P-04-08

Forsmark site investigation

Borehole: KFM02A

Results of tilt testing

Panayiotis Chryssanthakis
Norwegian Geotechnical Institute, Oslo

May 2004

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

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Keywords: Rock mechanics, Joint properties, JRC_{100}, JCS_{100}, Angles of joint friction and tilt test.

Summary

The Norwegian Geotechnical Institute (NGI) has carried out tilt testing on joint surfaces of drill cores from borehole KFM02A, Forsmark during the period 10–18 June 2003. From a total drill core length of about 902 m, 40 tilt tests were performed 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 5.8. The mean value of the joint wall compressive strength (JCS_o) from Schmidt hammer testing of all the joint samples is 81.5 MPa. The mean values of the basic (Φ_b) and residual (Φ_r) friction angles of all the tested samples are 31.2 and 26.7 degrees respectively.

Sammanfattning

Norges Geotekniska Institut (NGI) har gjort sk tilttester på öppna sprickor i borrkärneprover från borrhål KFM02A i Forsmark. Utifrån en sammanlagd borrkärnelängd på ca 902 m utvaldes 40 prover för tilttester som utfördes på tre sprickgrupper.

Huvudresultaten är relativt enhetliga för samtliga sprickor och uppvisar inga stora variationer. Medelvärdet för råhetskoefficienten, JRC_o, för alla sprickor är 5,8. För sprickväggens tryckhållfasthet, JCS_0, som uppmättes med Schmidthammarprovning, uppgår medelvärdet till 81,5 MPa. Medelvärdet för basfriktionsvinkeln, Φ_b, och residualfriktionsvinkeln Φ_r, beräknat utifrån alla testade prover, är 32,1 respektive 26,7 grader.

Contents

1 Introduction

The Norwegian Geotechnical Institute (NGI) has carried out tilt testing on joint surfaces of drill cores from borehole KFM02A at Forsmark in Sweden according to SKB Activity Plan AP 400-03-44 (SKB internal controlling document). The work has been carried out by Panayiotis Chryssanthakis and Pawel Jankowski during the period 10–18 June 2003 in accordance with SKB's method description MD 190.006 Version 1.0 (SKB internal controlling document).

2 Objective and scope

The purpose of the testing is to determine the joint properties JRC and JCS as well as the basic and residual friction angles. The joint properties are parameters used in the rock mechanical model which will be established for the candidate area selected for site investigations at Forsmark.

The number of tests performed and the number of joint sets are given in Table 2-1

Table 2-1. Total number of tilt tests.

Borehole	Tilt tests	No of joint sets
KFM 02A	40	3*

* Joint set 1 (steep joints) represents two joint sets with different dip and dip directions

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 (field note no Forsmark 141).

3 Equipment and methods

The tilt angles (α and Φ_b) are measured by a simple tilt apparatus, see Figure 3-1.

The tilt test apparatus is a self-weight tilt testing machine used for predicting the peak shear strength of a joint. Usually such joints, that are well preserved and considered representative of a joint set to which they belong, are selected for testing. The test consists of forcing the upper half of a jointed specimen to slide under its own weight.

The tilt test table consists of a hand driven rotating apparatus attached to an aluminium frame which is able to rotate 90 degrees in both directions (see Figure 3-1). The specimen is attached to a simple workshop clamp fastened upon the tilt test table. The joint area is then levelled to zero degrees before the tilt testing can start, (see Figure 3-1) The angle of tilting (α) can be read from a protractor attached to the rotating apparatus. The mass of the upper joint half and the fracture surface area are measured before tilt testing.

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

The profiling is carried out by means of a profilometer, see Figure 3-3. In addition, a planimeter is necessary to measure the area of the fracture face.

Figure 3-1. *NGI´s Tilt test apparatus.*

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

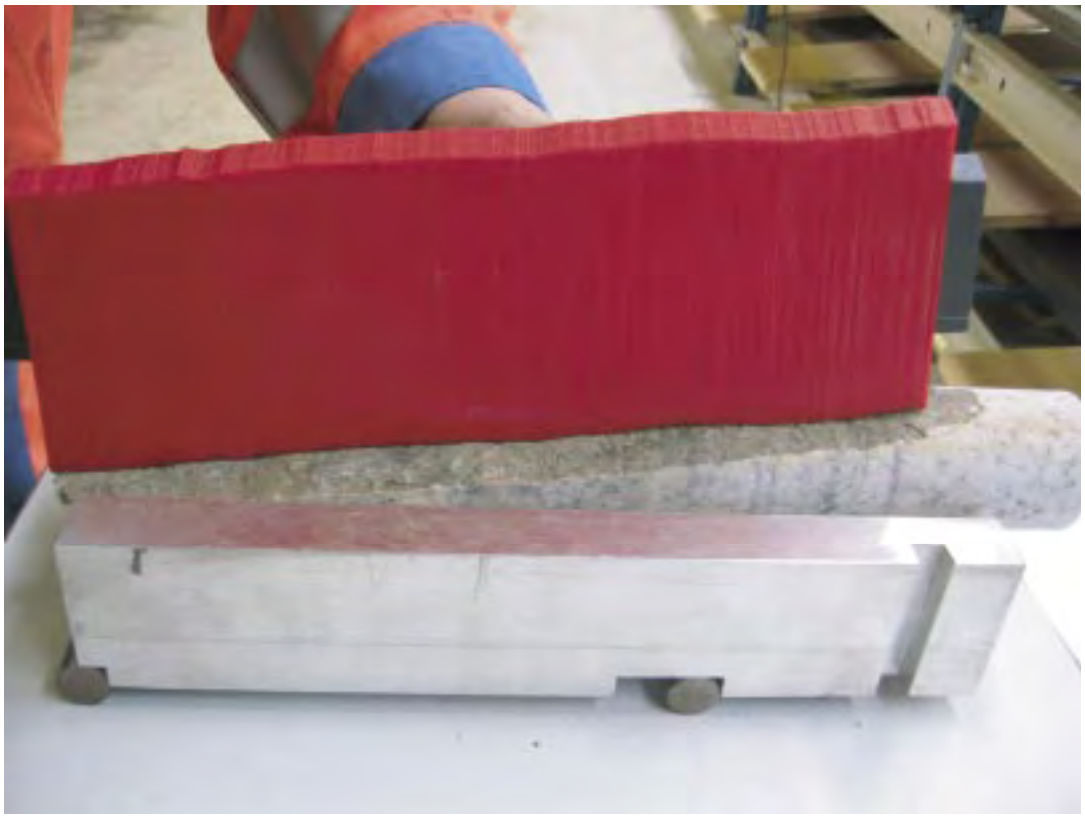

Figure 3-3. *Profilometer applied on a joint surface.*

4 Execution

4.1 The sampling

The samples were taken from drill cores with a diameter of approximately 50 mm in such a way that each sample contained both faces of a joint, see Figure 4-1. To prepare the sample, sawing is usually necessary.

The frequency of the tilt test samples was determined by choosing one specimen for approximately 15 to 18 m in the depth range between 200 m and 840 m. A total of 40 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 joints was not known, and therefore the various joints, were classified according to their angle of intersection with the core in the way it is displayed in Table 4-1.

Figure 4-1. *Sample for tilt testing in the tilt apparatus.*

Joint set number	Angle of intersection in degrees	Number of tilt tests
Set 1 (steep joints, representing two joint sets)	0–30°	20
Set 2 (ca 45 degrees joints)	30–60°	10
Set 3 (sub-horizontal joints)	60–90°	10

Due to 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 only few horizontal joints were found at depths exceeding 650 m. From the core mapping carried out by SKB, it is believed that there are two different joint sets defined as steep joints. These joints were precipitated with either calcite or chlorite coating. Due to this fact, twice as many specimens defined as steep joints were chosen for tilt testing.

Three profiles on each tilt joint surface have also been carried out. The rocks can be classified as mainly metamorphic including granite, granodiorite, tonalite with same veins of amphibolite, and pegmatite, but since core logging 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 laumontite. All 40 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.

4.2 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, and the tilt angle should not vary more than 3° in these tests. However, in some cases the characteristics of the sample change during testing. For example fracture coating may be removed, and therefore variation of more than 3° may (in some cases) 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 on dry cores with 10 blows. The lower five blow values were again eliminated. It may be noted that the quality of drilling has not been the same in this borehole as in the two previous ones (KFM01A and KSH01A). The core surface wall could be considered as not uniform (straight) and was rather wavy with a typical wave length varying between 20 and 100 cm and wave depth of up to 1.5 mm. Placing such a wavy core on the clamp influences the Schmidt hammer readings, depending on whether one hits a valley or a peak with the Schmidt hammer. However, it is believed that this influence on the R-value measurements is rather limited.

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, 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 samples were taken directly from the racks in the core shed, and consequently the measurements were done on air-dried samples. The unit weight specimens are chosen at approximately 100 m intervals. The specimens are cut as perfect cylinders from which the volumes are calculated. The balance used for weighing the specimens has an accuracy of 0.01g. The calliper used for measuring the size (height and diameter) of the specimens has an accuracy of 0.01 mm. The results were in the range 2.61–2.66 g/cm^3. In the calculations 2.65 g/cm^3 has been used from 200 m and up to 420 m depth, 2.61 g/cm^3 from 420 m to 580 m, while 2.66 g/cm^3 was applied from 580 m to 840 m.

4.3 Nonconformities

None

5 Results from the tilt testing

5.1 General

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

Tables showing all the input and output data are given in Appendix A. Separate tables are presented for each of the three joint sets. A Table displaying all the joint sets is also presented in 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 40 tilt test specimens have been selected from the total of 902.3 m of core material of borehole KFM02A in the depth range between 200 m and 840 m. As mentioned earlier, the fractures were classified in three sets according to the angle of intersection with the core. Joint set 1 (steep joints) represents two joint sets with different dip and dip directions. Each set may, however, consist of fractures with different dip, dip directions and different mineralization.

5.2 Results from Borehole KFM02A

In the depth range 200–840 m from borehole KFM02A, 40 tilt tests and 40x3 profilings on joints have been performed. Complete input data and output data from tilt tests and profiling are found in Appendix A. Figures 5-1, 5-2 and 5-3 show the variation of the parameters JCS_o, JRC_o, Φ_r and Φ_b versus depth for each of the three joint sets respectively. It may be noted from Figures 5-1 and 5-2 that the values of JCS_o at the depths 535.13 m and 508.71 m respectively are higher compared to other values. This may be attributed to a broad range of rebound values for Schmidt hammer measurements at these depths. Since the lower 5 values are usually eliminated (see Section 4.2), the higher values remain for calculation purposes. This may sometimes give a false impression of a fresh joint as in this case. The presence of hard fillings in joints, such as quartz, can also cause higher rebound values resulting in high JCS_o values.

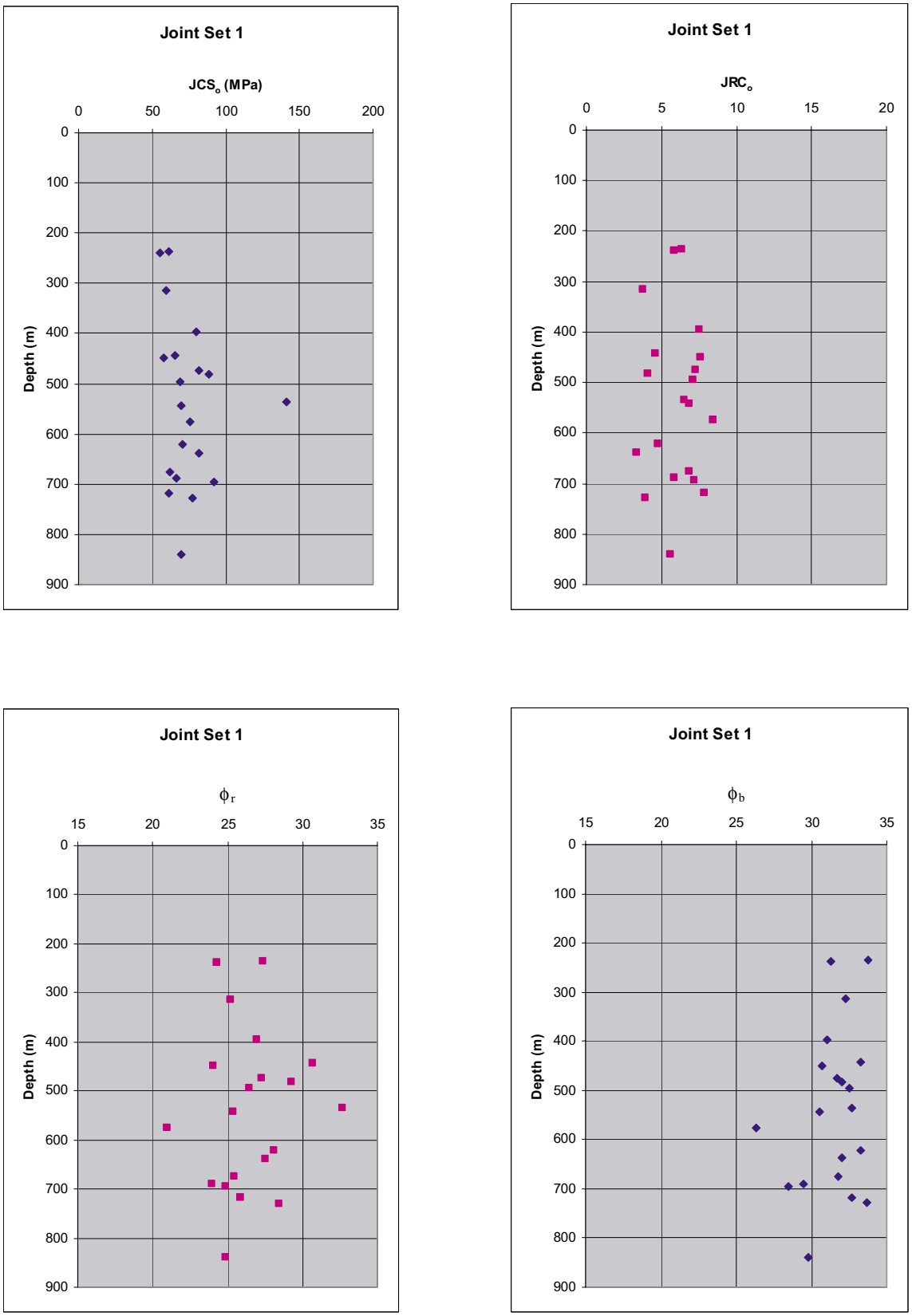

Figure 5-1. *Variation of joint parameters with depth for Set 1.*

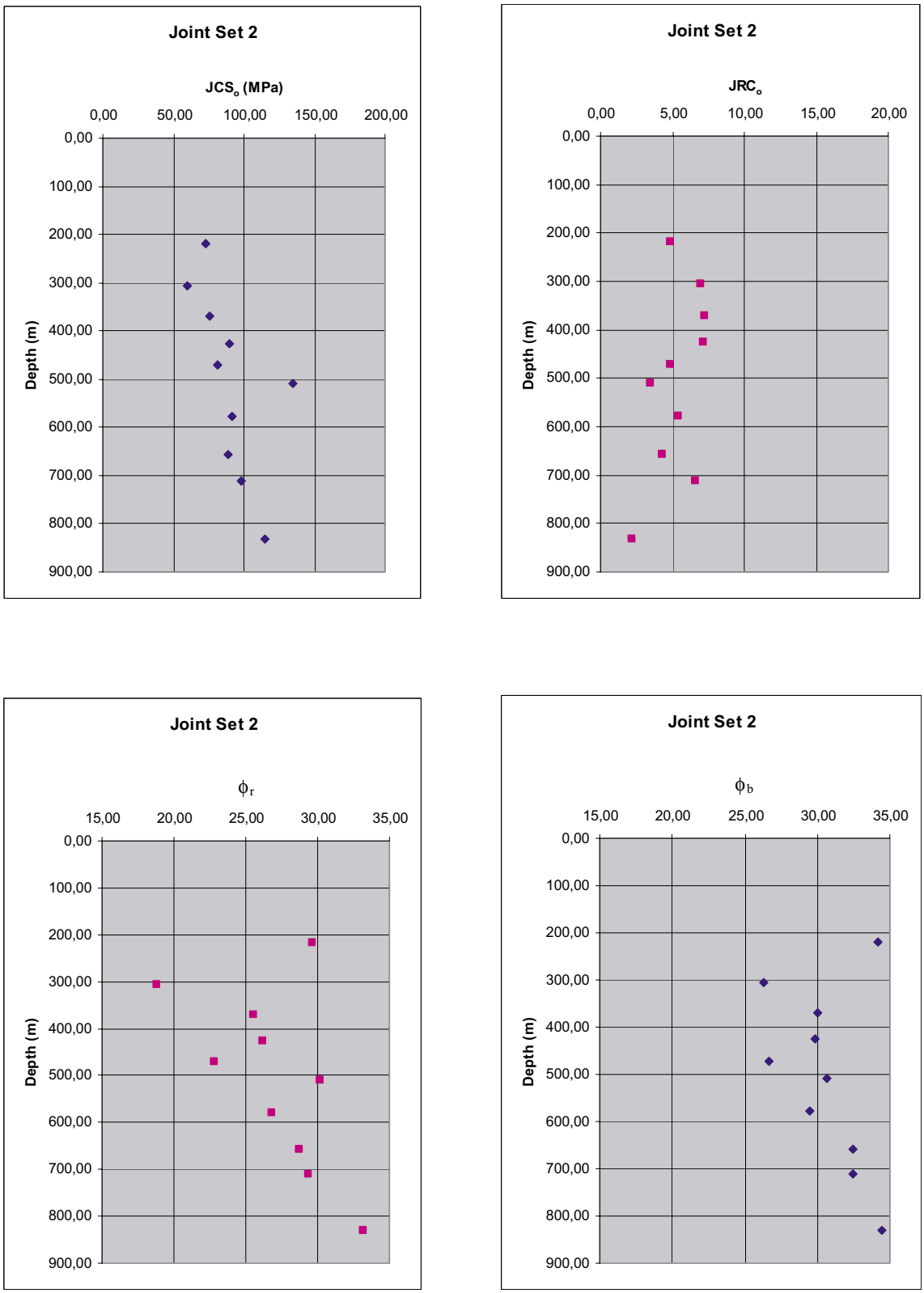

Figure 5-2. *Variation of joint parameters with depth for Set 2.*

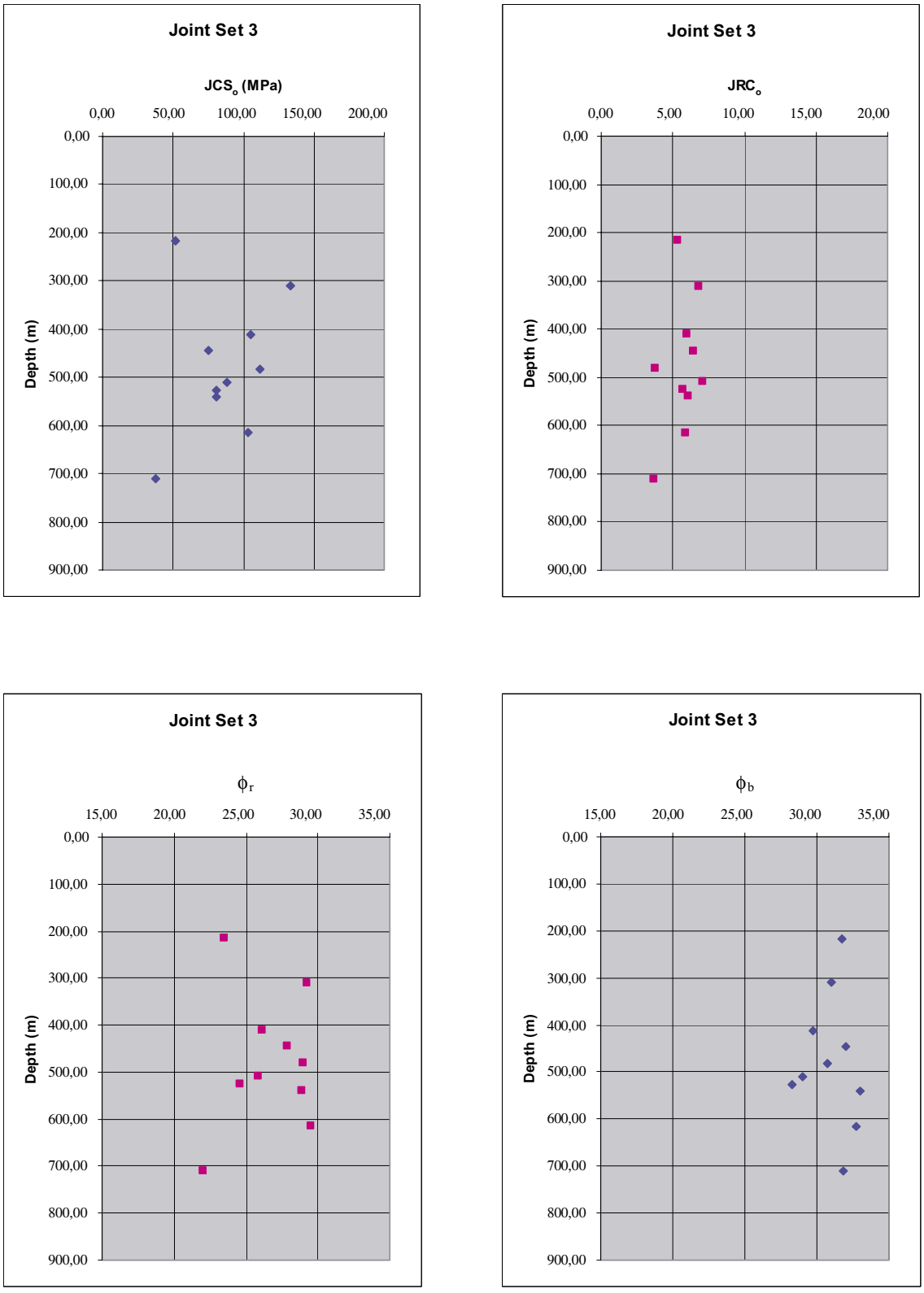

Figure 5-3. *Variation of joint parameters with depth for Set 3.*

Table 5-1 shows the arithmetic mean values of these parameters.

Table 5-1. Arithmetic mean JCS_o, JRC_o, Φ_r and Φ_b -values, Borehole KFM 02A.

Fracture set	JRCo	JCSo (tilt)	Φb (°) MPa	Φr (°)	Number (tilt)	Number (profiles)
Set 1	6.1	74.3	31.5	26.5	20	20
Set 2	5.3	90.7	30.7	27.1	10	10
Set 3	5.7	86.6	31.0	26.7	10	10
Mean/Total	5.8	81.5	31.2	26.7	40	40

5.3 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 2.2 and 8.5. This means that the sample selection for tilt testing is representative for borehole KFM02A.

Appendix A

The main results from tilt testing

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1 | Operator: PC | Date: 25.06.2003 | Borehole: KFM02A

INPUT DATA Depth zone: 100-1002.3 m

F:\P\2003\10\20031089\Reports\Rap KFM02A\[set1.xls]INPUT DATA 1

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT AMP. a (mm)	MEAN JOINT LENG. L (mm)	MASS m (g)	AREA A (cm^2)	MEAN TILT ANGLE (°)	JOINT REBOUN NUMBE (r)	ROCK REBOUND NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m^3)
1	set 1	236.222	Sicada	8.8	225.7	301.78	99.80	66.3	33.4	49.2	33.8	26.516
# 2	set 1	238.421	Sicada	5.2	114.3	321.89	45.50	56.0	31.4	48.2	31.3	26.516
3	set 1	314.731	Sicada	2.1	101.0	281.30	47.90	45.3	32.8	50.8	32.3	26.516
4	set 1	396.442	Sicada	2.3	124.3	299.13	57.50	75.0	38.2	47.8	31.0	26.516
5	set 1	443.261	Sicada	7.2	167.3	250.44	77.60	57.7	35.0	40.2	33.3	26.139
6	set 1	448.928	Sicada	9.1	267.3	565.30	120.30	69.7	32.8	49.2	30.7	26.139
7	set 1	474.684	Sicada	5.5	119.3	299.68	53.40	72.7	39.2	50.2	31.7	26.139
8	set 1	482.357	Sicada	2.0	90.7	317.85	40.70	51.7	40.8	47.2	32.0	26.139
9	set 1	495.517	Sicada	3.9	80.7	127.90	35.10	70.8	36.0	51.6	32.5	26.139
10	set 1	535.135	Sicada	1.8	68.7	241.75	32.80	74.5	49.6	49.6	32.7	26.139
11	set 1	542.780	Sicada	7.3	96.7	190.50	48.30	67.0	36.2	48.8	30.5	26.139
12	set 1	575.198	Sicada	4.0	177.7	419.75	85.50	74.7	37.8	51.4	26.3	26.139
13	set 1	621.431	Sicada	1.9	83.3	116.44	39.90	56.3	36.0	48.6	33.3	26.510
14	set 1	638.051	Sicada	4.2	114.3	331.45	50.60	45.7	38.6	49.6	32.0	26.510
15	set 1	675.216	Sicada	3.6	199.0	328.20	92.50	67.3	33.6	49.2	31.8	26.510
16	set 1	689.272	Sicada	4.7	287.0	687.12	119.10	57.0	34.8	48.0	29.5	26.510
17	set 1	717.388	Sicada	4.1	142.0	353.40	66.20	74.7	33.4	50.6	32.7	26.510
18	set 1	694.424	Sicada	2.8	172.3	250.70	78.60	71.5	40.8	49.8	28.5	26.510
19	set 1	839.537	Sicada	3.8	117.7	296.60	48.20	56.2	35.6	47.2	29.8	26.570
20	set 1	729.197	Sicada	4.0	280.7	984.80	120.40	49.3	37.6	51.0	33.7	26.570
			Arithmetic a	4.4	151.5	348.3	68.0	63.0	36.7	48.9	31.5	26.369
			maximum v	9.1	287.0	984.8	120.4	75.0	49.6	51.6	33.7	26.570
			minimum va	1.8	68.7	116.4	32.8	45.3	31.4	40.2	26.3	26.139

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3 | Operator: PC | Date: 25.06.2003 | Borehole: KFM02A

OUTPUT DATA Depth zone: 100-1002.3 m

F:\P\2003\10\20031089\Reports\Rap KFM02A\[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)
1	set 1	236.222	61.57	4.79E-05	27.4	6.37	0.44	7.07	71.93
2	set 1	238.421	55.30	2.17E-04	24.3	5.86	0.87	5.95	56.61
3	set 1	314.731	59.62	2.85E-04	25.2	3.78	0.99	3.78	59.68
4	set 1	396.442	79.68	3.42E-05	27.0	7.54	0.80	7.79	83.70
5	set 1	443.261	65.33	9.04E-05	30.7	4.61	0.60	4.83	70.14
6	set 1	448.928	58.14	5.55E-05	24.0	7.59	0.37	8.81	72.72
7	set 1	474.684	81.60	4.87E-05	27.3	7.29	0.84	7.48	84.81
8	set 1	482.357	88.82	2.94E-04	29.3	4.09	1.10	4.06	87.76
9	set 1	495.517	68.88	3.86E-05	26.5	7.09	1.24	6.88	65.81
10	set 1	535.135	141.55	5.16E-05	32.7	6.49	1.46	6.18	131.57
11	set 1	542.780	69.61	5.91E-05	25.3	6.86	1.03	6.83	69.13
12	set 1	575.198	75.77	3.35E-05	21.0	8.45	0.56	9.31	87.66
13	set 1	621.431	70.77	8.81E-05	28.1	4.77	1.20	4.69	68.94
14	set 1	638.051	81.38	3.13E-04	27.6	3.35	0.87	3.38	82.48
15	set 1	675.216	62.21	5.18E-05	25.5	6.88	0.50	7.57	71.71
16	set 1	689.272	66.35	1.68E-04	24.0	5.90	0.35	6.68	79.95
17	set 1	717.388	61.54	3.65E-05	25.9	7.84	0.70	8.28	66.83
18	set 1	694.424	91.58	3.15E-05	24.9	7.21	0.58	7.80	103.02
19	set 1	839.537	69.56	1.87E-04	24.9	5.62	0.85	5.72	71.50
20	set 1	729.197	77.47	3.41E-04	28.4	3.89	0.36	4.22	87.40
		Arithmetic av.	74.34	1.24E-04	26.50	6.07	0.79	6.37	78.67
		maximum val.	141.55	3.41E-04	32.70	8.45	1.46	9.31	131.57
		minimum val.	55.30	3.15E-05	21.01	3.35	0.35	3.38	56.61

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

	PAGE 1	
	Operator:	PC
	Date:	25.06.2003
	Borehole:	KFM02A

INPUT DATA

Depth zone: 100-1002.3 m

F:\P\2003\10\20031089\Reports\Rap KFM02A\[set2.xls]INPUT DATA 1

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT AMP. a (mm)	MEAN JOINT LENG. L (mm)	MASS m (g)	AREA A (cm^2)	MEAN TILT ANGLE (°)	JOINT REBOUN NUMBE (r)	ROCK REBOUND NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m^3)
1	set 2	218.129	Sicada	5.3	84.0	324.70	35.60	56.2	36.5	47.2	34.2	26.516
2	set 2	306.638	Sicada	1.8	87.7	303.90	37.60	56.7	33.0	52.8	26.3	26.516
3	set 2	369.896	Sicada	2.6	58.7	202.23	29.10	68.3	37.3	48.0	30.0	26.516
4	set 2	425.814	Sicada	1.6	50.7	136.70	23.40	70.3	40.9	49.8	29.8	26.139
5	set 2	471.532	Sicada	2.7	76.7	234.20	36.30	49.7	39.1	48.4	26.7	26.139
6	set 2	508.706	Sicada	3.8	80.0	233.20	36.60	50.3	48.6	50.0	30.7	26.139
7	set 2	578.489	Sicada	3.4	67.3	257.33	30.40	57.0	41.3	47.8	29.5	26.139
8	set 2	657.840	Sicada	2.4	74.7	245.34	33.60	52.3	40.3	49.8	32.5	26.510
9	set 2	710.468	Sicada	1.8	50.3	207.38	25.30	68.8	42.1	49.8	32.5	26.510
10	set 2	830.945	Sicada	3.1	52.0	154.97	24.10	45.2	45.0	48.2	34.5	26.570
			Arithmetic a	2.9	68.2	230.0	31.2	57.5	40.4	49.2	30.7	26.369
			maximum v	3.8	87.7	303.9	37.6	70.3	48.6	52.8	34.5	26.570
			minimum va	1.6	50.3	136.7	23.4	45.2	33.0	47.8	26.3	26.139

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

	PAGE 3	
	Operator:	PC
	Date:	25.06.2003
	Borehole:	KFM02A

OUTPUT DATA

Depth zone: 100-1002.3 m

F:\P\2003\10\20031089\Reports\Rap KFM02A\[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)
1	set 2	218.129	72.73	2.77E-04	29.7	4.90	1.19	4.81	70.89
2	set 2	306.638	60.26	2.39E-04	18.8	7.02	1.14	6.89	58.62
3	set 2	369.896	75.92	9.32E-05	25.5	7.23	1.70	6.70	67.63
4	set 2	425.814	89.29	6.51E-05	26.2	7.18	1.97	6.51	77.13
5	set 2	471.532	81.17	2.65E-04	22.9	4.89	1.30	4.77	78.07
6	set 2	508.706	134.25	2.55E-04	30.1	3.52	1.25	3.47	131.12
7	set 2	578.489	91.20	2.46E-04	26.8	5.43	1.49	5.20	85.51
8	set 2	657.840	89.16	2.68E-04	28.7	4.28	1.34	4.17	85.88
9	set 2	710.468	98.21	1.05E-04	29.4	6.60	1.99	6.03	85.72
10	set 2	830.945	115.08	3.13E-04	33.2	2.16	1.92	2.10	110.30
	Arithmetic av.	507.846	90.7	2.13E-04	27.1	5.3	1.5	5.06	85.086
maximum val.	maximum val.	830.945	134.2	3.13E-04	33.2	7.2	2.0	6.89	131.120
minimum val.	minimum val.	306.638	60.3	6.51E-05	18.8	2.2	1.1	2.10	58.617

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	25.06.2003
Borehole:	KFM02A

INPUT DATA

Depth zone: 100-1002.3 m

F:\P\2003\10\20031089\Reports\Rap KFM02A\[set3.xls]INPUT DATA 1

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT AMP. a (mm)	MEAN JOINT LENG. L (mm)	MASS m (g)	AREA A (cm^2)	MEAN TILT ANGLE (°)	JOINT REBOUN NUMBE (r)	ROCK REBOUND NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m^3)
1	set 3	216.569	Sicada	1.2	49.7	205.90	22.60	51.0	30.0	51.0	31.7	26.516
2	set 3	310.540	Sicada	3.4	49.7	143.77	20.80	72.8	47.8	52.4	31.0	26.516
3	set 3	411.393	Sicada	2.4	45.0	112.59	20.40	62.0	43.3	52.6	29.7	26.516
4	set 3	444.587	Sicada	1.8	45.0	91.36	20.30	66.7	37.7	47.4	32.0	26.139
5	set 3	482.082	Sicada	1.1	46.7	141.10	20.60	50.0	45.1	49.4	30.7	26.139
6	set 3	510.010	Sicada	1.8	47.0	125.10	20.50	68.7	40.6	48.2	29.0	26.139
7	set 3	540.272	Sicada	1.9	45.7	119.70	20.50	65.0	39.0	49.0	33.0	26.139
8	set 3	614.939	Sicada	2.3	41.3	116.70	18.70	64.7	43.0	51.0	32.7	26.510
9	set 3	711.179	Sicada	2.0	47.7	120.47	22.70	40.7	24.2	47.4	31.8	26.510
10	set 3	525.702	Sicada	2.2	44.7	127.10	20.20	56.8	39.0	48.0	28.3	26.139
			Arithmetic a	2.0	46.3	130.4	20.7	59.8	39.0	49.6	31.0	26.326
			maximum v	3.4	49.7	205.9	22.7	72.8	47.8	52.6	33.0	26.516
			minimum va	1.1	41.3	91.4	18.7	40.7	24.2	47.4	28.3	26.139

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3	
Operator:	PC
Date:	25.06.2003
Borehole:	KFM02A

OUTPUT DATA

Depth zone: 100-1002.3 m

F:\P\2003\10\20031089\Reports\Rap KFM02A\[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)
1	set 3	216.569	51.29	3.54E-04	23.5	5.34	2.01	4.95	45.86
2	set 3	310.540	133.47	5.93E-05	29.2	6.86	2.01	6.23	115.59
3	set 3	411.393	104.80	1.19E-04	26.2	6.03	2.22	5.48	90.71
4	set 3	444.587	75.37	6.91E-05	27.9	6.42	2.22	5.80	64.62
5	set 3	482.082	111.53	2.78E-04	29.0	3.75	2.14	3.55	102.37
6	set 3	510.010	87.88	7.90E-05	25.8	7.09	2.13	6.37	74.85
7	set 3	540.272	80.74	1.02E-04	28.9	6.12	2.19	5.56	69.93
8	set 3	614.939	103.07	1.12E-04	29.6	5.89	2.42	5.31	88.16
9	set 3	711.179	37.55	2.99E-04	22.0	3.67	2.10	3.47	34.61
10	set 3	525.702	80.74	1.85E-04	24.6	5.72	2.24	5.22	70.32
		Arithmetic av.	86.64	1.66E-04	26.7	5.69	2.17	5.19	75.70
		maximum val.	133.47	3.54E-04	29.6	7.09	2.42	6.37	115.59
		minimum val.	37.55	5.93E-05	22.0	3.67	2.01	3.47	34.61

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

	PAGE 1
	Operator: PC
	Date: 25.06.2003
	Borehole: KFM02A

INPUT DATA

Depth zone: 100-1002.3 m

F:\P\2003\10\20031089\Reports\Rap KFM02A\[alljointsn.xls]INPUT DATA 1

	SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT AMP. a (mm)	MEAN JOINT LENG. L (mm)	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)
	1	set 1	236.222	Sicada	8.8	225.7	301.78	99.80	66.3	33.4	49.2	33.8	26.516
	2	set 2	218.129	Sicada	5.3	84.0	324.70	35.60	56.2	36.5	47.2	34.2	26.516
	3	set 3	216.569	Sicada	1.2	49.7	205.90	22.60	51.0	30.0	51.0	31.7	26.516
#	4	set 1	238.421	Sicada	5.2	114.3	321.89	45.50	56.0	31.4	48.2	31.3	26.516
	5	set 2	306.638	Sicada	1.8	87.7	303.90	37.60	56.7	33.0	52.8	26.3	26.516
	6	set 3	310.540	Sicada	3.4	49.7	143.77	20.80	72.8	47.8	52.4	31.0	26.516
	7	set 1	314.731	Sicada	2.1	101.0	281.30	47.90	45.3	32.8	50.8	32.3	26.516
	8	set 2	369.896	Sicada	2.6	58.7	202.23	29.10	68.3	37.3	48.0	30.0	26.516
	9	set 3	411.393	Sicada	2.4	45.0	112.59	20.40	62.0	43.3	52.6	29.7	26.516
	10	set 1	396.442	Sicada	2.3	124.3	299.13	57.50	75.0	38.2	47.8	31.0	26.516
	11	set 2	425.814	Sicada	1.6	50.7	136.70	23.40	70.3	40.9	49.8	29.8	26.139
	12	set 3	444.587	Sicada	1.8	45.0	91.36	20.30	66.7	37.7	47.4	32.0	26.139
	13	set 1	443.261	Sicada	7.2	167.3	250.44	77.60	57.7	35.0	40.2	33.3	26.139
	14	set 2	471.532	Sicada	2.7	76.7	234.20	36.30	49.7	39.1	48.4	26.7	26.139
	15	set 3	482.082	Sicada	1.1	46.7	141.10	20.60	50.0	45.1	49.4	30.7	26.139
	16	set 1	448.928	Sicada	9.1	267.3	565.30	120.30	69.7	32.8	49.2	30.7	26.139
	17	set 2	508.706	Sicada	3.8	80.0	233.20	36.60	50.3	48.6	50.0	30.7	26.139
	18	set 3	510.010	Sicada	1.8	47.0	125.10	20.50	68.7	40.6	48.2	29.0	26.139
	19	set 1	474.684	Sicada	5.5	119.3	299.68	53.40	72.7	39.2	50.2	31.7	26.139
	20	set 2	578.489	Sicada	3.4	67.3	257.33	30.40	57.0	41.3	47.8	29.5	26.139
	21	set 3	540.272	Sicada	1.9	45.7	119.70	20.50	65.0	39.0	49.0	33.0	26.139
	22	set 1	482.357	Sicada	2.0	90.7	317.85	40.70	51.7	40.8	47.2	32.0	26.139
	23	set 2	657.840	Sicada	2.4	74.7	245.34	33.60	52.3	40.3	49.8	32.5	26.510
	24	set 3	614.939	Sicada	2.3	41.3	116.70	18.70	64.7	43.0	51.0	32.7	26.510
	25	set 1	495.517	Sicada	3.9	80.7	127.90	35.10	70.8	36.0	51.6	32.5	26.139
	26	set 2	710.468	Sicada	1.8	50.3	207.38	25.30	68.8	42.1	49.8	32.5	26.510
	27	set 3	711.179	Sicada	2.0	47.7	120.47	22.70	40.7	24.2	47.4	31.8	26.510
	28	set 1	535.135	Sicada	1.8	68.7	241.75	32.80	74.5	49.6	49.6	32.7	26.139
	29	set 2	830.945	Sicada	3.1	52.0	154.97	24.10	45.2	45.0	48.2	34.5	26.570
	30	set 3	525.702	Sicada	2.2	44.7	127.10	20.20	56.8	39.0	48.0	28.3	26.139
	31	set 1	542.780	Sicada	7.3	96.7	190.50	48.30	67.0	36.2	48.8	30.5	26.139
	32	set 1	575.198	Sicada	4.0	177.7	419.75	85.50	74.7	37.8	51.4	26.3	26.139
	33	set 1	621.431	Sicada	1.9	83.3	116.44	39.90	56.3	36.0	48.6	33.3	26.510
	34	set 1	638.051	Sicada	4.2	114.3	331.45	50.60	45.7	38.6	49.6	32.0	26.510
	35	set 1	675.216	Sicada	3.6	199.0	328.20	92.50	67.3	33.6	49.2	31.8	26.510
	36	set 1	689.272	Sicada	4.7	287.0	687.12	119.10	57.0	34.8	48.0	29.5	26.510
	37	set 1	717.388	Sicada	4.1	142.0	353.40	66.20	74.7	33.4	50.6	32.7	26.510
	38	set 1	694.424	Sicada	2.8	172.3	250.70	78.60	71.5	40.8	49.8	28.5	26.510
	39	set 1	839.537	Sicada	3.8	117.7	296.60	48.20	56.2	35.6	47.2	29.8	26.570
	40	set 1	729.197	Sicada	4.0	280.7	984.80	120.40	49.3	37.6	51.0	33.7	26.570
				Arithmetic a	3.4	104.4	264.2	47.0	60.8	38.2	49.2	31.2	26.358
				maximum v	9.1	287.0	984.8	120.4	75.0	49.6	52.8	34.5	26.570
				minimum va	1.1	41.3	91.4	18.7	40.7	24.2	40.2	26.3	26.139

ROCK JOINT CHARACTERISATION

PAGE 3

CLIENT: SKB- Tilt tests

Operator: PC

Date: 25.06.2003

OUTPUT DATA

Depth zone: 100-1002.3 m

Borehole: KFM02A

F:\P\2003\10\20031089\Reports\Rap KFM02A\[alljointsn.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	236.222	61.57	4.79E-05	27.4	6.37	0.44	7.07	71.93
2	set 2	218.129	72.73	2.77E-04	29.7	4.90	1.19	4.81	70.89
3	set 3	216.569	51.29	3.54E-04	23.5	5.34	2.01	4.95	45.86
4	set 1	238.421	55.30	2.17E-04	24.3	5.86	0.87	5.95	56.61
5	set 2	306.638	60.26	2.39E-04	18.8	7.02	1.14	6.89	58.62
6	set 3	310.540	133.47	5.93E-05	29.2	6.86	2.01	6.23	115.59
7	set 1	314.731	59.62	2.85E-04	25.2	3.78	0.99	3.78	59.68
8	set 2	369.896	75.92	9.32E-05	25.5	7.23	1.70	6.70	67.63
9	set 3	411.393	104.80	1.19E-04	26.2	6.03	2.22	5.48	90.71
10	set 1	396.442	79.68	3.42E-05	27.0	7.54	0.80	7.79	83.70
11	set 2	425.814	89.29	6.51E-05	26.2	7.18	1.97	6.51	77.13
12	set 3	444.587	75.37	6.91E-05	27.9	6.42	2.22	5.80	64.62
13	set 1	443.261	65.33	9.04E-05	30.7	4.61	0.60	4.83	70.14
14	set 2	471.532	81.17	2.65E-04	22.9	4.89	1.30	4.77	78.07
15	set 3	482.082	111.53	2.78E-04	29.0	3.75	2.14	3.55	102.37
16	set 1	448.928	58.14	5.55E-05	24.0	7.59	0.37	8.81	72.72
17	set 2	508.706	134.25	2.55E-04	30.1	3.52	1.25	3.47	131.12
18	set 3	510.010	87.88	7.90E-05	25.8	7.09	2.13	6.37	74.85
19	set 1	474.684	81.60	4.87E-05	27.3	7.29	0.84	7.48	84.81
20	set 2	578.489	91.20	2.46E-04	26.8	5.43	1.49	5.20	85.51
21	set 3	540.272	80.74	1.02E-04	28.9	6.12	2.19	5.56	69.93
22	set 1	482.357	88.82	2.94E-04	29.3	4.09	1.10	4.06	87.76
23	set 2	657.840	89.16	2.68E-04	28.7	4.28	1.34	4.17	85.88
24	set 3	614.939	103.07	1.12E-04	29.6	5.89	2.42	5.31	88.16
25	set 1	495.517	68.88	3.86E-05	26.5	7.09	1.24	6.88	65.81
26	set 2	710.468	98.21	1.05E-04	29.4	6.60	1.99	6.03	85.72
27	set 3	711.179	37.55	2.99E-04	22.0	3.67	2.10	3.47	34.61
28	set 1	535.135	141.55	5.16E-05	32.7	6.49	1.46	6.18	131.57
29	set 2	830.945	115.08	3.13E-04	33.2	2.16	1.92	2.10	110.30
30	set 3	525.702	80.74	1.85E-04	24.6	5.72	2.24	5.22	70.32
31	set 1	542.780	69.61	5.91E-05	25.3	6.86	1.03	6.83	69.13
32	set 1	575.198	75.77	3.35E-05	21.0	8.45	0.56	9.31	87.66
33	set 1	621.431	70.77	8.81E-05	28.1	4.77	1.20	4.69	68.94
34	set 1	638.051	81.38	3.13E-04	27.6	3.35	0.87	3.38	82.48
35	set 1	675.216	62.21	5.18E-05	25.5	6.88	0.50	7.57	71.71
36	set 1	689.272	66.35	1.68E-04	24.0	5.90	0.35	6.68	79.95
37	set 1	717.388	61.54	3.65E-05	25.9	7.84	0.70	8.28	66.83
38	set 1	694.424	91.58	3.15E-05	24.9	7.21	0.58	7.80	103.02
39	set 1	839.537	69.56	1.87E-04	24.9	5.62	0.85	5.72	71.50
40	set 1	729.197	77.47	3.41E-04	28.4	3.89	0.36	4.22	87.40
		Arithmetic av.	81.51	1.56E-04	26.70	5.79	1.32	5.75	79.53
		maximum val.	141.55	3.54E-04	33.15	8.45	2.42	9.31	131.57
		minimum val.	37.55	3.15E-05	18.80	2.16	0.35	2.10	34.61