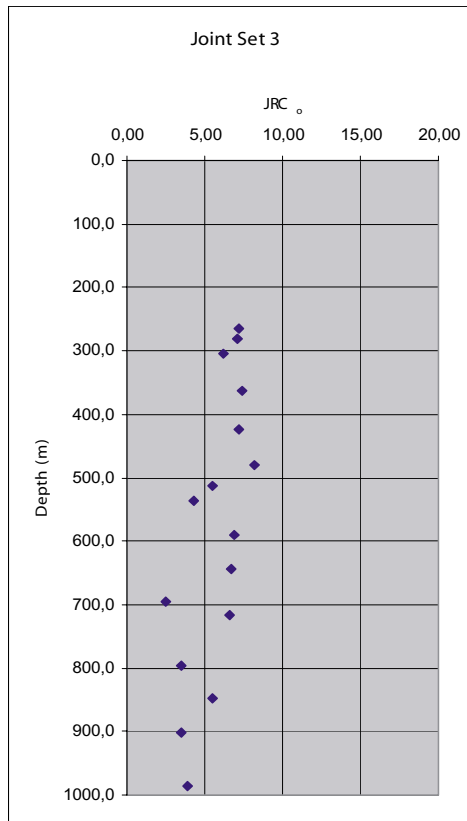
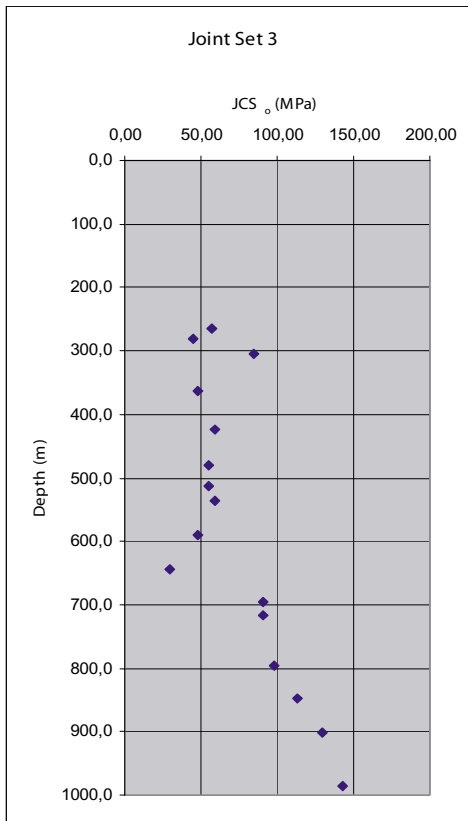


Figure 3-3. Variation of joint parameters with depth for Set 3.

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_{100} . 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 prove 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 2.5 and 8.5. This means that the sample selection for tilt testing is representative for the borehole KSH 02.

Appendix A

The main results from tilt testing

ROCK JOINT CHARACTERISATION												
CLIENT: SKB- Tilt tests												
INPUT DATA												
Depth zone: 80 -1000 m												
F:\P\2003\10\20031089\Reports\Rap KSH02\alljoints.xls\INPUT DATA 1												
SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT		MASS m (g)	AREA A (cm ²)	MEAN TILT ANGLE (°)	JOINT REBOUND NUMBER (r)	ROCK REBOUND (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m ³)
				AMP. a (mm)	LENG. L (mm)							
1	set 1	274.890	Sicada	2.6	111.0	289.70	55.1	58.5	41.8	47.0	31.7	27.01
2	set 2	292.822	Sicada	2.0	68.3	193.90	30.5	49.0	27.8	51.0	32.3	27.01
3	set 3	265.110	Sicada	2.0	42.7	97.70	19.7	69.7	31.3	41.6	31.5	27.01
4	set 1	278.733	Sicada	2.7	162.0	313.30	80.1	55.2	32.2	49.8	31.2	27.01
5	set 2	299.142	Sicada	2.1	57.3	174.15	26.0	57.3	32.6	38.0	33.0	27.01
6	set 3	281.810	Sicada	2.0	62.3	229.24	34.8	63.0	26.9	45.8	32.3	27.01
7	set 1	316.578	Sicada	4.5	141.0	386.13	74.3	76.0	34.4	46.6	35.0	27.92
8	set 2	312.807	Sicada	1.7	55.0	176.45	25.1	71.0	43.3	48.0	32.7	27.92
9	set 3	305.256	Sicada	1.2	46.7	125.10	20.9	61.8	37.3	49.8	31.0	27.92
10	set 1	369.969	Sicada	2.8	277.0	354.70	125.7	57.7	32.0	45.8	28.3	27.78
11	set 2	371.456	Sicada	2.3	73.3	238.70	35.1	64.3	37.7	50.4	30.7	27.78
12	set 3	362.241	Sicada	1.1	45.0	148.00	21.1	63.7	27.3	47.2	31.0	27.78
13	set 1	421.188	Sicada	2.4	114.3	433.28	51.6	66.0	26.6	50.0	28.3	27.78
14	set 2	421.035	Sicada	1.8	59.0	194.10	28.5	58.0	33.0	46.2	29.7	27.78
15	set 3	423.044	Sicada	1.9	44.0	123.20	20.3	63.0	31.3	44.2	27.7	27.78
16	set 1	497.842	Sicada	1.9	99.3	220.30	46.3	54.3	30.8	43.4	31.2	27.27
17	set 2	510.246	Sicada	1.4	57.3	177.10	24.6	62.7	31.8	32.0	34.7	27.27
18	set 3	480.478	Sicada	1.9	48.7	308.40	21.6	67.7	30.6	46.0	30.0	27.27
19	set 1	480.777	Sicada	2.8	170.3	174.30	69.6	66.3	36.0	43.2	32.3	27.27
20	set 2	488.063	Sicada	1.8	53.7	164.40	23.6	66.7	34.7	42.2	31.7	27.27
21	set 3	512.390	Sicada	2.9	48.7	165.70	21.1	57.7	30.4	38.2	32.0	27.27
22	set 1	521.927	Sicada	10.7	162.7	193.40	71.8	80.7	30.0	31.4	34.0	27.27
23	set 2	528.002	Sicada	2.3	55.3	160.30	23.1	64.8	24.0	45.6	34.0	27.27
24	set 3	536.602	Sicada	1.4	47.3	71.10	20.5	51.3	31.9	47.6	33.5	27.27
25	set 1	587.423	Sicada	3.2	161.7	612.50	77.3	58.5	28.6	44.8	33.5	27.86
26	set 2	587.541	Sicada	2.4	53.7	160.40	24.6	70.2	27.8	44.8	33.2	27.86
27	set 3	590.241	Sicada	2.2	50.7	151.60	22.8	66.0	27.3	42.0	34.0	27.86
28	set 1	642.381	Sicada	4.1	162.3	459.30	72.1	64.2	38.8	49.8	32.3	27.86
29	set 2	645.559	Sicada	2.8	61.3	186.90	29.6	75.3	32.4	49.0	31.2	27.86
30	set 3	643.142	Sicada	1.6	46.0	241.40	21.7	50.8	19.1	49.0	30.7	27.86
31	set 1	692.218	Sicada	8.8	208.0	517.86	106.8	68.5	34.0	51.4	30.0	27.86
32	set 2	690.575	Sicada	1.8	114.3	282.50	52.0	56.7	29.6	49.8	29.5	27.86
33	set 3	695.831	Sicada	1.2	48.0	148.35	23.5	40.0	38.7	50.6	31.3	27.86
34	set 1	733.167	Sicada	4.1	116.0	250.36	58.7	61.2	26.2	46.6	29.3	28.12
35	set 2	717.392	Sicada	1.6	64.7	195.60	28.4	50.0	34.1	48.8	32.0	27.86
36	set 3	717.092	Sicada	1.4	51.0	141.30	22.8	66.3	38.7	49.8	31.5	27.86
37	set 1	793.533	Sicada	1.9	79.0	151.10	38.4	56.5	39.8	49.0	31.2	28.12
38	set 2	792.715	Sicada	1.1	55.3	176.10	26.1	40.3	32.8	49.0	30.2	28.12
39	set 3	795.164	Sicada	1.1	44.7	218.27	20.6	47.7	39.6	49.0	32.8	28.12
40	set 1	846.680	Sicada	1.9	102.0	255.29	49.6	65.7	37.6	49.0	29.5	27.79
41	set 2	845.546	Sicada	1.3	44.6	222.58	35.7	72.5	34.5	50.0	30.8	27.79
42	set 3	846.935	Sicada	1.2	48.0	130.84	26.7	61.2	42.7	48.8	30.8	27.79
43	set 1	898.592	Sicada	2.3	126.0	257.80	59.3	71.0	40.6	48.0	30.7	28.44
44	set 2	899.130	Sicada	3.7	89.3	240.60	39.3	64.5	38.5	48.0	31.0	28.44
45	set 3	901.699	Sicada	0.8	43.0	133.03	22.3	48.2	44.0	48.8	30.0	28.44
46	set 1	961.825	Sicada	1.3	115.0	162.37	53.3	54.2	39.2	49.6	32.0	28.44
47	set 2	963.038	Sicada	2.5	57.0	192.30	27.5	66.5	45.8	47.2	32.2	28.44
48	set 3	985.593	Sicada	1.4	47.7	158.40	21.7	53.8	45.7	50.0	32.8	28.44
			Arithmetic a	2.4	85.2	224.2	40.2	61.2	34.0	46.5	31.5	27.7
			maximum v	0.8	42.7	71.1	19.7	40.0	19.1	31.4	27.7	27.0
			minimum v	10.7	277.0	612.5	125.7	80.7	45.8	51.4	35.0	28.4

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3

Operator: PC

Date: 16.09.2003

OUTPUT DATA

Depth zone:

80 -1000 m

Borehole: KSH02

F:\P\2003\10\20031089\Reports\Rap KSH02\alljoints.xls]OUTPUT DATA

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS ₀ (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC ₀ AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC ₁₀₀ VALUES 100 mm	EXTRPL'D JCS ₁₀₀ VALUES 100 mm (MPa)
1	set 1	274.890	100.82	1.41E-04	29.5	4.96	0.90	5.01	102.39
2	set 2	292.822	46.86	2.68E-04	23.2	4.92	1.46	4.74	44.29
3	set 3	265.110	56.75	5.85E-05	26.5	7.21	2.34	6.38	47.21
4	set 1	278.733	59.61	1.25E-04	24.1	5.47	0.62	5.77	64.53
5	set 2	299.142	60.93	1.92E-04	30.2	4.93	1.75	4.67	56.11
6	set 3	281.810	44.60	1.33E-04	24.0	7.05	1.61	6.60	40.36
7	set 1	316.578	71.65	2.98E-05	29.8	7.25	0.71	7.62	77.20
8	set 2	312.807	118.54	7.31E-05	30.7	6.48	1.82	6.00	105.53
9	set 3	305.256	84.42	1.31E-04	26.0	6.17	2.14	5.61	73.33
10	set 1	369.969	61.98	7.90E-05	22.3	6.01	0.36	6.79	74.48
11	set 2	371.456	85.43	1.25E-04	25.7	6.62	1.36	6.36	80.32
12	set 3	362.241	47.58	1.35E-04	22.6	7.42	2.22	6.59	39.83
13	set 1	421.188	45.74	1.36E-04	18.9	8.52	0.87	8.71	47.33
14	set 2	421.035	65.57	1.88E-04	24.0	6.14	1.69	5.75	59.50
15	set 3	423.044	59.59	1.23E-04	21.9	7.23	2.27	6.42	49.86
16	set 1	497.842	56.12	1.59E-04	25.4	5.21	1.01	5.21	56.06
17	set 2	510.246	59.31	1.49E-04	34.6	5.02	1.75	4.75	54.54
18	set 3	480.478	55.50	2.02E-04	23.3	8.16	2.05	7.26	46.54
19	set 1	480.777	74.80	3.97E-05	29.0	5.95	0.59	6.34	82.26
20	set 2	488.063	69.43	1.07E-04	28.1	6.64	1.86	6.11	61.34
21	set 3	512.390	54.89	2.20E-04	27.9	5.52	2.05	5.10	48.73
22	set 1	521.927	53.69	6.90E-06	33.1	6.91	0.61	7.39	59.39
23	set 2	528.002	38.44	1.23E-04	24.5	7.34	1.81	6.72	33.74
24	set 3	536.602	59.64	1.33E-04	26.9	4.32	2.11	4.05	54.13
25	set 1	587.423	51.43	2.12E-04	26.3	5.99	0.62	6.34	56.06
26	set 2	587.541	49.15	7.34E-05	25.6	7.65	1.86	6.96	42.62
27	set 3	590.241	47.79	1.08E-04	27.0	6.91	1.97	6.29	41.51
28	set 1	642.381	91.46	1.18E-04	27.9	6.17	0.62	6.55	100.04
29	set 2	645.559	63.73	3.99E-05	24.4	8.20	1.63	7.57	56.50
30	set 3	643.142	30.08	4.36E-04	18.5	6.68	2.17	6.02	25.75
31	set 1	692.218	69.75	6.39E-05	23.2	7.50	0.48	8.37	82.24
32	set 2	690.575	54.41	1.61E-04	21.4	6.39	0.87	6.50	55.82
33	set 3	695.831	90.95	3.63E-04	26.6	2.48	2.08	2.39	86.11
34	set 1	733.167	45.53	9.71E-05	20.5	7.17	0.86	7.32	47.01
35	set 2	717.392	69.95	2.79E-04	26.0	4.45	1.55	4.28	66.00
36	set 3	717.092	90.95	9.82E-05	27.0	6.58	1.96	6.02	79.63
37	set 1	793.533	98.83	1.18E-04	27.4	4.90	1.27	4.79	95.46
38	set 2	792.715	66.32	3.85E-04	23.6	3.19	1.81	3.07	62.66
39	set 3	795.164	97.71	4.71E-04	29.0	3.52	2.24	3.33	89.73
40	set 1	846.680	85.02	8.55E-05	24.8	6.81	0.98	6.83	85.36
41	set 2	845.546	71.20	5.53E-05	24.6	7.84	2.24	6.91	58.88
42	set 3	846.935	113.30	1.12E-04	28.3	5.48	2.08	5.05	100.43
43	set 1	898.592	106.20	4.52E-05	27.6	6.81	0.79	7.03	111.33
44	set 2	899.130	94.09	1.11E-04	27.0	6.32	1.12	6.23	92.09
45	set 3	901.699	129.18	2.60E-04	28.0	3.54	2.33	3.33	118.10
46	set 1	961.825	97.96	1.02E-04	27.8	4.41	0.87	4.47	99.79
47	set 2	963.038	142.89	1.09E-04	31.6	5.71	1.75	5.35	129.78
48	set 3	985.593	142.48	2.50E-04	31.1	3.95	2.10	3.72	130.52
		Arithmetic av.	73.59	1.51E-04	26.20	6.04	1.50	5.85	70.26
		maximum val.	142.89	4.71E-04	34.58	8.52	2.34	8.71	130.52
		minimum val.	30.08	6.90E-06	18.50	2.48	0.36	2.39	25.75

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	16.09.2003
Borehole:	KSH02

INPUT DATA Depth zone: 80 - 1000 m

F:\P\2003\10\20031089\Reports\Rap KSH02\set1.xls\INPUT DATA 1

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT		MASS m (g)	AREA A (cm ²)	MEAN TILT ANGLE (°)	JOINT REBOUND NUMBER (r)	ROCK REBOUND NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m ³)
				AMP. a (mm)	LENG. L (mm)							
1	set 1	274.890	Sicada	2.6	111.0	289.70	55.1	58.5	41.8	47.0	31.7	28.04
2	set 1	278.733	Sicada	2.7	162.0	313.30	80.1	55.2	32.2	49.8	31.2	28.04
3	set 1	316.578	Sicada	4.5	141.0	386.13	74.3	76.0	34.4	46.6	35.0	28.04
4	set 1	369.969	Sicada	2.8	277.0	354.70	125.7	57.7	32.0	45.8	28.3	28.04
5	set 1	421.188	Sicada	2.4	114.3	433.28	51.6	66.0	26.6	50.0	28.3	27.78
6	set 1	497.842	Sicada	1.9	99.3	220.30	46.3	54.3	30.8	43.4	31.2	27.27
7	set 1	480.777	Sicada	2.8	170.3	174.30	69.6	66.3	36.0	43.2	32.3	27.27
8	set 1	521.927	Sicada	10.7	162.7	193.40	71.8	80.7	30.0	31.4	34.0	27.27
9	set 1	587.423	Sicada	3.2	161.7	612.50	77.3	58.5	28.6	44.8	33.5	27.86
10	set 1	642.381	Sicada	4.1	162.3	459.30	72.1	64.2	38.8	49.8	32.3	27.86
11	set 1	692.218	Sicada	8.8	208.0	517.86	106.8	68.5	34.0	51.4	30.0	27.86
12	set 1	733.167	Sicada	4.1	116.0	250.36	58.7	61.2	26.2	46.6	29.3	28.12
13	set 1	793.533	Sicada	1.9	79.0	151.10	38.4	56.5	39.8	49.0	31.2	28.12
14	set 1	846.680	Sicada	1.9	102.0	255.29	49.6	65.7	37.6	49.0	29.5	27.79
15	set 1	898.592	Sicada	2.3	126.0	257.80	59.3	71.0	40.6	48.0	30.7	28.44
16	set 1	961.825	Sicada	1.3	115.0	162.37	53.3	54.2	39.2	49.6	32.0	28.44
Arithmetic av.				3.6	144.2	314.5	68.1	63.4	34.3	46.6	31.3	27.9
maximum val.				1.3	79.0	151.1	38.4	54.2	26.2	31.4	28.3	27.3
minimum val.				10.7	277.0	612.5	125.7	80.7	40.6	51.4	35.0	28.4

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3	
Operator:	PC
Date:	16.09.2003
Borehole:	KSH02

OUTPUT DATA Depth zone: 80 - 1000 m

F:\P\2003\10\20031089\Reports\Rap KSH02\set1.xls\OUTPUT DATA

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS ₀ (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC ₀ AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC ₁₀₀ VALUES 100 mm	EXTRPL'D JCS ₁₀₀ VALUES 100 mm (MPa)
2	set 1	278.733	63.76	1.25E-04	24.1	5.44	0.62	5.74	68.98
3	set 1	316.578	72.25	2.98E-05	29.8	7.24	0.71	7.61	77.85
4	set 1	369.969	63.04	7.90E-05	22.3	6.00	0.36	6.78	75.73
5	set 1	421.188	45.74	1.36E-04	18.9	8.52	0.87	8.71	47.33
6	set 1	497.842	56.12	1.59E-04	25.4	5.21	1.01	5.21	56.06
7	set 1	480.777	74.80	3.97E-05	29.0	5.95	0.59	6.34	82.26
8	set 1	521.927	53.69	6.90E-06	33.1	6.91	0.61	7.39	59.39
9	set 1	587.423	51.43	2.12E-04	26.3	5.99	0.62	6.34	56.06
10	set 1	642.381	91.46	1.18E-04	27.9	6.17	0.62	6.55	100.04
11	set 1	692.218	69.75	6.39E-05	23.2	7.50	0.48	8.37	82.24
12	set 1	733.167	45.53	9.71E-05	20.5	7.17	0.86	7.32	47.01
13	set 1	793.533	98.83	1.18E-04	27.4	4.90	1.27	4.79	95.46
14	set 1	846.680	85.02	8.55E-05	24.8	6.81	0.98	6.83	85.36
15	set 1	898.592	106.20	4.52E-05	27.6	6.81	0.79	7.03	111.33
16	set 1	961.825	97.96	1.02E-04	27.8	4.41	0.87	4.47	99.79
Arithmetic av.			74.10	9.74E-05	26.11	6.25	0.76	6.53	78.54
maximum val.			110.01	2.12E-04	33.11	8.52	1.27	8.71	111.72
minimum val.			45.53	6.90E-06	18.94	4.41	0.36	4.47	47.01

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	16.09.2003
Borehole:	KSH02

INPUT DATA Depth zone: 80 - 1000 m

F:\P\2003\10\20031089\Reports\Rap KSH02\set2.xls\INPUT DATA 1

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT		MASS m (g)	AREA A (cm ²)	MEAN TILT ANGLE (°)	JOINT REBOUN NUMBER (r)	ROCK REBOUN NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m ³)
				AMP. a (mm)	LENG. L (mm)							
1	set 2	292.822	Sicada	2.0	68.3	193.90	30.5	49.0	27.8	51.0	32.3	27.01
2	set 2	299.142	Sicada	2.1	57.3	174.15	26.0	57.3	32.6	38.0	33.0	27.01
3	set 2	312.807	Sicada	1.7	55.0	176.45	25.1	71.0	43.3	48.0	32.7	27.92
4	set 2	371.456	Sicada	2.3	73.3	238.70	35.1	64.3	37.7	50.4	30.7	27.78
5	set 2	421.035	Sicada	1.8	59.0	194.10	28.5	58.0	33.0	46.2	29.7	27.78
6	set 2	510.246	Sicada	1.4	57.3	177.10	24.6	62.7	31.8	32.0	34.7	27.27
7	set 2	488.063	Sicada	1.8	53.7	164.40	23.6	66.7	34.7	42.2	31.7	27.27
8	set 2	528.002	Sicada	2.3	55.3	160.30	23.1	64.8	24.0	45.6	34.0	27.27
9	set 2	587.541	Sicada	2.4	53.7	160.40	24.6	70.2	27.8	44.8	33.2	27.86
10	set 2	645.559	Sicada	2.8	61.3	186.90	29.6	75.3	32.4	49.0	31.2	27.86
11	set 2	690.575	Sicada	1.8	114.3	282.50	52.0	56.7	29.6	49.8	29.5	27.86
12	set 2	717.392	Sicada	1.6	64.7	195.60	28.4	50.0	34.1	48.8	32.0	27.86
13	set 2	792.715	Sicada	1.1	55.3	176.10	26.1	40.3	32.8	49.0	30.2	28.12
14	set 2	845.546	Sicada	1.3	44.6	222.58	35.7	72.5	34.5	50.0	30.8	27.79
15	set 2	899.130	Sicada	3.7	89.3	240.60	39.3	64.5	38.5	48.0	31.0	28.44
16	set 2	963.038	Sicada	2.5	57.0	192.30	27.5	66.5	45.8	47.2	32.2	28.44
Arithmetic av.				2.0	63.7	196.0	30.0	61.9	33.8	46.3	31.8	27.7
maximum val.				1.1	44.6	160.3	23.1	40.3	24.0	32.0	29.5	27.0
minimum val.				3.7	114.3	282.5	52.0	75.3	45.8	50.4	34.7	28.4

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3	
Operator:	PC
Date:	16.09.2003
Borehole:	KSH02

OUTPUT DATA Depth zone: 80 - 1000 m

F:\P\2003\10\20031089\Reports\Rap KSH02\set2.xls\OUTPUT DATA

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS ₀ (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC ₀ AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC ₁₀₀ -VALUES 100 mm	EXTRPL'D JCS ₁₀₀ -VALUES 100 mm (MPa)
2	set 2	299.142	60.93	1.92E-04	30.2	4.93	1.75	4.67	56.11
3	set 2	312.807	118.54	7.31E-05	30.7	6.48	1.82	6.00	105.53
4	set 2	371.456	85.43	1.25E-04	25.7	6.62	1.36	6.36	80.32
5	set 2	421.035	65.57	1.88E-04	24.0	6.14	1.69	5.75	59.50
6	set 2	510.246	59.31	1.49E-04	34.6	5.02	1.75	4.75	54.54
7	set 2	488.063	69.43	1.07E-04	28.1	6.64	1.86	6.11	61.34
8	set 2	528.002	38.44	1.23E-04	24.5	7.34	1.81	6.72	33.74
9	set 2	587.541	49.15	7.34E-05	25.6	7.65	1.86	6.96	42.62
10	set 2	645.559	63.73	3.99E-05	24.4	8.20	1.63	7.57	56.50
11	set 2	690.575	54.41	1.61E-04	21.4	6.39	0.87	6.50	55.82
12	set 2	717.392	69.95	2.79E-04	26.0	4.45	1.55	4.28	66.00
13	set 2	792.715	66.32	3.85E-04	23.6	3.19	1.81	3.07	62.66
14	set 2	845.546	71.20	5.53E-05	24.6	7.84	2.24	6.91	58.88
15	set 2	899.130	94.09	1.11E-04	27.0	6.32	1.12	6.23	92.09
16	set 2	963.038	142.89	1.09E-04	31.6	5.71	1.75	5.35	129.78
Arithmetic av.			72.27	1.52E-04	26.57	6.12	1.65	5.75	66.23
maximum val.			142.89	3.85E-04	34.58	8.20	2.24	7.57	129.78
minimum val.			38.44	3.99E-05	21.39	3.19	0.87	3.07	33.74

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	16.09.2003
Borehole:	KSH02

INPUT DATA Depth zone: 80 - 1000 m

F:\P\2003\10\20031089\Reports\Rap KSH02\set3.xls\INPUT DATA 1

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT		MASS m (g)	AREA A (cm ²)	MEAN TILT ANGLE (°)	JOINT REBOUN NUMBER (r)	ROCK REBOUN NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m ³)
				AMP. a (mm)	LENG. L (mm)							
1	set 3	265.110	Sicada	2.0	42.7	97.70	19.7	69.7	31.3	41.6	31.5	27.01
2	set 3	281.810	Sicada	2.0	62.3	229.24	34.8	63.0	26.9	45.8	32.3	27.01
3	set 3	305.256	Sicada	1.2	46.7	125.10	20.9	61.8	37.3	49.8	31.0	27.92
4	set 3	362.241	Sicada	1.1	45.0	148.00	21.1	63.7	27.3	47.2	31.0	27.92
5	set 3	423.044	Sicada	1.9	44.0	123.20	20.3	63.0	31.3	44.2	27.7	27.78
6	set 3	480.478	Sicada	1.9	48.7	308.40	21.6	67.7	30.6	46.0	30.0	27.27
7	set 3	512.390	Sicada	2.9	48.7	165.70	21.1	57.7	30.4	38.2	32.0	27.27
8	set 3	536.602	Sicada	1.4	47.3	71.10	20.5	51.3	31.9	47.6	33.5	27.27
9	set 3	590.241	Sicada	2.2	50.7	151.60	22.8	66.0	27.3	42.0	34.0	27.86
10	set 3	643.142	Sicada	1.6	46.0	241.40	21.7	50.8	19.1	49.0	30.7	27.86
11	set 3	695.831	Sicada	1.2	48.0	148.35	23.5	40.0	38.7	50.6	31.3	27.86
12	set 3	717.092	Sicada	1.4	51.0	141.30	22.8	66.3	38.7	49.8	31.5	27.86
13	set 3	795.164	Sicada	1.1	44.7	218.27	20.6	47.7	39.6	49.0	32.8	28.12
14	set 3	846.935	Sicada	1.2	48.0	130.84	26.7	61.2	42.7	48.8	30.8	27.79
15	set 3	901.699	Sicada	0.8	43.0	133.03	22.3	48.2	44.0	48.8	30.0	28.44
16	set 3	985.593	Sicada	1.4	47.7	158.40	21.7	53.8	45.7	50.0	32.8	28.44
Arithmetic av.				1.6	47.8	162.0	22.6	58.2	33.9	46.8	31.4	27.7
maximum val.				0.8	42.7	71.1	19.7	40.0	19.1	38.2	27.7	27.0
minimum val.				2.9	62.3	308.4	34.8	69.7	45.7	50.6	34.0	28.4

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3

Operator:	PC
Date:	16.09.2003
Borehole:	KSH02

OUTPUT DATA Depth zone: 80 - 1000 m

F:\P\2003\10\20031089\Reports\Rap KSH02\set3.xls\OUTPUT DATA

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS ₀ (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC ₀ AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC ₁₀₀ VALUES 100 mm	EXTRPL'D JCS ₁₀₀ VALUES 100 mm (MPa)
2	set 3	281.810	44.60	1.33E-04	24.0	7.05	1.61	6.60	40.36
3	set 3	305.256	84.42	1.31E-04	26.0	6.17	2.14	5.61	73.33
4	set 3	362.241	47.95	1.35E-04	22.6	7.41	2.22	6.58	40.15
5	set 3	423.044	59.59	1.23E-04	21.9	7.23	2.27	6.42	49.86
6	set 3	480.478	55.50	2.02E-04	23.3	8.16	2.05	7.26	46.54
7	set 3	512.390	54.89	2.20E-04	27.9	5.52	2.05	5.10	48.73
8	set 3	536.602	59.64	1.33E-04	26.9	4.32	2.11	4.05	54.13
9	set 3	590.241	47.79	1.08E-04	27.0	6.91	1.97	6.29	41.51
10	set 3	643.142	30.08	4.36E-04	18.5	6.68	2.17	6.02	25.75
11	set 3	695.831	90.95	3.63E-04	26.6	2.48	2.08	2.39	86.11
12	set 3	717.092	90.95	9.82E-05	27.0	6.58	1.96	6.02	79.63
13	set 3	795.164	97.71	4.71E-04	29.0	3.52	2.24	3.33	89.73
14	set 3	846.935	113.30	1.12E-04	28.3	5.48	2.08	5.05	100.43
15	set 3	901.699	129.18	2.60E-04	28.0	3.54	2.33	3.33	118.10
16	set 3	985.593	142.48	2.50E-04	31.1	3.95	2.10	3.72	130.52
Arithmetic av.			75.36	2.02E-04	25.91	5.76	2.11	5.26	67.01
maximum val.			142.48	4.71E-04	31.08	8.16	2.34	7.26	130.52
minimum val.			30.08	5.85E-05	18.50	2.48	1.61	2.39	25.75