VDM CONSULTING

Sino Iron Project Construction Camp At Cape Preston, WA

Krinner Ground Screw Site Testing

Prepared By Per Sauer

Date 3nd June 2009

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Contents Page

1. Introduction

Over 5th and 6th May 2009 we conducted numerous pull-out tests at the Sino Iron Project Construction Camp at Cape Preston, approximately 80km South West of Karratha Western Australia, with the aim of establishing a representative ultimate load capacity of the Krinner Ground Screws in rock and soil conditions typical of the region.

2. Site Procedure and Results

The screw types tested were the KSF PV M24 76(OD) x 1200 and KSF PV M24 76(OD) x 1600, each with 860mm of threaded length from the tip (details in Appendix A). The screws that are proposed to be used in the area are 1600mm long, 76mm diameter and 3.6mm wall thickness with a 1500mm threaded length, these screws were not available at the time of testing.

Two areas were chosen as representative of typical rock and soil conditions, as shown in Appendix B. Pull-out tests of the screws were conducted using a static load test as described in AS 2159 – 1995 'Piling Design and Installation' in which a load is applied to the screw and increased incrementally at regular time intervals. The time intervals were chosen based on the observed movement of the piles during the initial tests with the applied load being increased only after movement due to the previous load increment had ceased. Load was applied using a 22T mobile crane and recorded using a 25T load cell with hand held readout. The horizontal and vertical movement of the screws was recorded before and after the application of each load increment using a Total Station. See Appendix C for test records.

2.1 Rock Tests

Three pull-out tests were conducted in an area of rock exposed by recent rock breaking and excavation. As the screws are unable to displace rock 90mm diamter 1200m deap holes were pre-drilled using the KF55 Ground Screw Driver and in-hole hammer attachment (see Appendix A), this is marginally less than the outside diameter of the threads. The screws were inserted to a depth of 1100mm depth and sand was pushed into the holes during isertion to fill the voids. The results are tabulated below.

Table 1. Results of Krinner Ground Screw tests in rock

Test No.	Description of Ground Conditions	Angle of Pull	Vertical Pull Out Load	Failure Mode
1	Fractured rock and some Sandy Gravelly Clay	Straight	4.2T	Slip/Soil rupture
2	Fractured rock and some Sandy Gravelly Clay	Inclined 15°	4.6T	Slip/Soil rupture
3	Un-fractured rock (solid rock)	Straight	8.5T	Slip

The pull out capacity of these screws is based on the skin friction between the screw and surrounding rock and soil. After pull-out it could clearly be seen that only the un-tapered portion of the thread (450mm) had deformed and provided pull-out resistance. Therefore an un-tapered screw of greater length would be expected to provide a directly proportional increase in pull-out capacity, for example a doubled thread length of 900mm would be expected to provide an observed pull out resistance of approximately 17T in the same ground conditions. The maximum pullout capacity is then limited by the ultimate tension capacity of the screw in tension, which is 18.8T for a 76dia. x 3.6mm screw.

The slight increase in pull-out load observed for the inclined test was due to a slightly longer thread length being brought into contact with the surrounding ground.

2.2 Soil Tests

Three pull-out tests were conducted in an area of prepared fill adjacent to future camp accommodation units. 76mm diameter holes were pre-drilled using the KF55 Ground Screw Driver and percussion hammer drill (see Appendix A) to a depth of 1000mm, the screws were then inserted into the unfilled holes with sand was pushed into the hole during insertion in order to fill any voids . In these instances the hole diameter matches the outside diameter of the screw shaft. On inserting the screw a zone of surrounding soil is further compacted as the threads push into the soil. The results of these tests are tabulated below.

Table 2. Results of Krinner Ground Screws in compacted fill

Test No.	Description of Ground Conditions	Angle of Pull	Vertical Pull Out Load	Failure Mode
4	*Compacted Fill	Straight	6.1T	Cone failure
5	*Compacted Fill	Inclined 15°	8.4T	Cone failure
6	*Compacted Fill	Inclined 15°	10.3T	Cone failure

*For details of compacted fill see Appendix D

The varying results are most likely due to a varying level of compaction from one side of test area to the other.

The pull-out capacity of these screws is based on the weight of the cone of soil mobilized by the screw plus the effective cohesion of the soil at the slip plane of the cone, with the effective cohesion being the dominant factor in these tests. Conservatively, the pullout capacity of the screw is proportional to the thread length squared. For example a similar screw of double the thread length would be expected to provide four times the capacity. Again this is limited to the ultimate capacity of the screw in tension.

2.3 Recommendations

From the tests conducted the ultimate tension capacity of the screws can be given for the soil conditions observed, these are based on the minimum observed pullout loads and are specific to the soil conditions encountered during the tests. It is important to note that the capacity of the screws will vary from site to site due to changing soil conditions and therefore the capacities given should be used as a guide only.

AS 2159 – 1995 stipulates that for static testing of less than 1% of the sample size a geotechnical strength reduction factor of 0.70 shall be used. Due to the varying results we recommend a further 10% reduction be used giving an overall strength reduction of factor of 0.60. The resulting ultimate tension capacities are given below. In combination with ultimate wind loads this gives an overall factor of safety of 2.5.

The expected ultimate load capacities for the proposed 1600mm screws are also given ignoring the top 300mm of soil.

Table 3. Ultimate tension capacities of KSF PV M24 76(OD) x 1200 and 1600 screws based on test results

Observed Ground Conditions	Effective Thread Length	Ultimate Tension Capacity	Observed Pullout
Fractured rock and some Sandy Gravelly Clay	450mm	2.5T	9mm
Un-fractured rock (solid rock)	450mm	5.1T	46mm
Compacted Fill	840mm	3.7T	1mm

Note. Capacities given are specific to the soil conditions under which they were tested

Table 4. Expected ultimate tension capacities for proposed 1600mm screws

Observed Ground Conditions	Effective Thread Length	Expected Ultimate Tension Capacity	Expected Pullout
Fractured rock and some Sandy Gravelly Clay	1200mm	6.7T	9mm
Un-fractured rock (solid rock)	1200mm	13.6T	46mm
Compacted Fill	1200mm	7.6T	1mm

Note. Capacities are given as a guide only

Due to the varyability of soil conditions the screws should be tested before their use to give site specific capacities. The results given in this report must be used as a guide only and are not intended for use as general design capacity tables.

Appendix 1

Krinner Ground Screw Details

KSF PV M24 76 x 1200

Technical Details

Side View (mm)

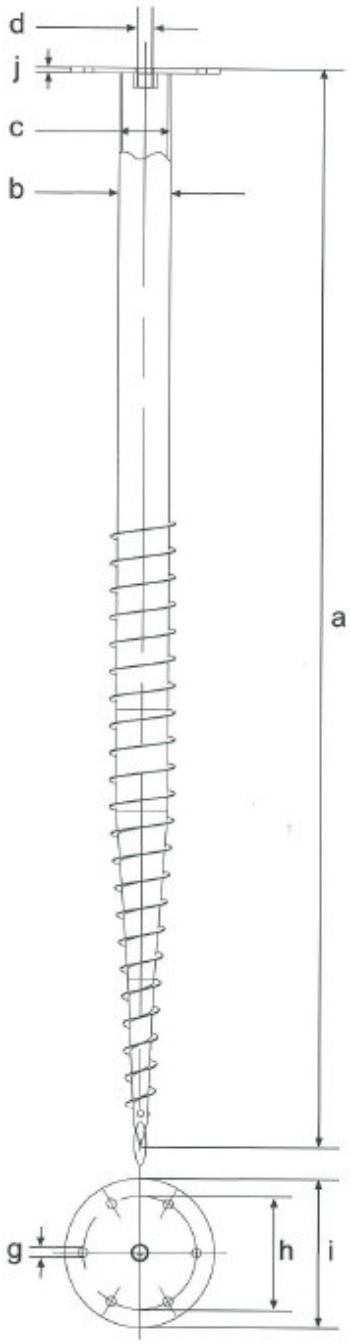
a	Length	1200
b	Outer Ø	76,1
c	Inner Ø	68,1
d	Adjustment Ø	M 24
j	Flange	8

Top View (mm)

g	Hole diameter	6 x Ø 14
h	Throat Ø	167
i	Flange outer Ø	220

Product information

Material	Steel, galvanized to DIN EN ISO 1461
Weight	9 kg
Item No.	25712
EAN	40 11972 25712 1



All technical data is subject to change!

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KSF PV M24 76 x 1200

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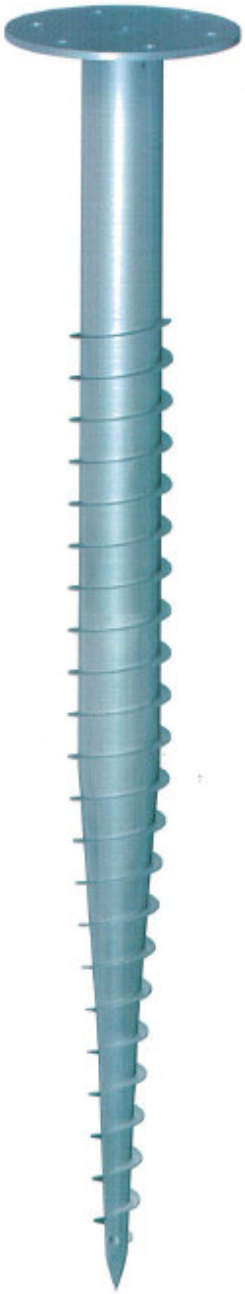
Material	Steel, galvanized to DIN EN ISO 1461
Length	1200 mm
Pipe-Ø	76,1 mm
Weight	9 kg
Item No.	25712
EAN	40 11972 25712 1
Quality	■ Patented conical body forged from single piece of tubing ■ Continuous welded spiral ■ More detailed information on request.



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KSF PV M24 76 x 1600

KRINNER GROUNDSCREWS AUSTRALIA

Material	Steel, galvanized to DIN EN ISO 1461
Length	1600 mm
Pipe-Ø	76,1 mm
Weight	12 kg
Item No.	25716
EAN	40 11972 25716 9
Quality	■ Patented conical body forged from single piece of tubing ■ Continuous welded spiral ■ More detailed information on request.

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KSF PV M24 76 x 1600

KRINNER GROUNDSCREWS AUSTRALIA

Technical Details

Side View (mm)

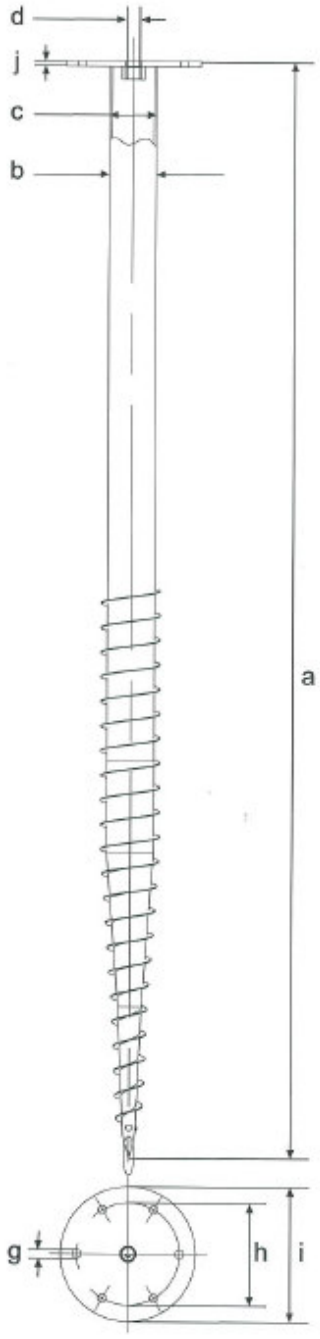
a	Length	1600
b	Outer ø	76,1
c	Inner ø	68,1
d	Adjustment ø	M 24
j	Flange	8

Top View (mm)

g	Hole diameter	6 x Ø 14
h	Throat ø	167
i	Flange outer ø	220

Product Information

Material	Steel, galvanized to DIN EN ISO 1461
Weight	12 kg
Item No.	25716
EAN	40 11972 25716 9



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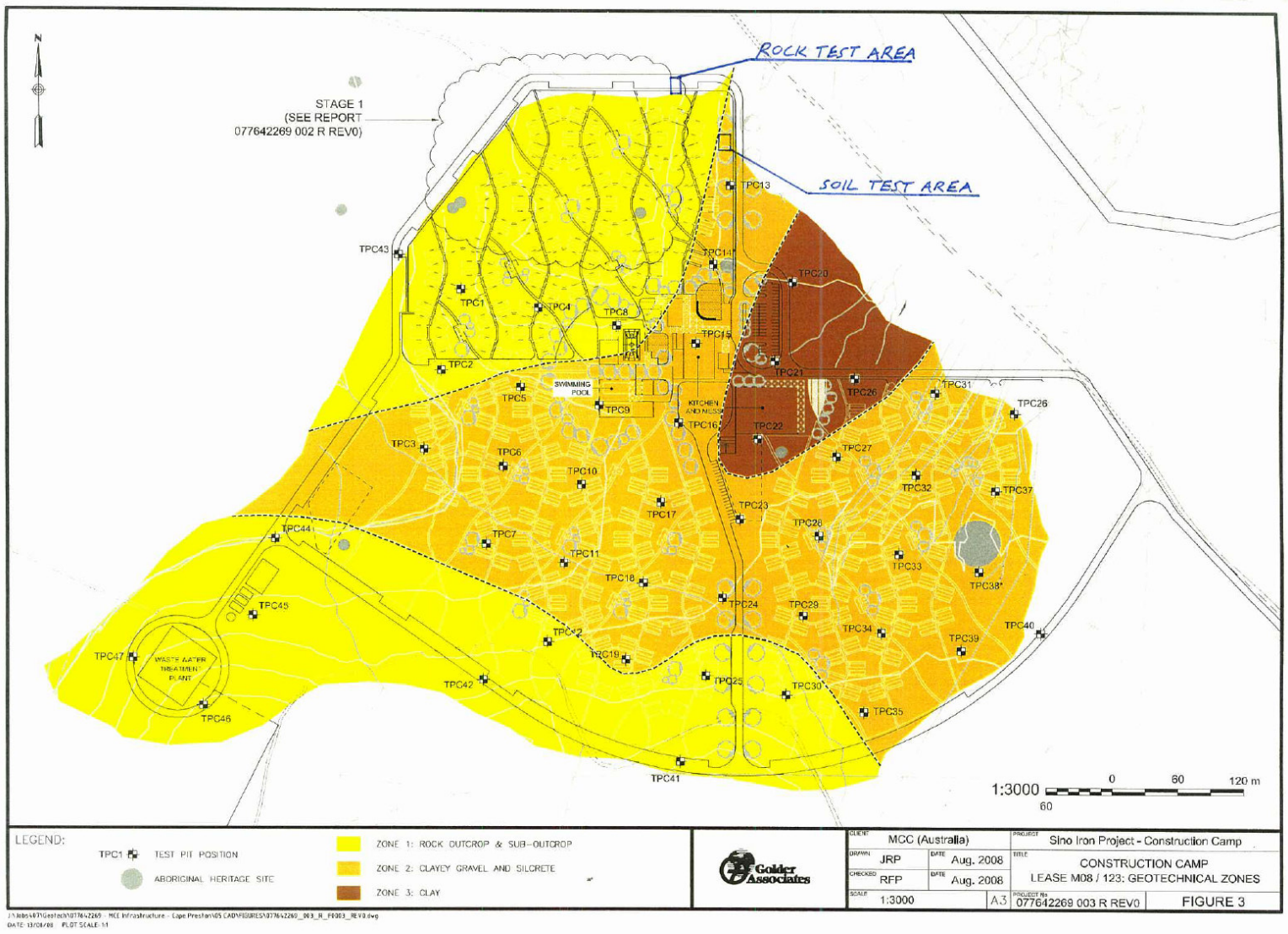
Appendix 2

Site Test Locations



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Appendix 3

Test Results

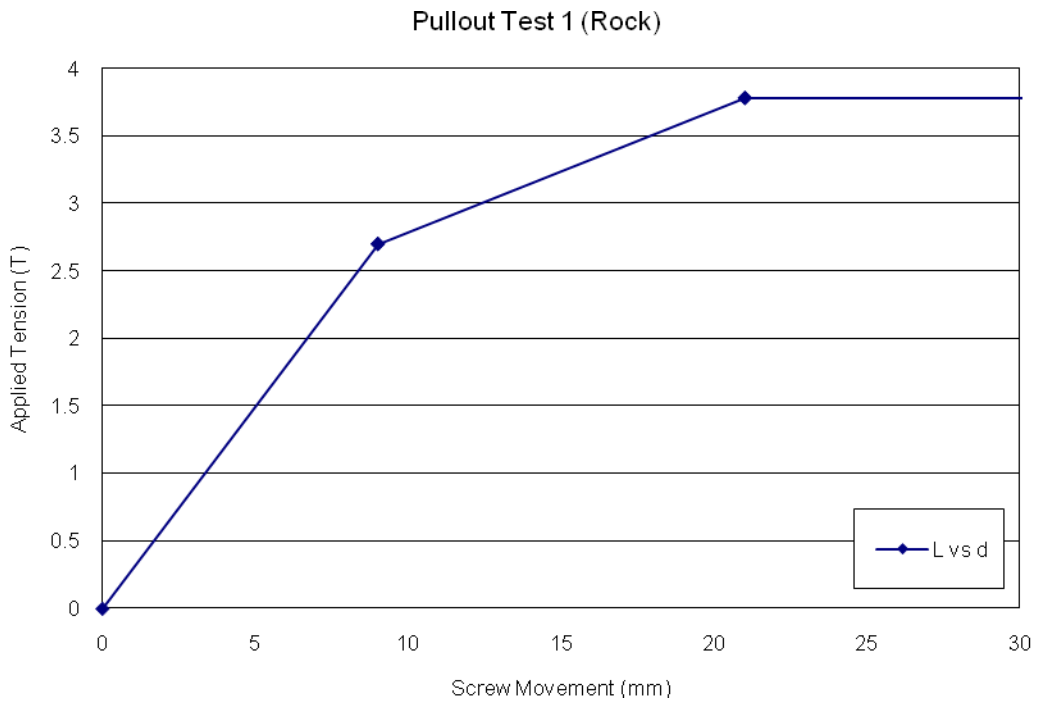
Nonclementure

d1 Observed RL immediately prior to application of load
d1' Observed RL above converted to pullout distance
L Observed load measured from load cell
L' Applied load, observed load minus initial load cell readout before application of load
d2 Observed RL immediately after the application of load
d2' Observed RL above converted to pullout distance

Test 1 Rock, some soil and gravel, straight pull

Initial Load 0.021 T
d1 1.784 m

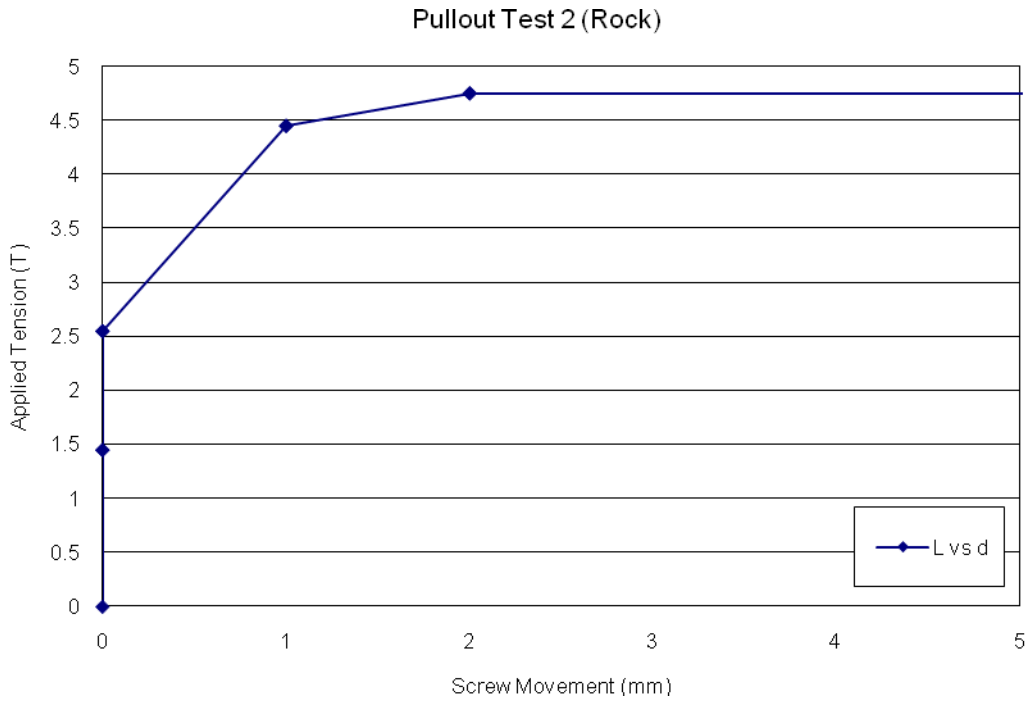
Time	d1(m)	d1'(mm)	L(T)	L'(T)	d2(m)	d2'(mm)	
0	1.784	0	2.72	2.70	1.775	9	
5	1.775	9	3.80	3.78	1.763	21	
10	1.763	21	4.20	4.18			**Failed**



Test 2 Rock, some soil and gravel, inclined pull - approx 15 degrees

Initial Load 0.55 T
d1 1.536 m

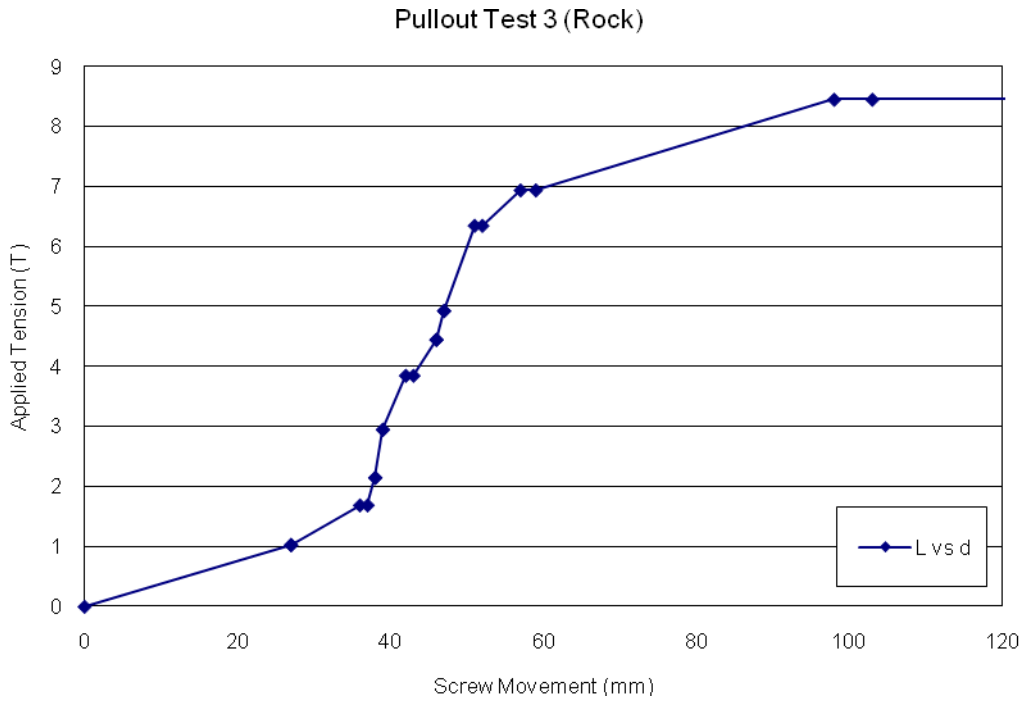
Time	d1(m)	d1'(mm)	L(T)	L'(T)	d2(m)	d2'(mm)	
0	1.536	0	2	1.45	1.536	0	
1	1.536	0	3.1	2.55	1.536	0	
2	1.536	0	5	4.45	1.535	1	
3	1.535	1	5.3	4.75	1.534	2	
4	1.534	2		4.75			**Failed**



Test 3 Solid rock, straight pull

Initial Load 0.55 T
d1 1.606 m

Time	d1(m)	d1'(mm)	L(T)	L'(T)	d2(m)	d2'(mm)	
0	1.606	0	1.58	1.03	1.579	27	
5	1.579	27	2.24	1.69	1.57	36	
10	1.569	37	2.7	2.15	1.568	38	
15	1.568	38	3.5	2.95	1.567	39	
20	1.567	39	4.4	3.85	1.564	42	
25	1.563	43	5	4.45	1.56	46	
30	1.560	46	5.48	4.93	1.559	47	
35	1.559	47	6.9	6.35	1.555	51	
40	1.554	52	7.49	6.94	1.549	57	
45	1.547	59	9	8.45	1.508	98	
50	1.503	103		8.45			**Failed**

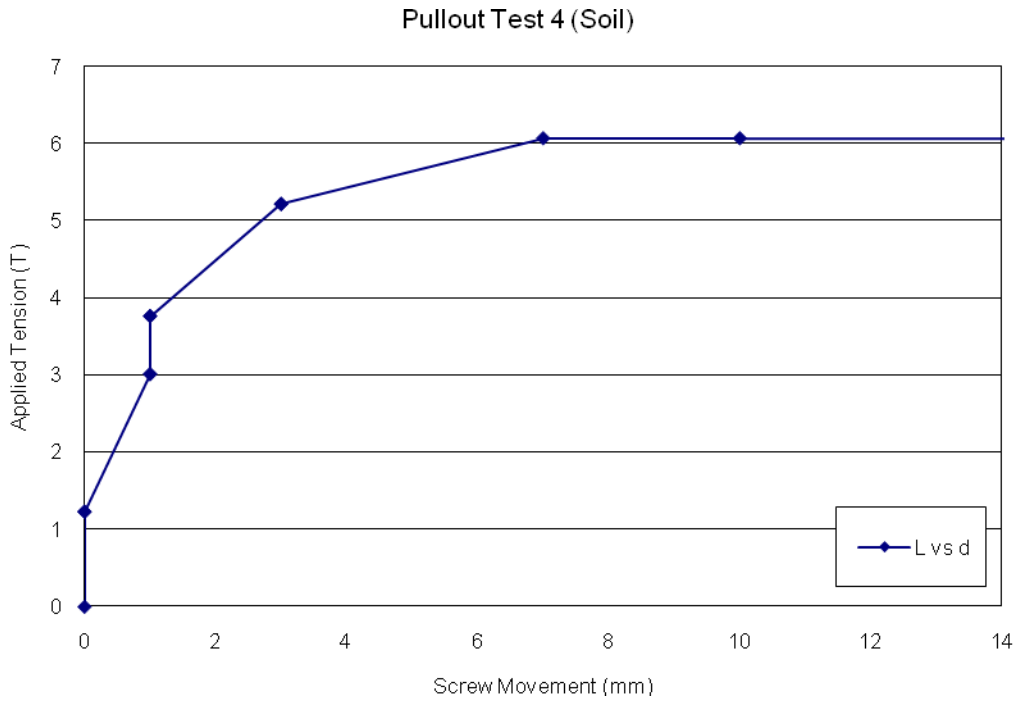


Test 4 Compacted fill, area of less treatment, straight pull

Initial	Load	0.59	T
	d1	1.373	m

Time	d1(m)	d1'(mm)	L(T)	L'(T)	d2(m)	d2'(mm)
0	1.373	0	1.82	1.23	1.373	0
2	1.373	0	3.6	3.01	1.372	1
4	1.372	1	4.35	3.76	1.372	1
6	1.372	1	5.8	5.21	1.37	3
8	1.37	3	6.65	6.06	1.366	7
10	1.363	10		6.06		

Failed
1.3m
Cone

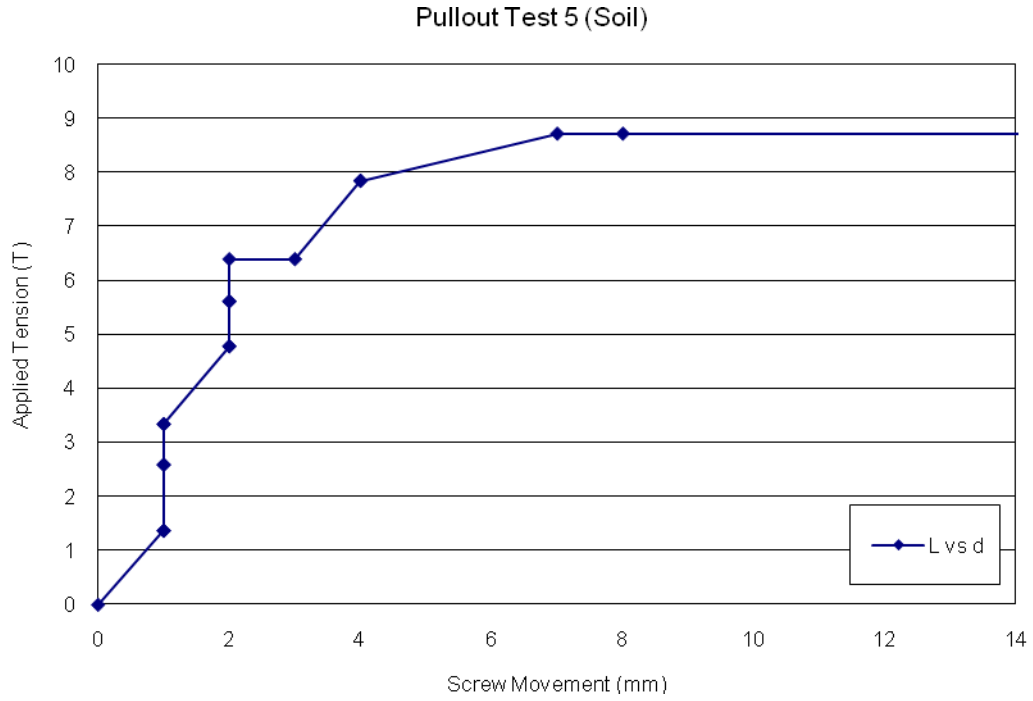


Test 5 Compacted fill, inclined pull -approx 15 degrees

Initial Load 0.59 T
d1 1.167 m

Time	d1(m)	d1'(mm)	L(T)	L'(T)	d2(m)	d2'(mm)
0	1.167	0	1.96	1.37	1.166	1
2	1.166	1	3.18	2.59	1.166	1
4	1.166	1	3.93	3.34	1.166	1
6	1.166	1	5.37	4.78	1.165	2
8	1.165	2	6.2	5.61	1.165	2
10	1.165	2	6.98	6.39	1.165	2
12	1.164	3	8.43	7.84	1.163	4
14	1.163	4	9.3	8.71	1.16	7
16	1.159	8		8.71		

Failed
1.5m
Cone

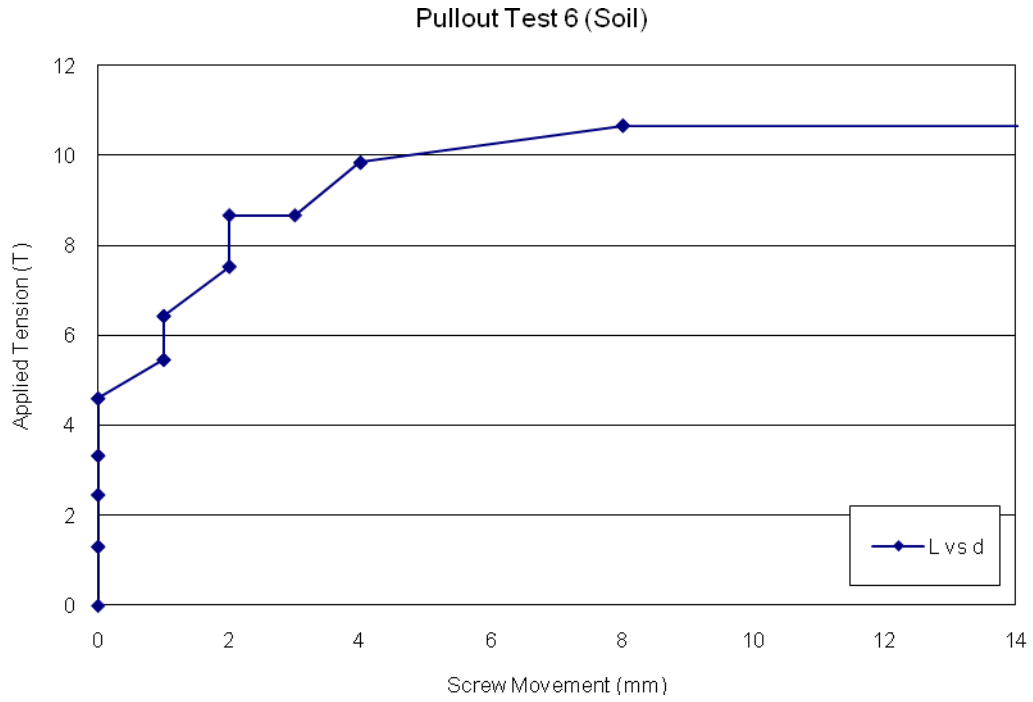


Test 6 Compacted fill, inclined pull -approx 15 degrees

Initial Load 0.78 T
d1 1.396 m

Time	d1(m)	d1'(mm)	L(T)	L'(T)	d2(m)	d2'(mm)
0	1.396	0	2.09	1.31	1.396	0
2	1.396	0	3.24	2.46	1.396	0
4	1.396	0	4.11	3.33	1.396	0
6	1.396	0	5.38	4.60	1.396	0
8	1.396	0	6.24	5.46	1.395	1
10	1.395	1	7.21	6.43	1.395	1
12	1.395	1	8.31	7.53	1.394	2
14	1.394	2	9.45	8.67	1.394	2
16	1.393	3	10.62	9.84	1.392	4
18	1.392	4	11.44	10.66	1.388	8
20	1.386	10		10.66		

Failed
2.0m
Cone



Appendix 4

Photos

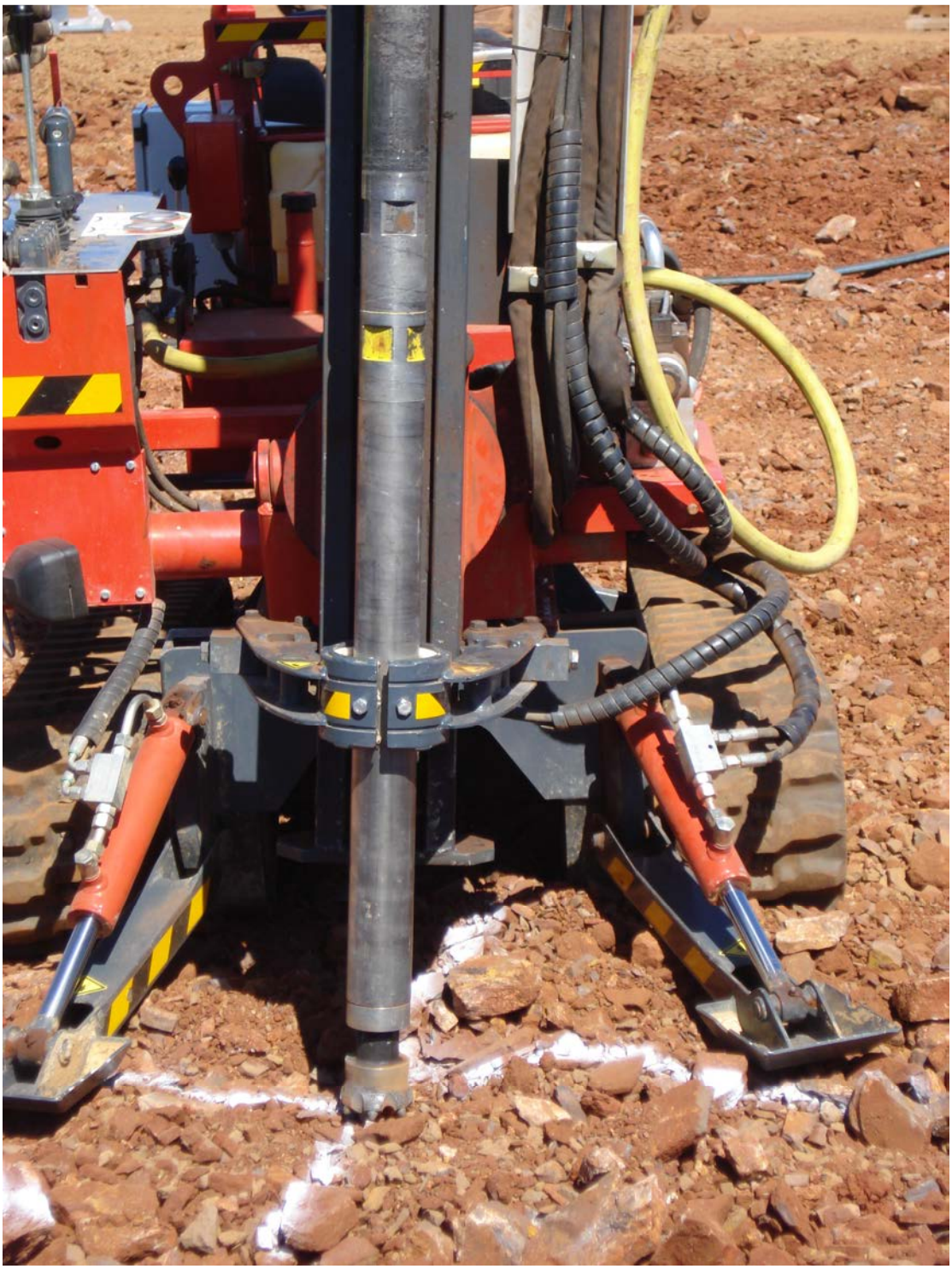


Photo 1. Pre-drilling in rock

Photo 2. Pre-drilling in compacted fill

Photo 3. Pullout Test 2 in rock

Photo 4. Screw after pullout Test 3 in rock, note deformation of upper threads.

Photo 5. Pullout Test 6 in compacted fill, photo taken immediately before failure

Photo 6. Ground screws after pullout in compacted fill