

**P-03-108**

## **Forsmark site investigation**

### **Borehole: KFM01A**

### **Results of tilt testing**

Panayiotis Chryssanthakis  
Norwegian Geotechnical Institute, Oslo

June 2003

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June 2003

*Keywords:* Rock mechanics, Joint properties,  $JRC_{100}$ ,  $JCS_{100}$ , Angles of joint friction, Tilt test, Schmidt hammer 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](http://www.skb.se)

# Summary

The Norwegian Geotechnical Institute (NGI) has carried out tilt testing on joint surfaces of drill cores from the borehole KFM01A. From a total 908 m of cores, 41 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 6.2. The mean value of the joint wall compressive strength ( $JCS_o$ ) from Schmidt hammer testing of all the joint samples is 90.9 MPa. The mean values of the basic ( $\Phi_b$ ) and residual ( $\Phi_r$ ) friction angles of all the tested samples are 28.9 and 24.2 degrees respectively.

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# 1 Introduction

The Norwegian Geotechnical Institute (NGI) has performed tilt testing on joint surfaces of drill cores from borehole KFM01A at Forsmark in Sweden according to SKB Activity Plan AP PF400-03-10 (SKB internal controlling document). The work has been carried out by Panayiotis Chryssanthakis during the period 19–26 February 2003 in accordance with SKB's method description MD 190.006, version 1.0.

## 2 Objective and scope

The purpose of the testing is to determine the joint properties JRC, JCS as well as the basic and residual friction angle. 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 is given in Table 2-1.

The results from the tilt tests are presented in this report by means of tables, figures and spreadsheets.

**Table 2-1. Total number of tilt tests and number of joint sets.**

<b>Borehole</b>	<b>Tilt tests</b>	<b>No. of joint sets</b>
KFM01A	41	3

### 3 Equipment and methods

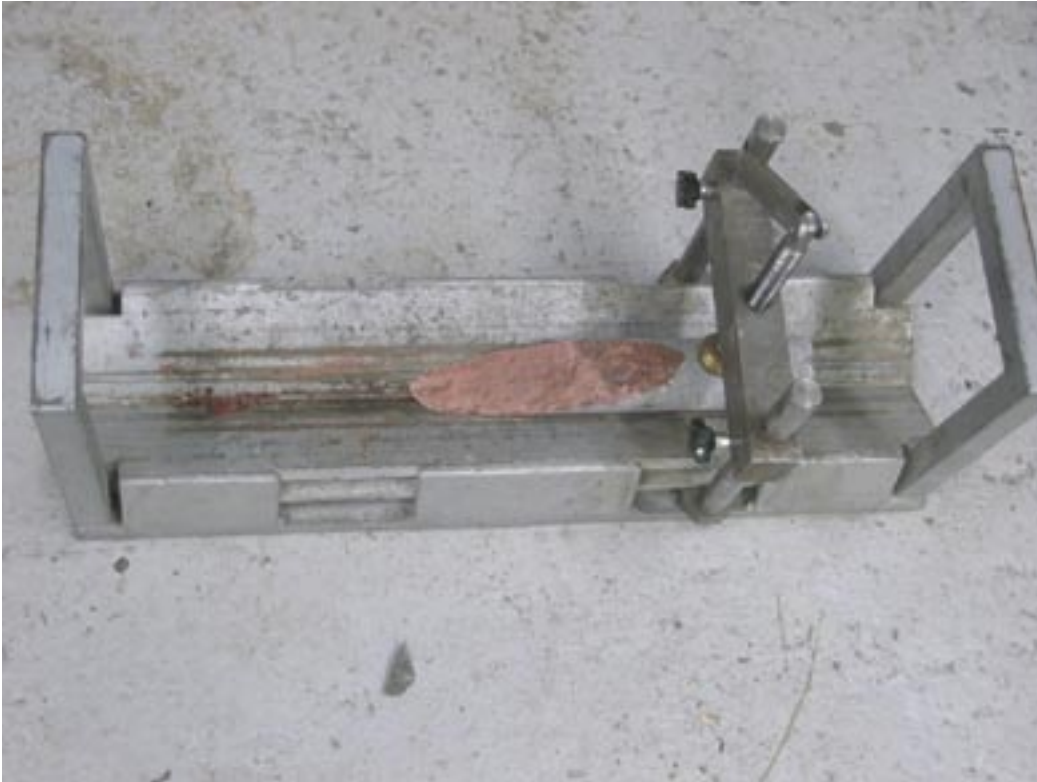
The tilt angles ( $\alpha$  and  $\Phi_b$ ) are measured by a simple tilt apparatus, see Figure 3-1.

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. Tilt apparatus.*



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



*Figure 3-3. Profilometer.*



## 4 Execution

### 4.1 Sampling

The samples were collected from drill cores with a diameter of 51 mm. Each sample contained both faces of a joint, see Figure 4-1. To prepare the sample, sawing was usually necessary.

The frequency of the tilt test samples was determined by selecting one specimen for approximately 20 to 25 metres. A total of 41 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 were classified according to their angle of intersection with the core in the way it is displayed in Table 4-1.

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



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

**Table 4-1. Joint set classification according to the angle of intersection with the drill core.**

Joint set number	Angle of intersection in degrees	Number of tilt tests
Set 1 (steep joints)	0–30°	15
Set 2 (ca 45° joints)	30–60°	12
Set 3 (sub-horizontal joints)	60–90°	14

Three profiles on each tilt joint surface have also been carried out. The main rock types can be classified as granodiorite, granite with veins of amphibolite and pegmatite. 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 and hematite. All 41 tilt joint surfaces can be directly identified within the database SICADA. 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 included tilting, Schmidt hammer measurements and profiling of the joint faces.

The measurements of the tilt angle  $\alpha$  were performed on wet (humid) joint surfaces. The sample was fixed to the tilt apparatus and tilted. At least three tilts were 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 a variation of more than 3° may (in such specific cases) be accepted.

The same procedure was applied for determining  $\Phi_b$ , which is the tilt angle core to core, but in this case the tests were performed on dry cores.

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

For determination 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.

Also the weight of the tilting block was measured as well as the fracture surface area, which 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 determined.

A few density measurements of the rock were carried out during tilt testing, and the results were in the range 2.65–2.80 g/cm<sup>3</sup>. In the calculations, 2.72 g/cm<sup>3</sup> has been used for all samples.

## 5 Results

### 5.1 General

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

Tables with all input and output data are shown in Appendix A. Separate tables are presented for each of the three joint sets. A table with 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 41 tilt test specimens were selected from 908 m of core material of borehole KFM01A. As mentioned earlier, the fractures have been classified in three sets according to the angle of intersection with the core. Each set may, however, consist of fractures with different dip directions.

### 5.2 Results from borehole KFM01A

In borehole section 100–1008 m, 41 tilt tests and 41x3 profilings on joints were performed. Complete input and output data from tilt tests and profiling are found in Appendix A. Figures 5-1, 5-2 and 5-3 illustrate the variation of the parameters  $JCS_o$ ,  $JRC_o$ ,  $\Phi_r$  and  $\Phi_b$  with depth for each of the three joint sets respectively. Table 5-1 shows the arithmetic mean values of these parameters. A summary of the tilt tests and profiling is also given in Table 2.

**Table 5-1. Borehole KFM01A – Arithmetic mean  $JCS_o$ ,  $JRC_o$ ,  $\Phi_r$  and  $\Phi_b$  -values.**

Fracture set	$JRC_o$ (tilt)	$JCS_o$ MPa	$\Phi_b$ (°)	$\Phi_r$ (°)	Number (tilt)	Number (profiles)
Set 1	6.6	90.41	28.7	24.2	15	15
Set 2	6.3	95.3	28.5	24.0	12	12
Set 3	5.6	87.8	29.4	24.4	14	14
Mean/Total	6.1	90.9	28.9	24.2	41	41

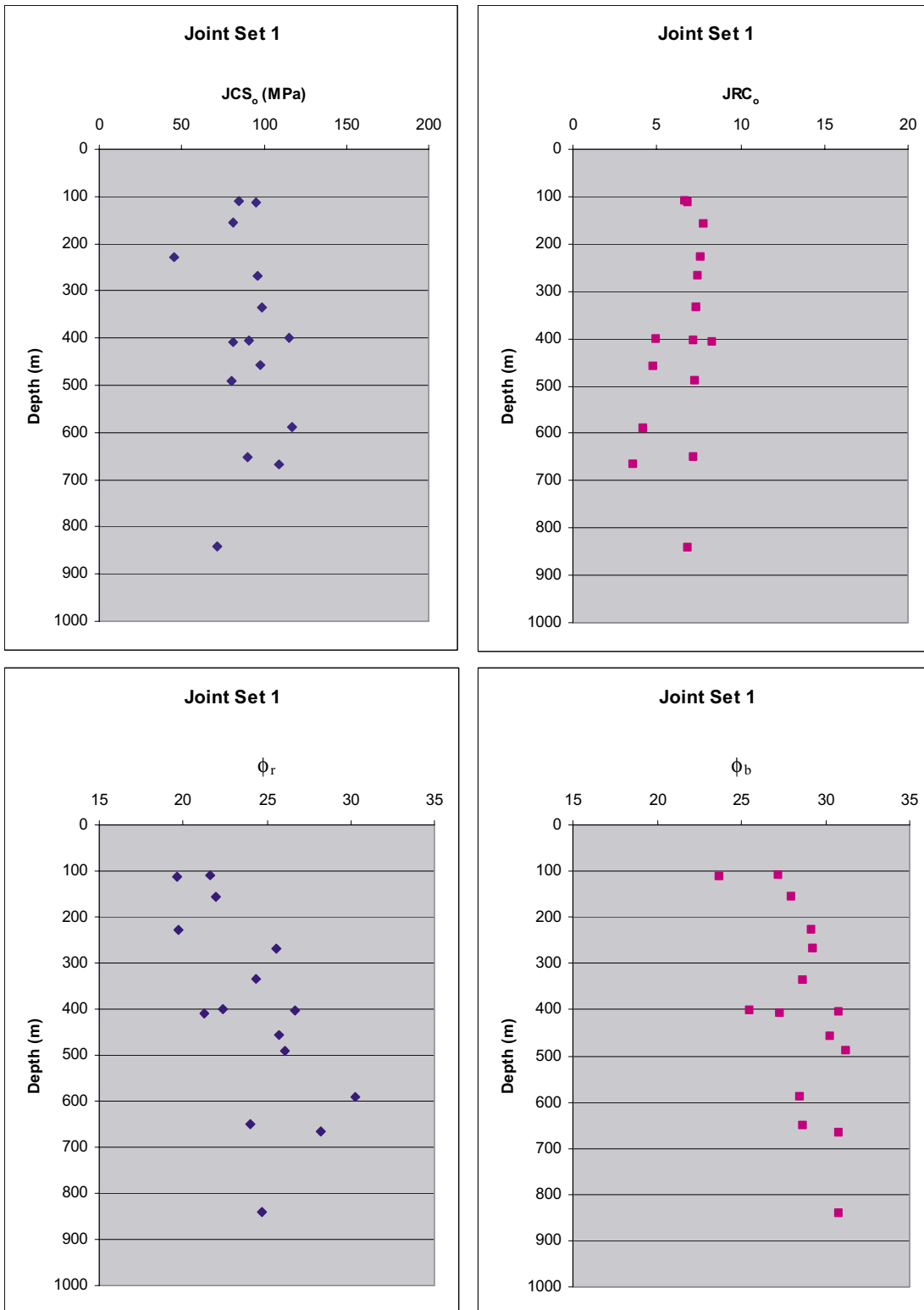


Figure 5-1. Variation of joint parameters with depth for Set 1.

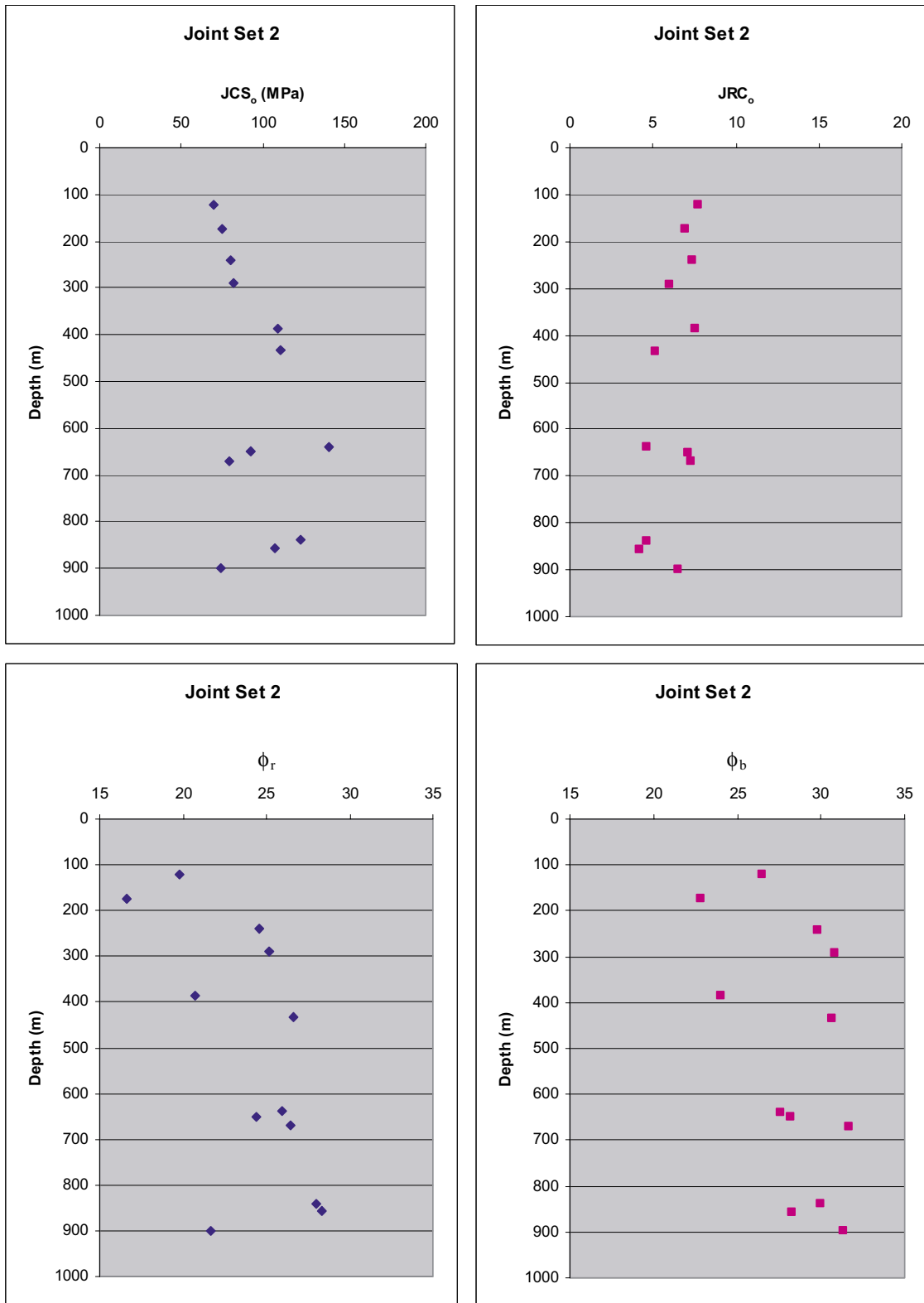


Figure 5-2. Variation of joint parameters with depth for Set 2.

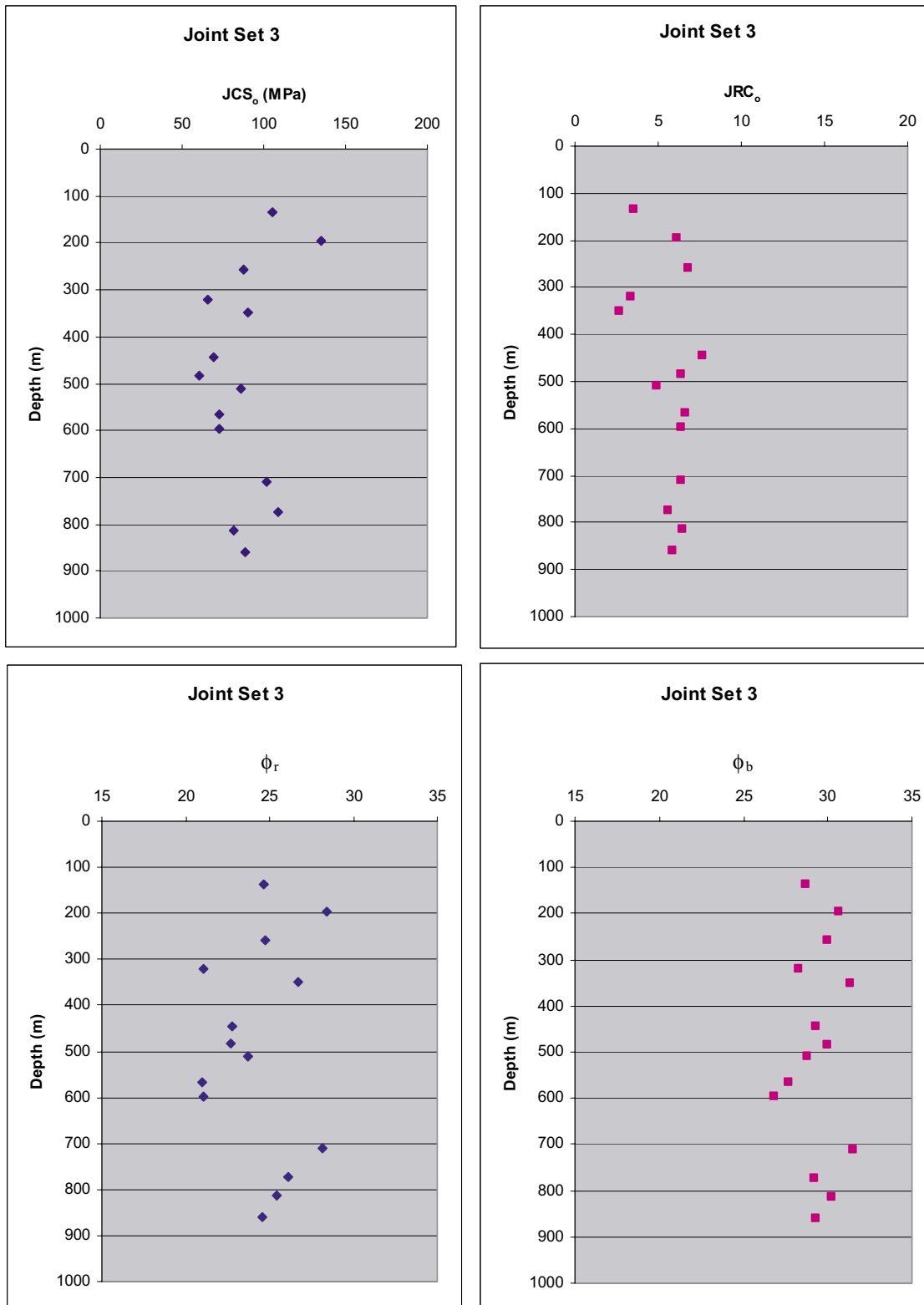


Figure 5-3. Variation of joint parameters with depth for Set 3.

### 5.3 Discussion

The joint faces are rather similar concerning mineralisation, and the tilt tests show rather uniform JRC- and JCS values. Due to 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, since toppling occurs before sliding. However, the selection of the tilt test samples did not take into account the possibility of 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 used for comparison 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 2.6 and 8.3. This means that the sample selection for tilt testing is representative for borehole KFM01A.

## 6 References

**SKB SICADA.** Field note number 90.



The main results from tilt testing

ROCK JOINT CHARACTERISATION										PAGE	1		
CLIENT: SKB- Tilt tests										Chkd	Operator: PC		
INPUT DATA										Date	04.03.2003		
Depth zone: 100-1008 m										Borehole:	KFM01A		
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 <sup>2</sup> )	MEAN TILT ANGLE (°)	JOINT REBOUND NUMBER (r)	ROCK REBOUND NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m <sup>3</sup> )	
1	set 1	108,766	Sicada	3,20	177,3	337,90	84	61,9	38,4	53,4	27,20	27,2	
2	set 1	111,872	Sicada	6,10	146,0	393,50	71,6	59,8	40,4	50,8	23,70	27,2	
3	set 1	156,702	Sicada	2,90	200,3	401,10	96,5	70,7	37,6	53,8	28,00	27,2	
4	set 1	228,489	Sicada	4,00	248,3	505,70	113,7	63,2	27,2	51,8	29,20	27,2	
5	set 1	268,869	Sicada	2,30	211,5	417,70	82,4	73,2	40,6	50,0	29,30	27,2	
6	set 1	335,473	Sicada	5,77	142,2	202,70	61,9	72,5	41,2	52,6	28,70	27,2	
7	set 1	400,621	Sicada	2,40	154,5	528,30	73,1	50,2	44,0	52,2	25,50	27,2	
8	set 1	457,567	Sicada	2,50	103,0	130,20	45,1	54,8	41,0	53,0	30,30	27,2	
9	set 1	589,585	Sicada	2,60	115,7	421,20	51	54,0	44,2	40,6	28,50	27,2	
10	set 1	666,92	Sicada	2,40	139,0	247,20	64,2	49,3	43,0	49,4	30,80	27,2	
11	set 1	841,378	Sicada	10,50	245,7	587,80	119,8	65,7	35,4	50,8	30,80	27,2	
12	set 1	651,449	Sicada	3,70	105,3	367,80	55,2	67,2	39,4	51,4	28,70	27,2	
13	set 1	489,982	Sicada	8,20	195,3	525,20	86,3	70,7	37,4	50,4	31,20	27,2	
14	set 1	404,355	Sicada	3,83	148,0	332,45	71,6	72,3	39,6	49,8	30,80	27,2	
15	set 1	408,712	Sicada	3,70	202,7	378,60	95,2	76,0	37,6	53,8	27,30	27,2	
			Arithmetic a	4,27	168,99	385,16	78,11	64,10	39,13	50,92	#	28,67	27,20
			maximum v.	10,50	248,30	587,80	119,80	76,00	44,20	53,80	#	31,20	27,20
			minimum ve	2,30	103,00	130,20	45,10	49,30	27,20	40,60	#	23,70	27,20

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3  
Operator: PC  
Date: 04.03.2003

Borehole: KFM01A

## OUTPUT DATA

Depth zone:

100-1008 m

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SAMPLE No	J OINT SET NO	DEPTH (m)	JCS <sub>0</sub> (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC <sub>0</sub> AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC <sub>100</sub> VALUES 100 mm	EXTRPL'D JCS <sub>100</sub> VALUES 100 mm (MPa)
1	set 1	108,766	84,95	8,75E-05	21,6	6,73	0,56	7,27	95,36
2	set 1	111,872	94,84	1,36E-04	19,6	6,88	0,68	7,25	102,55
3	set 1	156,702	81,28	4,45E-05	22,0	7,78	0,50	8,67	95,59
4	set 1	228,489	45,82	8,87E-05	19,7	7,61	0,40	8,74	56,40
5	set 1	268,869	95,90	4,15E-05	25,5	7,49	0,47	8,38	113,47
6	set 1	335,473	99,12	2,90E-05	24,4	7,37	0,70	7,76	107,14
7	set 1	400,621	115,66	2,90E-04	22,4	4,97	0,65	5,19	123,41
8	set 1	457,567	98,03	9,41E-05	25,8	4,82	0,97	4,84	98,45
9	set 1	589,585	116,94	2,80E-04	30,3	4,22	0,86	4,27	119,12
10	set 1	666,92	109,46	1,61E-04	28,2	3,62	0,72	3,70	113,44
11	set 1	841,378	72,00	8,15E-05	24,7	6,89	0,41	7,80	86,70
12	set 1	651,449	89,76	9,81E-05	24,0	7,24	0,95	7,30	90,77
13	set 1	489,982	80,39	6,52E-05	26,0	7,33	0,51	8,09	93,14
14	set 1	404,355	90,75	4,21E-05	26,7	7,20	0,68	7,62	98,77
15	set 1	408,712	81,28	2,28E-05	21,3	8,35	0,49	9,40	97,03
		Arithmetic av.	90,41	1,04E-04	24,15	6,57	0,64	7,09	99,42
		maximum val.	116,94	2,90E-04	30,27	8,35	0,97	9,40	123,41
		minimum val.	45,82	2,28E-05	19,61	3,62	0,40	3,70	56,40

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

Chk'd	Operator:	PC
Date	Date:	04.03.2003
Borehole:		KFM01A

DEPTH	100-1008 m
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## INPUT DATA

SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR.	ORIENT. a (mm)	MEAN JOINT LENG. L (mm)	MASS m (g)	AREA A (cm <sup>2</sup> )	MEAN TILT ANGLE (°)	JOINT REBOUND NUMBER (r)	ROCK REBOUND NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m <sup>3</sup> )
1	set 2	122,059	Sicada	2,30	52,3	139,60	22,8	64,8	34,90	52,40	26,50	27,2
2	set 2	173,271	Sicada	2,20	46,5	117,40	19,5	55,3	36,10	52,20	22,80	27,2
3	set 2	240,855	Sicada	1,80	72,8	178,40	31,2	69,3	37,30	50,40	29,80	27,2
4	set 2	290,803	Sicada	2,80	58,2	112,40	25,4	60,8	37,70	52,60	30,80	27,2
5	set 2	386,46	Sicada	3,40	57,5	167,20	25,2	66,3	42,90	51,40	24,00	27,2
6	set 2	433,949	Sicada	2,60	45,5	180,40	33,8	57,0	43,30	54,40	30,70	27,2
7	set 2	639,778	Sicada	2,80	84,7	101,20	41,6	54,8	47,60	52,00	27,60	27,2
8	set 2	669,925	Sicada	3,50	69,3	181,10	29,5	70,8	37,10	50,40	31,70	27,2
9	set 2	839,859	Sicada	2,20	97,3	215,30	41,7	55,2	45,10	50,20	30,00	27,2
10	set 2	856,525	Sicada	4,70	106,7	418,80	53,1	51,8	42,70	50,20	31,30	27,2
11	set 2	650,561	Sicada	1,56	54,7	383,60	24	55,5	35,90	53,20	28,20	27,2
12	set 2	898,942	Sicada	1,87	97,3	275,90	43,2	66,8	39,9	49,60	28,30	27,2

Arithmetic a 2,64 70,23 205,94 32,58 60,70 40,04 51,58 # 28,48 27,20  
 maximum v 4,70 106,70 418,80 53,10 70,80 47,60 54,40 # 31,70 27,20  
 minimum ve 1,56 45,50 101,20 19,50 51,80 34,90 49,60 # 22,80 27,20

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# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3

Operator: PC

Date: 04.03.2003

Depth zone: 100-1008 m

Depth zone: 100-1008 m

## OUTPUT DATA

SAMPLE No	JO INT SET NO	DEPTH (m)	JCS <sub>0</sub> (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC <sub>0</sub> AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC <sub>100</sub> VALUES 100 mm	EXTRPL'D JCS <sub>100</sub> VALUES 100 mm (MPa)
1	set 2	122,059	70,04	1,09E-04	19,8	7,74	1,91	7,00	60,25
2	set 2	173,271	74,83	1,91E-04	16,6	6,91	2,15	6,22	63,84
3	set 2	240,855	79,95	7,01E-05	24,6	7,38	1,37	7,04	74,52
4	set 2	290,803	81,73	1,03E-04	25,1	6,05	1,72	5,66	74,09
5	set 2	386,46	108,86	1,05E-04	20,7	7,58	1,74	6,97	95,98
6	set 2	433,949	111,28	1,55E-04	26,6	5,19	2,20	4,78	98,45
7	set 2	639,778	141,04	7,93E-05	25,9	4,62	1,18	4,55	137,83
8	set 2	669,925	79,07	6,51E-05	26,4	7,29	1,44	6,91	72,98
9	set 2	839,859	122,89	1,65E-04	28,0	4,64	1,03	4,63	122,42
10	set 2	856,525	107,66	2,96E-04	28,3	4,22	0,94	4,25	108,55
11	set 2	650,561	74,01	5,03E-04	21,7	6,54	1,83	6,04	65,75
12	set 2	898,942	92,27	9,72E-05	24,4	7,10	1,03	7,07	91,73
		Arithmetic av.	95,30	1,62E-04	24,02	6,27	1,54	5,93	88,87
		maximum val.	141,04	5,03E-04	28,31	7,74	2,20	7,07	137,83
		minimum val.	70,04	6,51E-05	16,63	4,22	0,94	4,25	60,25

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

Chkd	Operator:	PC
Date	Date:	04.03.2003
	Borehole:	KFM01A

PAGE	1
------	---

## INPUT DATA

Depth zone: 100-1008 m

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 <sup>2</sup> )	MEAN TILT ANGLE (°)	JOINT REBOUND NUMBER (r)	ROCK REBOUND NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m <sup>3</sup> )
1	set 3	135,626	Sicada	1,40	46,2	126,70	20,5	44,3	42,3	53,0	28,70	27,2
2	set 3	196,091	Sicada	2,40	49,2	100,40	20,8	67,0	46,8	52,8	30,70	27,2
3	set 3	257,893	Sicada	2,60	46,7	106,60	19,4	65,7	39,0	52,8	30,00	27,2
4	set 3	320,516	Sicada	1,20	48,0	110,70	20,4	39,0	33,8	53,0	28,30	27,2
5	set 3	349,702	Sicada	1,23	50,0	112,90	21,4	41,5	39,6	51,4	31,30	27,2
6	set 3	444,734	Sicada	1,30	47,3	107,20	20,7	68,7	34,8	51,6	29,30	27,2
7	set 3	483,622	Sicada	1,40	46,5	125,70	20,5	58,0	32,3	50,8	30,00	27,2
8	set 3	565,927	Sicada	1,47	41,8	130,50	18,1	57,8	35,7	53,8	27,70	27,2
9	set 3	509,506	Sicada	0,70	45,3	150,20	17,2	50,2	38,7	52,0	28,80	27,2
10	set 3	710,909	Sicada	1,10	46,0	122,20	19,6	66,8	41,7	50,0	31,50	27,2
11	set 3	773,217	Sicada	0,56	45,0	156,30	21,2	58,3	42,9	50,8	29,20	27,2
12	set 3	813,37	Sicada	2,03	45,8	138,90	20,1	62,8	37,7	49,6	30,20	27,2
13	set 3	858,769	Sicada	1,00	46,7	131,80	20,8	58,0	39,2	51,4	29,30	27,2
14	set 3	597,568	Sicada	2,60	47,0	134,40	19,6	56,7	35,6	49,8	26,80	27,2

Arithmetic a	1,50	46,54
maximum v	2,60	50,00
minimum ve	0,56	41,80

51,63 #	38,58	56,77
53,80 #	46,80	68,70
49,60 #	32,30	39,00

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAGE 3  
Operator: PC  
Date: 04.03.2003  
Borehole: KFM01A

OUTPUT DATA  
Depth zone: 100-1008 m

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SAMPLE No	J OINT SET NO	DEPTH (m)	JCS <sub>0</sub> (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC <sub>0</sub> AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D JRC <sub>100</sub> VALUES 100 mm (MPa)	EXTRPL'D JCS <sub>100</sub> VALUES 100 mm (MPa)
1	set 3	135,626	105,32	3,10E-04	24,7	3,55	2,16	3,36	97,00
2	set 3	196,091	134,96	7,23E-05	28,4	6,15	2,03	5,64	118,40
3	set 3	257,893	87,80	9,13E-05	24,8	6,84	2,14	6,16	75,10
4	set 3	320,516	65,92	3,21E-04	21,1	3,38	2,08	3,21	61,20
5	set 3	349,702	90,75	2,90E-04	26,7	2,69	2,00	2,59	85,81
6	set 3	444,734	69,66	6,70E-05	22,8	7,63	2,11	6,81	58,69
7	set 3	483,622	60,69	1,69E-04	22,7	6,35	2,15	5,76	52,45
8	set 3	565,927	73,20	2,01E-04	21,0	6,62	2,39	5,90	61,55
9	set 3	509,506	86,36	3,51E-04	23,7	4,92	2,21	4,55	76,84
10	set 3	710,909	101,89	9,49E-05	28,2	6,40	2,17	5,80	87,77
11	set 3	773,217	108,86	2,00E-04	26,1	5,61	2,22	5,13	95,16
12	set 3	813,37	81,73	1,42E-04	25,4	6,49	2,18	5,87	70,20
13	set 3	858,769	88,78	1,74E-04	24,6	5,86	2,14	5,36	77,65
14	set 3	597,568	72,80	2,03E-04	21,1	6,41	2,13	5,82	62,96
Arithmetic av.			87,77	1,92E-04	24,36	5,64	2,15	5,14	77,20
maximum val.			134,96	3,51E-04	28,43	7,63	2,39	6,81	118,40
minimum val.			60,69	6,70E-05	20,97	2,69	2,00	2,59	52,45

# ROCK JOINT CHARACTERISATION

CLIENT: SKB- Tilt tests

PAG	E 1	
Chk'd	Operator:	PC
Date	Date:	04.03.2003
	Borehole:	KFM01A

## INPUT DATA

Depth zone: 100-1008 m

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SAMPLE No	JOINT SET No	DEPTH (m)	ORIENT. DIP/ DIP DIR. (°)	MEAN JOINT		MASS m (g)	AREA A (cm <sup>2</sup> )	MEAN TILT ANGLE (°)	JOINT REBOUND NUMBER (r)	ROCK REBOUND NUMBER (R)	BASIC FRICTION ANGLE (°)	ROCK UNIT WEIGHT (kN/m <sup>3</sup> )
				AMP. a (mm)	LENG. L (mm)							
1	set 1	108,766	Sicada	3,20	177,3	337,90	84	61,9	38,4	53,4	27,20	27,2
2	set 1	111,872	Sicada	6,10	146,0	393,50	71,6	59,8	40,4	50,8	23,70	27,2
3	set 2	122,059	Sicada	2,30	52,3	139,60	22,8	64,8	34,9	52,4	26,50	27,2
4	set 3	135,626	Sicada	1,40	46,2	126,70	20,5	44,3	42,3	53,0	28,70	27,2
5	set 1	156,702	Sicada	2,90	200,3	401,10	96,5	70,7	37,6	53,8	28,00	27,2
6	set 2	173,271	Sicada	2,20	46,5	117,40	19,5	55,3	36,1	52,2	22,80	27,2
7	set 3	196,091	Sicada	2,40	49,2	100,40	20,8	67,0	46,8	52,8	30,70	27,2
8	set 1	228,489	Sicada	4,00	248,3	505,70	113,7	63,2	27,2	51,8	29,20	27,2
9	set 2	240,855	Sicada	1,80	72,8	178,40	31,2	69,3	37,3	50,4	29,80	27,2
10	set 3	257,893	Sicada	2,60	46,7	106,60	19,4	65,7	39,0	52,8	30,00	27,2
11	set 1	268,869	Sicada	2,30	211,5	417,70	82,4	73,2	40,6	50,0	29,30	27,2
12	set 2	290,803	Sicada	2,80	58,2	112,40	25,4	60,8	37,7	52,6	30,80	27,2
13	set 3	320,516	Sicada	1,20	48,0	110,70	20,4	39,0	33,8	53,0	28,30	27,2
14	set 1	335,473	Sicada	5,77	142,2	202,70	61,9	72,5	41,2	52,6	28,70	27,2
15	set 3	349,702	Sicada	1,23	50,0	112,90	21,4	41,5	39,6	51,4	31,30	27,2
16	set 2	386,46	Sicada	3,40	57,5	167,20	25,2	66,3	42,9	51,4	24,00	27,2
17	set 1	400,621	Sicada	2,40	154,5	528,30	73,1	50,2	44,0	52,2	25,50	27,2
18	set 2	433,949	Sicada	2,60	45,5	180,40	33,8	57,0	43,3	54,4	30,70	27,2
19	set 3	444,734	Sicada	1,30	47,3	107,20	20,7	68,7	34,8	51,6	29,30	27,2
20	set 1	457,567	Sicada	2,50	103,0	130,20	45,1	54,8	41,0	53,0	30,30	27,2
21	set 3	483,622	Sicada	1,40	46,5	125,70	20,5	58,0	32,3	50,8	30,00	27,2
22	set 3	565,927	Sicada	1,47	41,8	130,50	18,1	57,8	35,7	53,8	27,70	27,2
23	set 1	589,585	Sicada	2,60	115,7	421,20	51	54,0	44,2	40,6	28,50	27,2
24	set 2	639,778	Sicada	2,80	84,7	101,20	41,6	54,8	47,6	52,0	27,60	27,2
25	set 3	509,506	Sicada	0,70	45,3	150,20	17,2	50,2	38,7	52,0	28,80	27,2
26	set 1	666,92	Sicada	2,40	139,0	247,20	64,2	49,3	43,0	49,4	30,80	27,2
27	set 2	669,925	Sicada	3,50	69,3	181,10	29,5	70,8	37,1	50,4	31,70	27,2
28	set 3	710,909	Sicada	1,10	46,0	122,20	19,6	66,8	41,7	50,0	31,50	27,2
29	set 3	773,217	Sicada	0,56	45,0	156,30	21,2	58,3	42,9	50,8	29,20	27,2
30	set 2	839,859	Sicada	2,20	97,3	215,30	41,7	55,2	45,1	50,2	30,00	27,2
31	set 1	841,378	Sicada	10,50	245,7	587,80	119,8	65,7	35,4	50,8	30,80	27,2
32	set 3	813,37	Sicada	2,03	45,8	138,90	20,1	62,8	37,7	49,6	30,20	27,2
33	set 2	856,525	Sicada	4,70	106,7	418,80	53,1	51,8	42,7	50,2	31,30	27,2
34	set 3	858,769	Sicada	1,00	46,7	131,80	20,8	58,0	39,2	51,4	29,30	27,2
35	set 1	898,942	Sicada	1,87	97,3	275,90	43,2	66,8	39,9	49,6	28,30	27,2
36	set 1	651,449	Sicada	3,70	105,3	367,80	55,2	67,2	39,4	51,4	28,70	27,2
37	set 2	650,561	Sicada	1,56	54,7	383,60	24	55,5	35,9	53,2	28,20	27,2
38	set 1	489,982	Sicada	8,20	195,3	525,20	86,3	70,7	37,4	50,4	31,20	27,2
39	set 1	404,355	Sicada	3,83	148,0	332,45	71,6	72,3	39,6	49,8	30,80	27,2
40	set 1	408,712	Sicada	3,70	202,7	378,60	95,2	76,0	37,6	53,8	27,30	27,2
41	set 3	597,568	Sicada	2,60	47,0	134,40	19,6	56,7	35,6	49,8	26,80	27,2

Arithmetic a	2,85	98,27	243,98	44,95	60,60	39,21	51,36 #	28,87	27,20
maximum v	10,50	248,30	587,80	119,80	76,00	47,60	54,40 #	31,70	27,20
minimum v	0,56	41,80	100,40	17,20	39,00	27,20	40,60 #	22,80	27,20

ROCK JOINT CHARACTERISATION								PAGE 3	
CLIENT: SKB- Tilt tests								Operator:	PC
OUTPUT DATA								Date:	04.03.2003
								Depth zone:	
SAMPLE No	JO INT SET NO	DEPTH (m)	JCS <sub>0</sub> (MPa)	NORMAL STRESS (MPa)	RESIDUAL FRICTION ANGLE (°)	JRC <sub>0</sub> AT JOINT LENGTH TESTED	100mm DIVIDED BY JOINT LENGTH TESTED	EXTRPL'D VALUES 100 mm	EXTRPL'D VALUES 100 mm (MPa)
1	set 1	108,766	84,95	8,75E-05	21,6	6,73	0,56	7,27	95,36
2	set 1	111,872	94,84	1,36E-04	19,6	6,88	0,68	7,25	102,55
3	set 2	122,059	70,04	1,09E-04	19,8	7,74	1,91	7,00	60,25
4	set 3	135,626	105,32	3,10E-04	24,7	3,55	2,16	3,36	97,00
5	set 1	156,702	81,28	4,45E-05	22,0	7,78	0,50	8,67	95,59
6	set 2	173,271	74,83	1,91E-04	16,6	6,91	2,15	6,22	63,84
7	set 3	196,091	134,96	7,23E-05	28,4	6,15	2,03	5,64	118,40
8	set 1	228,489	45,82	8,87E-05	19,7	7,61	0,40	8,74	56,40
9	set 2	240,855	79,95	7,01E-05	24,6	7,38	1,37	7,04	74,52
10	set 3	257,893	87,80	9,13E-05	24,8	6,84	2,14	6,16	75,10
11	set 1	268,869	95,90	4,15E-05	25,5	7,49	0,47	8,38	113,47
12	set 2	290,803	81,73	1,03E-04	25,1	6,05	1,72	5,66	74,09
13	set 3	320,516	65,92	3,21E-04	21,1	3,38	2,08	3,21	61,20
14	set 1	335,473	99,12	2,90E-05	24,4	7,37	0,70	7,76	107,14
15	set 3	349,702	90,75	2,90E-04	26,7	2,69	2,00	2,59	85,81
16	set 2	386,46	108,86	1,05E-04	20,7	7,58	1,74	6,97	95,98
17	set 1	400,621	115,66	2,90E-04	22,4	4,97	0,65	5,19	123,41
18	set 2	433,949	111,28	1,55E-04	26,6	5,19	2,20	4,78	98,45
19	set 3	444,734	69,66	6,70E-05	22,8	7,63	2,11	6,81	58,69
20	set 1	457,567	98,03	9,41E-05	25,8	4,82	0,97	4,84	98,45
21	set 3	483,622	60,69	1,69E-04	22,7	6,35	2,15	5,76	52,45
22	set 3	565,927	73,20	2,01E-04	21,0	6,62	2,39	5,90	61,55
23	set 1	589,585	116,94	2,80E-04	30,3	4,22	0,86	4,27	119,12
24	set 2	639,778	141,04	7,93E-05	25,9	4,62	1,18	4,55	137,83
25	set 3	509,506	86,36	3,51E-04	23,7	4,92	2,21	4,55	76,84
26	set 1	666,92	109,46	1,61E-04	28,2	3,62	0,72	3,70	113,44
27	set 2	669,925	79,07	6,51E-05	26,4	7,29	1,44	6,91	72,98
28	set 3	710,909	101,89	9,49E-05	28,2	6,40	2,17	5,80	87,77
29	set 3	773,217	108,86	2,00E-04	26,1	5,61	2,22	5,13	95,16
30	set 2	839,859	122,89	1,65E-04	28,0	4,64	1,03	4,63	122,42
31	set 1	841,378	72,00	8,15E-05	24,7	6,89	0,41	7,80	86,70
32	set 3	813,37	81,73	1,42E-04	25,4	6,49	2,18	5,87	70,20
33	set 2	856,525	107,66	2,96E-04	28,3	4,22	0,94	4,25	108,55
34	set 3	858,769	88,78	1,74E-04	24,6	5,86	2,14	5,36	77,65
35	set 1	898,942	92,27	9,72E-05	24,4	7,10	1,03	7,07	91,73
36	set 1	651,449	89,76	9,81E-05	24,0	7,24	0,95	7,30	90,77
37	set 2	650,561	74,01	5,03E-04	21,7	6,54	1,83	6,04	65,75
38	set 1	489,982	80,39	6,52E-05	26,0	7,33	0,51	8,09	93,14
39	set 1	404,355	90,75	4,21E-05	26,7	7,20	0,68	7,62	98,77
40	set 1	408,712	81,28	2,28E-05	21,3	8,35	0,49	9,40	97,03
41	set 3	597,568	72,80	2,03E-04	21,1	6,41	2,13	5,82	62,96
Arithmetic av.			90,94	1,51E-04	24,18	6,16	1,42	6,08	88,74
maximum val.			141,04	5,03E-04	30,27	8,35	2,39	9,40	137,83
minimum val.			45,82	2,28E-05	16,63	2,69	0,40	2,59	52,45