

P-04-179

Forsmark site investigation

Borehole: KFM04A

Tilt testing

Panayiotis Chryssanthakis
Norwegian Geotechnical Institute, Oslo

June 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: AP PF 400-04-02, Field note no Forsmark 303, Rock mechanics, Joint properties, JRC100, JCS100, Angles of joint friction and tilt test.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author and do not necessarily coincide with those of the client.

A pdf version of this document can be downloaded from www.skb.se

Summary

The Norwegian Geotechnical Institute (NGI) has carried out tilt testing on joint surfaces of drill cores from borehole KFM04A, Forsmark, during the period January 20–26, 2004. From a total drill core length of about 900 m, 26 tilt tests were performed on three sets of joints.

The main results from the tilt tests are rather uniform regarding all 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 6.1. The mean value of the joint wall compressive strength (JCS_o) from Schmidt hammer testing of all the joint samples is 86.0 MPa. The mean values of the basic (Φ_b) and residual (Φ_r) friction angles of all the tested samples are 31.4 and 28.0 degrees respectively.

Sammanfattning

Norges Geotekniska Institut (NGI) har gjort s.k. tilttester på öppna sprickor i borrhärneprover från borrhål KFM04A i Forsmark. Utifrån en sammanlagd borrhärnelängd på ca 900 m utvaldes 26 prover för tilttester på tre sprickgrupper.

Resultaten är relativt enhetliga för samtliga sprickor och uppvisar inga stora variationer. Medelvärdet för råhetskoefficienten, JRC_0 , för alla sprickor är 6.1. För sprickväggens tryckhållfasthet, JCS_0 , som uppmättes med Schmidthammarprovning, uppgår medelvärdet till 86.0 MPa. Medelvärdet för basfriktionsvinkeln, Φ_b , och residualfriktionsvinkeln, Φ_r , beräknat utifrån alla testade prover, är 31.4 respektive 28.0 grader.

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1 Introduction

The Norwegian Geotechnical Institute (NGI) has carried out 26 tilt tests on joint surfaces of drill cores from borehole KFM04A at Forsmark in Sweden according to SKB Activity Plan AP PF 400-04-02, Version 1.0 (SKB internal controlling document). The work has been performed by Panayiotis Chryssanthakis and Pawel Jankowski during the period January 20–26, 2004, 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.

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 303).

Table 2-1. Total number of tilt tests.

Borehole	Tilt tests	No. of joint sets
KFM04A	26	3

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 the 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.

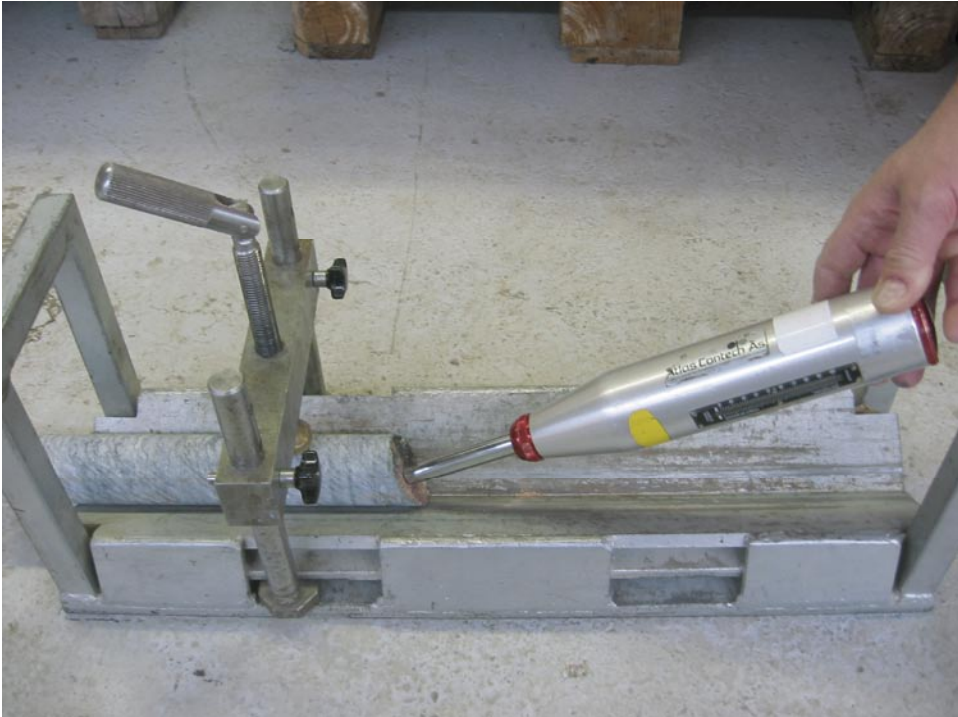


Figure 3-2. Clamp for the Schmidt hammer tests.



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

4 Execution

4.1 Sampling

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

The frequency of the tilt test samples was determined by choosing one specimen per approximately 16 to 22 metres in the range between 480 m and 970 m borehole length, see Appendix A. The collaring of borehole KFM04A is situated outside the Forsmark candidate area and the borehole is inclined towards this with an angle of 60 degrees to the horizontal. A transition in the drill core to the rock types prevailing in the candidate area occurs at approximately 480 m borehole length, indicating that the border between the candidate area and the surrounding deformed rock is near-vertical. A selection of 26 tilt samples were collected 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. Lower joint surface of a core sample at test position in the tilt test apparatus.

Table 4-1. Joint set numbers and orientations.

Joint set number	Angle of intersection in degrees	Number of tilt tests
Set 1 (steep joints)	0–30°	8
Set 2 (ca 45 degrees joints)	30–60°	9
Set 3 (sub-horizontal joints)	60–90°	9

Each set may consist of fractures with different dip, dip directions and different mineralization.

Three profilings on each tilt joint surface have also been carried out. The rocks can be classified as mainly metamorphic, including granite, granodiorite, tonalite with some veins of amphibolite, and pegmatite. However, 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 26 tilt joint surfaces from borehole KFM04A 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 of time 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 a 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 the 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 were measured, and the fracture surface area was measured with a planimeter.

Profiling of the tilt tested fractures was carried out by means of a profilometer, and the profiles were drawn on a paper by pulling a pencil along the edge of the profilometer. For each fracture, three parallel profiles were 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) were measured.

Several density measurements of the rock were performed during tilt testing. The samples were taken directly from the racks in the core shed, and consequently the measurements were made 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 were calculated. The balance used for weighing the specimens has an accuracy of 0.01 g. The accuracy of the calliper used for measuring the size (height and diameter) of the specimens is 0.01 mm.

The results were in the range 2.64–2.68 g/cm³. The densities listed in Table 4-2 have been used for the calculations.

Table 4-2. Depth ranges in borehole KFM04A with the relevant unit weight used.

Depth Interval		Unit Weight
m	m	kN/m ³
485.20	517.70	26.47
517.70	601.05	26.64
601.05	701.35	26.69
701.35	801.00	26.36
801.00	897.25	26.60
897.25	1,001.40	26.81

4.3 Nonconformities

None.

5 Results from the tilt testing

5.1 General

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

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. Separate tables are presented for each of the three joint sets. A table displaying all the joint sets is also presented in Appendix A.

5.2 Results from Borehole KFM04A

26 tilt tests and 26×3 profilings on joints were performed on core samples from section 480–970 m (borehole length) in borehole KFM04A. 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. All the results from borehole KFM04A are presented together in the plots. Table 5-1 shows the arithmetic mean values of these parameters. A summary of the tilt tests and profiling is also given in Table 5-1.

Table 5-1. Arithmetic mean JCS_o , JRC_o , Φ_r and Φ_b -values, borehole KFM04A.

Fracture set	JRC_o (tilt)	JCS_o MPa	Φ_b (°)	Φ_r (°)	Number (tilt)	Number (profiles)
Set 1	6.60	79.71	31.8	27.76	8	8
Set 2	6.04	88.17	31.2	27.65	9	9
Set 3	5.60	89.54	31.4	28.49	9	9
Mean/Total	6.06	86.04	31.4	27.97	26	26

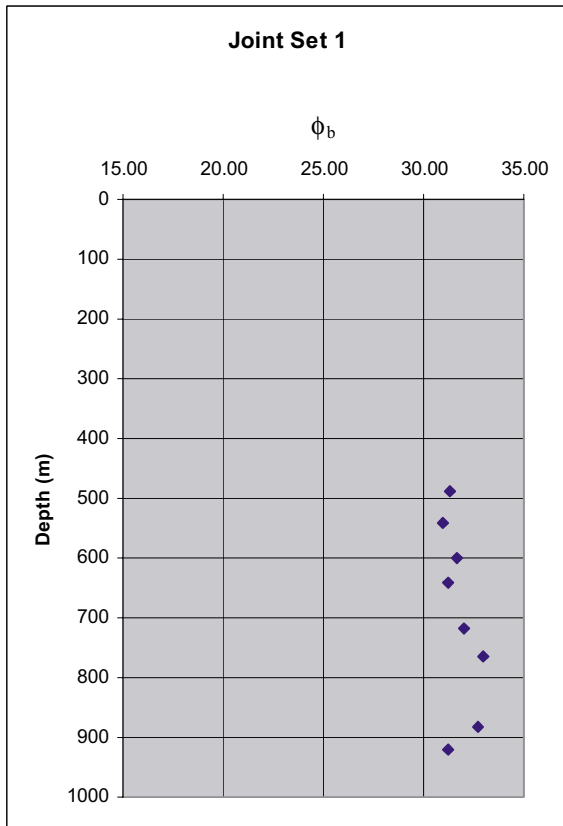
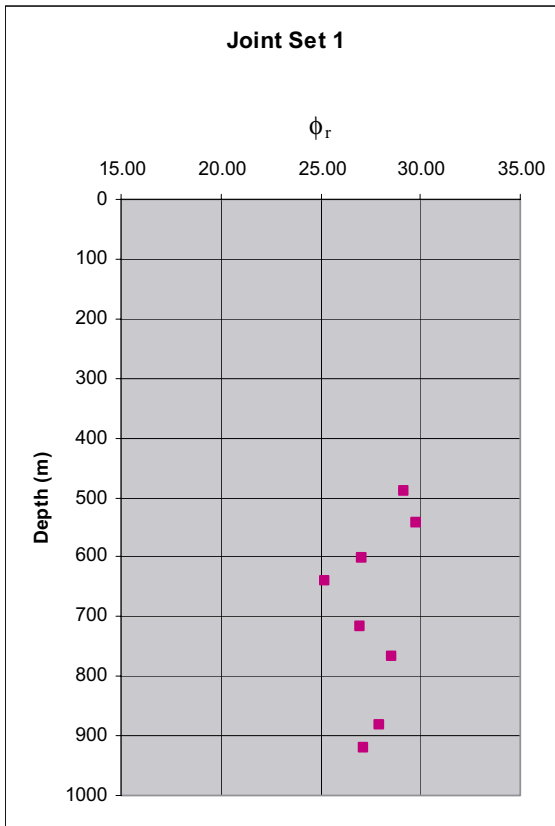
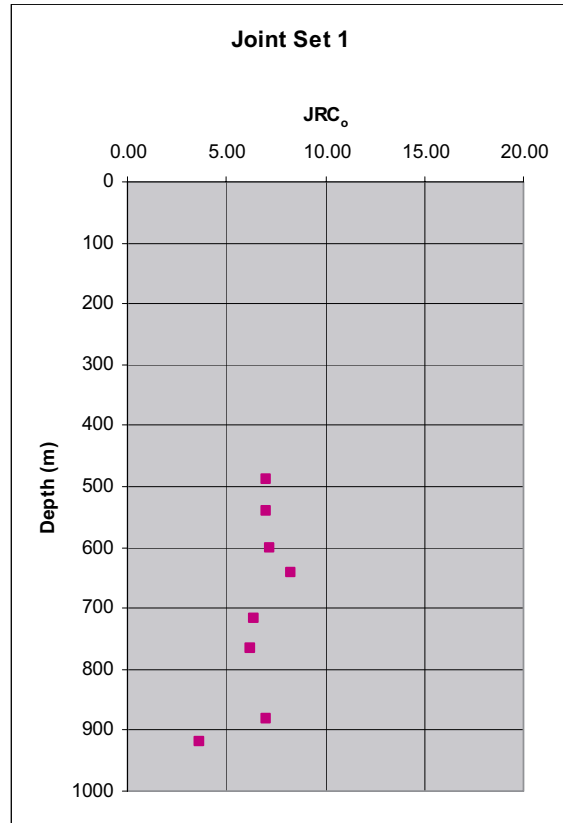
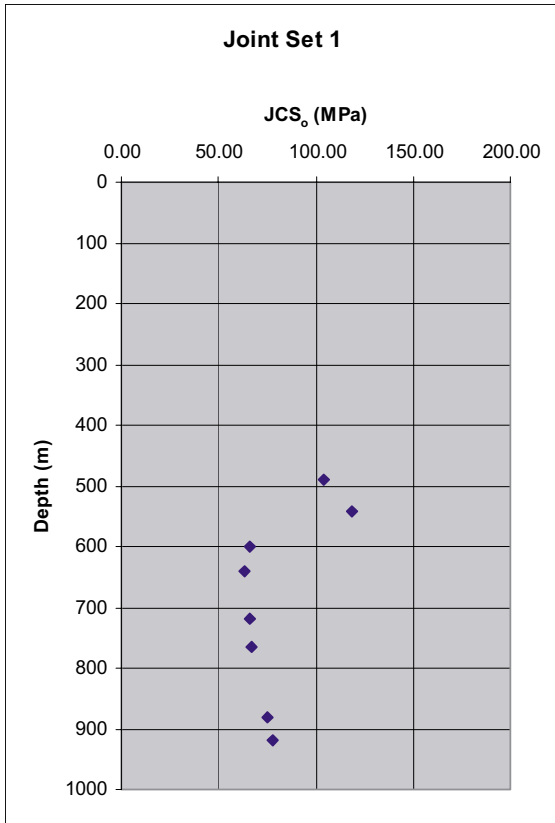


Figure 5-1. Variation of joint parameters with depth for Set 1.

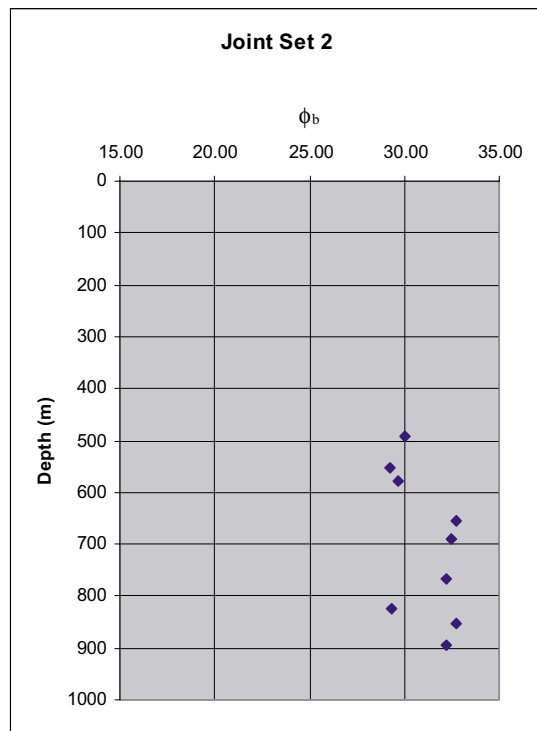
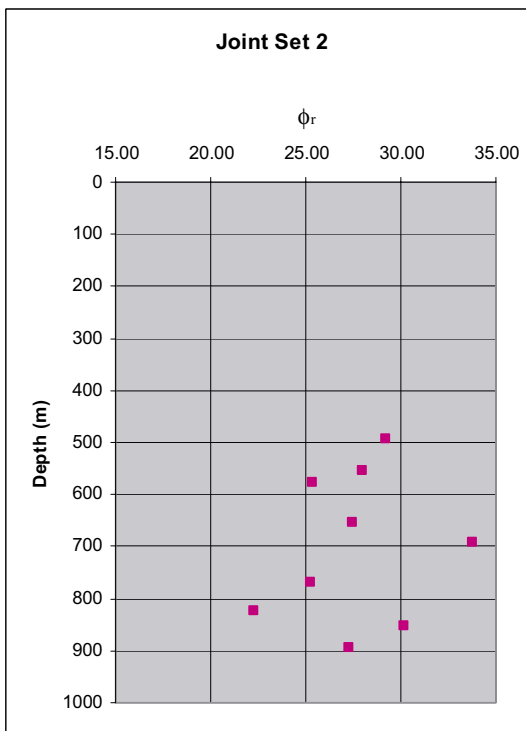
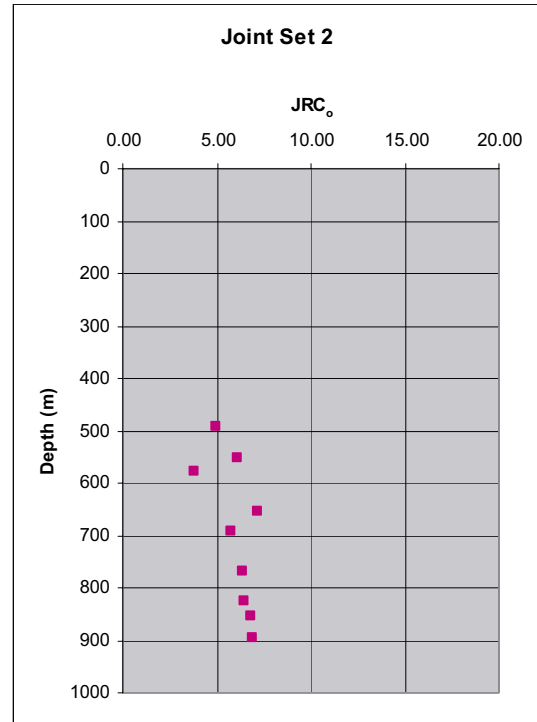
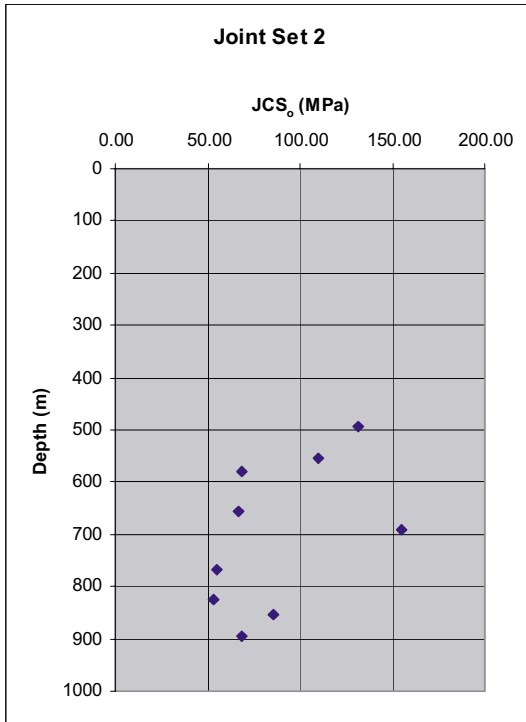


Figure 5-2. Variation of joint parameters with depth for Set 2.

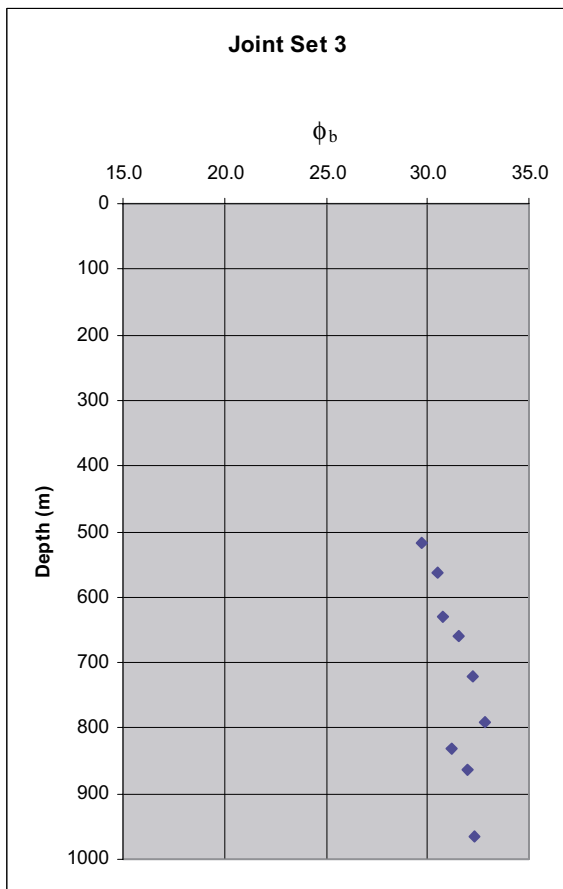
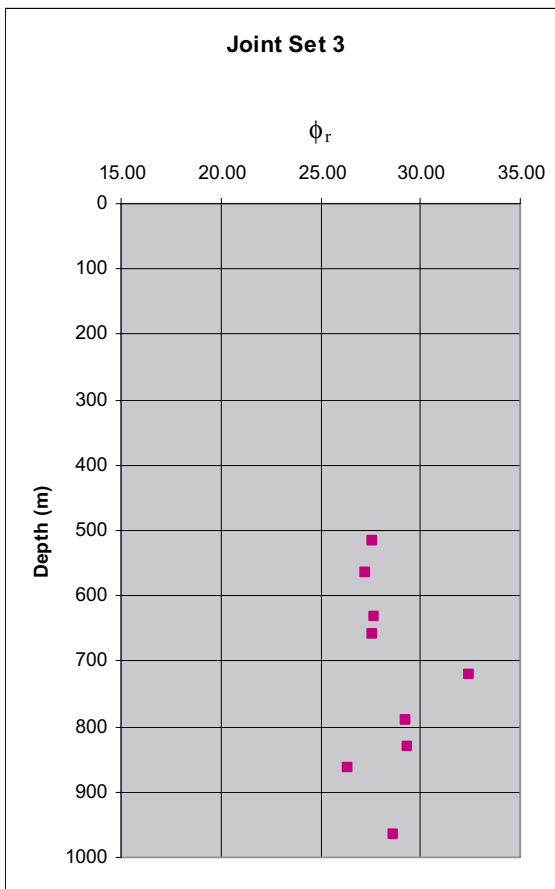
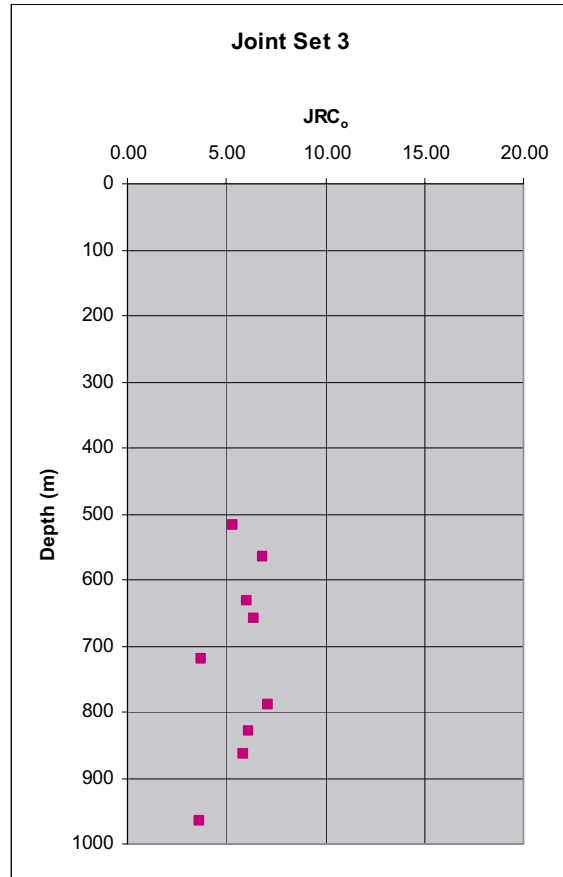
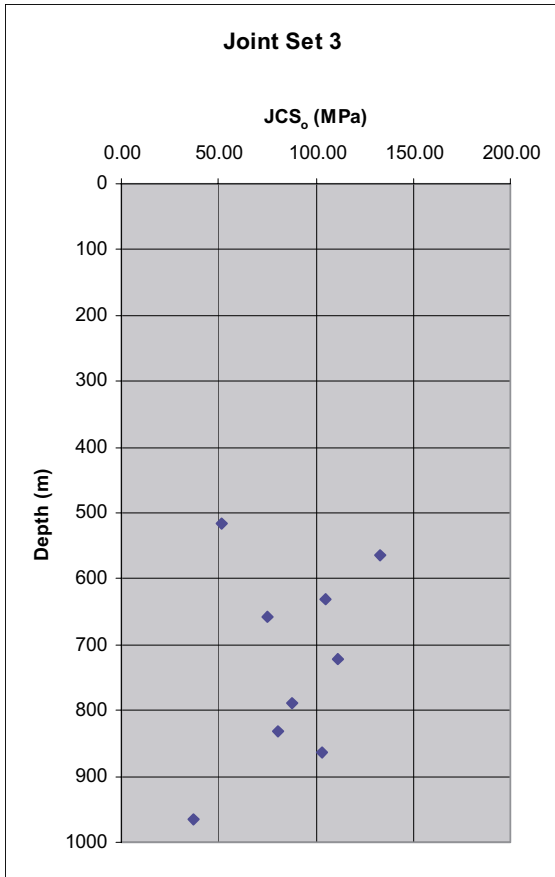


Figure 5-3. Variation of joint parameters with depth for Set 3.

5.3 Evaluation of the results

The joint faces are rather similar concerning mineralisation, and the tilt tests show rather uniform JRC-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 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 3.6 and 8.3. This means that the sample selection for tilt testing is representative for borehole KFM04A.

Appendix A

The main results from tilt testing

ROCK JOINT CHARACTERISATION												
CLIENT: SKB- Tilt tests												
INPUT DATA												
Depth zone: 107 -1001.4 m												
F:\p\2003\10\20031089\Reports\Rap KFM04A\alljointsSIC.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 NUMBER (r)	ROCK REBOUN NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m ³)
1	set 1	488.795	Sicada	1.2	104.7	134.20	47.5	78.0	43.2	48.4	31.3	26.47
2	set 2	493.588	Sicada	1.7	44.0	155.70	22.4	58.2	47.6	49.6	30.0	26.47
3	set 3	516.879	Sicada	2.2	40.0	146.40	18.4	57.7	43.2	48.2	29.7	26.47
4	set 1	541.865	Sicada	1.8	101.3	377.90	47.8	73.8	45.4	48.2	31.0	26.64
5	set 2	553.898	Sicada	1.2	67.0	221.00	30.1	64.2	44.0	46.8	29.2	26.64
6	set 3	564.018	Sicada	1.7	47.3	115.60	20.2	56.7	40.1	47.8	30.5	26.64
7	set 1	600.954	Sicada	3.1	175.3	252.20	80.9	73.7	34.6	45.0	31.7	26.64
8	set 2	578.086	Sicada	1.5	59.3	147.90	23.2	45.5	35.1	44.8	29.7	26.64
9	set 3	630.750	Sicada	1.6	49.3	118.80	20.5	60.3	38.9	46.0	30.8	26.69
10	set 1	641.411	Sicada	2.1	96.3	220.80	48.1	83.3	33.6	47.8	31.2	26.69
11	set 2	654.759	Sicada	3.5	60.3	127.40	29.1	71.7	34.7	47.0	32.7	26.69
12	set 3	658.635	Sicada	1.7	48.0	102.80	20.3	73.0	38.5	47.8	31.5	26.69
13	set 1	717.797	Sicada	5.9	182.3	377.90	74.2	64.3	34.8	46.4	32.0	26.36
14	set 2	690.780	Sicada	0.9	54.3	127.40	26.2	71.0	50.2	47.2	32.5	26.69
15	set 3	720.860	Sicada	0.8	52.3	122.90	23.7	62.0	46.2	45.6	32.2	26.36
16	set 1	765.491	Sicada	1.8	80.0	181.70	36.6	65.0	35.2	45.2	33.0	26.36
17	set 2	768.259	Sicada	1.9	51.0	132.00	25.3	61.7	31.4	48.0	32.2	26.36
18	set 3	790.025	Sicada	1.0	47.7	135.20	23.8	63.7	40.2	48.8	32.8	26.36
19	set 1	882.122	Sicada	2.2	74.3	223.90	33.8	70.3	37.0	48.4	32.7	26.60
20	set 2	824.030	Sicada	2.0	64.7	162.60	28.9	58.3	30.6	47.0	29.3	26.60
21	set 3	830.580	Sicada	1.6	47.0	102.20	20.6	67.8	42.1	46.4	31.2	26.60
22	set 1	919.226	Sicada	1.5	80.0	267.60	37.3	46.7	37.4	46.8	31.2	26.81
23	set 2	853.071	Sicada	2.1	59.7	224.90	30.2	71.2	39.5	45.2	32.7	26.60
24	set 3	863.325	Sicada	3.2	51.0	168.40	22.5	47.0	34.4	47.8	32.0	26.60
25	set 2	895.744	Sicada	1.5	67.0	210.90	29.9	67.7	35.3	46.8	32.2	26.60
26	set 3	965.216	Sicada	1.3	47.7	144.70	20.8	64.5	36.5	44.6	32.3	26.81
			Arithmetic a	2.0	71.2	180.9	32.4	64.5	38.8	47.0	31.4	26.6
			minimum v	0.8	40.0	102.2	18.4	45.5	30.6	44.6	29.2	26.4
			maximum v	5.9	182.3	377.9	80.9	83.3	50.2	49.6	33.0	26.8

ROCK JOINT CHARACTERISATION

TESTED

PAGE 3

CLIENT: SKB- Tilt tests

Operator: PC

Date: 25.01.2004

OUTPUT DATA

Depth zone: 107 -1001.4 m

Borehole: KFM04A

F:\p\2003\10\20031089\Reports\Rap KFM04A\alljointsSIC.xls\OUTPUT DATA

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS ₀ (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC ₀ AT JOINT LENGTH	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC ₁₀₀ VALUES 100 mm	EXTRPL'D JCS ₁₀₀ VALUES 100 mm (MPa)
1	set 1	488.795	103.82	1.20E-05	29.2	7.04	0.96	7.09	104.83
2	set 2	493.588	131.45	1.89E-04	29.2	4.97	2.27	4.58	116.32
3	set 3	516.879	103.82	2.23E-04	27.6	5.31	2.50	4.81	89.73
4	set 1	541.865	118.66	6.03E-05	29.8	6.99	0.99	7.00	118.99
5	set 2	553.898	110.03	1.36E-04	28.0	6.13	1.49	5.83	102.22
6	set 3	564.018	89.14	1.69E-04	27.3	5.14	2.11	4.76	79.42
7	set 1	600.954	66.24	2.41E-05	27.1	7.24	0.57	7.85	74.83
8	set 2	578.086	68.05	3.07E-04	25.4	3.77	1.69	3.62	64.15
9	set 3	630.750	83.88	1.40E-04	27.7	5.64	2.03	5.21	74.42
10	set 1	641.411	62.98	6.13E-06	25.3	8.28	1.04	8.23	62.39
11	set 2	654.759	66.84	4.23E-05	27.5	7.14	1.66	6.64	59.98
12	set 3	658.635	82.08	4.25E-05	27.6	7.22	2.08	6.49	70.02
13	set 1	717.797	65.65	9.39E-05	27.0	6.38	0.55	6.89	73.65
14	set 2	690.780	154.55	5.05E-05	33.8	5.74	1.84	5.35	139.12
15	set 3	720.860	120.70	1.12E-04	32.5	4.90	1.91	4.60	109.73
16	set 1	765.491	67.07	8.70E-05	28.6	6.19	1.25	6.02	64.35
17	set 2	768.259	54.75	1.15E-04	25.3	6.41	1.96	5.88	48.10
18	set 3	790.025	87.60	1.09E-04	29.3	5.83	2.10	5.35	76.96
19	set 1	882.122	75.18	7.38E-05	28.0	7.04	1.35	6.75	70.61
20	set 2	824.030	53.25	1.52E-04	22.3	6.49	1.55	6.13	48.92
21	set 3	830.580	98.96	6.95E-05	29.3	6.25	2.13	5.69	85.90
22	set 1	919.226	78.05	3.31E-04	27.2	3.63	1.25	3.57	76.17
23	set 2	853.071	86.02	7.58E-05	30.2	6.78	1.68	6.32	77.46
24	set 3	863.325	65.35	3.41E-04	26.4	3.90	1.96	3.70	60.40
25	set 2	895.744	68.60	9.96E-05	27.3	6.92	1.49	6.55	63.12
26	set 3	965.216	74.33	1.26E-04	28.7	6.21	2.10	5.67	64.75
		Arithmetic av.	86.04	1.23E-04	27.97	6.06	1.63	5.79	79.87
		minimum val.	53.25	6.13E-06	22.32	3.63	0.55	3.57	48.10
		maximum val.	154.55	3.41E-04	33.77	8.28	2.50	8.23	139.12

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	25.01.2004
Borehole:	KFM04A

INPUT DATA Depth zone: 107 -1001.4 m

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 1	488,795	Sicada	1,2	104,7	134,20	47,5	78,0	43,2	48,4	31,3	26,47
2	set 1	541,865	Sicada	1,8	101,3	377,90	47,8	73,8	45,4	48,2	31,0	26,64
3	set 1	600,954	Sicada	3,1	175,3	252,20	80,9	73,7	34,6	45,0	31,7	26,64
4	set 1	641,411	Sicada	2,1	96,3	220,80	48,1	83,3	33,6	47,8	31,2	26,69
5	set 1	717,797	Sicada	5,9	182,3	377,90	74,2	64,3	34,8	46,4	32,0	26,36
6	set 1	765,491	Sicada	1,8	80,0	181,70	36,6	65,0	35,2	45,2	33,0	26,36
7	set 1	882,122	Sicada	2,2	74,3	223,90	33,8	70,3	37,0	48,4	32,7	26,60
8	set 1	919,226	Sicada	1,5	80,0	267,60	37,3	46,7	37,4	46,8	31,2	26,81
Arithmetic av.				2,5	111,8	254,5	50,8	69,4	37,7	47,0	31,8	26,6
minimum val.				1,2	74,3	134,2	33,8	46,7	33,6	45,0	31,0	26,4
maximum val.				5,9	182,3	377,9	80,9	83,3	45,4	48,4	33,0	26,8

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

TESTED

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Operator: PC

Date: 25.01.2004

OUTPUT DATA Depth zone: 107 -1001.4 m

Borehole: KFM04A

F:\p\2003\10\20031089\Reports\Rap KFM04A\set1 KFM04A.xls]OUTPUT DATA

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS ₀ (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC ₀ AT JOINT LENGTH	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC ₁₀₀ VALUES 100 mm	EXTRPL'D JCS ₁₀₀ VALUES 100 mm (MPa)
1	set 1	488.795	103.82	1.20E-05	29.2	7.04	0.96	7.09	104.83
2	set 1	541.865	118.66	6.03E-05	29.8	6.99	0.99	7.00	118.99
3	set 1	600.954	66.24	2.41E-05	27.1	7.24	0.57	7.85	74.83
4	set 1	641.411	62.98	6.13E-06	25.3	8.28	1.04	8.23	62.39
5	set 1	717.797	65.65	9.39E-05	27.0	6.38	0.55	6.89	73.65
6	set 1	765.491	67.07	8.70E-05	28.6	6.19	1.25	6.02	64.35
7	set 1	882.122	75.18	7.38E-05	28.0	7.04	1.35	6.75	70.61
8	set 1	919.226	78.05	3.31E-04	27.2	3.63	1.25	3.57	76.17
Arithmetic av.			79.71	8.60E-05	27.76	6.60	0.99	6.68	80.73
minimum val.			62.98	6.13E-06	25.26	3.63	0.55	3.57	62.39
maximum val.			118.66	3.31E-04	29.84	8.28	1.35	8.23	118.99

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	25.01.2004
Borehole:	KFM04A

INPUT DATA

Depth zone: 107 -1001.4 m

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SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT AMP. a (mm) LENG. L (mm)		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)
1	set 2	493.588	Sicada	1.7	44.0	155.70	22.4	58.2	47.6	49.6	30.0	26.47
2	set 2	553.898	Sicada	1.2	67.0	221.00	30.1	64.2	44.0	46.8	29.2	26.64
3	set 2	578.086	Sicada	1.5	59.3	147.90	23.2	45.5	35.1	44.8	29.7	26.64
4	set 2	654.759	Sicada	3.5	60.3	127.40	29.1	71.7	34.7	47.0	32.7	26.69
5	set 2	690.780	Sicada	0.9	54.3	127.40	26.2	71.0	50.2	47.2	32.5	26.69
6	set 2	768.259	Sicada	1.9	51.0	132.00	25.3	61.7	31.4	48.0	32.2	26.36
7	set 2	824.030	Sicada	2.0	64.7	162.60	28.9	58.3	30.6	47.0	29.3	26.60
8	set 2	853.071	Sicada	2.1	59.7	224.90	30.2	71.2	39.5	45.2	32.7	26.60
9	set 2	895.744	Sicada	1.5	67.0	210.90	29.9	67.7	35.3	46.8	32.2	26.60
Arithmetic av.				1.8	58.6	167.8	27.3	63.3	38.7	46.9	31.2	26.6
minimum val.				0.9	44.0	127.4	22.4	45.5	30.6	44.8	29.2	26.4
maximum val.				3.5	67.0	224.9	30.2	71.7	50.2	49.6	32.7	26.7

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

TESTED

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OUTPUT DATA

Depth zone: 107 -1001.4 m

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SAMPLE No	JOINT SET NO	DEPTH (m)	JCS ₀ (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC ₀ AT JOINT LENGTH	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC ₁₀₀ VALUES 100 mm	EXTRPL'D JCS ₁₀₀ VALUES 100 mm (MPa)
1	set 2	493.588	131.45	1.89E-04	29.2	4.97	2.27	4.58	116.32
2	set 2	553.898	110.03	1.36E-04	28.0	6.13	1.49	5.83	102.22
3	set 2	578.086	68.05	3.07E-04	25.4	3.77	1.69	3.62	64.15
4	set 2	654.759	66.84	4.23E-05	27.5	7.14	1.66	6.64	59.98
5	set 2	690.780	154.55	5.05E-05	33.8	5.74	1.84	5.35	139.12
6	set 2	768.259	54.75	1.15E-04	25.3	6.41	1.96	5.88	48.10
7	set 2	824.030	53.25	1.52E-04	22.3	6.49	1.55	6.13	48.92
8	set 2	853.071	86.02	7.58E-05	30.2	6.78	1.68	6.32	77.46
9	set 2	895.744	68.60	9.96E-05	27.3	6.92	1.49	6.55	63.12
Arithmetic av.			88.17	1.30E-04	27.65	6.04	1.74	5.66	79.93
minimum val.			53.25	4.23E-05	22.32	3.77	1.49	3.62	48.10
maximum val.			154.55	3.07E-04	33.77	7.14	2.27	6.64	139.12

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

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Operator:	PC
Date:	25.01.2004
Borehole:	KFM04A

INPUT DATA Depth zone: 107 -1001.4 m

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	516.879	Sicada	2.2	40.0	146.40	18.4	57.7	43.2	48.2	29.7	26.47
2	set 3	564.018	Sicada	1.7	47.3	115.60	20.2	56.7	40.1	47.8	30.5	26.64
3	set 3	630.750	Sicada	1.6	49.3	118.80	20.5	60.3	38.9	46.0	30.8	26.69
4	set 3	658.635	Sicada	1.7	48.0	102.80	20.3	73.0	38.5	47.8	31.5	26.69
5	set 3	720.860	Sicada	0.8	52.3	122.90	23.7	62.0	46.2	45.6	32.2	26.36
6	set 3	790.025	Sicada	1.0	47.7	135.20	23.8	63.7	40.2	48.8	32.8	26.36
7	set 3	830.580	Sicada	1.6	47.0	102.20	20.6	67.8	42.1	46.4	31.2	26.60
8	set 3	863.325	Sicada	3.2	51.0	168.40	22.5	47.0	34.4	47.8	32.0	26.60
9	set 3	965.216	Sicada	1.3	47.7	144.70	20.8	64.5	36.5	44.6	32.3	26.81
Arithmetic av.				1.7	47.8	128.6	21.2	61.4	40.0	47.0	31.4	26.6
minimum val.				0.8	40.0	102.2	18.4	47.0	34.4	44.6	29.7	26.4
maximum val.				3.2	52.3	168.4	23.8	73.0	46.2	48.8	32.8	26.8

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

TESTED

PAGE 3	
Operator:	PC
Date:	25.01.2004
Borehole:	KFM04A

OUTPUT DATA Depth zone: 107 -1001.4 m

SAMPLE No	JOINT SET NO	DEPTH (m)	JCS ₀ (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC ₀ AT JOINT LENGTH	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC _{100'} VALUES 100 mm	EXTRPL'D JCS _{100'} VALUES 100 mm (MPa)
2	set 3	564.018	89.14	1.69E-04	27.3	5.14	2.11	4.76	79.42
3	set 3	630.750	83.88	1.40E-04	27.7	5.64	2.03	5.21	74.42
4	set 3	658.635	82.08	4.25E-05	27.6	7.22	2.08	6.49	70.02
5	set 3	720.860	120.70	1.12E-04	32.5	4.90	1.91	4.60	109.73
6	set 3	790.025	87.60	1.09E-04	29.3	5.83	2.10	5.35	76.96
7	set 3	830.580	98.96	6.95E-05	29.3	6.25	2.13	5.69	85.90
8	set 3	863.325	65.35	3.41E-04	26.4	3.90	1.96	3.70	60.40
9	set 3	965.216	74.33	1.26E-04	28.7	6.21	2.10	5.67	64.75
Arithmetic av.			89.54	1.48E-04	28.49	5.60	2.10	5.14	79.04
minimum val.			65.35	4.25E-05	26.39	3.90	1.91	3.70	60.40
maximum val.			120.70	3.41E-04	32.46	7.22	2.50	6.49	109.73