

P-04-178

Forsmark site investigation

Boreholes: KFM03A and KFM03B

Tilt testing

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October 2003

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Keywords: AP PF 400-03-77, Field note no Forsmark 189, Rock mechanics, Joint properties, JRC_{100} , JCS_{100} , 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.

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Summary

The Norwegian Geotechnical Institute (NGI) has carried out tilt testing on joint surfaces of drill cores from boreholes KFM03A and KFM03B, Forsmark, during the period October 6th–13th, 2003. From a total drill core length of about 1,000 m, 38 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 6.0. The mean value of the joint wall compressive strength (JCS_o) from Schmidt hammer testing of all the joint samples is 75.0 MPa. The mean values of the basic (Φ_b) and residual (Φ_r) friction angles of all the tested samples are 32.0 and 26.8 degrees respectively.

Sammanfattning

Norges Geotekniska Institut (NGI) har gjort s k tilttester på öppna sprickor i borrhärneprover från borrhålen KFM03A och KFM03B i Forsmark. Utifrån en sammanlagd borrhärnelängd på ca 1 000 m utvaldes 38 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 6.0. För sprickväggens tryckhållfasthet, JCS_0 , som uppmättes med Schmidthammarprovning, uppgår medelvärdet till 75.0 MPa. Medelvärdet för basfriktionsvinkeln, Φ_b , och residualfriktionsvinkeln, Φ_r , beräknat utifrån alla testade prover, är 32,0 respektive 26,8 grader.

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1 Introduction

The Norwegian Geotechnical Institute (NGI) has carried out 35 tilt tests on joint surfaces of drill cores from borehole KFM03A and 3 tilt tests from borehole KFM03B at Forsmark in Sweden according to SKB Activity Plan AP PF 400-03-77, Version 1.0 (SKB internal controlling document). The work has been performed by Panayiotis Chryssanthakis and Pawel Jankowski during the period October 6th–13th, 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
KFM03A	35	3
KFM03B	3	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 (field note no Forsmark 189).

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.

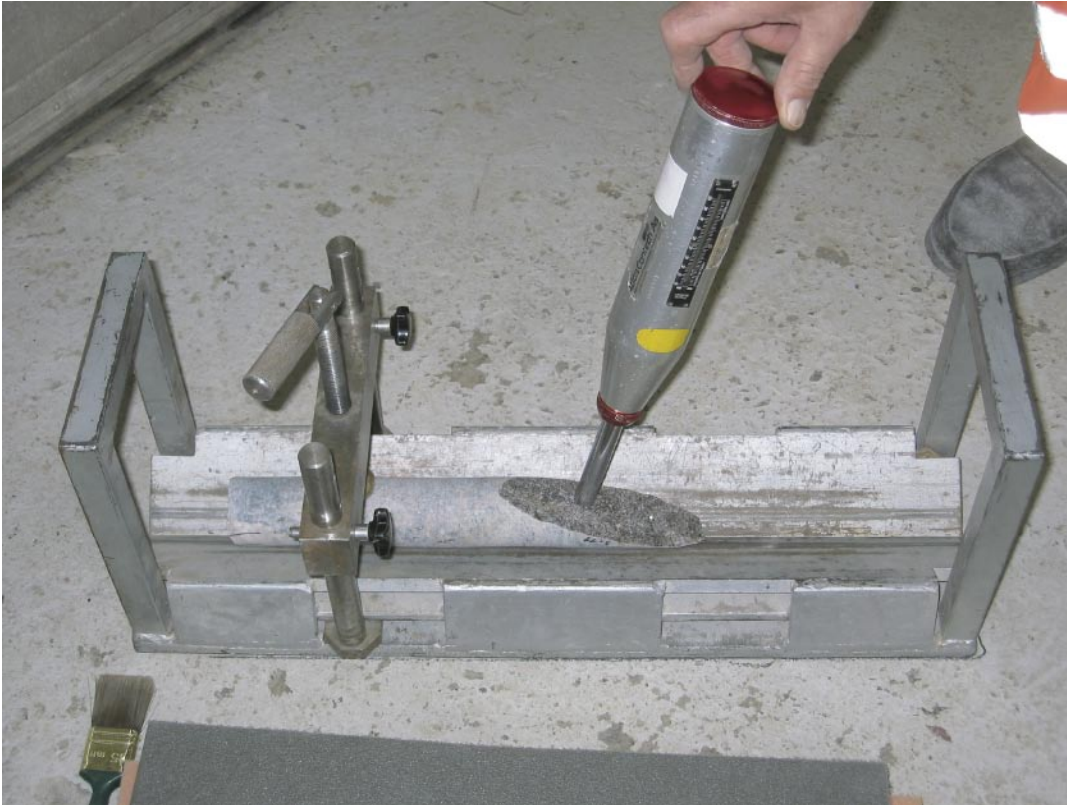


Figure 3-2. Clamp for the Schmidt hammer tests.



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 joint surfaces 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 15 to 22 m in the depth range between 207 m and 954 m in the near-vertical borehole KFM03A, see Appendix. Three samples were selected from borehole KFM03B in the range of 0 m to 100 m. Also KFM03B is near-vertical. A total of 38 tilt samples from boreholes KFM03A and KFM03B were selected 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. Single joint surface for the tilt testing.

Table 4-1. Joint set numbering and orientation.

Joint set number	Angle of intersection in degrees	Number of tilt tests
Set 1 (steep joints)	0-30°	14
Set 2 (ca 45 degrees joints)	30-60°	12
Set 3 (sub-horizontal joints)	60-90°	12

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.

Due to the small core diameter, and many artificial fractures, it was rather difficult to find good samples for tilt testing. This is especially valid for joint set 3 where only few horizontal joints were found at depths exceeding 650 m.

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 35 tilt joint surfaces from borehole KFM03A can be directly identified within the database SICADA at SKB. The three tests from borehole KFM03B can be identified from core box depths 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 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 from KFM01A 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 2.64–2.82 g/cm³. The densities listed in Table 4-2 have been used for the calculations.

Table 4-2. Depth ranges in borehole KFM03A with the relevant unit weight used.

Depth interval		Unit weight
m	m	kN/m ³
102.50	217.55	26.62
217.55	294.78	27.97
294.78	399.88	28.23
399.88	510.65	26.57
510.65	603.83	26.51
603.83	708.58	26.52
708.58	809.05	28.00
809.05	902.65	26.38
902.65	992.20	26.46

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

5.2 Results from Boreholes KFM03A and KFM03B

35 tilt tests and 35×3 profilings on joints were performed on core samples from section 207–954 m in borehole KFM03A. In addition to these, 3 tests and 3×3 profiles were conducted on samples from borehole KFM03B from the depth range 0 to 100 m. Complete input and output data from tilt tests and profiling are found in Appendix. 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 relevant results from boreholes KFM03A and KFM03B are presented together in the same plots. The points in the plots at the range from 0 to 100 m correspond to specimens from borehole KFM03B. Table 5-1 shows the arithmetic 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, boreholes KFM03A and KFM03B (only 3 tests from 0-100 m depth).

Fracture set	JRC_o (tilt)	JCS_o MPa	Φ_b (°)	Φ_r (°)	Number (tilt)	Number (profiles)
Set 1	6.19	75.86	32.1	27.10	14	14
Set 2	6.12	73.61	31.9	26.36	12	12
Set 3	5.70	75.10	31.9	26.75	12	12
Mean/Total	6.01	75.05	32.0	26.76	38	38

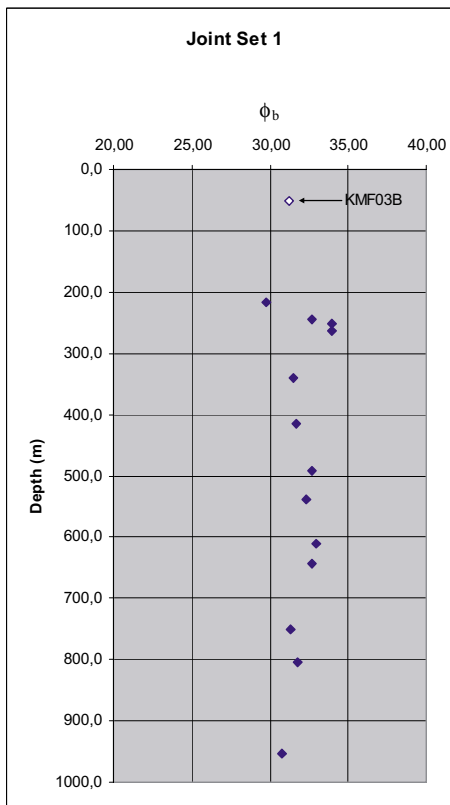
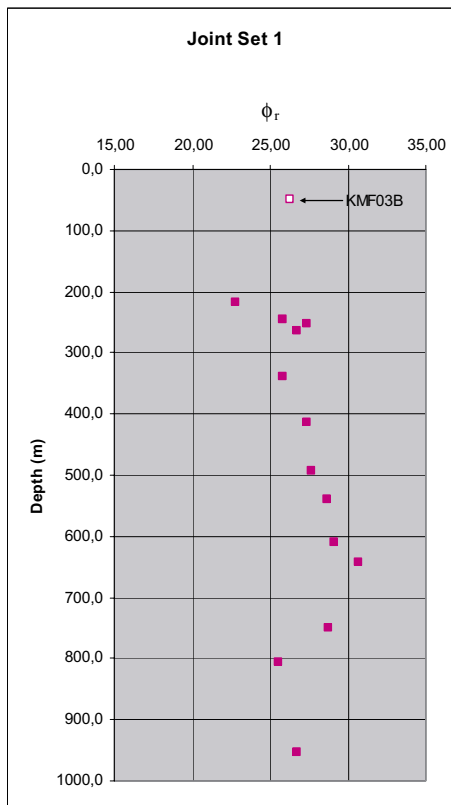
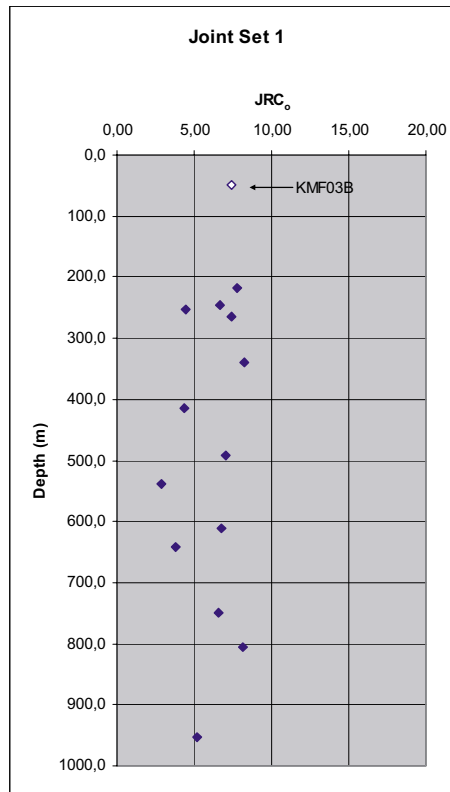
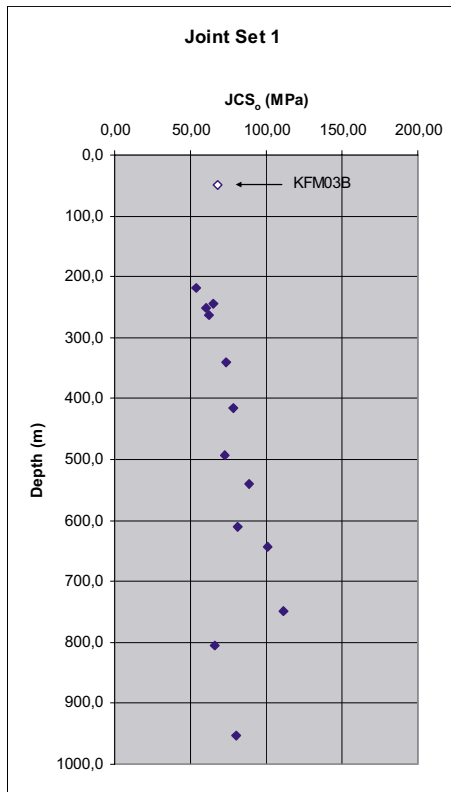


Figure 5-1. Variation of joint parameters with depth for Set 1

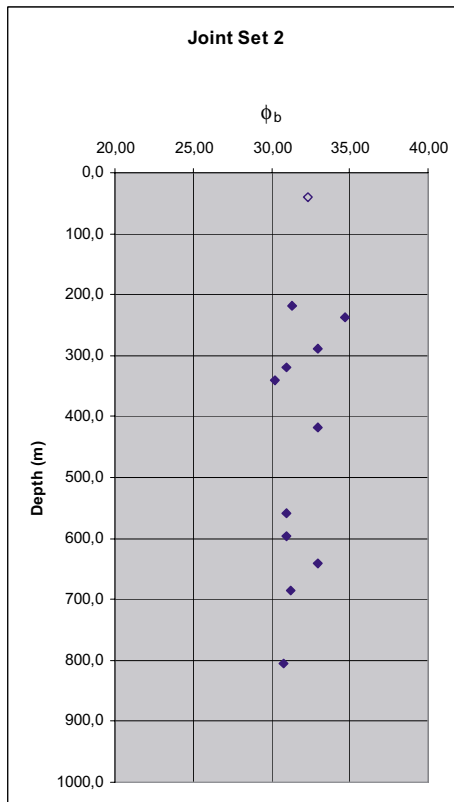
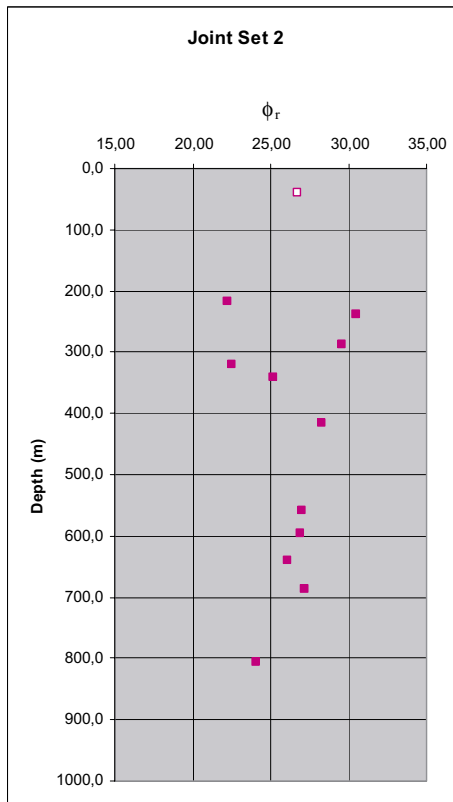
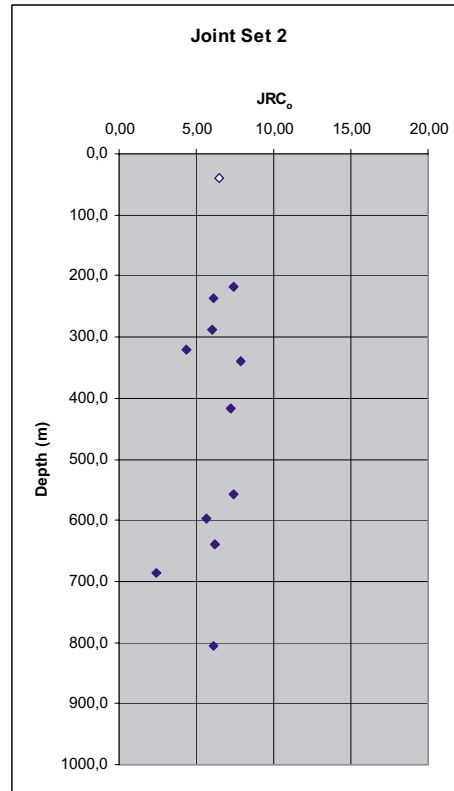
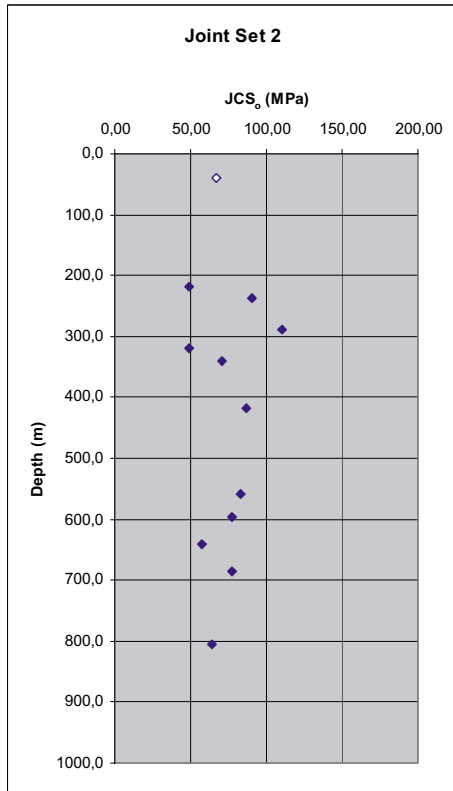


Figure 5-2. Variation of joint parameters with depth for Set 2.

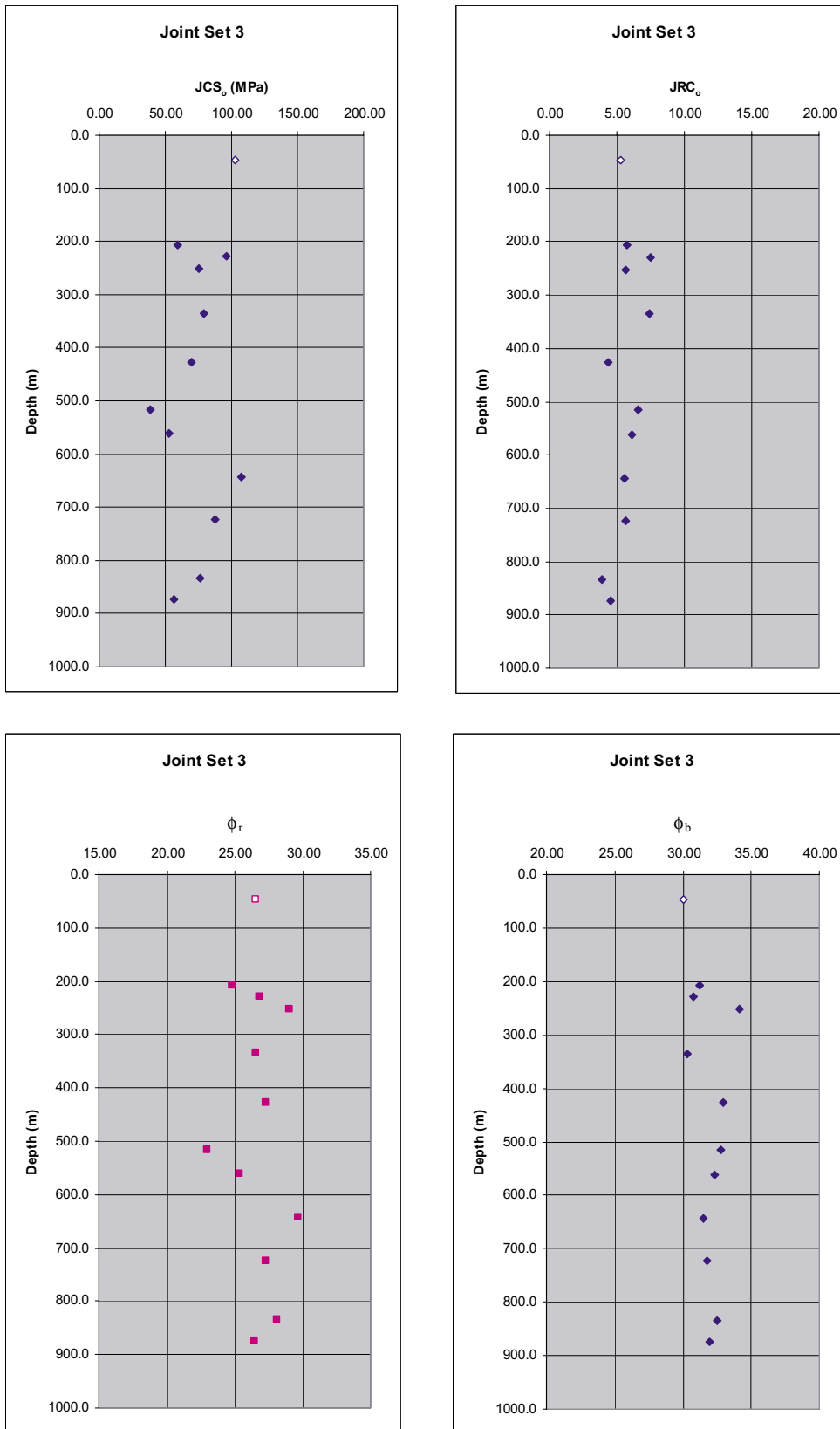


Figure 5-3. Variation of joint parameters with depth for Set 3.

5.3 Evaluation of the results

The joint faces are rather similar concerning mineralisation, and the tilt tests show rather uniform JRC- 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 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 2.4 and 8.3. This means that the sample selection for tilt testing is representative for borehole KFM03A. The results from specimens from borehole KFM03B are in the same range of results as from borehole KFM03A.

The main results from tilt testing

ROCK JOINT CHARACTERISATION												
CLIENT: SKB- Tilt tests												
INPUT DATA												
Depth zone: 102 - 992 m for KFM03A and 0 -100 m for KFM03B												
Borehole: KFM03A, KFM03B												
#/T												
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 REBOUND NUMBER (r)	ROCK REBOUND NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m ³)
1	set 1	217,535	Sicada	3,1	117,0	272,02	52,7	69,0	30,8	47,4	29,8	26,62
2	set 2	217,876	Sicada	1,4	55,0	152,69	24,4	64,0	27,6	50,6	31,3	27,97
3	set 3	207,062	Sicada	2,0	49,0	120,60	20,1	56,7	32,5	47,6	31,2	27,97
4	set 1	244,994	Sicada	2,2	76,0	202,56	34,5	64,0	32,6	49,8	32,7	27,97
5	set 2	237,405	Sicada	0,9	52,0	139,76	21,6	67,0	38,5	48,8	34,7	27,97
6	set 3	228,855	Sicada	1,7	49,3	128,70	22,0	74,7	39,6	49,4	30,8	27,97
7	set 1	252,276	Sicada	1,5	87,2	229,10	36,2	51,2	31,4	47,0	34,0	27,97
8	set 2	287,884	Sicada	2,2	54,7	138,70	24,4	66,5	41,9	50,4	33,0	27,97
9	set 3	252,034	Sicada	1,1	49,0	134,90	20,9	61,5	35,2	47,4	34,2	27,97
10	set 1	263,840	Sicada	2,5	91,0	133,70	42,9	74,3	31,8	50,0	34,0	27,97
11	set 2	320,388	Sicada	1,9	67,0	262,98	29,9	44,3	27,5	47,8	31,0	28,23
12	set 1	339,567	Sicada	3,0	204,0	719,14	93,0	78,7	34,6	48,4	31,5	28,23
13	set 2	340,724	Sicada	1,7	68,0	169,26	29,1	74,0	33,9	45,2	30,2	28,23
14	set 1	414,620	Sicada	1,7	93,2	200,10	41,2	51,7	37,8	48,2	31,7	26,57
15	set 2	416,912	Sicada	2,5	56,0	132,60	23,3	73,8	39,7	51,8	33,0	26,57
16	set 3	335,067	Sicada	2,1	48,3	122,36	20,8	72,2	35,7	44,0	30,3	28,23
17	set 1	491,999	Sicada	3,0	139,0	225,10	64,3	72,7	36,4	48,6	32,7	26,57
18	set 2	557,667	Sicada	2,3	65,7	167,10	28,3	73,3	38,9	48,6	31,0	26,51
19	set 3	426,999	Sicada	1,6	48,3	131,50	21,6	51,2	35,7	50,0	33,0	26,57
20	set 1	539,113	Sicada	3,7	129,7	305,60	59,8	44,7	40,2	49,0	32,3	26,51
21	set 2	596,578	Sicada	1,2	51,7	146,99	23,1	59,0	37,7	47,4	31,0	26,51
22	set 3	516,146	Sicada	1,3	50,3	132,50	21,9	58,5	24,6	48,4	32,8	26,51
23	set 1	610,162	Sicada	2,8	93,0	202,80	46,9	71,7	38,6	48,0	33,0	26,52
24	set 2	640,031	Sicada	2,4	55,3	138,70	25,4	61,3	32,0	49,0	33,0	26,52
25	set 3	561,280	Sicada	1,9	49,0	137,20	21,9	59,2	30,6	47,0	32,3	26,51
26	set 1	642,293	Sicada	3,4	77,3	224,96	37,2	52,3	42,6	47,4	32,7	26,52
27	set 2	685,806	Sicada	2,3	59,0	160,70	26,5	40,0	37,7	47,0	31,2	26,52
28	set 3	642,878	Sicada	1,4	45,7	122,00	20,4	63,0	43,8	48,2	31,5	26,52
29	set 1	749,462	Sicada	3,0	133,7	344,40	62,0	69,7	42,0	48,0	31,3	28,00
30	set 2	806,014	Sicada	1,7	54,0	148,00	24,0	58,2	32,4	48,8	30,8	28,00
31	set 3	723,578	Sicada	1,5	45,3	117,20	20,1	60,3	37,9	48,8	31,8	28,00
32	set 1	804,954	Sicada	4,0	115,3	302,60	50,1	77,0	32,8	47,8	31,8	28,00
33	set 3	834,353	Sicada	1,2	46,7	133,10	20,1	49,3	37,5	48,0	32,5	26,38
34	set 1	953,337	Sicada	2,5	136,3	322,20	60,1	56,3	38,4	48,2	30,8	26,46
35	set 3	873,162	Sicada	2,4	47,3	112,97	20,4	51,0	31,9	44,0	32,0	26,38
36	set 1	50,150	core box	2,8	108,7	159,30	49,6	74,2	34,0	45,0	31,2	27,40
37	set 2	39,450	core box	1,8	52,3	148,20	23,9	64,3	33,9	47,0	32,3	27,40
38	set 3	47,120	core box	2,9	51,7	133,70	22,4	57,0	41,5	50,2	30,0	27,40
			Arithmetic av.		75,6	191,5	33,9	62,3	35,6	48,1	32,0	27,27
			maximum val.		204,0	719,1	93,0	78,7	43,8	51,8	34,7	28,23
			minimum val.		45,3	113,0	20,1	40,0	24,6	44,0	30,0	26,38

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3

Operator: PC

Date: 16.10.2003

Borehole: KFM03A,
KFM03B

OUTPUT DATA

Depth zone: 102 - 992 m for KFM03A and 0 - 100 m for KFM03B

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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 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	217.535	53.89	6.50E-05	22.8	7.81	0.85	8.00	55.91
2	set 2	217.876	48.90	1.18E-04	22.2	7.44	1.82	6.81	42.79
3	set 3	207.062	64.56	1.77E-04	24.9	5.73	2.04	5.28	57.11
4	set 1	244.994	64.92	1.11E-04	25.8	6.62	1.32	6.39	61.48
5	set 2	237.405	90.70	9.69E-05	30.5	6.12	1.92	5.65	80.45
6	set 3	228.855	96.54	4.00E-05	26.8	7.50	2.03	6.75	82.34
7	set 1	252.276	60.66	2.44E-04	27.4	4.42	1.15	4.36	59.56
8	set 2	287.884	109.98	8.86E-05	29.6	6.05	1.83	5.62	98.57
9	set 3	252.034	75.23	1.44E-04	29.1	5.67	2.04	5.23	66.63
10	set 1	263.840	62.05	2.24E-05	26.7	7.38	1.10	7.28	60.76
11	set 2	320.388	49.34	4.42E-04	22.5	4.32	1.49	4.17	46.84
12	set 1	339.567	74.05	2.91E-05	25.8	8.26	0.49	9.29	88.36
13	set 2	340.724	71.15	4.33E-05	25.2	7.85	1.47	7.39	64.97
14	set 1	414.620	78.31	1.83E-04	27.4	4.32	1.07	4.29	77.60
15	set 2	416.912	86.75	4.34E-05	28.3	7.22	1.79	6.64	76.51
16	set 3	335.067	78.86	5.39E-05	26.5	7.41	2.07	6.65	67.09
17	set 1	491.999	72.63	3.04E-05	27.7	7.06	0.72	7.39	77.87
18	set 2	557.667	82.70	4.78E-05	27.0	7.42	1.52	6.97	75.31
19	set 3	426.999	69.94	2.34E-04	27.3	4.37	2.07	4.10	63.58
20	set 1	539.113	88.68	2.53E-04	28.7	2.88	0.77	2.93	90.70
21	set 2	596.578	77.53	1.66E-04	26.9	5.66	1.93	5.25	69.32
22	set 3	516.146	38.36	1.62E-04	23.0	6.61	1.99	6.04	33.47
23	set 1	610.162	81.44	4.19E-05	29.1	6.78	1.08	6.71	80.25
24	set 2	640.031	57.12	1.23E-04	26.1	6.22	1.81	5.78	51.14
25	set 3	561.280	52.95	1.61E-04	25.3	6.14	2.04	5.63	46.43
26	set 1	642.293	100.97	2.22E-04	30.7	3.82	1.29	3.75	98.03
27	set 2	685.806	77.59	3.49E-04	27.2	2.39	1.69	2.33	74.72
28	set 3	642.878	107.69	1.21E-04	29.7	5.60	2.19	5.13	94.42
29	set 1	749.462	110.89	6.56E-05	28.8	6.57	0.75	6.82	117.42
30	set 2	806.014	64.32	1.68E-04	24.1	6.11	1.85	5.67	57.45
31	set 3	723.578	87.87	1.40E-04	27.3	5.69	2.21	5.20	76.77
32	set 1	804.954	65.79	3.00E-05	25.5	8.12	0.87	8.31	68.12
33	set 3	834.353	75.95	2.76E-04	28.1	3.89	2.14	3.67	69.49
34	set 1	953.337	80.19	1.62E-04	26.7	5.19	0.73	5.36	84.16
35	set 3	873.162	56.30	2.15E-04	26.5	4.52	2.11	4.23	50.87
36	set 1	50.150	67.58	2.34E-05	26.3	7.41	0.92	7.50	68.84
37	set 2	39.450	67.20	1.14E-04	26.7	6.51	1.91	5.99	59.21
38	set 3	47.120	102.48	1.74E-04	26.5	5.28	1.93	4.92	92.31
		Arithmetic av.	75.05	1.36E-04	26.76	6.01	1.55	5.78	70.71
		maximum val.	110.89	4.42E-04	30.67	8.26	2.21	9.29	117.42
		minimum val.	38.36	2.24E-05	22.21	2.39	0.49	2.33	33.47

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	16.10.03
Borehole:	KFM03A and KFM03B

INPUT DATA Depth zone 102-992 m for KFM03A and 0-100 m for KFM03B

F:\p\2003\10\20031089\Reports\Rap KFM03A\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 REBOUNDE NUMBER (r)	ROCK REBOUNDE NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m ³)
				AMP. a (mm)	LENG. L (mm)							
1	set 1	217.535	Sicada	3.1	117.0	272.02	52.7	69.0	30.8	47.4	29.8	26.62
2	set 1	244.994	Sicada	2.2	76.0	202.56	34.5	64.0	32.6	49.8	32.7	27.97
3	set 1	252.276	Sicada	1.5	87.2	229.10	36.2	51.2	31.4	47.0	34.0	27.97
4	set 1	263.840	Sicada	2.5	91.0	133.70	42.9	74.3	31.8	50.0	34.0	27.97
5	set 1	339.567	Sicada	3.0	204.0	719.14	93.0	78.7	34.6	48.4	31.5	28.23
6	set 1	414.620	Sicada	1.7	93.2	200.10	41.2	51.7	37.8	48.2	31.7	26.57
7	set 1	491.999	Sicada	3.0	139.0	225.10	64.3	72.7	36.4	48.6	32.7	26.57
8	set 1	539.113	Sicada	3.7	129.7	305.60	59.8	44.7	40.2	49.0	32.3	26.51
9	set 1	610.162	Sicada	2.8	93.0	202.80	46.9	71.7	38.6	48.0	33.0	26.52
10	set 1	642.293	Sicada	3.4	77.3	224.96	37.2	52.3	42.6	47.4	32.7	26.52
11	set 1	749.462	Sicada	3.0	133.7	344.40	62.0	69.7	42.0	48.0	31.3	28.00
12	set 1	804.954	Sicada	4.0	115.3	302.60	50.1	77.0	32.8	47.8	31.8	28.00
13	set 1	953.337	Sicada	2.5	136.3	322.20	60.1	56.3	38.4	48.2	30.8	26.46
14	set 1	50.150	core box	2.8	108.7	159.30	49.6	74.2	34.0	45.0	31.2	27.40
Arithmetic av.					114.4	274.5	52.2	64.8	36.0	48.1	32.1	27.24
maximum val.					204.0	719.1	93.0	78.7	42.6	50.0	34.0	28.23
minimum val.					76.0	133.7	34.5	44.7	31.4	45.0	30.8	26.46

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3	
Operator:	PC
Date:	16.10.2003
Borehole:	KFM03A and KFM03B

OUTPUT DATA Depth zone 102-992 m for KFM03A and 0-100 m for KFM03B

F:\p\2003\10\20031089\Reports\Rap KFM03A\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	244.994	64.92	1.11E-04	25.8	6.62	1.32	6.39	61.48
3	set 1	252.276	60.66	2.44E-04	27.4	4.42	1.15	4.36	59.56
4	set 1	263.840	62.05	2.24E-05	26.7	7.38	1.10	7.28	60.76
5	set 1	339.567	74.05	2.91E-05	25.8	8.26	0.49	9.29	88.36
6	set 1	414.620	78.31	1.83E-04	27.4	4.32	1.07	4.29	77.60
7	set 1	491.999	72.63	3.04E-05	27.7	7.06	0.72	7.39	77.87
8	set 1	539.113	88.68	2.53E-04	28.7	2.88	0.77	2.93	90.70
9	set 1	610.162	81.44	4.19E-05	29.1	6.78	1.08	6.71	80.25
10	set 1	642.293	100.97	2.22E-04	30.7	3.82	1.29	3.75	98.03
11	set 1	749.462	110.89	6.56E-05	28.8	6.57	0.75	6.82	117.42
12	set 1	804.954	65.79	3.00E-05	25.5	8.12	0.87	8.31	68.12
13	set 1	953.337	80.19	1.62E-04	26.7	5.19	0.73	5.36	84.16
14	set 1	50.150	67.58	2.34E-05	26.3	7.41	0.92	7.50	68.84
Arithmetic av.			75.86	1.06E-04	27.10	6.19	0.94	6.31	77.79
maximum val.			110.89	2.53E-04	30.67	8.26	1.32	9.29	117.42
minimum val.			53.89	2.24E-05	22.80	2.88	0.49	2.93	55.91

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1

Operator: PC

Date: 16.10.03

Borehole: KFM03A and KFM03B

INPUT DATA

Depth zone 102-992 or KFM03A and 0-100 for KFM03B

F:\p\2003\10\20031089\Reports\Rap KFM03A\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 REBOUNDE NUMBER (r)	ROCK REBOUNDE NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m ³)
				AMP. a (mm)	LENG. L (mm)							
1	set 2	217.876	Sicada	1.4	55.0	152.69	24.4	64.0	27.6	50.6	31.3	27.97
2	set 2	237.405	Sicada	0.9	52.0	139.76	21.6	67.0	38.5	48.8	34.7	27.97
3	set 2	287.884	Sicada	2.2	54.7	138.70	24.4	66.5	41.9	50.4	33.0	27.97
4	set 2	320.388	Sicada	1.9	67.0	262.98	29.9	44.3	27.5	47.8	31.0	28.23
5	set 2	340.724	Sicada	1.7	68.0	169.26	29.1	74.0	33.9	45.2	30.2	28.23
6	set 2	416.912	Sicada	2.5	56.0	132.60	23.3	73.8	39.7	51.8	33.0	26.57
7	set 2	557.667	Sicada	2.3	65.7	167.10	28.3	73.3	38.9	48.6	31.0	26.51
8	set 2	596.578	Sicada	1.2	51.7	146.99	23.1	59.0	37.7	47.4	31.0	26.51
9	set 2	640.031	Sicada	2.4	55.3	138.70	25.4	61.3	32.0	49.0	33.0	26.52
10	set 2	685.806	Sicada	2.3	59.0	160.70	26.5	40.0	37.7	47.0	31.2	26.52
11	set 2	806.014	Sicada	1.7	54.0	148.00	24.0	58.2	32.4	48.8	30.8	28.00
12	set 2	39.450	core box	1.8	52.3	148.20	23.9	64.3	33.9	47.0	32.3	27.40
Arithmetic av.					57.6	158.8	25.3	62.1	35.1	48.5	31.9	27.37
maximum val.					68.0	263.0	29.9	74.0	41.9	51.8	34.7	28.23
minimum val.					51.7	132.6	21.6	40.0	27.5	45.2	30.2	26.51

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3

Operator: PC

Date: 16.10.2003

Borehole: KFM03A and KFM03B

OUTPUT DATA

Depth zone: 102-992 or KFM03A and 0-100 for KFM03B m

F:\p\2003\10\20031089\Reports\Rap KFM03A\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	237.405	90.70	9.69E-05	30.5	6.12	1.92	5.65	80.45
3	set 2	287.884	109.98	8.86E-05	29.6	6.05	1.83	5.62	98.57
4	set 2	320.388	49.34	4.42E-04	22.5	4.32	1.49	4.17	46.84
5	set 2	340.724	71.15	4.33E-05	25.2	7.85	1.47	7.39	64.97
6	set 2	416.912	86.75	4.34E-05	28.3	7.22	1.79	6.64	76.51
7	set 2	557.667	82.70	4.78E-05	27.0	7.42	1.52	6.97	75.31
8	set 2	596.578	77.53	1.66E-04	26.9	5.66	1.93	5.25	69.32
9	set 2	640.031	57.12	1.23E-04	26.1	6.22	1.81	5.78	51.14
10	set 2	685.806	77.59	3.49E-04	27.2	2.39	1.69	2.33	74.72
11	set 2	806.014	64.32	1.68E-04	24.1	6.11	1.85	5.67	57.45
12	set 2	39.450	67.20	1.14E-04	26.7	6.51	1.91	5.99	59.21
Arithmetic av.			73.61	1.50E-04	26.36	6.11	1.75	5.69	66.44
maximum val.			109.98	4.42E-04	30.48	7.85	1.93	7.39	98.57
minimum val.			48.90	4.33E-05	22.21	2.39	1.47	2.33	42.79

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 1	
Operator:	PC
Date:	16.10.2003
Borehole:	KFM03A and KFM03B

INPUT DATA

Depth zone 102-992 for KFM03A and 0-100 for KFM03B

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 3	207.062	Sicada	2.0	49.0	120.60	20.1	56.7	32.5	47.6	31.2	26.62
2	set 3	228.855	Sicada	1.7	49.3	128.70	22.0	74.7	39.6	49.4	30.8	27.97
3	set 3	252.034	Sicada	1.1	49.0	134.90	20.9	61.5	35.2	47.4	34.2	27.97
4	set 3	335.067	Sicada	2.1	48.3	122.36	20.8	72.2	35.7	44.0	30.3	28.23
5	set 3	426.999	Sicada	1.6	48.3	131.50	21.6	51.2	35.7	50.0	33.0	26.57
6	set 3	516.146	Sicada	1.3	50.3	132.50	21.9	58.5	24.6	48.4	32.8	26.51
7	set 3	561.280	Sicada	1.9	49.0	137.20	21.9	59.2	30.6	47.0	32.3	26.51
8	set 3	642.878	Sicada	1.4	45.7	122.00	20.4	63.0	43.8	48.2	31.5	26.52
9	set 3	723.578	Sicada	1.5	45.3	117.20	20.1	60.3	37.9	48.8	31.8	28.00
10	set 3	834.353	Sicada	1.2	46.7	133.10	20.1	49.3	37.5	48.0	32.5	26.38
11	set 3	873.162	Sicada	2.4	47.3	112.97	20.4	51.0	31.9	44.0	32.0	26.38
12	set 3	47.120	core box	2.9	51.7	133.70	22.4	57.0	41.5	50.2	30.0	27.4
Arithmetic av.				48.3	127.2	21.0	59.6	35.5	47.8	31.9	27.1	
maximum val.				51.7	137.2	22.4	74.7	43.8	50.2	34.2	28.2	
minimum val.				45.3	113.0	20.1	49.3	24.6	44.0	30.0	26.4	

ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3	
Operator:	PC
Date:	16.10.2003
Borehole:	KFM03A and KFM03B

OUTPUT DATA

Depth zone: 102-992 for KFM03A and 0-100 for KFM03B m

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	228.855	96.54	4.00E-05	26.8	7.50	2.03	6.75	82.34
3	set 3	252.034	75.23	1.44E-04	29.1	5.67	2.04	5.23	66.63
4	set 3	335.067	78.86	5.39E-05	26.5	7.41	2.07	6.65	67.09
5	set 3	426.999	69.94	2.34E-04	27.3	4.37	2.07	4.10	63.58
6	set 3	516.146	38.36	1.62E-04	23.0	6.61	1.99	6.04	33.47
7	set 3	561.280	52.95	1.61E-04	25.3	6.14	2.04	5.63	46.43
8	set 3	642.878	107.69	1.21E-04	29.7	5.60	2.19	5.13	94.42
9	set 3	723.578	87.87	1.40E-04	27.3	5.69	2.21	5.20	76.77
10	set 3	834.353	75.95	2.76E-04	28.1	3.89	2.14	3.67	69.49
11	set 3	873.162	56.30	2.15E-04	26.5	4.52	2.11	4.23	50.87
12	set 3	47.120	102.48	1.74E-04	26.5	5.28	1.93	4.92	92.31
Arithmetic av.			75.10	1.58E-04	26.75	5.70	2.07	5.24	66.30
maximum val.			107.69	2.76E-04	29.67	7.50	2.21	6.75	94.42
minimum val.			38.36	4.00E-05	22.97	3.89	1.93	3.67	33.47