APPENDICES

Appendix 1. Strike, dip values, and dip directions of the joints.

STRIKE (°)	DIP (°)	DIP DIRECTION (°)	STRIKE (°)	DIP (°)	DIP DIRECTION (°)
30	80	120	172	82	262
100	30	190	150	74	240
140	35	230	160	72	250
180	60	270	100	30	190
56	90	146	120	40	210
30	78	120	96	35	186
136	40	226	60	70	150
28	58	118	30	60	120
70	82	160	124	36	214
124	36	214	110	32	200
170	60	260	136	40	226
4	74	094	56	90	146
78	70	168	40	60	130
152	36	242	70	80	160
166	62	256	20	58	110
178	58	268	152	60	242
130	38	220	26	50	116
56	90	146	130	38	220
152	80	242	64	90	154
120	40	210	150	74	240
162	80	252	174	78	264
176	60	266	80	60	170
38	80	128	60	70	150
18	60	108	10	40	100
140	35	230	152	36	242
172	82	262	20	60	110
100	30	190	174	80	264
40	60	130	38	80	128
20	60	110	126	78	216
174	78	264	152	60	242
10	50	100	176	26	266
118	30	208	166	62	256
88	66	178	124	36	214
18	60	108	96	35	186
150	74	240	8	40	098
160	60	250	110	35	200
110	32	200	26	88	116
152	36	242	100	30	190
30	80	120	80	60	170
130	38	220	136	40	226
166	62	256	152	36	242
56	90	146	40	60	130

Appendix 2. Strike of foliation

STRIKE (°)
150
147
64
142
52
166
152
140
28
155
144
148
22
150
64
178
96
88
113
92
56
150
128
144
88
156
156
26
176
86
178
166
78
128
60
46
100

Appendix 3. Method of determination of physical properties of the Dinding schist:

The blocks were first saturated by complete immersion in water for some 24 hours, before their saturated weights in air (Wa) were measured after wiping water droplets from the surface of the sample. The Denver weighing apparatus (calibration in grams) was used for determination of all weights of the samples. Suspension of samples from the Denver weighing apparatus was done using a copper wire which weight was also determined (fig 4.4 and fig 4.5). The saturated weight in water (Ww) was obtained by completely immersing the samples in water for about 24hours, thereby eliminating any air bubbles (in case of the slightly weathered samples). Then the saturated weight in water was measured by completely immersing the samples in water while suspending the samples from the Denver weighing device with the copper wire whose weight was also ascertained. The samples were then dried overnight in the oven. The volumes of the samples were hence determined and the dry weight (Wd) obtained.

The results of the Dry Density, Saturated Density, Dry Unit Weight, Saturated Unit Weight, and the Apparent Porosity for unweathered and slightly weathered samples were then obtained as presented in tables 4.1 and 4.2 respectively.

Appendix 4. Physical properties of fresh (unweathered) samples of the Dinding schist.

Density of water ρw is $1 g/cm^3$ and Gravitational constant g is $9.8 m/s^2$.

Physical properties	Sample A1	Sample A2	Sample C1	Sample C2	Sample D1	Sample D2	Sample E1	Sample E2	**Mean**
Dry Weight **Wd** (gm)	201.7	242.4	429.3	548.3	461.2	198.9	498.4	630.8	
Saturated Weight in air **Wa** (gm)	204.6	245.3	432.1	551.1	464.5	201.9	502.6	635.4	
Saturated Weight in water **Ww** (gm)	127.1	153.9	273.2	342.5	290.0	123.6	315.8	397.6	
Bulk Volume **V** =Vol of water displaced. (cm^3)	77.5	91.4	158.9	208.6	174.5	78.3	186.8	237.8	
Bulk Volume **V** $= \frac{Wa-Ww}{\rho w}$ (m^3)	7.75 E-05	9.14 E-05	1.589 E-04	2.086 E-04	1.745 E-04	7.83 E-05	1.868 E-04	2.378 E -04	
Pore Volume **Vv** (cm^3)	2.9	2.9	2.8	2.8	3.3	3.0	4.2	4.6	
Pore Volume **Vv** $=\frac{Wa-Wd}{\rho w}$ (m^3)	2.9 E-06	2.9 E-06	2.8 E-06	2.8 E-06	3.3 E-06	3.0 E-06	4.2 E-06	4.6 E-06	
Porosity **n** $= \frac{Vv \times 100}{V}$ (%)	3.74	3.17	1.76	1.34	1.89	3.83	2.25	1.93	**2.5**
Dry Density **ρd** $= \frac{Wd}{V}$ (kg/m^3)	2,602.6	2,652.1	2,701.7	2,628.5	2,643.0	2,540.2	2,668.1	2,652.6	**2,636.1**
Saturated Density **ρsat** $=\frac{Wd+Vv\rho w}{V}$ (kg/m^3)	2,640	2,683.8	2,719.3	2,640.0	2,661.9	2,578.5	2,690.6	2,672.0	**2660.76**
Dry Unit Weight **ρdg** (kN/m^3)	25.51	25.99	26.48	25.76	25.77	24.89	26.15	26.0	**25.82**
Saturated Unit Weight **ρsatg** (kN/m^3)	25.87	26.30	26.65	25.87	26.09	25.27	26.37	26.19	**26.08**

Appendix 5. Physical properties of slightly weathered samples of the Dinding schist.

Density of water ρw is 1g/cm³ and Gravitational constant g is 9.8 m/s².

Physical properties	Sample B1	Sample B2	Sample B3	**Mean**
Dry Weight **Wd** (gm)	936.9	255.2	283.7	
Saturated Weight in air **Wa** (gm)	966.2	266.4	290.9	
Saturated Weight in water **Ww** (gm)	575.3	160.5	179.0	
Bulk Volume **V** =Vol of water displaced. (cm³)	390.9	105.9	111.9	
Bulk Volume **V** $= \frac{Wa-Ww}{\rho w}$ (m³)	3.909 E-04	1.059 E -04	1.119 E -04	
Pore Volume **Vv** (cm³)	29.3	11.2	7.2	
Pore Volume **Vv** $= \frac{Wa-Wd}{\rho w}$ (m³)	2.93 E-05	1.12 E-05	7.2 E-06	
Porosity **n** $= \frac{Vv \times 100}{V}$ (%)	7.50	10.58	6.43	**8.2**
Dry Density **ρd** $= \frac{Wd}{V}$ (kg/m³)	2,396.8	2,409.8	2,535.3	**2,447.3**
Saturated Density **ρsat** $= \frac{Wd+Vv\rho w}{V}$ (kg/m³)	2,471.7	2,515.6	2,599.6	**2,528.97**
Dry Unit Weight **ρdg** (kN/m³)	23.49	23.62	24.85	**23.99**
Saturated Unit Weight **ρsatg** (kN/m³)	24.22	24.65	25.48	**24.78**

Appendix 6. Method of determining basic friction angle:

Since it is known that shear strength in rocks may be reduced significantly in the presence of water by the reduction in normal stress across the failure surface, these blocks were air dried before the tilt tests were carried out. The apparatus for the tilt tests consists of lower holding and upper holding plates, then extra plates for loading and tilting of angles . In order to determine the basic friction angle (Φ_b), the tilt test was employed where two rock blocks having sawn or ground surfaces in contact are inclined (tilted) until the upper block starts to slide (fig.4.6). Several sets of the Tilt Tests were carried out at different orientations of the discontinuity surfaces of the blocks, and by adding weights to the upper block so as to have shear test conditions. The tilt angles **α** at different orientations were recorded as well as contact area **A** of the blocks at each test. As the total weights **Wt** acting upon the upper blocks were determined, and the tilt angles **α** known, it was possible to determine the:

Normal force **N** = Wt cos **α** (in N/m²) and Shear force **T** = Wt sin **α** (N/m²).

The Normal Stress **σ** is derived from

$$\frac{Wt \cos \boldsymbol{\alpha}}{\mathbf{A}}$$

and the Shear Stress **τ** from

$$\frac{Wt \sin \boldsymbol{\alpha}}{\mathbf{A}}$$

At the point of sliding, the angle of inclination (**α**) is theoretically equal to the angle of friction (**θ**) as defined in the Mohr-Coulomb yield criterion [$\tau f = \sigma' n \tan \theta$] (Priest, 1992). Results of the tilt tests involving diamond sawn surfaces (cut parallel to foliation) of slightly weathered and unweathered samples are presented in Appendices 7, 8, 9, 10, 11, 12, and 13, and the basic friction angles (*Φb*) obtained when the normal and shear stresses acting on the sliding plane are plotted in terms of the Mohr-Coulomb yield criterion (see appendices 14, 15, 16, 17, 18, 19, and 20).

Appendix 7: Results of Tilt Tests involving original discontinuity surfaces of unweathered block samples A1 and A2. Whereby 1Kg = 9.80665 Newton.

Samples A1 and A2: Original Discontinuity Surfaces					
	Surface 1	Surface 2	Surface 3	Surface 4	Surface 5
Tilt angle α (in degrees °)	32	29	31	33	30
Wt of upper plate (Kg)	4.85	4.85	4.85	4.85	4.85
Wt of extra plate(s) (Kg)	-	2	1	2	1
Wt of upper block (Kg)	0.2017	0.2017	0.2017	0.2017	0.2017
Total Weight acting upon the lower block (Kg)	5.0517	7.0517	6.0517	7.0517	6.0517
Contact Area A (m^2)	3.211 E-03	3.444 E-03	3.444 E-03	3.211 E-03	3.211 E-03
Normal force N= wt cos α (in Newton)	42.00	60.50	50.89	58.00	51.40
Shear force T=wt sin α (in Newton)	26.26	33.54	30.58	37.68	29.68
Normal Stress $\sigma = \frac{N}{A}$ (kN/m^2)	13.10	17.566	14.776	16.84	16.00
Shear Stress $\tau = \frac{T}{A}$ (kN/m^2)	8.18	9.738	8.879	10.94	9.243

Appendix 8: Results of Tilt Tests involving slightly weathered block samples B1 and B2. Whereby 1Kg = 9.80665 Newton.

Samples B1 and B2: Diamond Sawn and Not Polished					
	Surface 1	Surface 2	Surface 3	Surface 4	Surface 5
Tilt angle α (in degrees °)	23	24	23	24	23
Wt of upper plate (Kg)	4.85	4.85	4.85	4.85	4.85
Wt of extra plate(s) (Kg)	1.5	1	_	_	1
Wt of upper block (Kg)	0.2552	0.2552	0.2552	0.2552	0.2552
Total Weight acting upon the lower block (Kg)	6.6052	6.1052	5.1052	5.1052	6.1052
Contact Area A (m^2)	3.344 E-03	3.344 E-03	3.344 E-03	3.344 E-03	3.344 E-03
Normal force N= wt cos α (in Newton)	59.6	54.7	46	45.7	55
Shear force T=wt sin α (in Newton)	25	24.4	19.56	20.4	23.4
Normal Stress $\sigma = \frac{N}{A}$ (kN/m^2)	17.831	16.356	13.781	13.677	16.481
Shear Stress $\tau = \frac{T}{A}$ (kN/m^2)	7.569	7.282	5.850	6.090	6.996

Appendix 9: Results of Tilt Tests involving slightly weathered block samples B1 and B3. Whereby 1Kg = 9.80665 Newton.

Samples B1 and B3: Diamond Sawn and Not Polished					
	Surface 1	Surface 2	Surface 3	Surface 4	Surface 5
Tilt angle α (in degrees °)	28	26	26	28	27
Wt of upper plate (Kg)	4.85	4.85	4.85	4.85	4.85
Wt of extra plate(s) (Kg)	_	1	2	1	1
Wt of upper block (Kg)	0.2837	0.2837	0.2837	0.2837	0.2837
Total Weight acting upon the lower block (Kg)	5.1337	6.1337	7.1337	6,1337	6.1337
Contact Area A (m^2)	4.14 E-03	4.14 E-03	4.14 E-03	4.14 E-03	4.14 E-03
Normal force N= wt cos α (in Newton)	44.5	54	62.9	53	53.6
Shear force T=wt sin α (in Newton)	23.6	26	30.7	28	27
Normal Stress $\sigma = \frac{N}{A}$ (kN/m^2)	10.737	13.059	15.188	12.829	12.946
Shear Stress $\tau = \frac{T}{A}$ (kN/m^2)	5.709	6.369	7.408	6.821	6.596

Appendix 10: Results of Tilt Tests involving slightly weathered block samples B2 and B3. Whereby 1Kg = 9.80665 Newton.

Samples B2 and B3: Diamond Sawn and Not Polished					
	Surface 1	Surface 2	Surface 3	Surface 4	Surface 5
Tilt angle α (in degrees °)	35	37	35	31	34
Wt of upper plate (Kg)	4.85	4.85	4.85	4.85	4.85
Wt of extra plate(s) (Kg)	_	_	1	2	1
Wt of upper block (Kg)	0.2837	0.2837	0.2837	0.2837	0.2837
Total Weight acting upon the lower block (Kg)	5.1337	5.1337	6.1337	7.1337	6.1337
Contact Area A (m^2)	3.344 E-03	3.344 E-03	3.344 E-03	3.344 E-03	3.344 E-03
Normal force N= wt cos α (in Newton)	41	40	49	60	49.9
Shear force T=wt sin α (in Newton)	28.9	30	34.5	36	33.6
Normal Stress $\sigma = \frac{N}{A}$ (kN/m^2)	12.333	12.023	14.735	17.932	14.913
Shear Stress $\tau = \frac{T}{A}$ (kN/m^2)	8.635	9.060	10.317	10.775	10.059

Appendix 11: Results of Tilt Tests involving unweathered block samples C1 and C2.

Whereby 1Kg = 9.80665 Newton.

Samples C1 and C2: Diamond Sawn and Highly Polished					
	Surface 1	Surface 2	Surface 3	Surface 4	Surface 5
Tilt angle α (in degrees °)	25	25	24	24	23
Wt of upper plate (Kg)	4.85	4.85	4.85	4.85	4.85
Wt of extra plate(s) (Kg)	_	1	1	_	1
Wt of upper block (Kg)	0.4293	0.4293	0.4293	0.4293	0.4293
Total Weight acting upon the lower block (Kg)	5.2793	6.2793	6.2793	5.2793	6.2793
Contact Area A (m^2)	3.6 E-03	3.9 E-03	3.9 E-03	3.6 E-03	3.6 E-03
Normal force N= wt cos α (in Newton)	46.9	55.8	56	47	56.7
Shear force T=wt sin α (in Newton)	21.9	26	25	21	24
Normal Stress $\sigma = \frac{N}{A}$ (kN/m^2)	13.034	14.310	14.424	13.138	15.746
Shear Stress $\tau = \frac{T}{A}$ (kN/m^2)	6.078	6.673	6.422	5.849	6.684

Appendix 12: Results of Tilt Tests involving unweathered block samples D1 and D2.

Whereby 1Kg = 9.80665 Newton.

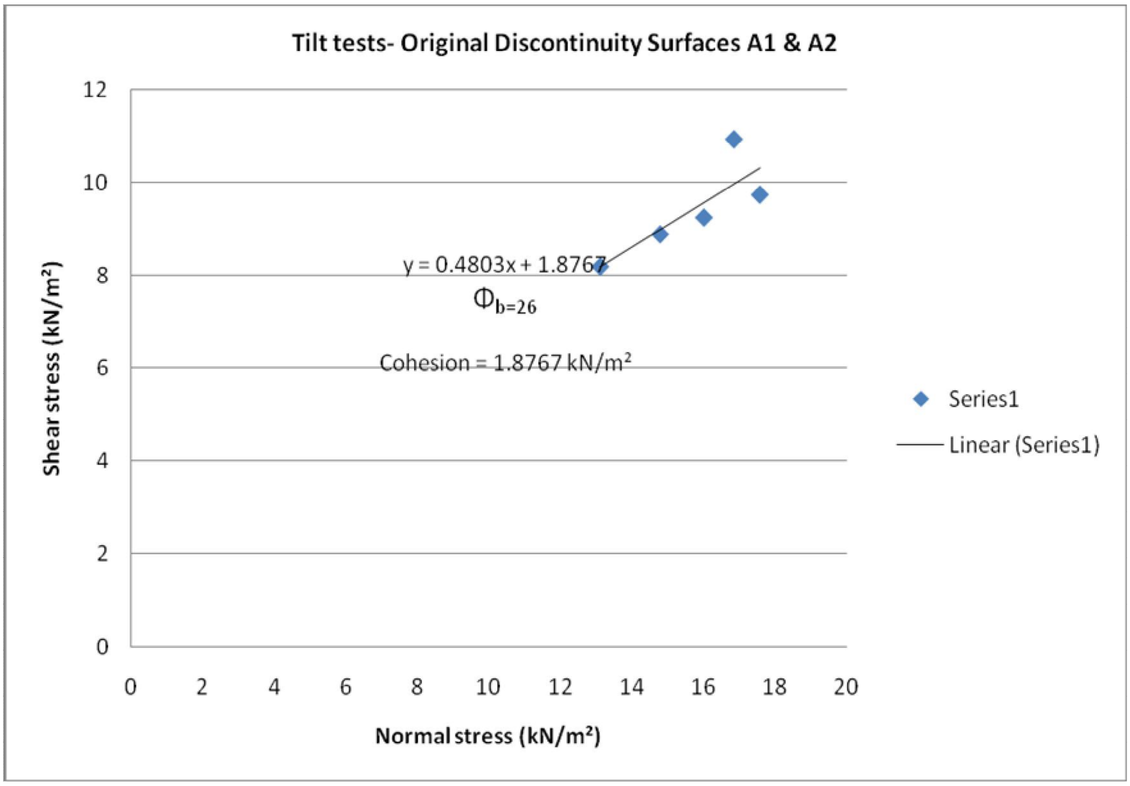
Samples D1 and D2: Diamond Sawn and Lightly Polished					
	Surface 1	Surface 2	Surface 3	Surface 4	Surface 5
Tilt angle α (in degrees °)	27	26	24	26	26
Wt of upper plate (Kg)	4.85	4.85	4.85	4.85	4.85
Wt of extra plate(s) (Kg)	–	–	–	1	–
Wt of upper block (Kg)	0.1989	0.1989	0.1989	0.1989	0.1989
Total Weight acting upon the lower block (Kg)	5.0489	5.0489	5.0489	6.0489	5.0489
Contact Area A (m^2)	3.24 E-03	3.24 E-03	2.88 E-03	3.24 E-03	2.88 E-03
Normal force N= wt cos α (in Newton)	44	44.5	45	53	44.5
Shear force T=wt sin α (in Newton)	22.5	21.7	20	26	21.7
Normal Stress $\sigma = \frac{N}{A}$ (kN/m^2)	13.616	13.735	15.706	16.456	15.452
Shear Stress $\tau = \frac{T}{A}$ (kN/m^2)	6.938	6.699	6.993	8.026	7.537

Appendix 13: Results of Tilt Tests involving unweathered block samples E1 and E2.

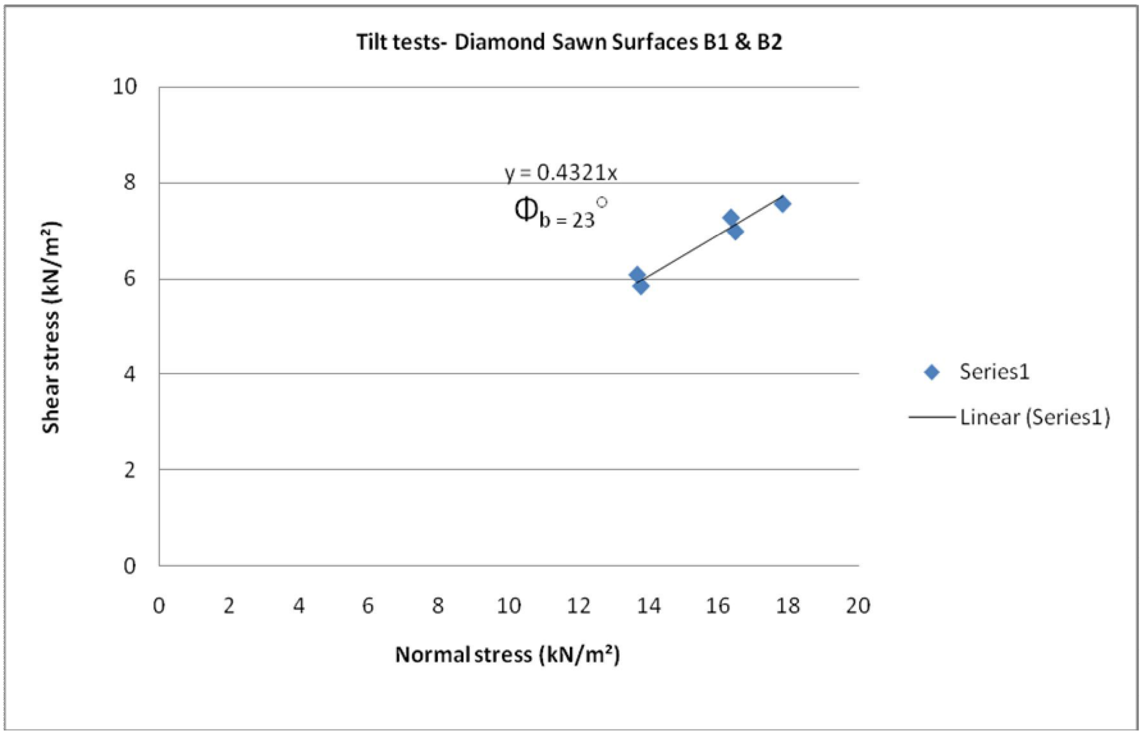
Whereby 1Kg = 9.80665 Newton.

Samples E1 and E2: Diamond Sawn and Not Polished					
	Surface 1	Surface 2	Surface 3	Surface 4	Surface 5
Tilt angle α (in degrees °)	32	30	30	31	29
Wt of upper plate (Kg)	4.85	4.85	4.85	4.85	4.85
Wt of extra plate(s) (Kg)	_	1	1	_	1
Wt of upper block (Kg)	0.4984	0.4984	0.4984	0.4984	0.4984
Total Weight acting upon the lower block (Kg)	5.3484	6.3484	6.3484	5.3484	6.3484
Contact Area A (m^2)	3.713 E-03	3.9 E-03	3.713 E-03	3.713 E-03	3.9 E-03
Normal force N= wt cos α (in Newton)	44.5	53.9	53.9	45	54.5
Shear force T=wt sin α (in Newton)	27.8	31	31	27	30
Normal Stress $\sigma = \frac{N}{A}$ (kN/m^2)	11.980	13.825	14.521	12.108	13.962
Shear Stress $\tau = \frac{T}{A}$ (kN/m^2)	7.486	7.982	8.384	7.275	7.739

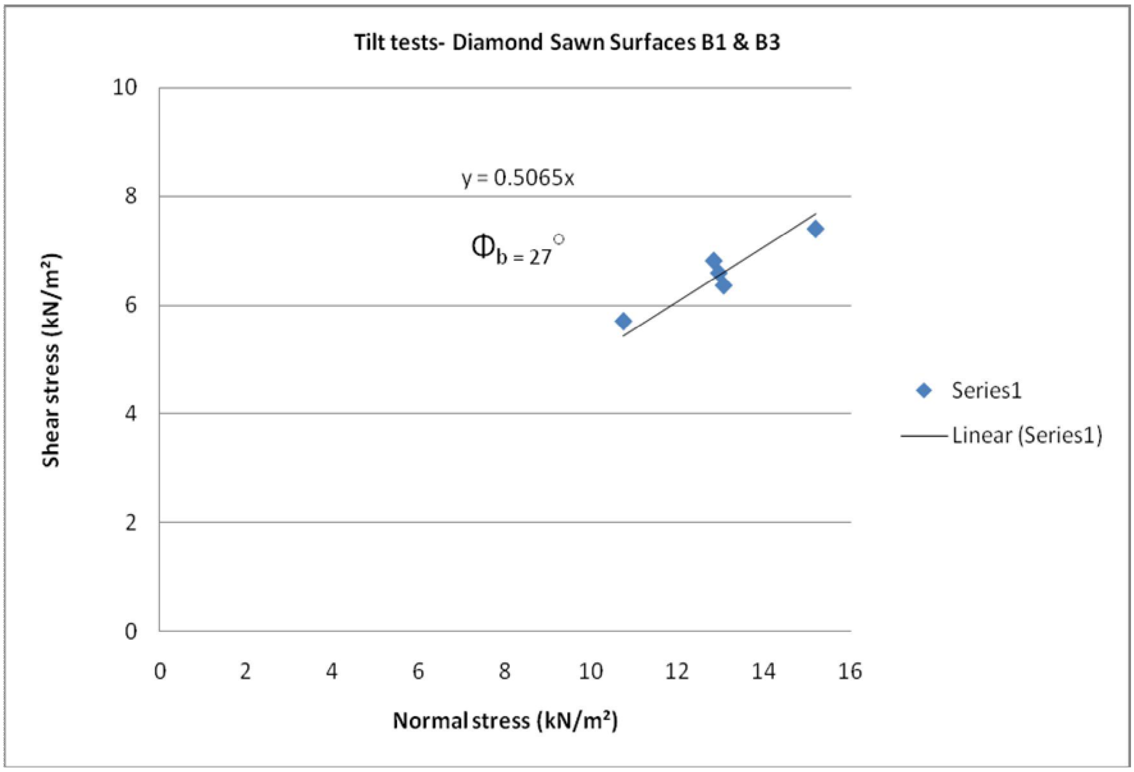
Appendix 14: Plot of shear stress against normal stress for original discontinuity surfaces of Block samples A1 and A2. It is observed that the cohesion intercept C is as high as 1.8767 kN/m².



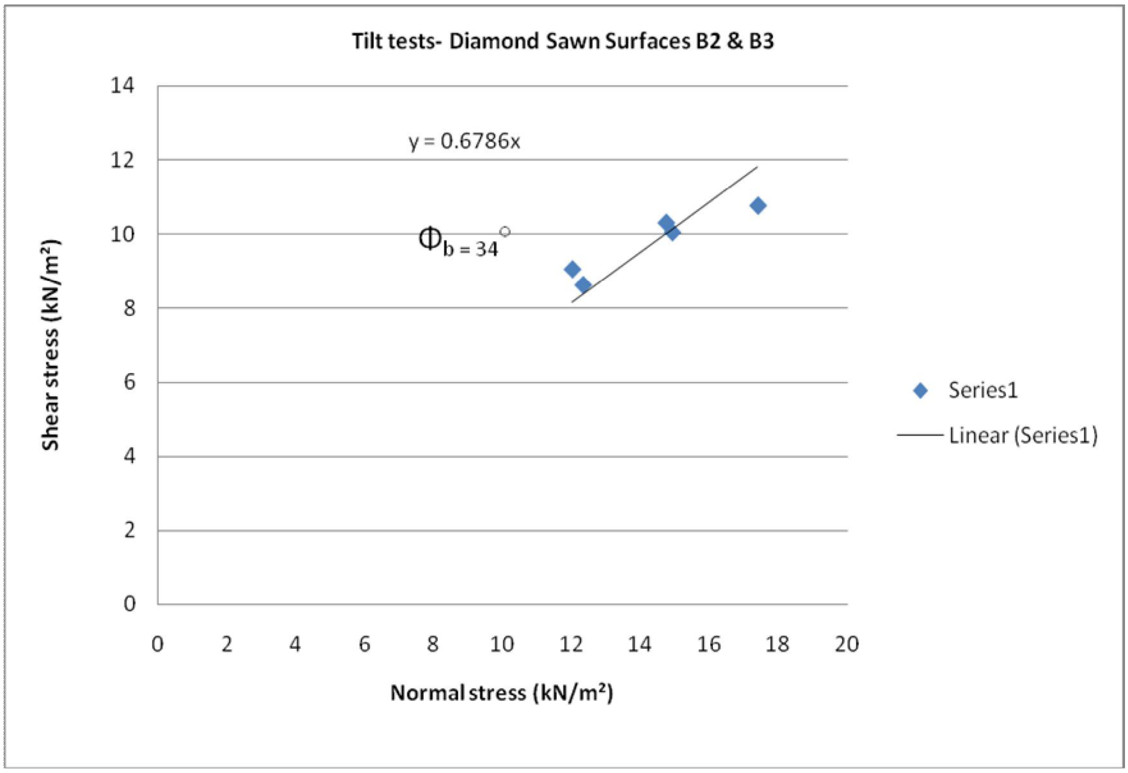
Appendix 15: Plot of shear stress against normal stress of diamond sawn but unpolished surfaces of slightly weathered samples B1 and B2.



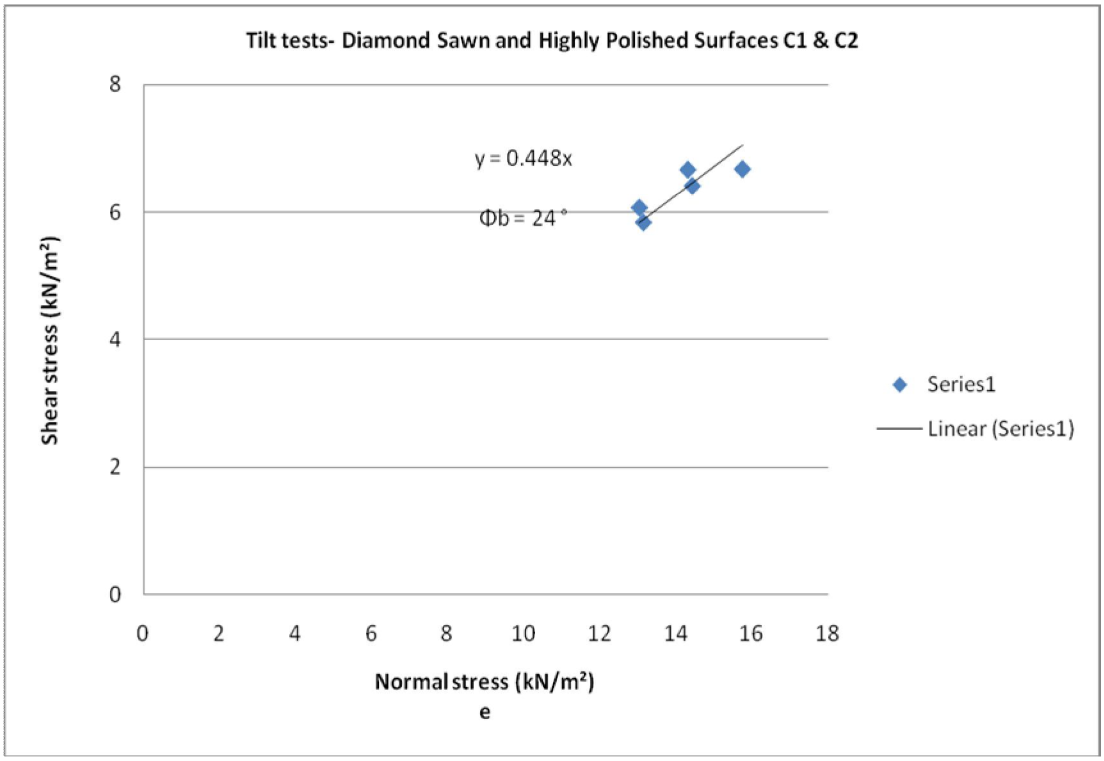
Appendix 16: Plot of shear stress against normal stress of diamond sawn but unpolished surfaces of slightly weathered samples B1 and B3.



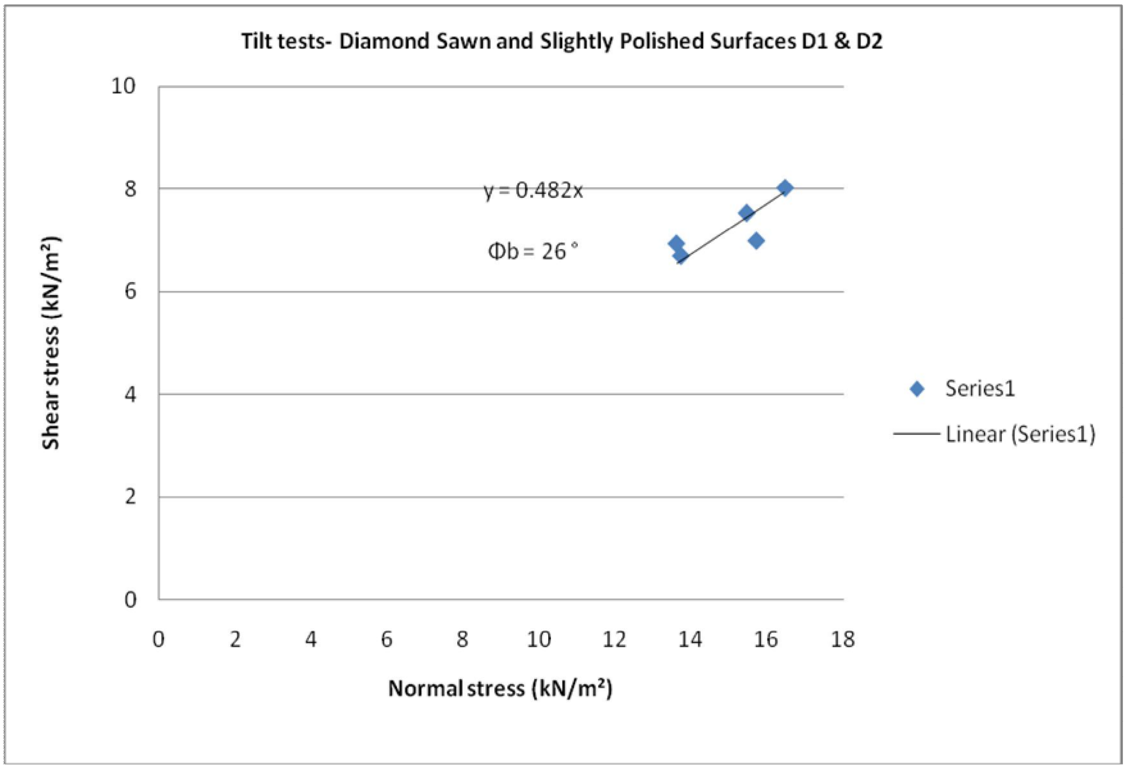
Appendix 17 : Plot of shear stress against normal stress of diamond sawn but unpolished surfaces of slightly weathered samples B2 and B3.



Appendix 18: Plot of shear stress against normal stress of diamond sawn and highly polished surfaces of unweathered samples C1 and C2.



Appendix 19: Plot of shear stress against normal stress of diamond sawn and slightly polished surfaces of unweathered samples D1 and D2.



Appendix 20: Plot of shear stress against normal stress of diamond sawn but unpolished surfaces of unweathered samples E1 and E2.