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An evaluation of the reliability of borehole core data in engineering rock mass classification systems

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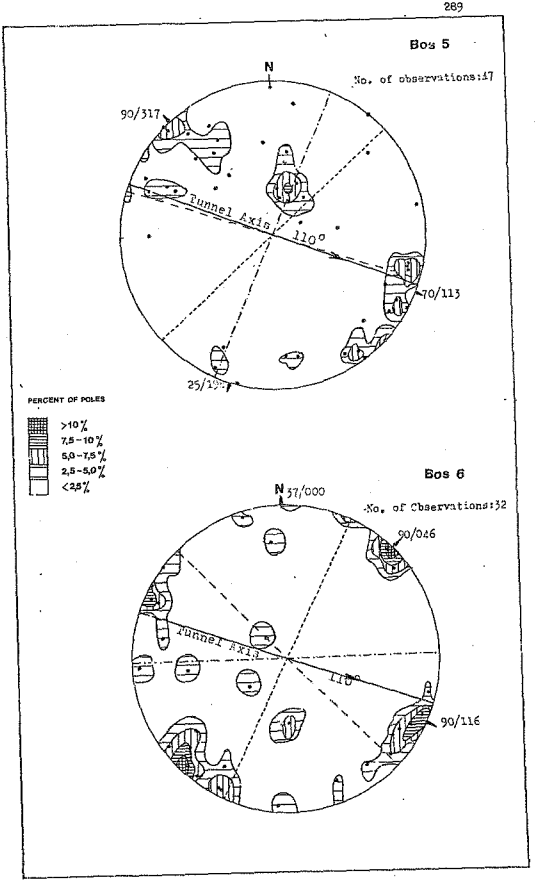
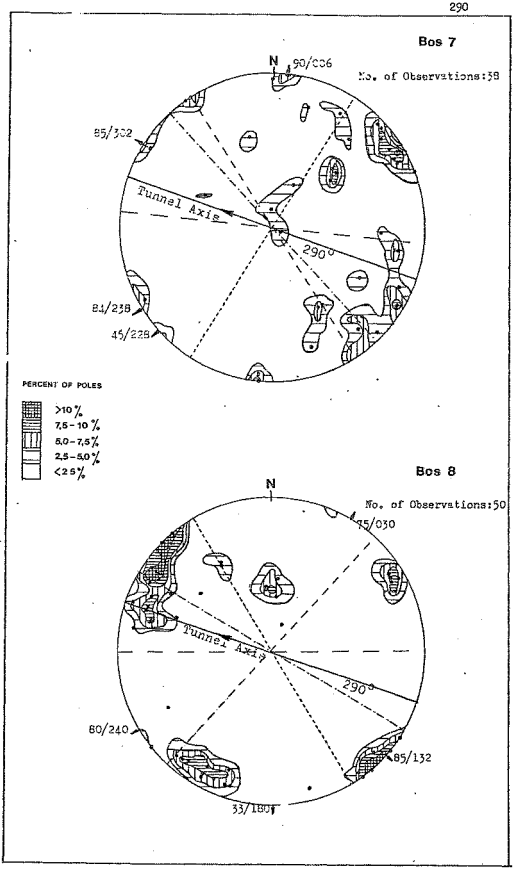
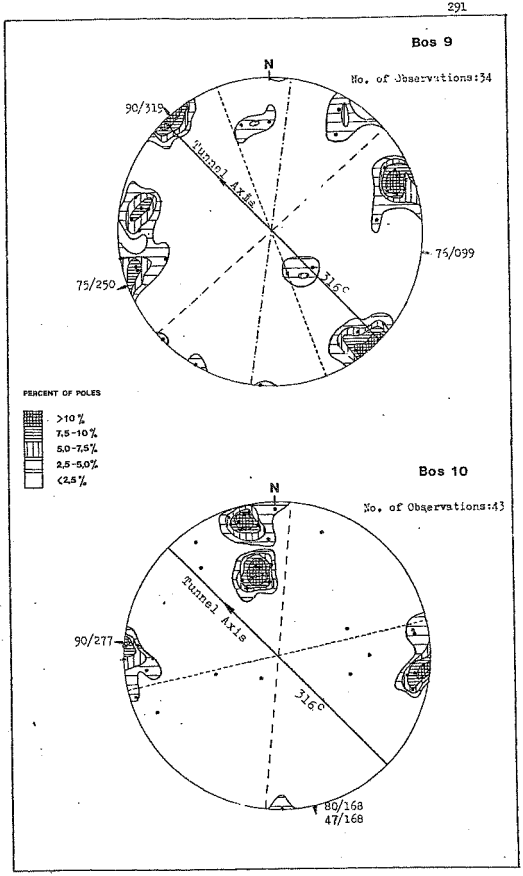
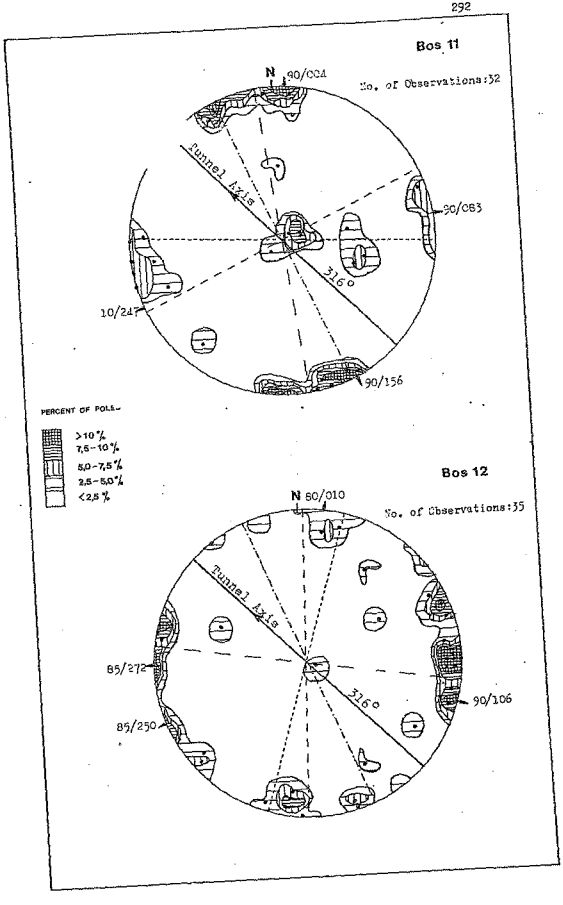
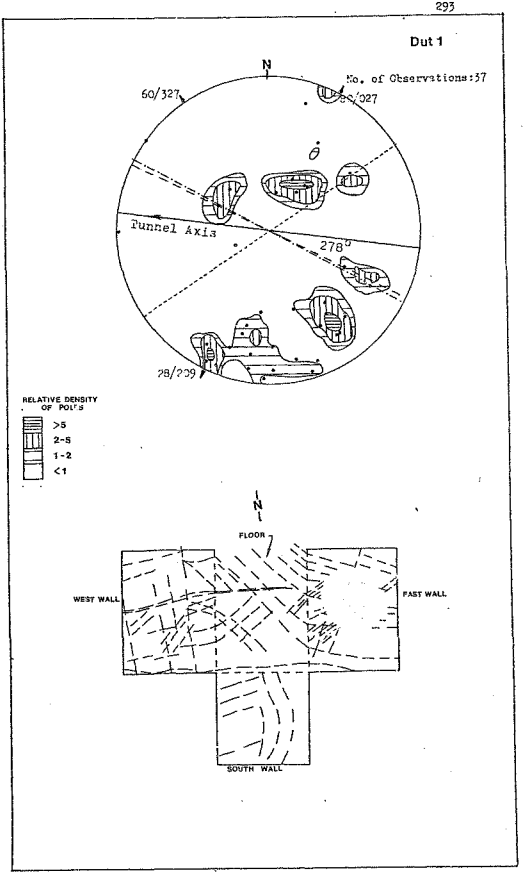

Bos 5
N
No. of observations:47
90/317
Tunnel Axis
110°
70/113
25/19
PERCENT OF POLES
>10 %
7,5-10 %
5,0-7,5 %
2,5-5,0 %
<2,5 %
Bos 6
N 57/000
No. of Observations:32
90/046
Tunnel Axis
110°
90/116

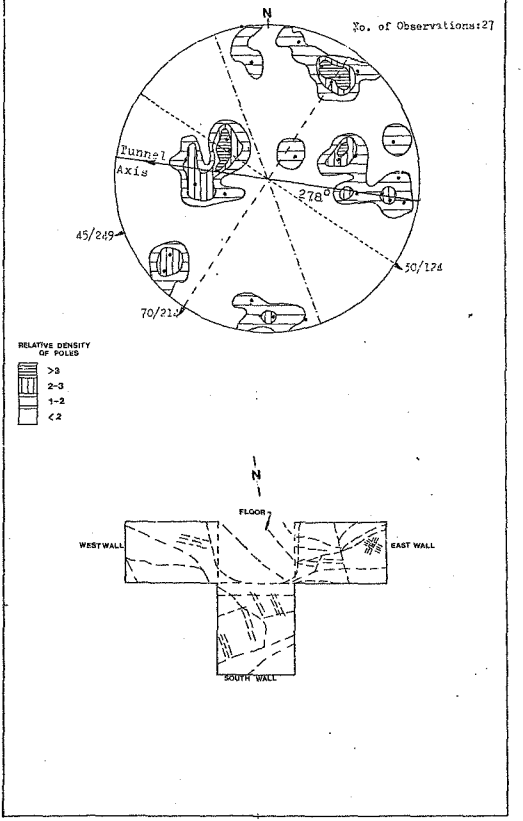

Bos 7
N
90/006
No. of Observations:58
85/302
Tunnel Axis
290°
84/238
45/228
PERCENT OF POLES
>10 %
7.5 - 10 %
5.0 - 7.5 %
2.5 - 5.0 %
<2.5 %
Bos 8
N
No. of Observations:50
45/030
Tunnel Axis
290°
80/240
85/132
33/180


Bos 9
N
No. of Observations:34
90/319
Tunnel Axis
75/099
75/250
316c
PERCENT OF POLES
>10 %
7.5-10 %
5.0-7.5 %
2.5-5.0 %
<2.5 %
Bos 10
N
No. of Observations:43
Tunnel Axis
90/277
316c
80/168
47/168

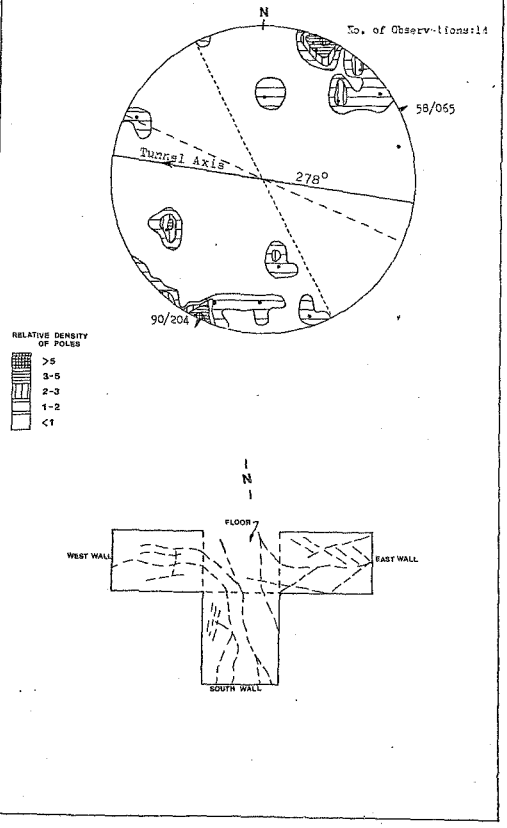

Bos 11
N 90/004
No. of Observations:32
Tunnel Axis
90/083
316°
10/247
90/156
PERCENT OF POLE-
>10 %
7,5-10 %
5,0-7,5 %
2,5-5,0 %
<2,5 %
Bos 12
N 80/010
No. of Observations:35
Tunnel Axis
85/272
316°
90/106
85/250


Dut 1
N
No. of Observations: 37
60/327
60/027
Tunnel Axis
278°
28/209
RELATIVE DENSITY OF POL'S
>5
2-5
1-2
<1
N
FLOOR
WEST WALL
EAST WALL
SOUTH WALL

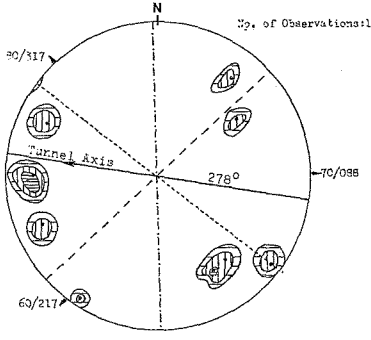
Dut 2


N
No. of Observations:27
Tunnel Axis
278°
45/249
50/124
70/214
RELATIVE DENSITY OF POLES
>3
2-3
1-2
<2
N
FLOOR
WEST WALL
EAST WALL
SOUTH WALL

Dut 3

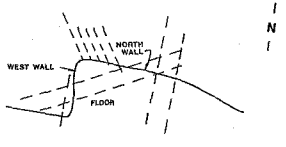

N
No. of Observations: 14
58/065
Tunnel Axis
278°
90/204
RELATIVE DENSITY OF POLES
>5
3-5
2-3
1-2
<1
N
FLOOR
WEST WALL
EAST WALL
SOUTH WALL

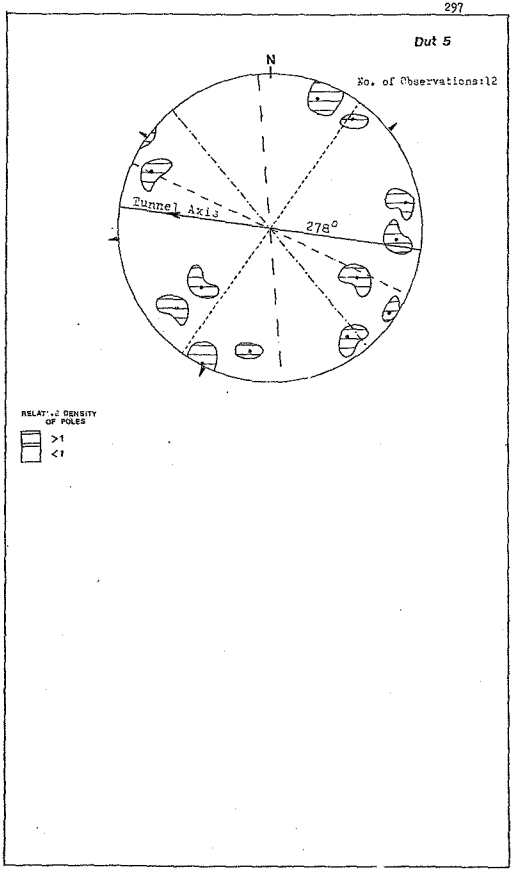
Dut 4

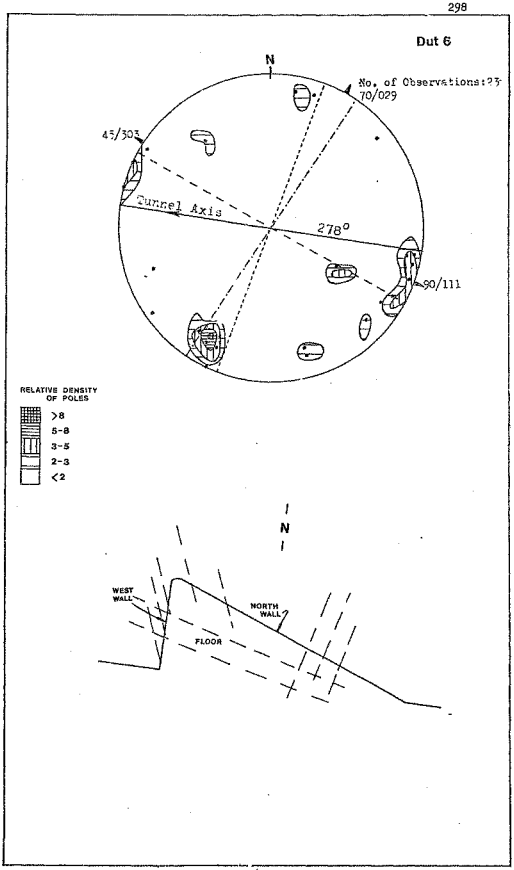


RELATIVE DENSITY OF POLES

- >2
- 1-2
- 0,5-1
- <0,5




Dut 5
N
No. of Observations:12
Tunnel Axis
278°
RELATIVE DENSITY OF POLES
>1
<1


Dut 6
N
No. of Observations: 23
70/029
43/303
Tunnel Axis
278°
90/111
RELATIVE DENSITY OF POLES
>8
5-8
3-5
2-3
<2
N
WEST WALL
NORTH WALL
FLOOR

APPENDIX IV

POINT LOAD STRENGTH TEST RESULTS

POINT LOAD STRENGTH INDEX TEST RESULTS

Project: BUSHKOPPIES TUNNEL

BOREHOLE NUMBER	NUMBER OF SPECIMENS TESTED	Is(54) MEAN	Is(54) MEDIAN	U.C.S.(MPa) 24Is(54)	UNIAXIAL TEST RESULTS* No. of Tests	U.C.S. (MPa)
Bos. 1	4	4,5	4,2	101		
Bos. 2					2	334,4
Bos. 3	3	2,5	2,5	60		
Bos. 4	6	12,7	13,8	331		
Bos. 5	3	3,8	4,1	98		
Bos. 6					2	278,3
Bos. 7	5	12,9	12,8	307		
Bos. 8	6	12,4	12,2	293		
Bos. 9	4	9,5	9,8	235		
Bos. 10	2	2,75	2,75	66		
Bos. 11					2	477,2
Bos. 12					2	384,4

* - A.B.A. BRINK AND ASSOCIATES

POINT LOAD STRENGTH INDEX TEST RESULTS

Project: DELVERS TUNNEL

BOREHOLE NUMBER	NUMBER OF SPECIMENS TESTED	Is(54) MEAN	Is(54) MEDIAN	U.C.S.(MPa) 24Is(54)	UNIAXIAL TEST RESULTS	
					No. of Tests	U.C.S. (MPa)
Del. 1	5	1,0	1,0	24		
Del. 2	11	2,8	2,2	53		
Del. 3	13	0,9	0,8	19		
Del. 4	10	6,1	6,3	151		
Del. 5	6	1,5	1,0	24		
Del. 6	9	1,7	1,6	38		

POINT LOAD STRENGTH INDEX TEST RESULTS

Project: DU TOITSKLOOF TUNNEL

BOREHOLE NUMBER	NUMBER OF SPECIMENS TESTED	Is(54) MEAN	Is(54) MEDIAN	U.C.S.(MPa) 24Is(54)	UNIAXIAL TEST RESULTS*	
					No. of Tests	U.C.S. (MPa)
Dut. 1-H	12	8,2	7,3	175	1	299
Dut. 1-V	5	5,7	4,2	101		
Dut. 2-H	12	4,8	4,2	101	3	85
Dut. 2-V	8	3,7	3,8	91		
Dut. 3-V	7	1,4	1,5	36		
Dut. 4-H	12	1,3	1,2	29		
Dut. 4-V	8	1,4	1,3	31		
Dut. 5-V	2	1,9	1,9	46		
Dut. 6-H	11	5,7	6,5	156		
Dut. 6-V	7	7,2	6,9	166		

* - VAN NIEKERK, KLEYN & EDWARDS

APPENDIX V

RESULTS OF THE STEPS FOR EVALUATING THE BOREHOLE CORE MEASUREMENTS

THE NUMBER OF JOINTS WITH SIMILAR INCLINATION ANGLES RECORDED IN EACH BOREHOLE

Project: BUSHKOPPIES TUNNEL STEP 1

BOREHOLE NUMBER	α^{o}	0	10	20	30	40	50	60	70	80	90	TOTAL CORRECTED JOINTS
	1/Sinα	∞	5,72	2,92	2,0	1,56	1,31	1,15	1,06	1,02	1,0	
Bos 1	A	1	3	2	1	2	3	8	1	2	0	45
	B	1	17	6	2	3	4	9	1	2	0	
	C	2	38	14	4	7	9	20	2	4	0	
Bos 2	A	1	1	3	0	1	0	1	7	1	0	27
	B	1	6	9	0	2	0	1	7	1	0	
	C	4	22	33	0	7	0	4	26	4	0	
Bos 3	A	1	2	4	1	4	4	1	1	1	1	42
	B	1	12	12	2	6	5	1	1	1	1	
	C	2	29	29	5	15	12	2	2	2	2	
Bos 4	A	0	0	2	3	3	4	0	3	0	0	25
	B	0	0	6	6	5	5	0	3	0	0	
	C	0	0	24	24	20	20	0	12	0	0	
Bos 5	A	0	1	0	3	1	1	2	6	0	0	23
	B	0	6	0	6	2	1	2	6	0	0	
	C	0	26	0	26	9	4	9	26	0	0	
Bos 6	A	1	1	0	2	2	1	8	1	0	0	25
	B	1	6	0	4	3	1	9	1	0	0	
	C	4	24	0	16	12	4	36	4	0	0	
Bos 7	A	2	4	3	3	3	0	1	0	0	4	50
	B	2	23	9	6	5	0	1	0	0	4	
	C	4	46	18	12	10	0	2	0	0	8	
Bos 8	A	0	3	6	1	2	1	4	1	4	0	51
	B	0	17	18	2	3	1	5	1	4	0	
	C	0	33	35	4	6	20	10	2	8	0	
Bos 9	A	0	1	2	0	0	0	0	0	0	0	12
	B	0	6	6	0	0	0	0	0	0	0	
	C	0	50	50	0	0	0	0	0	0	0	
Bos 10	A	1	5	5	3	0	1	2	3	2	0	59
	B	1	29	15	6	0	1	2	3	2	0	
	C	2	49	26	10	0	2	3	5	3	0	
Bos 11	A	0	3	8	0	2	1	3	2	1	0	50
	B	0	17	23	0	3	1	3	2	1	0	
	C	0	34	46	0	6	2	6	4	2	0	
Bos 12	A	0	0	1	3	0	1	0	1	1	1	13
	B	0	0	3	6	0	1	0	1	1	1	
	C	0	0	23	45	0	8	0	8	8	8	

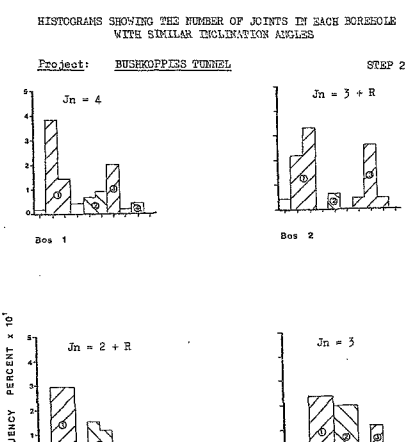
A - No. of joints recorded in the borehole.

B - No. of joints corrected for intersection angle α.

C - Corrected no. of joints expressed as percentages.

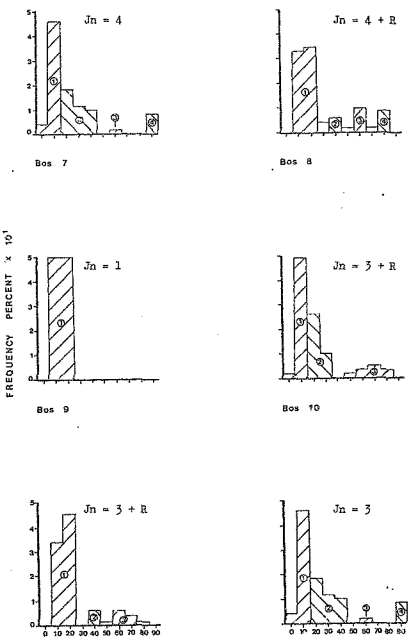
HISTOGRAMS SHOWING THE NUMBER OF JOINTS IN EACH BOREHOLE WITH SIMILAR INCLINATION ANGLES

Project: BUSHKOPPIES TUNNEL STEP 2



HISTOGRAMS SHOWING THE NUMBER OF JOINTS IN EACH BOREHOLE WITH SIMILAR INCLINATION ANGLES

Project: BUSHKOPPIES TUNNEL STEP 2



THE AVERAGE SPACING OF EACH JOINT SET

Project: BUSHKOPPIES TUNNEL STEP 3

BOREHOLE NUMBER	CORE LENGTH L (m)	DIP OF JOINT SET (°)	CORRECTED JOINT NUMBER N'	JOINT SPACING L/N'(m)	JOINT SPACING CATEGORY *
Bos 1	2,5	70 - 80	23	-	-
		40 - 50	7	0,3	0,05 - 0,3
		30	9	0,3	0,05 - 0,3
		10	2	1,25	1 - 3
Bos 2	8,0	70 - 80	15	-	-
		50	2	4,0	3
		10 - 30	9	0,9	0,3 - 1
Bos 3	8,0	70 - 80	24	-	-
		40 - 50	11	0,7	0,3 - 1
Bos 4	8,0	60 - 70	12	0,7	0,3 - 1
		40 - 50	10	0,8	0,3 - 1
		20	3	2,6	1 - 3
Bos 5	3,0	80	6	-	-
		50 - 60	8	0,4	1 - 3
		20 - 30	8	0,4	1 - 3
Bos 6	7,5	80 - 90	7	-	-
		50 - 60	7	1,1	1 - 3
		30	9	0,8	0,3 - 1
Bos 7	6,0	80 - 90	25	-	-
		50 - 70	20	0,3	0,3 - 1
		30	1	6,0	3
		0	4	1,5	1 - 3

*after Bieniawski

THE AVERAGE SPACING OF EACH JOINT SET

Project: BUSHKOPPIES TUNNEL STEP 3

BOREHOLE NUMBER	CORE LENGTH L (m)	DIP OF JOINT SET (°)	CORRECTED JOINT NUMBER N^1	JOINT SPACING L/N^1(m)	JOINT SPACING CATEGORY *
Bos 8	6,5	70 - 80	35	-	-
		50	3	2,2	1 - 3
		30	5	1,3	1 - 3
		10	4	1,6	1 - 3
Bos 9	8,0	70 - 80	12	0,7	0,5 - 1
Bos 10	6,5	80	29	-	-
		60 - 70	21	0,3	0,05 - 0,3
		10 - 30	7	0,9	0,3 - 1
Bos 11	4,0	70 - 80	40	-	-
		50	3	1,3	1 - 3
		20 - 30	5	0,8	0,3 - 1
Bos 12	6,5	60 - 70	9	0,7	0,3 - 1
		40	1	6,5	3
		0 - 20	3	2,2	1 - 3

*after Bieniawski

THE NUMBER OF JOINTS IN EACH SET WITH SIMILAR SURFACE ROUGHNESS AND ALTERATION CHARACTERISTICS

Project: BUSHKOPPIES TUNNEL

Data Source: BORE CORE

SAMPLE SITE NUMBER	JOINT SET ANGLE (°)*	SURFACE ROUGHNESS						SURFACE ALTERATION				
		Undulating		Slickensided	Planar		Slickensided	Closed	None or Staining only	Non-softening Mineral Coatings	Clay or Softening Mineral Coatings	Gouge
		Rough	Smooth		Rough	Smooth						
Bos 1	10 - 20	4			1			1	4			
	40 - 50	3			2			1	4			
	60	1			7				4			
	80	2								2		
Bos 2	10 - 20	1			3			4				
	40	1							1			
	60 - 80				8	1		2		7		
Bos 3	10 - 20	5			1				1	4	1	
	40 - 50	2	1		3	2	1		6		2	
Bos 4	20 - 30	4			1		1		4		1	
	40 - 50	7							6		1	
	70				3			1		2		
Bos 5	10	1						1				
	30 - 40	4						4				
	60 - 70	8						3	1		4	
Bos 6	0 - 10	1		1	1		1			2		
	30 - 40	4		2					1	3		
	60				7	1			3	5		
Bos 7	0 - 10	1	1		1	3		1	4	1		
	20 - 40	1			2	6		1	8			
	60					1			1			
	90	3				1		1	2	1		

*MEASURED FROM CORE AXIS

STEP 4

THE NUMBER OF JOINTS IN EACH SET WITH SIMILAR SURFACE ROUGHNESS AND ALTERATION CHARACTERISTICS

Project: BUSHKOPPIES TUNNEL

Data Source: BORE CORE

SAMPLE SITE NUMBER	JOINT SET AXIS (^{o})*	SURFACE ROUGHNESS						SURFACE ALTERATION			
		Undulating		With Striations	Planar		With Striations	Closed	None or Staining only	Non-softening Mineral Coatings	Clay or Staining Mineral Coatings	Gouge
		Rough	Smooth		Rough	Smooth						
Bos 8	10 - 20	5	1	1	2	1	1	1	3	5		
	40					2	1		2			
	60				4		3	1		3		
	80				4			2		2		
Bos 9	10 - 20	3						3				
Bos 10	10	3	1		1			1		4		
	20 - 30	4	1		1	2		3		5		
	50 - 80	4			2	1		1	3	3		
Bos 11	10 - 20	1	2			8		1	4		6	
	40	2							2			
	60 - 70					5			5			
Bos 12	20 - 30	4						1		3		
	50				1			1				
	70 - 90				2	1			1	2		

*MEASURED FROM CORE AXIS

STEP 4

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: BUSHKOPPIES TUNNEL *Data Source:* BORE CORE

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Bos 1	70 - 80	Undulating and rough.	None or surface staining.		One of the most common joint sets and only one with some clay coating.
	40 - 50	Undulating/planar and rough.	None or staining only.		
	30	Planar and rough.	Clay coatings and stain.	*	
	10	Undulating and rough.	Non-softening mineral coatings.		
Bos 2	70 - 80	Planar and rough.	Closed.		Most commonly recorded orientation.
	50	Undulating and rough.	None or staining only.		
	10 - 30	Planar and rough.	Non-softening mineral coatings.	*	
Bos 3	70 - 80	Undulating and rough.	Non-softening mineral coatings.		One of the most common joint sets with slickensides and clay in fragmented sections of core.
	40 - 50	Planar and rough or smooth with occasional slickensides.	None or staining only with some clay and chlorite coatings.	*	
Bos 4	60 - 70	Undulating and rough.	None or staining.	*	Most commonly recorded joint set.
	40 - 50	Undulating and rough.	None or staining.		
	20	Planar and rough.	Non-softening mineral coatings.		

*With respect to Tunnel Stability

STEP 5

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: BUSHKOPPIES TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Bos 5	80	Undulating and rough.	Closed.		
	50 - 60	Undulating and rough.	Closed.		
	20 - 30	Undulating and rough.	Closed or with softening mineral coatings.	*	Well-developed joint set with evidence of clay coatings.
Bos 6	80 - 90	Undulating/planar and rough with slickensides.	Non-softening mineral coatings.	*	Not well presented owing to vertical orientation but has poorest surface conditions.
	50 - 60	Undulating and rough with some slickensides.	Non-softening mineral coatings.		
	30	Planar and rough.	Non-softening mineral coatings and staining.		
Bos 7	80 - 90	Planar and smooth.	None or staining.		
	50 - 70	Planar and smooth.	None or staining.	* ?	Both sets are well represented and both show some evidence of clay coatings.
	30	Planar and smooth.	None or staining.		
	0	Undulating and rough.	None or staining.		
Bos 8	70 - 80	Undulating and rough with occasional slickensides.	Non-softening mineral coatings and staining.	*	Most frequently recorded despite low intersection angle, although not poorest surface conditions.
	50	Planar and smooth with some slickensides.	None or staining.		
	30	Planar and rough with slickensides.	Non-softening mineral coatings.		
	10	Planar and rough.	Closed or non-softening mineral coatings.		

*With respect to Tunnel Stability

STEP 5

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: BUSHKOPPIES TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Bos 9	70 - 80	Undulating and rough.	Closed.	*	Only set recorded in bore core.
Bos 10	80	Undulating and rough.	Non-softening mineral coatings.		Well-developed throughout core and only set with planar surface - could also be unfavourably orientated.
	60 - 70	Undulating and rough.	Non-softening mineral coatings and closed.		
	10 - 30	Undulating and rough, also planar.	Non-softening mineral coatings and staining.	*	
Bos 11	70 - 80	Planar and smooth.	Clay or softening mineral coatings and staining.	*	Well-developed joint set with poorest surface conditions.
	50	Undulating and rough.	None or staining.		
	20 - 30	Planar and smooth.	None or staining.		
Bos 12	60 - 70	Undulating and rough.	Non-softening mineral coatings.		Well-developed joint set and possibly unfavourably orientated.
	40	Planar and rough.	Closed.		
	0 - 20	Planar and rough.	Non-softening mineral coatings.	*	

*With respect to Tunnel Stability

STEP 5

GEOMECHANICS CLASSIFICATION SYSTEM - DATA FORM

Project: HUSHKOPPIES TUNNEL — Data Source: BORE CORE.

SAMPLE SITE NUMBER	ROCK TYPE	INTACT ROCK STRENGTH U.C.S. (Mpa)	INTACT ROCK STRENGTH P.L.SI. (Mpa)	RQD %	GROUND WATER	JOINT DESCRIPTION Dip (°)	Spacing (m)	Joint Condition Continuity	Joint Condition Separation (mm)	Joint Condition Roughness	Joint Condition Joint refill / Rock	Joint Orientation	REMARKS
Bos 1	LAVA		4,2	0	Moist	70-90	-	-	0,1-1	Rough	Hard	Fair	
						40-50	0,05-0,3	-	0,1-1	Rough	Hard		
						30	0,05-0,3	-	1-5	Rough.	Hard	Unfav.	
						10	1,0-3,0	-	1-5	Rough	Hard		
Bos 2	LAVA	334		95	Moist	70-80	-	-	< 0,1	Rough	Hard	Fair	
						50	> 3,0	-	0,1-1	Rough	Hard	Unfav.	
						10-30	0,3-1,0	-	1-5	Rough	Hard		
Bos 3	DIABASE		2,5	0	Moist	70-80	-	-	1-5	Rough	Med. Hard	Fair	
						40-50	0,3-1,0	-	0,1-1	Smooth	Med. Hard		With slicks.
Bos 4	DIABASE		13,8	80	Dry	60-70	0,3-1,0	-	0,1-1	Rough	Hard	Fair	
						40-50	0,3-1,0	-	0,1-1	Rough	Hard		
						20	1,0-3,0	-	1-5	Rough	Hard	Unfav.	
Bos 5	LAVA		4,1	100	Moist	80	-	-	< 0,1	Rough	Hard	Fair	
						50-60	0,3-1,0	-	< 0,1	Rough	Hard		
						20-30	0,3-1,0	-	0,1-1	Rough	Hard		
Bos 6	LAVA	278		80	Moist	80-90	-	-	0,1-1	Rough	Hard	Fair	
						50-60	1,0-3,0	-	0,1-1	Rough	Hard		With slicks.
						30	0,3-1,0	-	0,1-1	Rough	Hard		With slicks.
Bos 7	LAVA		12,8	10	Moist	80-90	-	-	0,1-1	Smooth	Hard	Fair	
						50-70	0,05-0,3	-	0,1-1	Smooth	Hard		
						30	> 3,0	-	0,1-1	Smooth	Hard	Unfav.	
						0	1,0-3,0	-	0,1-1	Rough	Hard		
Bos 8	LAVA		12,2	80	Moist	70-80	-	-	1-5	Rough	Hard	Fair	With slicks.
						50	1,0-3,0	-	0,1-1	Smooth	Hard		With slicks.
						30	1,0-3,0	-	1-5	Rough	Hard		With slicks.
						10	1,0-3,0	-	< 0,1	Rough	Hard	Unfav.	
Bos 9	LAVA		9,8	100	Dry	70-80	0,3-1,0	-	< 0,1	Rough	Hard	Fair	
Bos 10	LAVA		2,7	50	Moist	80	-	-	1-5	Rough	Hard	Fair	
						60-70	0,05-0,3	-	0,1-2	Rough	Hard		
						10-30	0,3-1,0	-	0,1-1	Rough	Hard	Unfav.	

STEP 6

GEOMECHANICS CLASSIFICATION SYSTEM - DATA FORM

Project: BUSHKOPPIES TUNNEL

Data Source: BORE CORE

SAMPLE SITE NUMBER	ROCK TYPE	INTACT ROCK STRENGTH U.C.S. (Mpa)	INTACT ROCK STRENGTH P.L.S.I. (Mpa)	RQD %	GROUND WATER	JOINT DESCRIPTION Dip (°)	Spacing (m)	Joint Condition Continuity	Joint Condition Separation (mm)	Joint Condition Roughness	Joint Condition Joint Wall Rock	Joint Orientation	REMARKS
Bos 11	LAVA	477		15	Moist	70-80 50 20-30	- 1,0-3,0 0,3-1,0	- - -	1-5 0,1-1 0,1-1	Smooth Rough Smooth	Hard Hard Hard	Fair	
Bos 12	LAVA	384		80	Moist	50-70 40 0-20	0,3-1,0 3,0 1,0-3,0	- - -	1-5 < 0,1 1-5	Rough Rough Rough	Hard Hard Hard	Fair Unfav.	

STEP 6

N.G.I. CLASSIFICATION SYSTEM -. DATA FORM

Project: BUSHKOPPIES TUNNEL Data Source: BORE CORE.

SAMPLE SIDE NUMBER	CROWN DEPTH BELOW SURFACE (m)	ROCK		EXCAVATION SPAN	ESR	RQD %	JOINT DATA				STRESS REDUCTION FACTOR	REMARKS
		Type	Density (kg/m³)				Joint Set Number	Roughness	Alteration	Water		
Bos 1	18,75	LAVA	2890	3,35	1,6	0	4	Planar & Rough	Stain & clay coating	Minor	Heavily jointed rock.	
Bos 2	40.75	LAVA	2890	3,35	1,6	95	3+R	Planar & Rough	Non-softening mineral coating	Minor	Low stress.	
Bos 3	64,50	DIABASE	-	3,35	1,6	0	2+R	Planar & Smooth with slicks.	Stain with clay & chlorite coat	Medium	Multiple shears with clay(>50m)	
Bos 4	64,50	DIABASE	2890	3,35	1,6	80	3	Undulating & Rough	None or stain	Minor	Medium stress.	* Assumed the same as Lava.
Bos 5	61,00	LAVA	2890	3,35	1,6	100	3+R	Undulating & Rough	Softening mineral coating	Minor	Medium stress.	
Bos 6	42,50	LAVA	2890	3,35	1,6	70	3+R	Planar & Rough with slicks.	Non-softening mineral coating	Minor	Single clay free shears in competent rock. (< 50m).	
Bos 7	27.50	LAVA	2890	2,6	1,6	10	4	Planar & smooth	None or stain	Minor	Heavily jointed rock.	
Bos 8	41,25	LAVA	2890	2,6	1,6	80*	4+R	Undulating & Rough with slicks.	Stain & non-softening minerals	Minor	Single clay free shears in competent rock (< 50m).	* Average value.
Bos 9	48,50	LAVA	2890	2,6	1,6	100	1	Undulating & Rough	Closed	Dry	Medium stress.	
Bos 10	32,00	LAVA	2890	2,6	1,6	50	3+R	Planar & Rough	Stain & non-softening minerals	Minor	Single clay free shears in competent rock (< 50m).	
Bos 11	21,50	LAVA	2890	2,6	1,6	15	3+R	Planar & Rough	Stain & occ. clay coatings	Minor	Single clay free shears in competent rock (<50m).	
Bos 12	8,5	LAVA	2890	2,6	1,6	80	3	Planar & Rough	Non-softening co	Minor	Low Stress.	

STEP 6

GEOMECHANICS CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: BUSHKOPPIES TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	CLASSIFICATION PARAMETER RATING						RMR.	ROCK CLASS
	Intact Rock Strength	RQD	Joint Spacing	Joint Condition	Ground Water	Orientation Adjustment		
Bos 1	12	3	15	13	7	- 6	44	III
Bos 2	15	20	25	15	7	- 7	75	II
Bos 3	7	3	20	6	7	- 5	38	IV
Bos 4	15	17	22	15	10	- 7	72	II
Bos 5	12	20	20	20	7	- 5	74	II
Bos 6	15	17	23	20	7	- 5	77	II
Bos 7	15	3	22	17	7	- 6	58	III
Bos 8	15	17	25	10	7	- 6	68	II
Bos 9	15	20	20	20	10	- 5	80	II
Bos 10	7	8	15	15	7	- 7	45	III
Bos 11	15	3	23	14	7	- 5	57	III
Bos 12	15	17	25	11	7	- 7	68	II

STEP 7

N.G.I. CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: BUSHKOPPIES TUNNEL Data Source: BOAL CORE

SAMPLE SITE NUMBER	CROWN DEPTH (m)	σ_v (kPa)	CLASSIFICATION PARAMETER RATINGS			Q	SPAN / ESR	SUPPORT CATEGORY
			RQD/Jn	Jr/Ja	Jw/SRF			
Bos 1	18,75	531	$\frac{10}{15}$ = 0,67	$\frac{1,5}{3,0}$ = 0,5	$\frac{1,0}{5,0}$ = 0,2	0,07	$\frac{3,35}{1,6}$ = 2,1	34
Bos 2	40,75	1143	$\frac{95}{12}$ = 7,92	$\frac{1,5}{2,0}$ = 0,75	$\frac{1,0}{2,5}$ = 0,4	2,38	"	21
Bos 3	64,50	1829	$\frac{10}{6}$ = 1,67	$\frac{0,5}{4,0}$ = 0,13	$\frac{0,66}{10,0}$ = 0,07	0,02	"	34
Bos 4	64,50	1829	$\frac{80}{9}$ = 8,89	$\frac{3,0}{1,0}$ = 3,0	$\frac{1,0}{2,0}$ = 1,0	26,67	"	13
Bos 5	61,0	1729	$\frac{100}{12}$ = 8,33	$\frac{3,0}{4,0}$ = 0,75	$\frac{1,0}{1,0}$ = 1,0	6,25	"	17
Bos 6	42,50	1199	$\frac{80}{12}$ = 6,67	$\frac{0,5}{2,0}$ = 0,25	$\frac{1,0}{5,0}$ = 0,2	0,33	"	29
Bos 7	27,50	780	$\frac{10}{15}$ = 0,67	$\frac{1,0}{1,0}$ = 1,0	$\frac{1,0}{5,0}$ = 0,2	0,13	$\frac{2,6}{1,6}$ = 1,6	29
Bos 8	41,25	1169	$\frac{80}{15}$ = 5,33	$\frac{1,5}{2,0}$ = 0,75	$\frac{1,0}{5,0}$ = 0,2	0,8	"	25

STEP 7

N.G.I. CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: BUSHKOPPIES TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	CROWN DEPTH (m)	σ_v (kPa)	CLASSIFICATION PARAMETER RATINGS			Q	SPAN / ESR	SUPPORT CATEGORY
			RQD/J_n	J_r/J_a	J_w/SRF			
Bos 9	48,50	1375	$\frac{100}{2} = 50$	$\frac{3,0}{0,75} = 4,0$	$\frac{1,0}{1,0} = 1,0$	200	$\frac{2,6}{1,6} = 1,6$	5
Bos 10	32,00	907	$\frac{50}{12} = 4,17$	$\frac{1,5}{2,0} = 0,75$	$\frac{1,0}{5,0} = 0,2$	0,63	"	25
Bos 11	21,50	614	$\frac{15}{12} = 1,25$	$\frac{1,0}{2,0} = 0,5$	$\frac{1,0}{5,0} = 0,2$	0,13	"	29
Bos 12	6,5	182	$\frac{80}{9} = 8,89$	$\frac{1,5}{2,0} = 0,75$	$\frac{1,0}{2,5} = 0,4$	2,67	"	21

STEP 7

THE NUMBER OF JOINTS WITH SIMILAR INCLINATION ANGLES RECORDED IN EACH BOREHOLE

Project: DELVERS TUNNEL STEP 1

BOREHOLE NUMBER	α^{o}	0	10	20	30	40	50	60	70	80	90	TOTAL CORRECTED JOINTS
	$1/\sin\alpha$	∞	5,76	2,92	2,0	1,56	1,31	1,15	1,06	1,02	1,0	
Del 1	A	1	6	0	0	1	1	2	1	16	1	59
	B	1	35	0	0	2	1	2	1	16	1	
	C	2	59	0	0	3	2	3	2	27	2	
Del 2	A	1	9	3	3	6	5	6	4	3	0	98
	B	1	52	9	6	9	7	7	4	3	0	
	C	1	54	9	6	9	7	7	4	3	0	
Del 3	A	1	0	2	3	10	26	34	24	7	5	139
	B	1	0	6	6	16	34	39	25	7	5	
	C	1	0	4	4	12	24	28	18	5	4	
Del 4	A	1	0	3	5	7	2	6	5	2	5	53
	B	1	0	9	10	11	3	7	5	2	5	
	C	2	0	17	19	21	6	13	9	4	9	
Del 5	A	0	2	5	2	1	3	8	0	4	0	50
	B	0	12	15	4	2	4	9	0	4	0	
	C	0	24	30	8	4	8	18	0	8	0	
Del 6	A	3	1	8	3	2	5	9	14	11	5	89
	B	3	6	23	6	3	7	10	15	11	5	
	C	3	7	26	7	3	8	11	17	12	6	
	A											
	B											
	C											
	A											
	B											
	C											
	A											
	B											
	C											
	A											
	B											
	C											
	A											
	B											
	C											
	A											
	B											
	C											

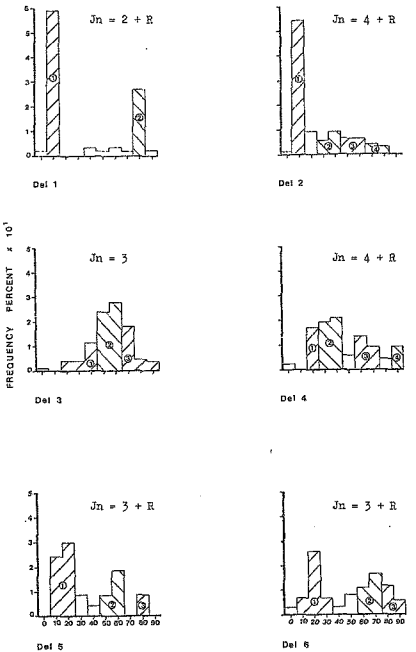
A - No. of joints recorded in the borehole.

B - No. of joints corrected for intersection angle α.

C - Corrected no. of joints expressed as percentages.

HISTOGRAMS SHOWING THE NUMBER OF JOINTS IN EACH BOREHOLE WITH SIMILAR INCLINATION ANGLES

Project: DELVERS TUNNEL STEP 2



THE AVERAGE SPACING OF EACH JOINT SET

Project: DELVERS TUNNEL STEP 3

BOREHOLE NUMBER	CORE LENGTH L (m)	DIP OF JOINT SET (°)	CORRECTED JOINT NUMBER N^1	JOINT SPACING L/N^1(m)	JOINT SPACING CATEGORY *
Del 1	4,5	80	-	-	-
		10	26	0,173	0,05 - 0,3
Del 2	6,6	80	-	-	-
		50 - 60	15	0,44	0,3 - 1
		30 - 40	14	0,47	0,3 - 1
		10 - 20	7	0,94	0,3 - 1
Del 3	10,9	5 - 25	20	0,55	0,3 - 1
		75 - 85	52	0,21	0,05 - 0,3
		45 - 65	27	0,40	0,3 - 1
Del 4	8,1	70	-	-	-
		50 - 60	40	0,20	0,05 - 0,3
		20 - 30	22	0,37	0,3 - 1
		0	9	0,9	0,3 - 1
Del 5	4,75	70 - 80	-	-	-
		30 - 40	26	0,18	0,05 - 0,3
		10	8	0,59	0,3 - 1
Del 6	8,5	60 - 80	-	-	-
		20 - 30	28	0,30	0,05 - 0,3
		0 - 10	18	0,47	0,3 - 1

*after Bieniawski NB. Del 3 - Inclined at 45°N.

THE NUMBER OF JOINTS IN EACH SET WITH SIMILAR SURFACE ROUGHNESS AND ALTERATION CHARACTERISTICS

Project: DELVERS TUNNEL

Data Source: BORE CORE

SAMPLE SITE NUMBER	JOINT SET ANGLE (°)*	SURFACE ROUGHNESS						SURFACE ALTERATION				
		Undulating		Planar				Closed	None or Staining only	Non-softening Mineral Coatings	Clay or Softening Mineral Coatings	Gouge
		Rough	Smooth	With Slickensides	Rough	Smooth	With Slickensides					
Del 1	10	1	4		1				2		4	
	80	4			12				16			
Del 2	10	5			3	1			1		8	
	30 - 40	8			1				3		6	
	50 - 60	11							6		5	
	70 - 80	5			2				6		1	
Del 3	20 - 40	13	2	1					5		10	
	50 - 60	17	20	1	6	17			5	5	50	
	70 - 90	24	5		2	5			19	1	16	
Del 4	20	3							1	1	1	
	30 - 40	7			3	2			4	5	3	
	60 - 70	10			1				11			
	90	4			1				5			
Del 5	10 - 20	6			1				6	1		
	50 - 60	11							8		3	
	80	4							1		3	
Del 6	10 - 30	7	3	1	1	1			2	1	9	
	60 - 70	20	1	2	1	1			10	1	12	
	80 - 90	11		1	4	1			5		11	

*MEASURED FROM CORE AXIS

STEP 4

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: DELVERS TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Del 1	80	Undulating and smooth.	Clay or softening coatings.	*	Appears to be the poorest set although possibly favourably orientated.
	10	Planar and rough.	None or staining.		
Del 2	80	Undulating and rough.	Clay or softening mineral coatings.	* ?	Poorest surface conditions.
	50 - 60	Undulating and rough.	Clay or softening mineral coatings.		
	30 - 40	Undulating and rough.	Staining and clay coatings.		
	10 - 20	Undulating and rough.	None or staining.		
Del 3	5 - 25	Undulating and rough.	Clay or softening mineral coatings.	*	Most unfavourably orientated.
	75 - 85	Undulating and smooth/rough.	Clay or softening mineral coatings.		
	45 - 65	Undulating and rough.	Stain and clay or softening minerals.		
Del 4	70	Undulating and rough.	Stain and both softening and non-softening coatings.	*	One of most common joint sets and poorest surface conditions.
	50 - 60	Undulating and rough.	Non-softening mineral coatings with staining and clay coatings.		
	20 - 30	Undulating and rough.	None or staining.		
	0	Undulating and rough.	None or staining.		

*With respect to Tunnel Stability

STEP 5

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: DELVERS TUNNEL — Data Source: BORE CORE

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Del 5	70 - 80	Undulating and rough. (Planar and slickensided joints of this orientation in fragments)	None or staining (clay coatings).	*	Often apparent in fragmented sections of core.
	30 - 40	Undulating and rough.	None or staining with occasional clay coatings.		
	10	Undulating and rough.	Clay or softening mineral coatings.		
Del 6	60 - 80	Undulating and rough with occasional slickensides.	Clay or softening mineral coatings.		
	20 - 30	Undulating and rough with occasional slickensides.	Clay or softening minerals and stain.		
	0 - 10	Undulating and rough with occasional slickensides.	Clay or softening minerals.	*	All joint sets similar; C-10° set possibly unfavourably orientated.

*With respect to Tunnel Stability

STEP 5

GEOMECHANICS CLASSIFICATION SYSTEM - DATA FORM

Project: DELVERS TUNNEL — Date Source: BORE CORE.

SAMPLE SITE NUMBER	ROCK TYPE	INTACT ROCK STRENGTH U.C.S. (Mpa)	INTACT ROCK STRENGTH P.L.S.I. (Mpa)	RQD %	GROUND WATER	JOINT DESCRIPTION Dip (°)	Spacing (m)	Joint Condition Continuity	Joint Condition Separation (mm)	Joint Condition Roughness	Joint Condition Joint Fill Rock	Joint Orientation	REMARKS
Del 1	ARGILL QUARTZITE		1,0	0	Dry	80 10	- 0,05-0,3	- -	1-5* 0,1-1	Smooth Rough	Soft Soft	Fair Unfav.	* Talcose material may be up to 10mm in thickness.
Del 2	ARGILL QUARTZITE		2,2	36	Dry	80 50-60 30-40 10-20	- 0,3-1,0 0,3-1,0 0,3-1,0	- - - -	0,1-1 0,1-1 0,1-1 0,1-1,	Rough Rough Rough Rough	Soft Soft Soft Soft	Fair Unfav.	
Del 3	QUARTZITE with ARGILL.bd.		0,8	38	Dry	5-25 75-85 45-65	0,3-1,0 0,05-0,3 0,3-1,0	- - -	1-5 0,1-1 0,1-1	Rough Smooth/Rgh. Rough	W.Soft V.Soft V.Soft	Unfav. Fair	
Del 4	QUARTZITE		6,3	66	Dry	70 50-60 20-30 0	- 0,05-0,3 0,3-1,0 0,3-1,0	- - - -	0,1-1 0,1-1 0,1-1 0,1-1,	Rough Rough Rough Rough	Hard Hard Hard Hard	Fair Unfav.	Occasional clay coatings 1-5mm thick on 0° joints.
Del 5	QUARTZITE SHALE & SILTSTONE		1,0	11	Dry	70-80 30-40 10	- 0,05-0,3 0,3-1,0	- - -	0,1-1 0,1-1 1-5	Slicks. Rough Rough	Soft Soft Soft	Fair Unfav.	Max. thickness assumed to be important because of poor core recv.
Del 6	QUARTZITE SHALE & SILTSTONE		1,6	43	Dry	60-80 20-30 0-10	- 0,05-0,3 0,3-1,0	- - -	1-5 1-5 1-5	Rough Rough Rough	Soft Soft Soft	Fair Unfav.	All joints have indications of clay coatings 1mm thick.

STEP 6

N.G.I. CLASSIFICATION SYSTEM - DATA FORM

Project: DELVERS TUNNEL

Data Source: BORE CORE.

SAMPLE SITE NUMBER	CROWN DEPTH BELOW SURFACE (m)	ROCK		EXCAV-ATION SPAN	ESR	RQD %	JOINT DATA				STRESS REDUCTION FACTOR	REMARKS
		Type	Density (kg/m³)				Joint Set Number	Roughness	Alteration	Water		
Del 1	6,7	ARGILL. QTZITE.	—	2,6	1.6	0	2+R	Undulating & smooth	Clay & softening mineral coatings	Dry	Multiple weakness zones with clay. (< 50m)	
Del 2	6,5	ARGILL. QTZITE.	—	2,5	1,6	36	4+R	Undulating & rough	Clay or softening mineral coatings.	Dry	Multiple weakness zones with clay. (< 50m)	
Del 3	6,5	QTZITE. & ARGIL hor.	—	2,6	1,6	38	3	Undulating & rough	Clay & softening mineral coatings	Dry	Multiple weakness zones with clay. (< 50m)	
Del 4	7,2	QTZITE	—	2,6	1,6	66	4+R	Undulating & rough	Non-softening mineral coat.	Dry	Low stress.	
Del 5	5,2	QTZITE, SHLE & SLTSTN.	—	2,6	1,6	11	3+R	Planar & slicks.	Clay & softening mineral coatings	Dry	Multiple weakness zones with clay. (< 50m)	
Del 6	4,8	QTZITE, SHLE & SLTSTN.	—	2,6	1,6	43	3+R	Undulating & rough	Clay & softening mineral coatings.	Dry	Multiple weakness zones with clay. (< 50m)	

STEP 6

GEOMECHANICS CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: DELVERS TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	CLASSIFICATION PARAMETER RATINGS						RMR.	ROCK CLASS
	Intact Rock Strength	RQD	Joint Spacing	Joint Condition	Ground Water	Orientation Adjustment		
Del 1	4	3	10	9	10	- 8	28	IV
Del 2	7	8	20	12	10	- 6	51	III
Del 3	2	8	17	10	10	- 7	40	IV
Del 4	12	13	17	20	10	- 6	66	II
Del 5	4	3	15	8	10	- 7	33	IV
Del 6	4	8	15	6	10	- 7	36	IV

STEP 7

N.G.I. CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: DeLVERS TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	CROWN DEPTH (m)	σ_v (kPa) *	CLASSIFICATION PARAMETER RATINGS			Q	SPAN / ESR	SUPPORT CATEGORY
			RQD/Jn	Jr/Ja	Jw/SRF			
Del 1	6,6	169	$\frac{10}{6}$ = 1,67	$\frac{2,0}{4,0}$ = 0,5	$\frac{1,0}{10,0}$ = 0,1	0,08	$\frac{2,6}{1,6}$ = 1,6	33
Del 2	6,6	160	$\frac{36}{15}$ = 2,4	$\frac{3,0}{4,0}$ = 0,75	$\frac{1,0}{10,0}$ = 0,1	0,18	"	29
Del 3	6,6	149	$\frac{20}{5}$ = 4,22	$\frac{3,0}{4,0}$ = 0,75	$\frac{1,0}{10,0}$ = 0,1	0,32	"	29
Del 4	7,2	176	$\frac{66}{15}$ = 4,4	$\frac{3,0}{3,0}$ = 1,0	$\frac{1,0}{2,5}$ = 0,4	1,76	"	21
Del 5	5,2	120	$\frac{11}{12}$ = 0,92	$\frac{0,5}{4,0}$ = 0,13	$\frac{1,0}{10,0}$ = 0,1	0,012	"	33
Del 6	4,8	118	$\frac{43}{12}$ = 3,58	$\frac{3,0}{4,0}$ = 0,75	$\frac{1,0}{10,0}$ = 0,1	0,27	"	29
	* From: Kirsten, Stacey and Warwick, Nov. 1976.							

STEP 7

THE NUMBER OF JOINTS WITH SIMILAR INCLINATION ANGLES RECORDED IN EACH BOREHOLE

Project: DU TOITSKLOOF TUNNEL STEP 1

BOREHOLE NUMBER	α^{o}	0	10	20	30	40	50	60	70	80	90	TOTAL CORRECTED JOINTS
	$1/\sin\alpha$	∞	5,72	2,92	2,0	1,56	1,31	1,15	1,06	1,02	1,0	
Dut 1-H	A	1	0	1	2	14	14	15	18	7	2	93
	B	1	0	3	4	22	18	17	19	7	2	
	C	1	0	3	4	24	20	18	20	8	2	
Dut 1-V	A	3	3	1	6	4	6	3	7	0	0	59
	B	3	17	3	12	6	8	3	7	0	0	
	C	5	29	5	20	10	14	5	12	0	0	
Dut 2-H	A	3	5	0	1	2	7	6	15	3	0	72
	B	3	29	0	2	3	9	7	16	3	0	
	C	4	40	0	3	4	13	10	22	4	0	
Dut 2-V	A	2	2	1	3	3	2	3	1	4	0	39
	B	2	12	3	6	5	3	3	1	4	0	
	C	5	31	8	15	13	8	8	2	10	0	
Dut 3-V	A	3	0	5	3	3	0	0	1	0	0	30
	B	3	0	15	6	5	0	0	1	0	0	
	C	10	0	50	20	17	0	0	3	0	0	
Dut 4-H	A	0	0	1	3	1	1	7	7	1	0	28
	B	0	0	3	6	2	1	8	7	1	0	
	C	0	0	11	21	7	4	25	24	4	0	
Dut 4-V	A	2	1	0	2	2	5	1	5	0	0	28
	B	2	6	0	4	3	7	1	5	0	0	
	C	7	21	0	14	11	25	4	18	0	0	
Dut 5-V	A	2	0	0	1	4	0	0	0	0	0	10
	B	2	0	0	2	6	0	0	0	0	0	
	C	20	0	0	20	60	0	0	0	0	0	
Dut 6-H	A	0	0	0	0	5	0	2	1	0	0	11
	B	0	0	0	0	8	0	2	1	0	0	
	C	0	0	0	0	73	0	18	9	0	0	
Dut 6-V	A	0	0	2	0	4	1	0	1	1	0	15
	B	0	0	6	0	6	1	0	1	1	0	
	C	0	0	39	0	39	8	0	7	7	0	
	A											
	B											
	C											
	A											
	B											
	C											

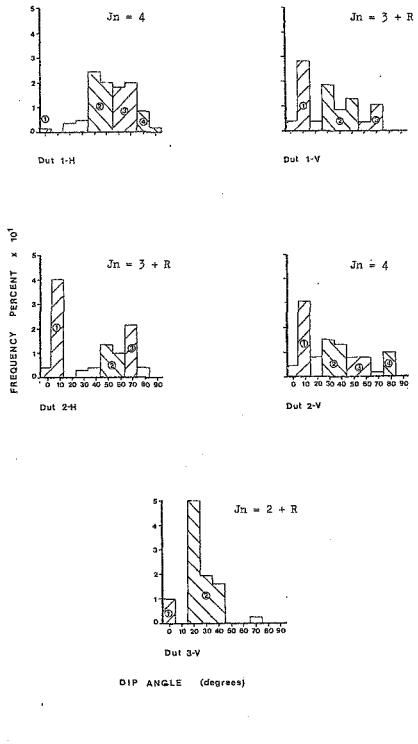
A - No. of joints recorded in the borehole.

B - No. of joints corrected for intersection angle α .

C - Corrected no. of joints expressed as percentages.

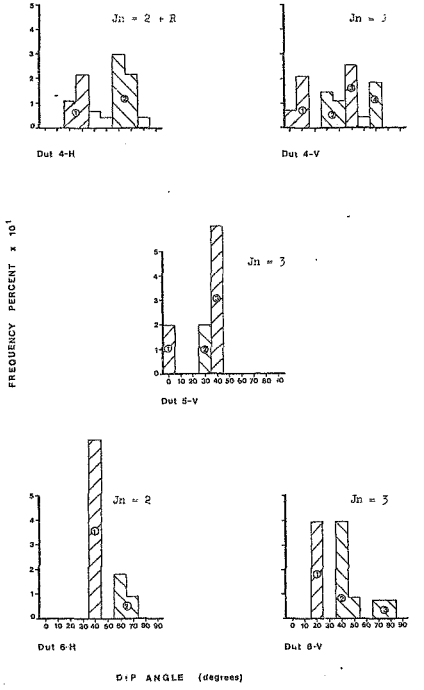
HISTOGRAMS SHOWING THE NUMBER OF JOINTS IN EACH BOREHOLE WITH SIMILAR INCLINATION ANGLES

Project: DU TOITSKLOOF TUNNEL STEP 2



HISTOGRAMS SHOWING THE NUMBER OF JOINTS IN EACH BOREHOLE WITH SIMILAR INCLINATION ANGLES

Project: DU TOITSKLOOF TUNNEL SHT 2



THE AVERAGE SPACING OF EACH JOINT SET

Project: DU TOITSKLOOF TUNNEL STEP 3

BOREHOLE NUMBER	CORE LENGTH L (m)	DIP OF JOINT SET (°)	CORRECTED JOINT NUMBER N^1	JOINT SPACING L/N^1(m)	JOINT SPACING CATEGORY *
Dut 1-H	10,5	0	-	-	-
		40 - 50	40	0,3	0,05 - 0,3
		60 - 70	36	0,3	0,05 - 0,3
		80 - 90	9	1,2	1 - 3
Dut 1-V	4,0	20 - 30	10	0,4	0,3 - 1
		40 - 60	26	0,2	0,05 - 0,3
		80 - 90	-	-	-
Dut 2-H	14,7	0 - 10	-	-	-
		50 - 60	16	0,9	0,3 - 1
		70	16	0,9	0,3 - 1
Dut 2-V	5,6	10	4	1,4	1 - 3
		30 - 40	6	0,9	0,3 - 1
		50 - 60	11	0,5	0,3 - 1
		80 - 90	-	-	-
Dut 3-V	5,3	50 - 70	26	0,2	0,05 - 0,3
		90	-	-	-
Dut 4-H	5,8	20 - 30	9	0,6	0,3 - 1
		60 - 70	15	0,4	0,3 - 1
Dut 4-V	5,90	20	5	1,2	1 - 3
		40	7	0,8	0,3 - 1
		50 - 60	7	0,8	0,3 - 1
		80 - 90	-	-	-

*After Bieniawski

THE AVERAGE SPACING OF EACH JOINT SET

Project: DU TOITSKLOOF TUNNEL STEP 3

BOREHOLE NUMBER	CORE LENGTH L (m)	DIP OF JOINT SET (°)	CORRECTED JOINT NUMBER N^1	JOINT SPACING L/N'(m)	JOINT SPACING CATEGORY *
Dut 5-V	2,44	90	-	-	-
		60	2	1,2	1 - 3
		50	6	0,4	0,3 - 1
Dut 6-H	2,60	40	8	0,3	0,05 - 0,3
		60 - 70	3	0,9	0,3 - 1,0
Dut 6-V	2,45	10 - 20	2	1,2	1 - 3
		40 - 50	7	0,4	0,3 - 1
		70	-	-	-

*after Bieniawski

THE NUMBER OF JOINTS IN EACH SET WITH SIMILAR SURFACE ROUGHNESS AND ALTERATION CHARACTERISTICS

Project: DU TOITSKLOOF TUNNEL

Data Source: BORE CORE

SAMPLE SITE NUMBER	JOINT SET ANGLE (°)*	SURFACE ROUGHNESS						SURFACE ALTERATION				
		Undulating		With Slicks	Planar		With Slicks	Closed	None or Staining only	Non-softening Mineral Coatings	Clay or Softening Mineral Coatings	Gouge
		Rough	Smooth		Rough	Smooth						
Dut 1-H	0	1							1			
	40 - 50	15			10	3			23	5		
	60 - 70	14			19		5		17	16		
	80 - 90	9		3					9			
Dut 1-V	20 - 30	4			6			1	5	4		
	40 - 60	14			2				11	5		
	80 - 90	6		2				1	3	2		
Dut 2-H	0 - 10	1			2	5	1	2	3	1	2	
	50 - 60	9	1		1	2			12	1		
	70	12				3			15			
Dut 2-V	10	3	1							1		3
	30 - 40	3			1	1		1	3	1		
	50 - 60	4			1	1			6			
	80 - 90	1	1		2				4			
Dut 3-V	50 - 70	7	3	3	1				8		3	
	90	2	1	3					2		1	
Dut 4-H	20 - 30	4		2				1			3	
	60 - 70	7	2	3	4	1		1	11		2	
Dut 4-V	20	5		2				2			3	
	40	4	1	3					2		3	
	50 - 60	4						1			3	
	80 - 90	2	1	2							3	

*MEASURED FROM CORE AXIS

STEP 4

THE NUMBER OF JOINTS IN EACH SET WITH SIMILAR SURFACE ROUGHNESS AND ALTERATION CHARACTERISTICS

Project: DU TOITSKLOOF TUNNEL

Data Source: BORE CORE

SAMPLE SITE NUMBER	JOINT SET AXIALE (°)*	SURFACE ROUGHNESS						SURFACE [illegible]				
		Undulating		With Slickensides	Planar		With Slickensides	Clayey	None or Staining only	Non-softening Mineral Coatings	Clay or Staining Mineral Coatings	Gouge
		Rough	Smooth		Rough	Smooth						
Dut 5-V	0	1			1				1	1		
	30	1							1			
	40	3	1						3	2		
Dut 6-H	40	5						2		3		
	60 - 70	2			1				1	2		
Dut 6-V	10 - 20	1			1				1	1		
	40 - 50	5								5		
	70	2								2		

*MEASURED FROM CORE AXIS

STEP 4

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: N1 TOTTSKLOOF TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Dut 1-H	0	Undulating and rough.	None or staining.		
	40 - 50	Undulating/planar and rough.	None or staining.		Well-developed joint set and poorest surface conditions.
	60 - 70	Planar/undulating and rough with occasional slickensides.	Staining with non-softening mineral coatings.	*	
	80 - 90	Undulating and rough with occasional slickensides.	None or staining.		
Dut 1-V	20 - 30	Planar/undulating and rough.	Staining with non-softening mineral coatings.	*	Well-developed joint set and poorest surface conditions.
	40 - 60	Undulating and rough.	None or staining.		
	80 - 90	Undulating and rough with occasional slickensides.	Staining with non-softening mineral coatings.		
Dut 2-H	0 - 10	Planar & smooth with occasional slickensides.	Staining with some clay coatings.		
	50 - 60	Undulating and rough.	None or staining.		
	70	Undulating and rough.	None or staining.	*	Most common joint set.
Dut 2-V	10	Undulating and rough.	Gouge.	*	Poorest surface conditions.
	30 - 40	Undulating and rough.	None or staining.		
	50 - 60	Undulating and rough.	None or staining.		
	80 - 90	Planar/undulating & rough.	None or staining.		

*With respect to Tunnel Stability

STEP 5

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: DU TOITSKLOOF TUNNEL Data Source: BORE CORE

SAMPLE STPE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J s' s)
Dut 3-V	50 - 70	Undulating and rough with occasional slickensides.	Staining with occasional clay coatings.	x	Most common joint set.
	90	Undulating and rough with slickensides.	Staining with some clay coatings.		
Dut 4-H	20 - 30	Undulating and rough with some slickensides.	Clay or softening mineral coatings.		
	60 - 70	Undulating/planar and rough with slickensides.	None or staining.	x	Most common joint set.
Dut 4-V	20	Undulating and rough with some slickensides.	Clay or softening mineral coatings.		
	40	Undulating and rough with slickensides.	Clay or softening mineral coatings.	x	Most common joint set.
	50 - 60	Undulating and rough.	Clay or softening mineral coatings.		
	80 - 90	Undulating and rough or smooth with slickensides.	Clay or softening mineral coatings.		
Dut 5-V	90	Undulating/planar and rough	Staining with non-softening mineral coatings.		
	60	Undulating and rough.	None or staining.		
	50	Undulating and rough.	None or staining.	x	Most common joint set.

*With respect to Tunnel Stability

STEP 5

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: DU TOITSKLOOF TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Dut 6-H	40	Undulating and rough.	Non-softening mineral coatings.	± ?	Both joint sets similar.
	60 - 70	Undulating and rough.	Non-softening mineral coatings and stain.		
Dut 6-V	10 - 20	Undulating/planar and rough.	Stain and non-softening mineral coatings.	±	Most common joint set.
	40 - 50	Undulating and rough.	Non-softening mineral coatings.		
	70	Undulating and rough.	Non-softening mineral coatings.		

*With respect to Tunnel Stability

STEP 5

GEOMECHANICS CLASSIFICATION SYSTEM - DATA FORM

Project: RU TOITSKLOOF TUNNEL

Data Source: BORE CORE.

SAMPLE SITE NUMBER	ROCK TYPE	INTACT ROCK STRENGTH U.C.S. (Mpa)	INTACT ROCK STRENGTH P.L.S.I. (Mpa)	RQD %	GROUND WATER	JOINT DESCRIPTION Dip (°)	Spacing (m)	Joint Condition Continuity	Joint Condition Separation (mm)	Joint Condition Roughness	Joint Condition Joint Fell Rock	Joint Orientation	REMARKS
Dut 1-H	QUARTZITIC SANDSTONE		7,3	30	Moist	0	-	-	< 0,1	Rough	Hard	Unfav.	
						40-50	0,05-0,3	-	0,1-1	Rough.	Hard		
						60-70	0,05-0,3	-	0,1-1	Rough	Hard	Fair	
						80-90	1,0-3,0	-	0,1-1	Rough	Hard		
Dut 1-V	QUARTZITIC SANDSTONE		4,2	18	Moist	20-30	0,3-1,0	-	< 0,1	Rough	Hard	Fair	
						40-60	0,05-0,3	-	< 0,1	Rough	Hard		
						80-90	-	-	< 0,1	Rough with Slicks.	Hard		
Dut 2-H	QUARTZITIC SANDSTONE		4,2	20	Moist	0-10	-	-	0,1-1	Smooth & Slicks	Hard	Unfav.	
						50-60	0,3-1,0	-	0,1-1	Rough	Hard	Fair	
						70	0,3-1,0	-	0,1-1	Rough	Hard		
Dut 2-V	QUARTZITIC SAND.TONE		3,8	40	Moist	10	1,0-3,0	-	1-5	Rough	Hard	Unfav.	
						30-40	0,3-1,0	-	< 0,1	Rough/Smth.	Hard	Fair	
						50-60	0,3-1,0	-	0,1-1	Rough	Hard		
						80-90	-	-	0,1-1.	Rough	Hard		
Dut 3-V	QUARTZITIC SANDSTONE (weathered & brecc.)		1,5	43	Moist	50-70	0,05-0,3	-	1-5	Rough with Slicks.	Med. Hard	Fair	
						90	-	-	1-5	Smooth & Slicks.	Med. Hard		
Dut 4-H	GRANITE (sheared)		1,2	55	Moist	25-30	0,3-1,0	-	0,1-1	Slicks.	Med. Hard	Fair	
						60-70	0,3-1,0	-	0,1-1	Slicks	Med. Hard		
Dut 4-V	GRANITE (sheared)		1,3	28	Moist	20	1,0-3,0	-	0,1-1	Rough & Slicks.	Med. Hard	Unfav.	The rock shows evidence of intense internal shearing.
						40	0,3-1,0	-	0,1-1	Rough & Slicks.	Med. Hard	Fair	
						50-60	0,3-1,0	-	0,1-1	Rough.	Med. Hard		
						80-90	-	-	0,1-1	Slicks.	Med. Hard		

STEP 6

GEOMECHANICS CLASSIFICATION SYSTEM - DATA FORM

Project: DU TOITSKLOOF TUNNEL — Data Source: BORE CORE

SAMPLE SITE NUMBER	ROCK TYPE	INTACT ROCK STRENGTH		RQD %	GROUND WATER	JOINT DESCRIPTION							REMARKS.
		U.C.S. (Mpa)	P.L.S.L (Mpa)			Dip (°)	Spacing (m)	Joint Condition: Continuity	Joint Condition: Separation (mm)	Joint Condition: Roughness	Joint Condition: Joint Wall Rock	Joint Orientation	
Dut 5-V	GRANITE		1,9	58	Dry	90	-	-	< 0,1	Rough	Hard	Unfav.	
						60	1,0-3,0	-	< 0,1	Rough	Hard	Fair	
						50	0,3-1,0	-	< 0,1	Rough	Hard		
Dut 6-H	GRANITE		6,5	89	Dry	40	0,05-0,3	-	< 0,1	Rough	Hard	Fair	
						60-70	0,3-1,0	-	< 0,1	Rough	Hard		
Dut 6-V	GRANITE		6,9	75	Dry	15-20	1,0-3,0	-	0,1-1	Rough	Hard	Unfav.	
						40-50	0,3-1,0	-	0,1-1	Rough	Hard	Fair	
						70	-	-	0,1-1	Rough	Hard		

N.G.I. CLASSIFICATION SYSTEM - DATA FORM

Project: DU TOITSKLOOF TUNNEL — Data Source: BORE CORE.

SAMPLE SIZE NUMBER	CROWN DEPTH BELOW SURFACE (m)	ROCK Type	ROCK Density (kg/m³)	EXCAVATION SPAN	ESR	RQD %	JOINT DATA Joint set Number	JOINT DATA Roughness	JOINT DATA Alteration	JOINT DATA Water	STRESS REDUCTION FACTOR	REMARKS
Cut 1-H	200	QUARTZITIC SNDSTN.	2640	3,0	1,6	30	4	Planar & rough	Stain & quartz coating	Minor	Single clay free weakness zones in competent rock (> 50m).	
Cut 1-V	200	QUARTZITIC SNDSTN.	2640	3,0	1,6	18	3+R	Planar & rough	Stain & quartz coating	Minor	Single clay free weakness zones in competent rock (> 50m).	
Cut 2-H	210	QUARTZITIC SNDSTN.	2704	3,0	1,6	20	3+R	Undulating & rough.	Stain	Minor	Single clay free weakness zones in competent rock (> 50m).	
Cut 2-V	210	QUARTZITIC SNDSTN	2704	3,0	1,6	40	4	Undulating & rough	Bands of clayey grit	Minor	Single weakness zones with clay (> 50m).	
Cut 3-V	190	QUARTZITIC SNDSTN. weath. & brec	2460	3,0	1,6	43	2+R	Undulating with slicks.	Stain & clay coating	Minor	Single weakness zones with clay (> 50m).	
Cut 4-H	200	GRANITE sheared	2570	3,0	1,6	55	2+R	Undulating with slicks.	Stain	Minor	Multiple clay free shear zone	Rock shows signs of intense shearing
Cut 4-V	200	GRANITE sheared	2570	3,0	1,6	28	4	Undulating with slicks.	Softening mineral coat	Minor	Multiple clay free shear zone	Rock shows signs of intense shearing
Cut 5-V	150	GRANITE	2650	3,0	1,6	58	3	Undulating & rough	Stain	Probably dry	Single clay free weakness zones (> 50m).	

STEP 6

N.G.I. CLASSIFICATION SYSTEM - DATA FORM

Project: DU TOITSKLOOF TUNNEL — Data Source: BORE CORE.

SAMPLE SITE NUMBER	CROWN DEPTH BELOW SURFACE (m)	ROCK		EXCAVATION SPAN	ESR	RQD %	JOINT DATA				STRESS REDUCTION FACTOR	REMARKS
		Type	Density (kg/m³)				Joint Set Number	Roughness	Alteration	Water		
Mut 6-H	280	GRANITE	2650	3,0	1,6	89	2	Undulating & rough	Calcite coating	Probably dry	Medium stress	$\frac{\sigma_c}{\sigma_v} = 23$
Mut 6-V	280	GRANITE	2650	3,0	1,6	75	3	Undulating & rough	Calcite coating	Probably dry	Medium stress	$\frac{\sigma_c}{\sigma_v} = 24$

STEP 6

GEOMECHANICS CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: DU TOITSKLOOP TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	CLASSIFICATION PARAMETER RATING						RMR	ROCK CLASS
	Intact Rock Strength	RQD	Joint Spacing	Joint Condition	Ground Water	Orientation Adjustment		
Dut 1-H	12	8	15	20	7	- 6	56	III
Dut 1-V	12	3	15	15	7	- 5	47	III
Dut 2-H	12	3	20	15	7	- 7	50	III
Dut 2-V	7	8	21	17	7	- 6	54	III
Dut 3-V	4	8	10	6	7	- 5	30	IV
Dut 4-H	4	13	20	6	7	- 5	45	III
Dut 4-V	4	8	21	12	7	- 6	46	III
Dut 5-V	4	13	23	20	10	- 6	64	II
Dut 6-H	12	17	15	20	10	- 5	69	II
Dut 6-V	12	17	22	20	10	- 7	74	II

STEP 7

N.G.I. CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: DU TOITSKLOOF TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	CROWN DEPTH (m)	σ_v (kPa)	CLASSIFICATION PARAMETER RATINGS			Q	SPAN / ESR	SUPPORT CATEGORY
			RQD/J_n	J_r/J_a	J_w/SRF			
Dut 1-H	200	5200	$\frac{30}{15} = 2,0$	$\frac{1,5}{1,0} = 1,5$	$\frac{1,0}{2,5} = 0,4$	1,2	$\frac{3,0}{1,6} = 1,9$	21
Dut 1-V	200	5200	$\frac{18}{12} = 1,5$	$\frac{1,5}{1,0} = 1,5$	$\frac{1,0}{2,5} = 0,4$	0,9	"	25
Dut 2-H	210	5400	$\frac{20}{12} = 1,7$	$\frac{3,0}{1,0} = 3,0$	$\frac{1,0}{2,5} = 0,4$	2,04	"	21
Dut 2-V	210	5400	$\frac{40}{15} = 2,7$	$\frac{3,0}{8,0} = 0,38$	$\frac{1,0}{2,5} = 0,4$	0,41	"	25
Dut 3-V	190	4800	$\frac{43}{6} = 7,2$	$\frac{1,5}{4,0} = 0,38$	$\frac{1,0}{2,5} = 0,4$	1,1	"	21
Dut 4-H	200	5100	$\frac{55}{6} = 9,2$	$\frac{1,5}{1,0} = 1,5$	$\frac{1,0}{7,5} = 0,13$	1,8	"	21
Dut 4-V	200	5100	$\frac{28}{15} = 1,9$	$\frac{1,5}{4,0} = 0,38$	$\frac{1,0}{7,5} = 0,13$	0,09	"	33
Dut 5-V	150	3800	$\frac{58}{9} = 6,4$	$\frac{3,0}{1,0} = 3,0$	$\frac{1,0}{2,5} = 0,4$	7,7	$\frac{5,0}{1,6} = 3,1$	17

STEP 7

N.G.I. CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: DU TOITSKLOOF TUNNEL Data Source: BORE CORE

SAMPLE SITE NUMBER	CROWN DEPTH (m)	σ_v (kPa)	CLASSIFICATION PARAMETER RATINGS			Q	SPAN / ESR	SUPPORT CATEGORY
			RQD/Jn	Jr/Ja	Jw/SRF			
Dut 6-H	280	7200	$\frac{89}{4}$ = 22,3	$\frac{3,0}{0,75}$ = 4,0	$\frac{1,0}{1,0}$ = 1,0	89,2	$\frac{3,0}{1,6}$ = 1,9	9
Dut 6-V	280	7200	$\frac{75}{9}$ = 8,3	$\frac{3,0}{0,75}$ = 4,0	$\frac{1,0}{1,0}$ = 1,0	33,2	"	13

STEP 7

APPENDIX VI

RESULTS OF THE STEPS FOR EVALUATING
THE IN SITU MEASUREMENTS

TABLE SHOWING THE INTERSECTION ANGLES (α) BETWEEN JOINT SETS AND THE TUNNEL AXIS; THE NUMBER OF JOINTS IN EACH SET CORRECTED FOR ORIENTATIONAL BIAS; JOINT SPACINGS AND RQD ESTIMATES

Project: BUSHKOPJES TUNNEL

SAMPLE LINE NUMBER	TUNNEL ADVANCE DIRECTION	JOINT SURVEY LENGTH (m) L	JOINT STRIKE DIRECTION (°)	α (°)	$1/\sin\alpha$	NUMBER OF JOINTS N	CORRECTED NUMBER OF JOINTS $Nc = N/\sin\alpha$	JOINT SPACING L/Nc	JOINT SPACING CATEGORY*	NO. OF JOINTS PER METRE	SUM OF NO. OF JTS/M. J_v	RQD % (115 - 3,3 J_v)	AVERAGE NO. OF JOINTS/ METRE	RQD % $[100e^{0,1\lambda}(0,1\lambda+1)]$
Bos 1	132	9,05	102	30	2,00	15	30	0,3	0,3-1,0	3,3	8,6	87	3,3	96
			216	84	1,01	9	9	1,0	1,0-3,0	1,0				
			166	34	1,79	1	-	-	0,3-1,0	3,3				
			355	43	1,47	2	-	-	1,0-3,0	1,0				
			R			25		0,4	0,3-1,0	2,3				
Bos 2	177	10,0	225	48	1,35	12	16	0,6	0,3-1,0	1,6	7,3	91	4,9	91
			153	24	2,46	6	15	0,7	0,3-1,0	1,4				
			153	24	2,46	8	20	0,5	0,3-1,0	2,0				
			R			23		0,4	0,3-1,0	2,3				
Bos 3	177	10,0	128	49	1,33	8	11	0,9	0,3-1,0	1,1	6,9	92	5,1	91
			213	36	1,70	5	9	1,1	1,0-3,0	0,9				
			161	16	3,63	4	15	0,7	0,3-1,0	1,4				
			046	49	1,33	2	3	3,3	> 3,0	0,3				
			R			32		0,3	0,3-1,0	3,2				
Bos 4	177	10,0	090	87	1,00	3	6	1,7	1,0-3,0	0,6	4,6	100	4,3	93
			254	77	1,03	4	4	2,5	1,0-3,0	0,4				
			146	31	1,94	6	12	0,8	0,3-1,0	1,2				
			R			24		0,4	0,3-1,0	2,4				
Bos 5	110	10,0	103	2	-	-	-	-	0,3-1,0*	3*	5,6	97	4,7	92
			47	63	1,1	7	8	1,2	1,0-3,0	0,8				
			023	87	1,0	3	3	3,3	> 3,0	0,3				
			R			25		0,4	0,3-1,0	2,5				

* AFTER BIENIAWSKI

STEP 3

TABLE SHOWING THE INTERSECTION ANGLES (α) BETWEEN JOINT SETS AND THE TUNNEL AXIS; THE NUMBER OF JOINTS IN EACH SET CORRECTED FOR ORIENTATIONAL BIAS; JOINT SPACINGS AND RQD ESTIMATES

Project: BUSHKOPPIES TUNNEL

SAMPLE SITE NUMBER	TUNNEL ADVANCE DIRECTION	JOINT SURVEY LENGTH(m) L	JOINT STRIKE DIRECTION (°)	α (°)	$1/\sin\alpha$	NUMBER OF JOINTS N	CORRECTED NUMBER OF JOINTS $Nc = N/\sin\alpha$	JOINT SPACING L/Nc	JOINT SPACING CATEGORY*	NO. OF JOINTS PER METRE	SUM OF NO. OF JTS/M. J.	RQD % (115 - 3,3 J.)	AVERAGE NO. OF JOINTS/METRE	RQD % $[100 \cdot e^{-0,1\lambda}(0,1\lambda+1)]$
Bos 6	110	10,0	136	26	2,3	7	16	0,6	0,3-1,0	1,7	4,6	100	3,2	96
			026	84	1,0	7	7	1,4	1,0-3,0	0,7				
			090	20	2,9	2	6	1,7	1,0-3,0	0,6				
			R			16		0,6	0,3-1,0	1,6				
Bos 7	290	10,0	148	38	1,6	8	13	0,8	0,3-1,0	1,3	5,3	98	3,8	94
			032	78	1,02	4	4	2,5	1,0-3,0	0,4				
			138	28	2,1	3	6	1,7	1,0-3,0	0,6				
			096	14	4,1	3	12	0,8	0,3-1,0	1,2				
			R			18		0,5	0,3-1,0	1,8				
Bos 8	290	10,0	042	68	1,1	15	16	0,6	0,3-1,0	1,6	9,9	82	5,0	91
			150	40	1,6	4	6	1,7	1,0-3,0	0,6				
			120	10	5,6	11	63	0,2	0,05-0,3	5				
			090	20	2,9	4	12	0,8	0,3-1,0	1,2				
			R			15		0,7	0,3-1,0	1,5				
Bos 9	316	10,0	229	87	1,0	9	9	1,1	1,0-3,0	0,9	4,4	100	3,4	95
			340	24	2,5	6	15	0,7	0,3-1,0	1,5				
			009	53	1,3	5	6	1,7	1,0-3,0	0,6				
			R			14		0,7	0,3-1,0	1,4				
Bos 10	316	10,0	007	51	1,3	8	10	1,0	0,3-1,0	1,0	4,9	99	4,3	93
			258	58	1,2	9	11	0,9	0,3-1,0	1,1				
			258	58	1,2	9	11	0,9	0,3-1,0	1,1				
			R			17		0,6	0,3-1,0	1,7				

* AFTER BIENIAWSKI

STEP 3

TABLE SHOWING THE INTERSECTION ANGLES (α) BETWEEN JOINT SETS AND THE TUNNEL AXIS; THE NUMBER OF JOINTS IN EACH SET CORRECTED FOR ORIENTATIONAL BIAS; JOINT SPACINGS AND RQD ESTIMATES

Project: BUSHMOPLES TUNNEL

SAMPLE SITE NUMBER	TUNNEL ADVANCE DIRECTION	JOINT SURVEY LENGTH(m) L	JOINT STRIKE DIRECTION (°)	α (°)	$1/\sin\alpha$	NUMBER OF JOINTS N	CORRECTED NUMBER OF JOINTS No = N/Sinα	JOINT SPACING L/No	JOINT SPACING CATEGORY*	NO. OF JOINTS PER METRE	SUM OF NO. OF J's/M. J.	RQD % (115 - 3,3 J.)	AVERAGE NO. OF JOINTS/ METRE	RQD % $[100e^{-0,1\lambda}(0,1\lambda+1)]$
Bos 11	316	18,0	246	70	1,1	8	9	1,1	1,0-3,0	0,9	4,4	100	3,2	96
			274	42	1,5	7	10	1,0	0,3-1,0	1,0				
			337	21	2,8	3	8	2,3	1,0-3,0	0,8				
			353	37	1,7	5	8	1,3	1,0-3,0	0,8				
			R			9		1,1	1,0-3,0	0,9				
Bos 12	316	10,0	002	46	1,4	7	8	1,3	1,0-3,0	0,8	4,7	100	3,5	95
			016	60	1,2	5	6	1,7	1,0-3,0	0,6				
			340	24	2,5	5	12	0,8	0,3-1,0	1,3				
			280	36	1,7	4	7	1,4	1,0-3,0	0,7				
			R			13		0,8	0,3-1,0	1,3				

* AFTER BIENIAWSKI

STEP 3

TABLE SHOWING THE RELATION BETWEEN THE TUNNEL DIRECTION AND THE ORIENTATION OF THE JOINT SETS

Project: BUSKOPPIES TUNNEL STEP 4

SAMPLE SITE NUMBER	TUNNEL ADVANCE DIRECTION (°)	JOINT SET DIP ANGLE (°)	DIP DIRECTION (°)	STRIKE (°)	STRIKE wrt TUNNEL DIRECTION	EFFECT ON TUNNEL STABILITY*
Bos 1	132	68	192	102	Parallel	V. Unfav.
		85	306	216	Perpend.	Fair
		30	256	166	Parallel	Fair
		85	085	355	Parallel	V. Unfav.
Bos 2	177	90	315	045	Perpend.	Fair
		90	243	153	Parallel	V. Unfav.
		20	243	153	Parallel	Fair
Bos 3	177	90	218	128	Perpend.	V. Fav.
		85	123	033	Parallel	V. Unfav.
		25	251	161	Parallel	Fair
		90	136	046	Perpend.	V. Unfav.
Bos 4	177	70	000	090	Perpend.	Fair
		80	344	254	Perpend.	Fair
		80	236	146	Parallel	V. Unfav.
Bos 5	110	25	198	108	Parallel	Fair
		90	317	227	Perpend.	Fair
		70	113	023	Perpend.	V. Fav.
Bos 6	110	90	046	136	Parallel	V. Unfav.
		90	116	206	Perpend.	V. Fav.
		37	000	090	Parallel	Fair
Bos 7	290	84	238	148	Parallel	V. Unfav.
		85	302	212	Perpend.	V. Fav.
		45	228	138	Parallel	V. Unfav.
		90	006	096	Parallel	V. Unfav.
Bos 8	290	85	132	042	Perpend.	Fair
		80	240	150	Parallel	V. Unfav.
		75	030	120	Parallel	V. Unfav.
		33	180	270	Parallel	Fair

* AFTER BIENIAWSKI

TABLE SHOWING ... TION BETWEEN THE TUNNEL DIRECTION AND THE ...LATION OF THE JOINT SETS

Proje... BUSHKOPPIES TUNNEL STEP 4

SAMPLE SITE NUMBER	TUNNEL ADVANCE DIRECTION (°)	JOINT SET DIP ANGLE (°)	DIP DIRECTION (°)	STRIKE (°)	STRIKE wrt TUNNEL DIRECTION	EFFECT ON TUNNEL STABILITY*
Bos 9	316	90	319	229	Perpend.	V. Fav.
		75	250	160	Parallel	V. Unfav.
		76	099	009	Perpend.	Fair
Bos 10	316	90	277	187	Perpend.	V. Fav.
		47	168	078	Perpend.	Fair
		80	168	078	Perpend.	Fair
Bos 11	316	90	156	066	Perpend.	Fair
		90	004	094	Parallel	V. Unfav.
		10	247	157	Parallel	Unfav.
		90	083	173	Parallel	V. Unfav.
Bos 12	316	85	272	002	Perpend.	V. Fav.
		90	106	016	Perpend.	Fair
		85	250	340	Parallel	V. Unfav.
		80	010	280	Parallel	V. Unfav.

* AFTER BIENIAWSKI

THE NUMBER OF JOINTS IN EACH SET WITH SIMILAR SURFACE ROUGHNESS AND ALTERATION CHARACTERISTICS

Project: BUSHKOPPIES TUNNEL

Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	JOINT SET ANGLE (°)*	SURFACE ROUGHNESS						SURFACE ALTERATION				
		Undulating		With Slickensides	Planar		With Slickensides	Closed	None or Staining only	Non-softening Mineral Coatings	Clay or Softening Mineral Coatings	Gouge
		Rough	Smooth		Rough	Smooth						
Bos 1	68	13			2				6		9	
	85	6			3						9	
	30				1							1
	85	2									2	
Bos 2	90	2			7	3		10	2			
	90	2			2	2		6				
	20	5	1		1	1		8				
Bos 3	90	1	2		3	2		5	1		2	
	85	5						5				
	25	1			2	1		2	1		1	
	90	1			1			1			1	
Bos 4	70	1			5			6				
	80	1			2	1		4				
	80		2		1	3		6				
Bos 5	25	3			1	1		5				
	90	3	1		2			6				
	70	2			1			2		1		
Bos 6	90	4			3			7				
	90	6			1			4		3		
	37	1	1					2				

* DIP

STEP 5

THE NUMBER OF JOINTS IN EACH SET WITH SIMILAR SURFACE ROUGHNESS AND ALTERATION CHARACTERISTICS

Project: BUSHKOPPIES TUNNEL

Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	JOINT SET ANGLE (θ)*	SURFACE ROUGHNESS						SURFACE ALTERATION				
		Undulating		With Slickensides	Planar		With Slickensides	Closed	None or Staining only	Non-softening Mineral Coatings	Clay or Softening Mineral Coatings	Gouge
		Rough	Smooth		Rough	Smooth						
Bos 7	84	2			5	1			6	1	1	
	85					4		2	1		1	
	45	2			1			3				
	90				1	2		1		2		
Bos 8	85	1			7	7		12	2	1		
	80	2			1	1		3	1			
	75					11		11				
	33				3	1		2		1	1	
Bos 9	90	6			3			5		4		
	75	3			2	1		6				
	76	4				1		5				
Bos 10	90	2			4	2		4	2		2	
	47				9			1	2	2	4	
	80	4			5			1	8			
Bos 11	90				4	4		1	5		2	
	90	1			2	4			5		2	
	10	1			2			1	1		1	
	90				2	3		1	3		1	
Bos 12	85	3			2	2		2	2		3	
	90	2			2	1		3	1		1	
	85	1	1		2	1		3	2			
	80	1			3				4			

* DIP

STEP 5

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: BUSHKOPPIES TUNNEL Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Bos 1	68	Undulating and rough.	Clay coatings with staining and non-softening minerals.		Most unfavourably orientated joint set - has caused main crown failure.
	85	Undulating and rough.	Clay coatings.		
	30	Planar/undulating and rough.	Gouge (up to 10 cm thick).	*	
	85	Undulating and rough.	Clay coatings.		
Bos 2	90	Planar and rough.	Closed.		Most unfavourably orientated joint set.
	90	Undulating/planar and rough.	Closed.	*	
	20	Undulating and rough.	Closed.		
Bos 3	90	Planar and rough/smooth.	Closed but with occasional staining and clay coatings.		Fair orientation but poorest surface characteristics.
	85	Undulating and rough.	Closed.		
	25	Planar and rough.	Closed but also staining and clay coatings.	*	
	90	Undulating/planar and rough.	Closed or with calcite and chlorite coatings.		
Bos 4	70	Planar and rough.	Closed.		Very unfavourably orientated.
	80	Planar and rough or smooth.	Closed.		
	90	Planar and rough or smooth.	Closed.	*	

*With respect to Tunnel Stability

STEP 6.

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: BUSHKOPPIES TUNNEL Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Bos 5	25	Undulating and rough.	Closed.	x	Appeared to be most unfavourably orientated joint set.
	90	Undulating/planar and rough.	Closed.		
	70	Undulating/planar and rough.	Closed and non-softening mineral coatings.		
Bos 6	90	Undulating/planar and rough.	Closed.	x	Most unfavourably orientated joint set.
	90	Undulating and rough.	Closed and with non-softening mineral coatings.		
	37	Undulating and rough or smooth.	Closed.		
Bos 7	84	Planar and rough.	Staining with occasional clay and non-softening and softening mineral coatings.	x	Poor orientation and poorest surface characteristics.
	85	Planar and smooth.	Closed with occasional staining and clay coatings.		
	45	Undulating/planar and rough.	Closed.		
	90	Planar and smooth/rough.	Non-softening mineral coatings.		

*With respect to Tunnel Stability

STEP 6

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: BUSKOPPIES TUNNEL Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Bos 8	85	Planar and rough/smooth.	Closed with some staining.		
	80	Undulating and rough.	Closed with some staining.		
	75	Planar and smooth.	Closed.	x	Most common unfavourably orientated joint set.
	33	Planar and rough.	Closed but with some non-softening and clay coatings.		
Bos 9	90	Undulating and rough.	Closed and non-softening mineral coatings.		
	75	Undulating/planar and rough.	Closed.	x	Most unfavourably orientated joint set.
	76	Undulating and rough.	Closed.		
Bos 10	90	Planar and rough/smooth.	Closed and with occasional clay coatings and stain.		
	47	Planar and rough.	Clay contings with some stain and non-softening minerals.	x	Poorest surface characteristics.
	80	Planar/undulating and rough	Staining.		
Bos 11	90	Planar and smooth/rough.	Staining with occasional clay coatings.		
	90	Planar and smooth/rough.	Staining with occasional clay coatings.		
	10	Planar and rough.	Staining and clay coatings.		
	90	Planar and smooth/rough.	Staining and occasional clay coatings.	x	Most unfavourably orientated joint set.

*With respect to Tunnel Stability

STEP 6

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: BUSHKOPPIES TUNNEL Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET ( )	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Bos I2	85	Planar and rough/smooth.	Clay coatings and staining.		
	90	Planar and undulating and rough.	Closed but with occasional staining and clay coatings.		
	85	Planar and rough/smooth.	Closed and stained.		
	80	Planar and rough.	Staining.	*	Unfavourably orientated joint set.

*With respect to Tunnel Stability

STEP 6

GEOMECHANICS CLASSIFICATION SYSTEM - DATA FORM

Project: BUSHKOPPIES TUNNEL

Date Source: IN SITU JOINT SURVEY.

SAMPLE SITE NUMBER	ROCK TYPE	INTACT ROCK STRENGTH U.C.S. (Mpa)	INTACT ROCK STRENGTH P.L.Pt. (Mpa)	RQD %	GROUND WATER	JOINT DESCRIPTION Dip (°)	Spacing (m)	Joint Condition Continuity	Joint Condition Separation (mm)	Joint Condition Roughness	Joint Condition Joint wall Rock	Joint Orientation	REMARKS
Bos 1	LAVA		4,2	87	Moist	66	0,3-1,0	Continous	0,1-1	Rough	Hard	V. Unfav.	Max. gouge thickness in crown.
						85	1,0-3,0	Continous	0,1-1	Rough	Hard	Fair.	
						30	0,3-1,0 *	Continous	> 5	Rough.	Hard	Fair.	*Estimated.
						85	1,0-3,0	Continous	0,1-1	Rough	Hard	V. Unfav.	
Bos 2	LAVA	334		91	Moist	90	0,3-1,0	Continous	< 0,1	Rough	Hard	Fair.	
						90	0,3-1,0	Continous	< 0,1	Rough	Hard	V. Unfav.	
						20	0,3-1,0	Continous	< 0,1	Rough	Hard	Fair.	
Bos 3	LAVA & DIABASE		2,5	92	Moist	90	0,3-1,0	Continous	0,1-1	Rough/Smooth	Hard*	V. Fav.	* Joints in diabase have soft wall rock.
						85	1-3	Continous	< 0,1	Rough	Hard	V. Unfav.	
						25	0,3-1,0	Discontinous	0,1-1	Rough	Hard	Fair.	
						90	> 3	Continous	0,1-1	Rough	Hard	V. Fav.	
Bos 4	DIABASE		13,8	100	Dry	70	1,0-3,0	Continous	< 0,1	Rough	Hard	Fair.	
						80	1,0-3,0	Discontinous	< 0,1	Rough/Smooth	Hard	Fair.	
						80	0,3-1,0	Discontinous	< 0,1	Rough/Smooth	Hard	V. Unfav.	
Bos 5	LAVA		4,1	97	Dry	25	0,3-1,0	Continous	< 0,1	Rough	Hard	Fair	
						90	1,0-3,0	Continous	< 0,1	Rough	Hard	Fair.	
						70	> 3	Continous	0,1-2	Rough	Hard	V. Fav.	
Bos 6	LAVA	278		100	Dry	90	0,3-1,0	Continous	< 0,1	Rough	Hard	V. Unfav.	
						90	1,0-3,0	Continous	0,1-1	Rough	Hard	V. Fav.	
						37	1,0-3,0	Discontinous	< 0,1	Rough/Smooth	Hard	Fair.	
Bos 7	LAVA		12,8	98	Moist	84	0,3-1,0	Continous	0,1-1	Rough	Hard	V. Unfav.	
						85	1,0-3,0	Continous	0,1-1	Smooth	Hard	V. Fav.	
						45	1,0-3,0	Discontinous	< 0,1	Rough	Hard	V. Unfav.	
						90	0,3-1,0	Discontinous	0,1-1	Rough/Smooth	Hard	V. Unfav.	
Bos 8	LAVA		12,2	82	Dry	85	0,3-1,0	Continous	< 0,1	Rough/Smooth	Hard	Fair.	
						80	1,0-3,0	Discontinous	< 0,1	Rough	Hard	V. Unfav.	
						75	0,05-0,3	Continous	< 0,1	Smooth	Hard	V. Unfav.	
						35	0,3-1,0	Continous	0,1-1	Rough	Hard	Fair.	
Bos 9	LAVA		9,8	100	Moist	90	1,0-3,0	Discontinous	0,1-1	Rough	Hard	V. Fav.	
						75	0,3-1,0	Continous	< 0,1	Rough	Hard	V. Unfav.	
						76	1,0-3,0	Continous	< 0,1	Rough	Hard	Fair.	

STEP 7

GEOMECHANICS CLASSIFICATION SYSTEM - DATA FORM

Project: BUSHKOPPIES TUNNEL

Data Source: IN SITU JOINT SURVEY.

SAMPLE SITE NUMBER	ROCK TYPE	INTACT ROCK STRENGTH U.C.S. (Mpa)	INTACT ROCK STRENGTH P.L.I. (Mpa)	RQD %	GROUND WATER	JOINT DESCRIPTION Dip (°)	Spacing (m)	Joint Condition Continuity	Joint Condition Separation (mm)	Joint Condition Roughness	Joint Condition Joint wall Rock	Joint Orientation	REMARKS.
Bos 10	LAVA		2,75	99	Moist	90 47 80	0,3-1,0 0,3-1,0 0,3-1,0	Continous Continous Continous	0,1-1 0,1-1 < 0,1	rough/Smooth Rough Smooth	Hard Hard Hard	V. Fav. Fair. Fair.	
Bos 11	LAVA	477		100	Moist	90 90 10 90	1,0-3,0 0,3-1,0 1,0-3,0 1,0-3,0	Continous Continous Continous Continous	0,1-1 0,1-1 0,1-2 0,1-1	Rough/Smooth Rough/Smooth Rough Rough/Smooth	Hard Hard Hard Hard	V.Fair. V. Unfav. Unfav. V. Unfav.	
Bos 12	LAVA	384		100	Moist	85 90 85 80	1,0-3,0 1,0-3,0 0,3-1,0 1,0-3,0	Continous Continous Continous Continous	0,1-1 0,1-1 < 0,1 < 0,1	Rough/Smooth Rough Rough/Smooth Rough	Hard Hard Hard Hard	V. Fav. Fair. V. Unfav. V. Unfav.	

STEP 7

N.G.I. CLASSIFICATION SYSTEM - DATA FORM

Project: BUSHKOPPIES TUNNEL — Data Source: IN SITU.

SAMPLE SITE NUMBER	CROWN DEPTH BELOW SURFACE (m)	ROCK		EXCAVATION SPAN	Σ R	RQD %	JOINT DATA				STRESS REDUCTION FACTOR	REMARKS
		Type	Density (kg/m³)				Joint set Number	Roughness	Alteration	Water		
Bos 1	18,75	LAVA	2890	3,35	1,6	87	4	Planar & rough	Clay gouge up to 10cm *.	Medium inflow	Single weakness zones with clay (< 50m).	* Maybe less.
Bos 2	40,75	LAVA	2890	3,35	1,6	91	3+R	Planar & rough	Closed	Minor	Low stress.	
Bos 3	64,50	LAVA & narrow DIABASE DYKE.	2890	3,35	1,6	92	4+R	Planar & rough	Stain & clay coating	Minor	Single shear zones with clay (> 50m).	Slickensided jts. occasionally present.
Bos 4	64,50	DIABASE	2890	3,35	1,6	100	3+R	Planar & smooth	Closed	Dry	Medium stress.	
Bos 5	61 00	LAVA	2890	3,35	1,6	97	3+R	Undulating & rough	Closed	Dry	Medium stress	
Bos 6	42,50	LAVA	2890	3,35	1,6	100	3+R	Planar & rough	Closed	Dry	Low stress.	
Bos 7	27,50	LAVA	2890	2,6	1,6	98	4+R	Planar & rough	Stain & occ. softening & non-softening mineral coating	Minor	Heavily jointed	
Bos 8	41,25	LAVA	2890	2,6	1,6	82	4+R	Planar & smooth	Closed	Dry	Low stress.	
Bos 9	48,50	LAVA	2890	2,6	1,6	100	3+R	Planar & rough	Closed	Minor	Medium stress.	
Bos 10	32,00	LAVA	2890	2,6	1,6	99	3+R	Planar & rough	Stain & clay coating	Minor	Single weakness zones with clay & crushed rock (< 50m).	
Bos 11	21,50	LAVA	2890	2,6	1,6	100	4+R	Planar & smooth	Stain & clay coatings	Minor	Single clay free weakness zones (< 50m) +	*Not always
Bos 12	6,5	LAVA	2890	2,6	1,6	100	4+R	Planar & rough	Stain	Minor	Single weakness zones with clay	(< 50m)

STEP 7

GEOMECHANICS CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: BUSHKUPPIES TUNNEL Data Source: IN SITU

SAMPLE SITE NUMBER	CLASSIFICATION PARAMETER RATINGS						RMR.	ROCK CLASS
	Intact Rock Strength	RQD	Joint Spacing	Joint Condition	Ground Water	Orientation Adjustment		
Bos 1	12	17	23	15	7	- 9	65	II
Bos 2	15	20	20	20	7	- 7	75	II
Bos 3	7	20	24	20	7	- 4	74	II
Bos 4	15	20	23	20	10	- 7	81	I
Bos 5	12	20	25	20	10	- 3	84	I
Bos 6	15	20	23	20	10	- 6	82	I
Bos 7	15	20	23	19	7	- 9	75	II
Bos 8	15	17	19	19	10	- 9	71	II
Bos 9	15	20	23	20	7	- 6	79	II
Bos 10	7	20	20	19	7	- 3	70	II
Bos 11	15	20	24	20	7	-10	84	I
Bos 12	15	20	24	20	7	- 7	87	I
							STEP 8	

N.G.I. CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: BUSHKOPPIES TUNNEL Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	CROWN DEPTH (m)	σ_v (kPa)	CLASSIFICATION PARAMETER RATINGS			Q	SPAN / ESR	SUPPORT CATEGORY
			RQD/Jn	Jr/Ja	Jw/SRF			
Bos 1	13,75	531	$\frac{87}{15}$ = 5,8	$\frac{1,5}{8,0}$ = 0,19	$\frac{0,65}{5,0}$ = 0,13	0,14	$\frac{3,35}{1,6}$ = 2,1	29
Bos 2	40,75	1143	$\frac{91}{12}$ = 7,58	$\frac{1,5}{0,75}$ = 2,0	$\frac{1,0}{2,5}$ = 0,4	6,06	"	17
Bos 3	64,50	1829	$\frac{92}{15}$ = 6,13	$\frac{1,5}{3,0}$ = 0,5	$\frac{1,0}{2,5}$ = 0,4	1,23	"	21
Bos 4	64,50	1829	$\frac{100}{12}$ = 8,33	$\frac{1,0}{0,75}$ = 1,33	$\frac{1,0}{1,0}$ = 1,0	11,08	"	13
Bos 5	61,00	1709	$\frac{97}{15}$ = 8,08	$\frac{3,0}{0,75}$ = 4,0	$\frac{1,0}{1,0}$ = 1,0	32,32	"	13
Bos 6	42,50	1199	$\frac{100}{12}$ = 8,33	$\frac{1,5}{0,75}$ = 2,0	$\frac{1,0}{2,5}$ = 0,4	6,66	"	17
Bos 7	27,50	780	$\frac{98}{15}$ = 6,53	$\frac{1,5}{2,0}$ = 0,75	$\frac{1,0}{5,0}$ = 0,2	0,98	$\frac{2,6}{1,6}$ = 1,6	25
Bos 8	41,25	1169	$\frac{82}{15}$ = 5,47	$\frac{1,0}{0,75}$ = 1,33	$\frac{1,0}{2,5}$ = 0,4	2,91	"	21

STEP 8

N.G.I. CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: BUSKOPPERS TUNNEL Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	CROWN DEPTH (m)	σ_v (kPa)	CLASSIFICATION PARAMETER RATINGS			Q	SPAN / ESR	SUPPORT CATEGORY
			RQD/J_n	J_r/J_a	J_w/SRF			
Bos 9	48,50	1375	$\frac{100}{12} = 8,33$	$\frac{1,5}{0,75} = 2,0$	$\frac{1,0}{1,0} = 1,0$	16,66	$\frac{2,6}{1,6} = 1,6$	13
Bos 10	32,00	907	$\frac{95}{12} = 8,25$	$\frac{1,5}{3,0} = 0,5$	$\frac{1,0}{5,0} = 0,2$	0,83	"	25
Bos 11	21,50	614	$\frac{100}{15} = 6,67$	$\frac{1,0}{3,0} = 0,33$	$\frac{1,0}{5,0} = 0,2$	0,44	"	25
Bos 12	6,50	182	$\frac{100}{15} = 6,67$	$\frac{1,5}{1,0} = 1,5$	$\frac{1,0}{5,0} = 0,2$	2,00	"	21

STEP 8

TABLE SHOWING THE RELATION BETWEEN THE TUNNEL DIRECTION AND THE ORIENTATION OF THE JOINT SETS

Project: DELVERS TUNNEL STEP 4

SAMPLE SITE NUMBER	TUNNEL ADVANCE DIRECTION (°)	JOINT SET DIP ANGLE (°)	DIP DIRECTION (°)	STRIKE (°)	STRIKE wrt TUNNEL DIRECTION	EFFECT ON TUNNEL STABILITY*
Del 1	262	85-90	S	E-W	Parallel	V. Unfav.
		0-20	N	E-W	Parallel	Unfav.
Del 2	262	85-90	S	E-W	Parallel	V. Unfav.
		90	-	E-W	Perpend.	Favourable*
Del 3	352	90	-	N-S	Parallel	V. Unfav.
		0-20	S	E-W	Perpend.	Unfav.
Del 4	172	80	W	N-S	Parallel	Fair
		90	-	N-S	Parallel	V. Unfav.
		60	SW	NW-SE	Parallel	V. Unfav.
Del 5	172	60-85	N	E-W	Perpend.	Fair
		0-20	N	E-W	Perpend.	Unfav.
		90	-	N-S	Parallel	V. Unfav.
Del 6	172	70	N	E-W	Perpend.	Fair
		20-25	S	E-W	Perpend.	Unfav.
		80	E	SSW	Parallel	V. Unfav.

* Compromise between "Fair" and "Very Unfavourable" owing to 90° dip.

* AFTER BIENIAWSKI

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: DELVERS TUNNEL

Data Source: IN SITU JOINT OBSERVATIONS

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Del 1	Vertical or steep south (E-W strike).	Planar and rough.	Clay or softening mineral coatings.	*	Least favourably orientated for stability.
	Subhorizontal Flat North.	Planar and rough.	Clay coating (1-5 mm).		
Del 2	Vertical or steep south (E-W strike).	Undulating and irregular.	Talc coating and sandy clay fill up to 5 cm thick.	*	Most common Joint Set.
	Flat North.	Undulating and rough.	Clay fill.		
Del 3	Vertical (E-W).	Undul. ting and irregular.	Staining.	*	Unfavourably orientated.
	Vertical (N-S).	Undulating and rough.	Staining.		
	Flat South	Undulating and rough.	Staining.		
Del 4	30° W.	Undulating and rough.	Clayey sand and stain.	*	Poor orientation and surface condition.
	Vertical (N-S strike).	Planar and rough.	Stain		
	60° SW	Undulating and rough.	Stain		
Del 5	80-85° N	Undulating and rough.	Staining or clayey layers	*	Poor orientation - worst surface conditions.
	Flat North.	Planar and rough.	Staining		
	Vertical (N-S strike)	Undulating and smooth.	Sandy clay 5-10 cms thick.		

*With respect to Tunnel Stability

STEP 6

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: DELVERS TUNNEL — Data Source: IN SITU JOINT OBSERVATIONS

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Del 6	70°N 20-25°S 80°E	Planar and rough. Planar and rough. Planar and rough.	Clay coatings (1-5 mm) Clay coating (1-5 mm) None	x	Most common joint set - poor surface conditions.

*With respect to Tunnel Stability

GEOMECHANICS CLASSIFICATION SYSTEM - DATA FORM

Project: DELVERS TUNNEL — Data Source: IN SITU JOINT OBSERVATIONS.

SAMPLE SITE NUMBER	ROCK TYPE	INTACT ROCK STRENGTH U.C.S (Mpa)	INTACT ROCK STRENGTH P.L.S.I (Mpa)	RQD %	GROUND WATER	JOINT DESCRIPTION Dip (°)	Spacing (m)	Joint Condition Continuity	Joint Condition Separation (mm)	Joint Condition Roughness	Joint Condition Joint Wall Rock	Joint Orientation	REMARKS.
Del 1	ROLLD. QUARTZITE		1,0	92	Moist	85-90 0-20	0,05-0,3 0,3-1,0	Continous Continous	1-5 1-5	Rough Rough	Soft soft	V. Unfav. Unfav.	Random jts.precen Rocks soften on exposure to moist air.
Del 2	ROLLD. QUARTZITE		2,2	82	Dry	85-90 0-28	0,05-0,3 Irreg. *	Continous Discontinous	> 5 > 5	Rough Rough	Soft Soft	V, Unfav. -	* Poss. random jts.
Del 3	QUARTZITE with ROLLD.hor.		0,8	65	Moist	90 30 20	0,05-0,3 0,3-1,0 0,3-1,0	Continous Continous Continous	0,1-1 0,1-1 0,1-1	Rough Rough Rough	Soft Soft Soft	Fav. V. Unfav. Unfav.	
Del 4	QUARTZITE		6,3	95	Dry	30 90 60	0,3-1,0 0,3-1,0 1-3	Continous Continous Discontinous	0,1-1 0,1-1 0,1-1	Rough Rough Rough	Hard Hard Hard	Fair. V. Unfav. V. Unfav.	
Del 5	QUARTZITE SHALS & SILTSTONE		1,0	92	Dry	80-85 0-20 85-90	0,3-1,0 0,3-1,0 0,3-1,0	Continous Continous Continous	1-5 0,1-1 > 5*	Smooth Rough Smooth	Soft Soft Soft	Fair. Unfav. V. Unfav.	* Clay gouge up to 10cm thick.
Del 6	QUARTZITE SHALE & SILTSTONE		1,6	69	Dry	70 25 80	0,05-0,3 0,05-0,3 1-3	Continous Continous Discontinous	1-5 1-5 0,1-1	Rough Rough Rough	Soft Soft Soft	Fair. Fair. V. Unfav.	} Stiff clay gouge.

STEP 7

N.G.I. CLASSIFICATION SYSTEM -. DATA FORM

Project: DELVERS TUNNEL — Data Source: IN SITU.

SAMPLE SIZE NUMBER	CROWN DEPTH BELOW SURFACE (m)	ROCK Type	ROCK Density (kg/m³)	EXCAVATION SPAN	ESR	RQD %	JOINT DATA Joint set Number	Roughness	Alteration	Water	STRESS REDUCTION FACTOR	REMARKS
Del 1	6,7	ARGILLACEOUS QUARTZITE.	–	2,6	1,6	92	2+R	Planar & rough	Clay & talc fill (< 5mm)	Minor	Multiple shear zones with clay (< 50m).	
Del 2	6,5	ARGILLACEOUS QUARTZITE.	–	2,6	1,6	82	1+R	Undulating & irregular	Talc & sandy clay up to 5mm.	Dry	Multiple shear zones with clay (< 50m).	
Del 3	6,5	QUARTZITE & ARGILLACEOUS.	–	2,6	1,6	69	3	Undulating & rough	Stain	Minor	Multiple clay free shear zones in competent rock (< 50m).	
Del 4	7,2	QUARTZITE	–	2,6	1,6	95	3+R	Planar & rough	Stain	Dry	Low stress.	
Del 5	5,2	QUARTZITE, CHLORITE & SILTSTONE.	–	2,6	1,6	92	3	Undulating & smooth	Clay gouge 5-10mm	Dry	Single weakness zones with clay (< 50m)	
Del 6	4,8	QUARTZITE, CHLORITE & SILTSTONE.	–	2,6	1,6	69	3+R	Planar & rough	Clay up to 5mm	Dry	Multiple weakness zones with clay (< 50m)	

STRP 7

GEOMECHANICS CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: DELIVERS TUNNEL Data Source: IN SITU

SAMPLE SITE NUMBER	CLASSIFICATION PARAMETER RATINGS						RMR.	ROCK CLASS
	Intact Rock Strength	RQD	Joint Spacing	Joint Condition	Ground Water	Orientation Adjustment		
Del 1	4	20	15	6	7	- 11	41	III
Del 2	7	17	10	0	10	- 12	32	IV
Del 3	2	13	17	12	7	- 8	43	III
Del 4	12	20	22	20	10	- 10	74	II
Del 5	4	20	20	6	10	- 9	51	III
Del 6	4	13	15	8	10	- 6	44	III

STEP 8

N.G.I. CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: DELVERS TUNNEL — Data Source: IN SITU JOINT OBSERVATIONS

SAMPLE SITE NUMBER	CROWN DEPTH (m)	σ_v (kPa)	CLASSIFICATION PARAMETER RATINGS			Q	SPAN / ESR	SUPPORT CATEGORY
			RQD/J_n	J_r/J_a	J_w/SRF			
Del 1	6,6	169	$\frac{92}{6} = 15,3$	$\frac{1,5}{4,0} = 0,38$	$\frac{1,0}{10,0} = 0,1$	0,58	$\frac{2,6}{1,6} = 1,6$	25
Del 2	6,6	160	$\frac{82}{3} = 27,3$	$\frac{3,0}{4,0} = 0,75$	$\frac{1,0}{10,0} = 0,1$	2,05	"	21
Del 3	6,6	149	$\frac{69}{9} = 7,67$	$\frac{3,0}{1,0} = 3,0$	$\frac{1,0}{7,5} = 0,13$	2,59	"	21
Del 4	7,2	176	$\frac{95}{12} = 7,92$	$\frac{1,5}{1,0} = 1,5$	$\frac{1,0}{4,5} = 0,4$	4,75	"	17
Del 5	5,2	120	$\frac{92}{9} = 10,2$	$\frac{2,0}{4,0} = 0,5$	$\frac{1,0}{5,0} = 0,2$	1,02	"	21
Del 6	4,8	118	$\frac{69}{12} = 5,75$	$\frac{1,5}{4,0} = 0,38$	$\frac{1,0}{10,0} = 0,1$	0,22	2	29
	*From:	Kirsten, Stacey and Warwick, Nov. 1976.						

STEP 8

TABLE SHOWING THE INTERSECTION ANGLES (α) BETWEEN JOINT SETS AND THE TUNNEL AXIS; THE NUMBER OF JOINTS IN EACH SET CORRECTED FOR ORIENTATIONAL BIAS; JOINT SPACINGS AND RQD ESTIMATES

Project: IN TOITSKLOOF TUNNEL.

SAMPLE SITE NUMBER	TUNNEL ADVANCE DIRECTION	JOINT SURVEY LENGTH(a) L	JOINT STRIKE DIRECTION (°)	α (°)	$1/\sin\alpha$	NUMBER OF JOINTS N	CORRECTED NUMBER OF JOINTS $N_c = N/\sin\alpha$	JOINT SPACING L/N_c	JOINT SPACING CATEGORY*	NO. OF JOINTS PER METRE	SUM OF NO. OF JTS/M. J_v	RQD % $(115 - 3{,}3\ J_v)$	AVERAGE NO. OF JOINTS/ METRE	RQD % $[100e^{0{,}1\lambda}(0{,}1\lambda+1)]$
			139	21	2,79	5	14	0,5	0,3-1,0	2				
			237	41	1,52	6	9	0,8	0,3-1,0	1,3				
Dut 1	278	7,4	117	19	3,07	3	9	0,8	0,3-1,0	1,3	7,5	90	5	91
			098	0	-	7	7	1,1	1,0-3,0	0,9				
			R	-	-	16	16	0,5	0,3-1,0	2				
			034	64	1,11	5	6	0,9	0,3-1,0	1,1				
			124	26	2,28	4	9	0,6	0,3-1,0	1,7				
Dut 2	278	5,4	159	61	1,14	2	2	2,7	1,0-3,0	0,4	10	82	5	91
			188	90	1,0	5	5	1,1	1,0-3,0	0,9				
			050	8	7,19	5	36	0,2	0,05-0,3	5				
			R	-	-	5	5	1,1	1,0-3,0	0,9				
			155	57	1,19	1	1	2,6	1,0-3,0	0,4				
Dut 3	278	2,6	294	16	3,63	4	15	0,2	0,05-0,3	5	9,9	82	5,4	90
			137	39	1,59	3	5	0,5	0,3-1,0	2				
			R	-	-	6	6	0,4	0,3-1,0	2,5				
			227	51	1,29	-	-	-	0,05-0,3	6				
			307	29	2,09	-	-	-	0,05-0,3	10				
Dut 4	278	8,15	178	80	1,02	-	-	-	0,3-1,0	2	18	56	*	*
			R	-	-	-	-	-	-	-				

* AFTER BIENIAWSKI

STEP 3

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TABLE SHOWING THE INTERSECTION ANGLES (α) BETWEEN JOINT SETS AND THE TUNNEL AXIS; THE NUMBER OF JOINTS IN EACH SET CORRECTED FOR ORIENTATIONAL BIAS; JOINT SPACINGS AND RQD ESTIMATES

Project: DU TOITSKLOOF TUNNEL

SAMPLE LINE NUMBER	TUNNEL ADVANCE DIRECTION	JOINT SURVEY LENGTH (m) L	JOINT SERIES DIRECTION (°)	α (°)	$1/\sin\alpha$	NUMBER OF JOINTS N	CORRECTED NUMBER OF JOINTS $Nc = N/\sin\alpha$	JOINT SPACING $1/Nc$	JOINT SPACING CATEGORY*	NO. OF JOINTS PER METRE	SUM OF NO. OF JTS/M. J_n	RQD % (115 - 3,3 J_n)	AVERAGE NO. OF JOINTS/ METRE	RQD % $[100e^{-0,1\lambda}(0,1\lambda+1)]$
Dut 5	278	7,6	295	17	3,42	-	-	-	0,3-1,0	3	8-28	89-56	*	*
			215	63	1,12	-	-	-	0,05-0,3	10				
			175	77	1,03	-	-	-	0,3-1,0	2				
			141	43	1,47	-	-	-	0,3-3,0	3				
			R	-	-	-	-	-	> 3,0	1				
Dut 6	278	11,5	119	21	2,79	4	11	1,0	0,3-1,0	1,0	2,8	100	2,4	98
			201	77	1,03	7	7	1,6	1,0-3,0	0,6				
			213	65	1,10	1	1	11,5	> 3,0	0,1				
			R	-	-	12	12	0,9	0,3-1,0	1,1				

* Joint spacing and RQD based on visual estimates because joint survey data insufficient.

* AFTER BIENIAWSKI

STEP 3

TABLE SHOWING THE RELATION BETWEEN THE TUNNEL DIRECTION AND THE ORIENTATION OF THE JOINT SETS

Project: DU TOITSKLOOF TUNNEL STEP 4

SAMPLE SITE NUMBER	TUNNEL ADVANCE DIRECTION (°)	JOINT SET DIP ANGLE (°)	DIP DIRECTION (°)	STRIKE (°)	STRIKE wrt TUNNEL DIRECTION	EFFECT ON TUNNEL STABILITY*
Dut 1	278	28	209	119	Parallel	Fair
		60	327	237	Parallel	V. Unfav.
		80	027	117	Parallel	V. Unfav.
		60-80	008	098	Parallel	V. Unfav.
Dut 2	278	30	124	034	Perpend.	Unfav.
		70	214	124	Parallel	V. Unfav.
		45	249	159	Perpend.	Favourable
		60	278	188	Perpend.	V. Fav.
		80	000	090	Parallel	V. Unfav.
Dut 3	278	58	065	155	Perpend.	Fair
		80	114	294	Parallel	V. Unfav.
		75	227	137	Parallel	V. Unfav.
Dut 4	278	80	317	227	Perpend.	V. Fav.
		60	217	307	Parallel	V. Unfav.
		70	088	178	Perpend.	Fair
Dut 5	278	0	-	-	-	Unfav.
		85	205	295	Parallel	V. Unfav.
		75	305	215	Perpend.	V. Fav.
		75	265	175	Perpend.	V. Fav.
		40	051	141	Parallel	Fair
Dut 6	278	70	029	119	Parallel	V. Unfav.
		90	111	201	Perpend.	Fair
		45	303	213	Perpend.	Favourable

* AFTER BIENIAWSKI

THE NUMBER OF JOINTS IN EACH SET WITH SIMILAR SURFACE ROUGHNESS AND ALTERATION CHARACTERISTICS

Project: DU TOITSKLOOF TUNNEL

Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	JOINT SET ANGLE (°)*	SURFACE ROUGHNESS						SURFACE ALTERATION				
		Undulating		Slickensided	Planar		Slickensided	Closed	None or Staining only	Non-softening Mineral Coatings	Clay or Softening Mineral Coatings	Gouge
		Rough	Smooth		Rough	Smooth						
Dut 1	28	3			2				3		2	
	60	4			2				6			
	80	1			1	1			3			
	50 - 80	4			3				7			
Dut 2	30	3			2				3		2	
	70	3			1				4			
	45				2				2			
	60				2	3			5			
	80	4			1				4		1	
Dut 3	58				1				1			
	90	2	2	1					1		3	
	75	1				2	1				3	
Dut 4	80	1	1	1		1	1				3	
	60					3	1		2		1	
	70		1	1		1			1		1	
Dut 5	85		2	2		1	1		2	1		
	75				2	2	1		3	1		
	75				2				2			
	40				1	1	1		1	1		
Dut 6	70	4								4		
	90	3			4				7			
	45				1				1			

* DIP

STEP 5

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: DU TOITSKLOOF TUNNEL Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Dut 1	28	Undulating/planar and rough.	None and clay coatings.		
	60	Undulating and rough.	None or staining.		
	80	Planar and rough/smooth with slickensides.	None or staining.	*	Most unfavourably orientated and poorest surface conditions.
	60	Undulating/planar and rough.	None or staining.		
Dut 2	30	Undulating/planar and rough.	Stain with some clay coatings.	*	Unfavourably orienteted and poor surface conditions.
	70	Undulating and rough.	None or staining.		
	45	Planar and rough.	None or staining.		
	60	Planar and smooth/rough.	None or staining.		
	80	Undulating and rough.	None or staining.		
Dut 3	58	Planar and rough.	None or staining.		
	90	Undulating and rough/smooth with slickensides.	Clay or softening minerals.	*	Very unfavourably orientated and most common joint set.
	75	Planar and smooth with slickensides.	Clay or softening minerals.		

*With respect to Tunnel Stability

STEP 6

GENERAL SURFACE CONDITIONS OF THE JOINT SETS RECORDED AT EACH SAMPLE SITE

Project: DU TOITSKLOOF TUNNEL Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	DIP ANGLE OF JOINT SET (°)	ROUGHNESS	ALTERATION	MOST SIGNIFICANT JOINT SET (J sig)*	REASONS FOR SELECTION OF (J sig)
Dut 4	80	Undulating/planar and smooth with slickensides.	Clay or softening minerals,	*	Very unfavourably orientated and poor surface conditions.
	60	Planar and smooth with slickensides.	None and some clay coatings.		
	70	Undulating/planar and smooth with slickensides.	None with some clay.		
Dut 5	0	-	-	*	Very unfavourably orientated and poor surface conditions.
	85	Undulating and smooth with slickensides.	Staining or non-softening minerals.		
	75	Planar and rough/smooth with some slickensides.	Staining or none.		
	75	Planar and rough.	None or staining only.		
	40	Planar and rough/smooth with slickensides.	Stain or non-softening minerals.		
Dut 6	70	Undulating and rough.	Non-softening minerals.	*	Unfavourably orientated.
	90	Planar/undulating and rough.	None or staining.		
	45	Planar and rough.	None or staining.		

*With respect to Tunnel Stability

STEP 6

GEOMECHANICS CLASSIFICATION SYSTEM - DATA FORM

Project: DU TOITSKLOOF TUNNEL — Data Source: IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	ROCK TYPE	INTACT ROCK STRENGTH U.C.S. (Mpa)	INTACT ROCK STRENGTH P.I.S.I. (Mpa)	RQD %	GROUND WATER	JOINT DESCRIPTION: Dip (°)	Spacing (m)	Joint Condition: Continuity	Joint Condition: Separation (mm)	Joint Condition: Roughness	Joint Condition: Joint Wall Rock	Joint Orientation	REMARKS
Dut 1	QUARTZITIC SANDSTONE		5,7	90	Moist	28 60 80 60-80*	0,3-1,0 0,3-1,0 0,3-1,0 1,0-3,0	Discontinous Continous Continous Continous	0,1-1 < 0,1 < 0,1 < 0,1	Rough Rough Smooth & Slicks. Rough	Hard Hard Hard Hard	Fair V. Unfav. V. Unfav. Fav.	* Poss. random joints
Dut 2	QUARTZITIC SANDSTONE		4,2	82	Moist	30 70 65 60) * 80)	0,3-1,0 0,3-1,0 1,0-3,0 - -	Continous Discontinous Discontinous - -	0,1-1 < 0,1 < 0,1 - -	Rough Rough Rough - -	Hard Hard Hard - -	Unfav. V. Unfav. Fair V. Fav. V. Unfav.	* Poss. joint set:
Dut 3	QUARTZITIC SANDSTONE (weathered & brecciated).		1,6	82	Moist	58 90 75	1,0-3,0 0,05-0,3 0,3-1,0	Discontinous Continous Continous	< 0,1 0,1-1 0,1-1	Rough Smooth & Slicks. Smooth & Slicks.	Soft to Medium-hard.	Fair. V. Unfav. V. Unfav.	
Dut 4	GRANITE (sheared)		1,3	56	Moist	80 60 70	0,05-0,3 0,05-0,3 0,3-1,0	Continous Continous Discontinous	1-5 0,1-1 0,1-1	Smooth & Slicks.	Soft to Medium-hard.	V. Fav. V. Unfav. Fair.	Spacing & RQD from visual estimates.
Dut 5	GRANITE		1,9	73	Dry	85 75 75 40*	0,3-1,0 0,05-0,3 0,3-1,0 1,0-3,0	Continous Continous Continous Continous	0,1-1 0,1-1 < 0,1 0,1-1	Smooth & Slicks. Rough Smooth & Slicks.	Medium-hard.	V. Unfav. V. Fav. V. Fav. Fair.	Spacing & RQD from visual estimates. *Poss. random set.
Dut 6	GRANITE		6,7	100	Dry	70 90 45	0,3-1,0 1,0-3,0 > 3	Continous Continous Continous	0,1-1 < 0,1 < 0,1	Rough Rough Rough	Hard Hard Hard	V. Unfav. Fair. Fav.	

STEP 7

N.G.I. CLASSIFICATION SYSTEM -. DATA FORM

Project: DU TOITSKLOOF TUNNEL — Data Source: IN SITU.

SAMPLE SITE NUMBER	CROWN DEPTH BELOW SURFACE (m)	ROCK		EXCAVATION SPAN	ESR	RQD %	JOINT DATA				STRESS REDUCTION FACTOR	REMARKS
		Type	Density (kg/m³)				Joint Set Number	Roughness	Alteration	Water		
Dut 1	240	..YZITIC ..NDSTN.	2640	3,0	1,6	90	4	Planar & smooth with slicks.	None or stain	Minor	Single weakness zones in competent rock, generally clay free (> 50m).	
Dut 2	210	..YZITIC ..NDSTN.	2704	3,0	1,6	82	4	*Planar & rough*	*Stain & clay* coating.	Minor	*Single* weakness zones with clay (> 50m).	
Dut 3	190	..YZITIC SNDSTN. weath. & brecc	2460	3,0	1,6	82	3+R	Undulating & smooth with slicks.	Clay & softening minerals.	Minor	Single weakness zones with clay (> 50m).	
Dut 4	200	GRANITE sheared	2570	3,0	1,6	56	3+R	Planar & smooth with slicks.	None but minor clay	Minor	Heavily jointed rock.	
Dut 5	150	GRANITE	2650	±5,0	1,6	73	4	Undulating & smooth *with* slicks.	Non-softening *mineral cement.*	Dry	Medium stress.	Joints usually *closed.*
Dut 6	280	GRANITE	2650	3,0	1,6	100	3+R	Undulating & rough	Non softening mineral cement.	Dry	Medium stress.	

STEP 7

GEOMECHANICS CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: DU TOITSKLOOF TUNNEL Data Source: IN SITU

SAMPLE SITE NUMBER	CLASSIFICATION PARAMETER RATINGS						RMR.	ROCK CLASS
	Intact Rock Strength	RQD	Joint Spacing	Joint Condition	Ground Water	Orientation Adjustment		
Dut 1	12	17	20	15	7	- 10	61	II
Dut 2	12	17	22	20	7	- 8	70	II
Dut 3	4	17	18	8	7	- 10	44	III
Dut 4	4	13	13	6	7	- 6	37	IV
Dut 5	4	13	17	11	10	- 9	46	III
Dut 6	12	20	25	20	10	- 6	81	I

STEP 8

N.G.I. CLASSIFICATION SYSTEM - CALCULATION SHEET

Project: DU TOITSKLOOF TUNNEL *Data Source:* IN SITU JOINT SURVEY

SAMPLE SITE NUMBER	CROWN DEPTH (m)	σ_v (kPa)	CLASSIFICATION PARAMETERS			Q	SPAN / ESR	SUPPORT CATEGORY
			RQD/J_n	J_r/J_a	J_w/SRF			
Cut 1	200	5200	$\frac{90}{15} = 6,0$	$\frac{0,5}{1,0} = 0,5$	$\frac{1,0}{2,5} = 0,4$	1,2	$\frac{3,0}{1,8} = 1,9$	21
Cut 2	210	5400	$\frac{82}{15} = 5,47$	$\frac{1,5}{3,0} = 0,5$	$\frac{1,0}{2,5} = 0,4$	1,09	"	21
Cut 3	190	4800	$\frac{82}{12} = 6,83$	$\frac{1,5}{4,0} = 0,38$	$\frac{1,0}{2,5} = 0,4$	1,02	"	21
Cut 4	200	5100	$\frac{56}{12} = 4,67$	$\frac{0,5}{1,0} = 0,5$	$\frac{1,0}{5,0} = 0,2$	0,47	"	25
Cut 5	150	3800	$\frac{73}{15} = 4,87$	$\frac{1,5}{0,75} = 2,0$	$\frac{1,0}{1,0} = 1,0$	9,74	$\frac{5,0}{1,6} = 3,1$	17
Cut 6	280	7200	$\frac{100}{12} = 8,33$	$\frac{2,0}{0,75} = 4,0$	$\frac{1,0}{1,0} = 1,0$	33,32	$\frac{3,0}{1,6} = 1,9$	13

STEP 8

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