Testing of the Lock-Tite portable surface anchor

Dates: July 7, 2010 and July 8, 2010

Location: Fabrication Technologies, Casper, WY

Witnesses:

Colemon Dean (Fabrication Technologies Inc. – Engineer)
Blake Nichols (Fabrication Technologies Inc. - Engineer)
Robert Geike (Fabrication Technologies Inc. - Operator)
Scott Griffiths (Lock-Tite - Owner)
Sam Whitney (Wyoming OSHA)*
Dennis Sheppard (Representing Wyoming OSHA)*
Gene Corson (Quadco Calibration Technician)*
Chris Green (Quadco District Manager)*
Bill Hodgden (B&H Rig and Tong – Owner)*

* following name means individual was there only for testing on July 8, 2010.

Basic testing set up of the Lock Tite portable surface anchor is shown in figure 1.

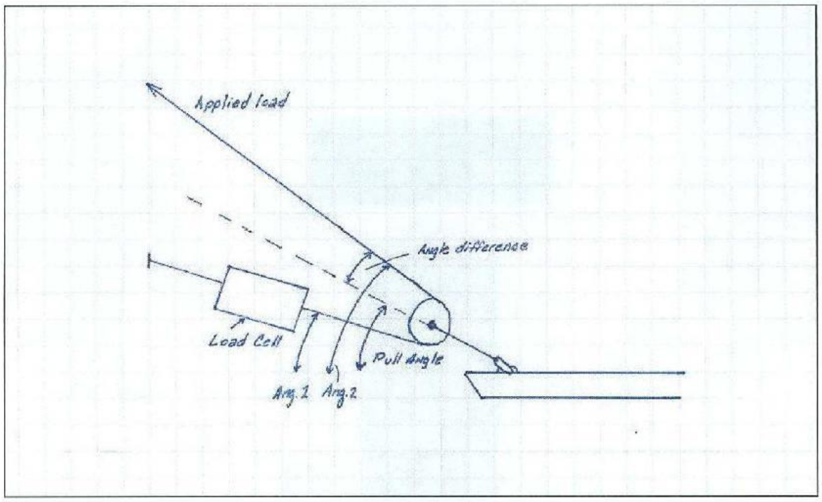


Figure 1

Angle 1 and angle 2 were measured. True pull angle was found by the following method:

$$Where$$

$$Where\ \theta_1 = angle\ 1$$

$$\theta_2 = angle\ 2$$

$$\theta_p = pull\ angle$$

$$\theta_p = \theta_1 + 0.5 * (\theta_2 - \theta_1)$$

Pull load was found by the following method:

$$Where$$

$$\theta_d = difference\ between\ angle\ 2\ and\ pull\ angle$$

$$P = measured\ force\ at\ load\ tester$$

$$L = Load\ at\ pull\ angle$$

$$L = 2 * (\mathrm{P} * \cos\theta_d)$$

The portable surface anchor is designed for use with the teeth deployed. It was tested with and without the teeth deployed to compare performance. Testing without the teeth deployed was used to find the coefficient of friction. This was used to calculate the side load on the teeth when they were deployed.

Figure 2 shows a free body diagram for the anchor without the teeth deployed.

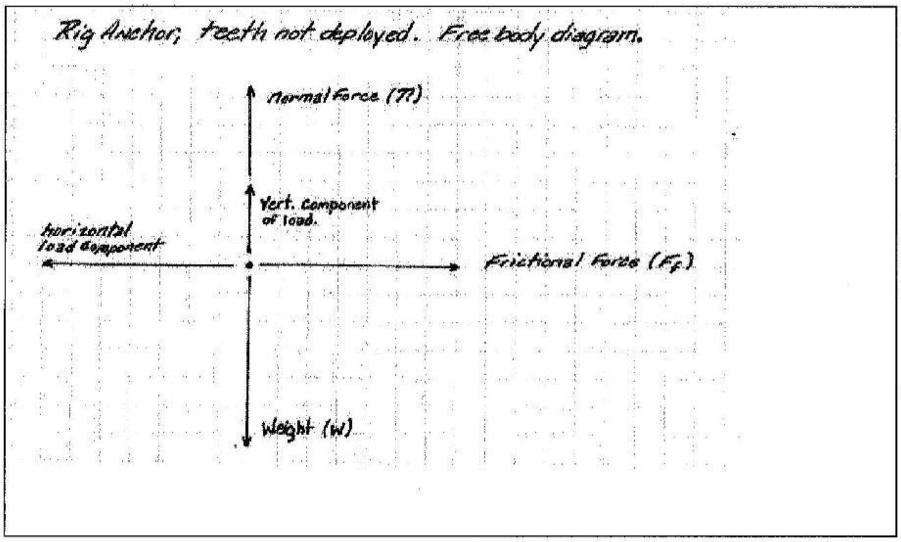


Figure 2

From the free body diagram frictional force equals the horizontal component of the pull load. The normal force is equal to the weight minus the vertical component of the pull load. The following method was used to calculate the coefficient of friction:

$$Where$$
$$W = weight$$
$$\theta_p = pull\ angle$$
$$L = Load\ at\ pull\ angle$$
$$\mu = coefficient\ of\ friction$$
$$n = normal\ force$$
$$F = frictional\ force$$

$$n = W - L * \sin\theta_p$$
$$F = L * \cos\theta_p$$
$$\mu = \frac{F}{n}$$

See Table 1 for a summary of our testing.

Table 1 **Portable rig anchor, teeth not deployed.**

	Date	Pull No.	Weight	measured load (lbs.)	Cable angles (deg.)		Pull Angle (deg.)	Angle diff. (deg.)	Load component in line w/ load angle (lbs.)	true pull load (lbs.)
Dry earth, in line with skids.	7/7/2010	1	47720	12500	26.6	47.0	36.80	10.20	12302	24605
	7/8/2010	8	47720	12000	21.2	44.5	32.85	11.65	11753	23506
Dry earth, perpendicular to skids.	7/7/2010	2	47720	14000	20.0	46.5	33.25	13.25	13627	27255
	7/8/2010	9	47720	13000	18.7	38.8	28.75	10.05	12801	25601
Rough concrete, perpendicular to skids.	7/7/2010	5	47720	14000	14.5	34.2	24.35	9.85	13794	27587
	7/8/2010	6	47720	13750	13.6	33.2	23.40	9.80	13549	27099
Rough conc., in line w/ skids.	7/8/2010	7	47720	13000	22.5	43.4	32.95	10.45	12784	25569

	vertical component (lbs.)	horizantal component (lbs.)	normal force (lbs.)	coefficient of friction
Dry earth, in line with skids.	14739	19702	32981	0.597
	12750	19747	34970	0.565
Dry earth, perpendicular to skids.	14944	22793	32776	0.695
	12314	22445	35406	0.634
Rough concrete, perpendicular to skids.	11374	25133	36346	0.692
	10762	24870	36958	0.673
Rough conc., in line w/ skids.	13907	21456	33813	0.635

When we compared our calculated coefficient of friction to published values of steel on concrete we found our values to be higher. Published values ranged from 0.4 to 0.45. However, material surface conditions were not stated.

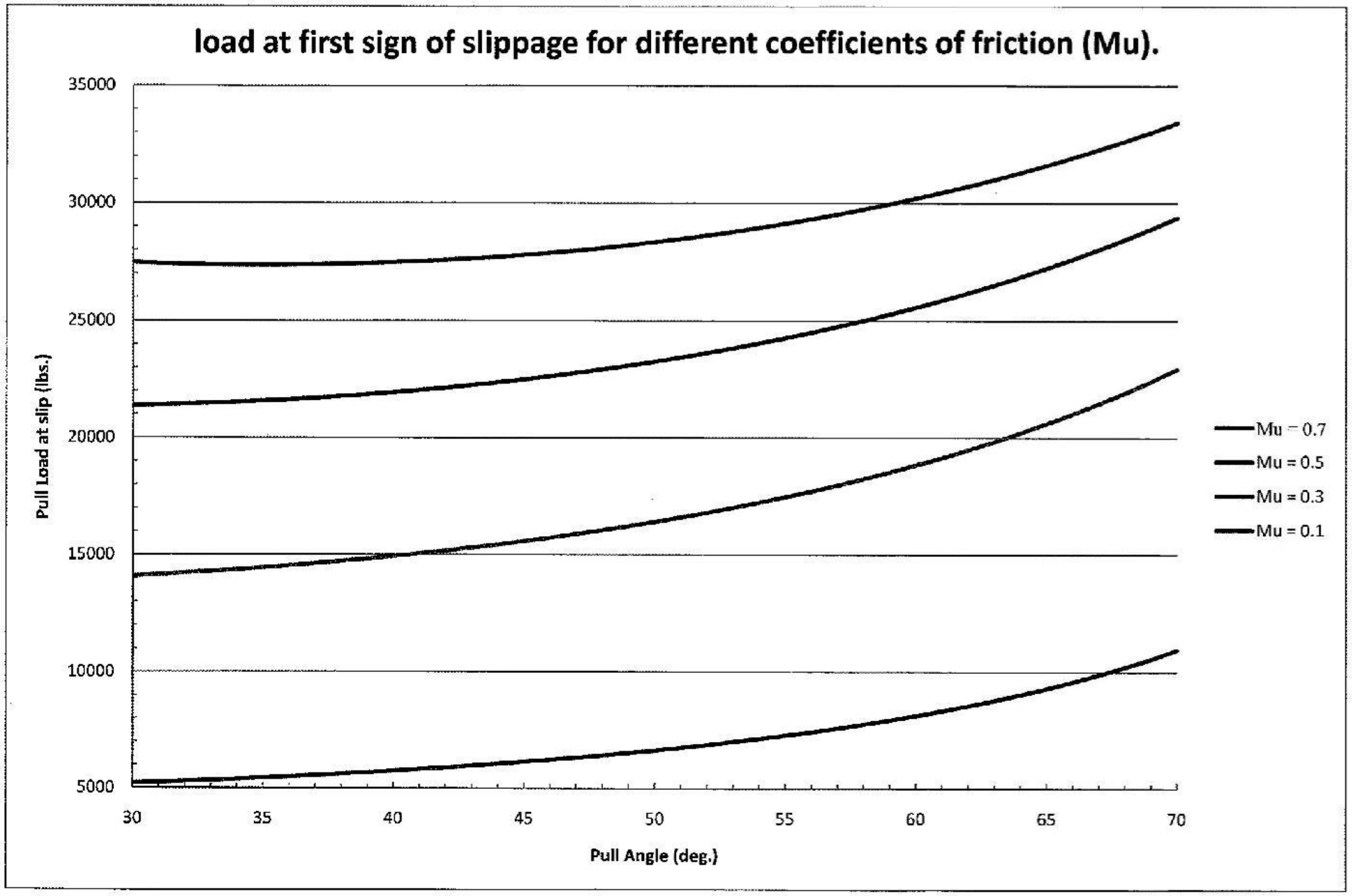
To verify the accuracy of our data we chose to test a smooth steel plate on a smooth level concrete surface and then test it again on our cement test surface.

A circular mild steel plate weighing 18.5 pounds was sanded smooth on one face. It was placed on a well swept smooth concrete surface. A horizontal force was applied and recorded at the first sign of slippage. This test was repeated five times with surfaces being dry. Since the applied load was purely horizontal the normal force equals the weight. The coefficient of friction was calculated by dividing the applied force by the normal force. With the result being a coefficient of friction of 0.35 for smooth steel on smooth concrete and 0.595 coefficient of friction for smooth steel on rough concrete.
These numbers are slightly less than the published values but correlate well with the calculated values on rough concrete. These variances can be attributed to differences in surface roughness.

Based on these numbers performance was evaluated at a coefficient of friction of 0.30. Performance was also evaluated at 0.1 (published static coefficient of friction for steel on ice) to simulate icy surfaces without the teeth deployed. The accompanying table and graph (Table 2 & Graph 1) shows the anchor's performance at various angles and coefficients of friction.

Table 2 Portable surface anchor teeth not deployed

Weight (lbs.)		47720		
Coefficients of Friction				
	0.7	0.5	0.3	0.1
pull angle (deg.)	Load at start of slipping (lbs.)			
30	27470	21379	14090	5209
31	27432	21405	14151	5252
32	27403	21437	14216	5296
33	27382	21476	14287	5343
34	27370	21522	14362	5392
35	27366	21574	14443	5444
36	27370	21634	14529	5499
37	27382	21700	14620	5556
38	27403	21773	14718	5617
39	27433	21854	14821	5680
40	27470	21941	14930	5747
41	27517	22037	15045	5817
42	27572	22140	15167	5891
43	27635	22250	15296	5968
44	27707	22369	15431	6050
45	27788	22495	15574	6135
46	27879	22631	15724	6225
47	27978	22774	15882	6319
48	28086	22927	16048	6419
49	28204	23089	16223	6523
50	28332	23260	16406	6633
51	28470	23441	16599	6749
52	28617	23632	16802	6872
53	28775	23833	17014	7000
54	28944	24045	17238	7136
55	29123	24269	17473	7280
56	29314	24504	17720	7432
57	29516	24752	17979	7593
58	29731	25012	18252	7763
59	29957	25286	18540	7943
60	30197	25573	18842	8135
61	30449	25875	19160	8339
62	30715	26193	19495	8556
63	30996	26526	19848	8787
64	31291	26876	20220	9034
65	31602	27245	20613	9298
66	31928	27631	21028	9581
67	32272	28038	21467	9884
68	32633	28466	21931	10211
69	33012	28916	22423	10564
70	33411	29389	22945	10945


load at first sign of slippage for different coefficients of friction (Mu).

In order to find the load on the teeth during tests where the teeth were deployed, the coefficient of friction previously found for that surface was used to calculate the force due to friction. This was then subtracted from the horizontal component of the pull load to find the load on the teeth. The force per tooth in the chart is simply this number divided by 6. Any lifting force due to the shape of the teeth was neglected.

$$\begin{gathered} Where \\ F = frictional\ force \\ \mu = coefficient\ of\ friction \\ n = normal\ force \\ T = load\ on\ teeth \\ L = Load\ at\ pull\ angle \end{gathered}$$

$$\begin{gathered} F = \mu n \\ T = L * \cos\theta_p - F \end{gathered}$$

The accompanying table (Table 3) summarizes the results of the testing. Note that the coefficient of friction used to calculate the load on the teeth was the mean of the coefficient of the two pulls without the teeth deployed in the same orientation (either in line with the skids or perpendicular to the skids) on the same surface.

Table 3 **Portable rig anchor, teeth deployed.**

	Date	Pull No.	Weight	measured load (lbs.)	Cable angles (deg.)		Pull Angle (deg.)	Angle diff. (deg.)	Load component in line w/ load angle (lbs.)	true pull load (lbs.)
Dry earth, in line with skids.	7/7/2010	3	47720	18250	22.6	44.8	33.70	11.10	17909	35817
	7/8/2010	10	47720	18500	20.2	44.1	32.15	11.95	18099	36198
Dry earth, perpendicular to skids.	7/7/2010	4	47720	20000	16.9	38.2	27.55	10.65	19655	39311
	7/8/2010	11	47720	20000	18.4	40.4	29.40	11.00	19633	39265

	vertical component (lbs.)	horizantal component (lbs.)	normal force (lbs.)	frictional force (lbs.)	teeth load (lbs.)	load per tooth (lbs.)
Dry earth, in line with skids.	19873	29798	27847	16180	13618	2270
	19262	30647	28458	16535	14113	2352
Dry earth, perpendicular to skids.	18182	34853	29538	19633	15221	2537
	19275	34208	28445	18906	15302	2550

The landing gear used as the basis of the deployable tooth system (SAF/Holland model LG 4000-720000000) has a load capacity of 140,000 lbs. and a side load capacity of 27,000 lbs. per leg (verified with manufacturer that the capacity was per leg and not per pair). Given the weight of the anchor at 47,720 lbs, a single leg could easily carry the entire weight of the anchor. The anchor has 6 legs, each terminating in a tooth. To ensure that side load capacity is not exceeded further analysis of the teeth was required.

Figure 3 shows the tooth dimensions when fully deployed.

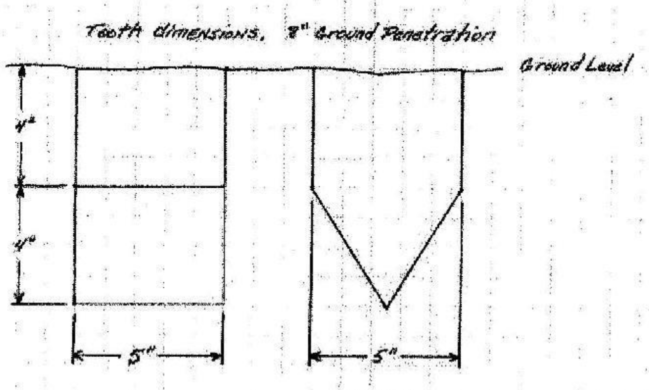


Figure 3

The left item in figure 3 shows the face dimensions of a tooth and the right item shows the side dimensions. 4 of the teeth have their sides perpendicular to the skids and 2 of the teeth have their sides in line with the skids. The face of each tooth has a frontal area of 40 square inches and the side of each has an area of 30 square inches. Given the larger area of the front face it will carry more load and is the limiting factor. The fact that 4 of the teeth have their side faces in line with the skids also makes a pull perpendicular to the skids a limiting factor due to less frontal area. A 27,000 lb. load on the front face of a single leg results in a pressure of 675 psi. If the applied load is perpendicular to the skid there are 200 sq. in. of tooth face (4x30 plus 2x40).

Assuming a frictionless surface this would allow a horizontal load component of 135,000 lbs. This is far beyond expected horizontal loading. If the teeth were deployed to half of their full depth reducing area to only 80 sq. in. a horizontal load of 108,000 lbs. could still be applied.

Based on the above testing with the teeth fully deployed we observed a unit that was more than capable of withstanding a 20,000 lbs single line pull within the angles shown.