# Addendum to "Qualifying a Rescue Rope"

**Tom Moyer**

**8/2/00**

After this paper was presented at the 1999 ITRS conference in Fort Collins, CO, I made several phone calls to Sterling Rope Co, the manufacturer of the rope listed as ABC/Sterling in this paper. This rope is not a nylon rope, but rather Sterling's HTP all-polyester kernmantle rope. Sterling's claim of superior cut and abrasion resistance for this rope is supported by my testing. The paper is presented here without changes, but one significant correction should be noted. We have never had the Sterling HTP rope in service for mountain rescue. The two ropes we have in service are both nylon and are manufactured by Blue Water and by New England Rope.

The Sterling HTP rope is fascinating to me for its outstanding cut and abrasion properties. However, in looking at the issue further, I believe that its extremely low elasticity makes it inappropriate for use as a belay line for mountain rescue uses unless it is used with a true load-limiting belay device or shock absorber. Autolocking, load limiting belay devices are available, but more testing is needed to verify their performance for rescue loads. To my knowledge, a stitched shock absorber appropriately sized for mountain rescue loads is not currently available.

We will soon begin to use Sterling HTP as anchor rope (in 50 foot pieces). Sterling HTP would also be excellent for use as a main line and as a high line on a Tyrolean (with appropriate caution against excessive preloading). Since we want our 200 foot rescue ropes to be interchangeable for any purpose on a rescue, we have chosen to stay with nylon ropes for general mountain-rescue use.

**1999 International Technical Rescue Symposium**

# Qualifying a Rescue Rope

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### *Abstract*

Some of the most important qualities of a rescue rope are not measured or reported to the consumer in a way which can be used for meaningful comparison. Tensile strength is commonly reported, but cut strength, abrasion resistance, and prusik slipping forces are not. Failures in mountain rescue systems are far more likely to be caused by these issues than by tensile overloads. A mountain rescue team which changes brands of rope or which uses more than one brand of rope will want to understand how these parameters vary from one manufacturer to the next. One series of tests was done on different brands of 11mm rope and on 1" tubular webbing. The results are presented here.

### *Purpose*

My purpose in writing this report is not to recommend for or against the use of any manufacturer's product. It is to discuss the properties of nylon rope which are most relevant to a mountain rescue team, and to describe a program for testing those properties. I hope that other mountain rescuers will find useful information in this report. However, there is no real substitute for doing your own testing on your own equipment and directly observing the failures. Having a rope explode on a rock edge is a sobering experience that every rescuer should see first hand. The tests described here are ones that any rescue team can perform for themselves. The understanding you'll gain from doing your own testing will beat anything you can get from reading a paper.

### *Background*

Our team, Salt Lake County Sheriff's Search and Rescue, currently has two brands of nylon rescue rope in service. I originally began this project to determine whether there are any practical differences between them that would lead us to treat them differently in the field, or to prefer one over the other in future purchasing. Other brands and sizes of rope were included in the testing to try to understand some of the parameters which affect properties like cut resistance and abrasion resistance. Goldline was included for my own curiosity and for the benefit of the Rocky Mountain Rescue Group in Boulder, Colorado, to determine whether its touted abrasion resistance justifies its lower strength and difficult handling. Tubular webbing was included because we and others often use it for anchors.

Of the various properties of a rescue rope, I consider tensile strength to be among the *least* important. It is certainly worth understanding how forces can be generated which exceed the tensile strength of a rope, but the likelihood of tensile overload is very small compared with the likelihood of failures from abrasion and cutting. Some amount of contact between unpadded rope and rock edges is often unavoidable on technical evacuations, and the chance of rockfall can never be eliminated. My initial interest in this subject began after witnessing a couple of partial rope cuts. One was across a sharp edge during training. The other was from rockfall on a rescue.

### *Test Methods*

To compare the ropes, I measured their weight and diameter, elasticity, cut strength, prusik holding force, abrasion *along* the rope, and abrasion *across* the rope. With the exception of a 10,000 pound load cell (generously donated to us by Sensotec) and a steel rigging ring that I machined for use as a cut testing surface, these tests used no special equipment. Many were done in the front yard at my house.

Rope diameter was measured at 40 pounds of tension. Each rope was measured with calipers in three places around the circumference and averaged. Weight was measured with a small (500 gram) spring scale.

Elasticity was measured with the load cell and a tape measure. Forces were applied with a cable puller, or come-a-long. Each rope was pulled four times to 1000 pounds tension, with forces and lengths measured on the first and fourth cycles.

Cut testing was done over a 90 degree steel corner, machined into a triangular rigging ring. The rope was tied as a loop through the ring, and the loop was pulled to failure. I do not know the radius of the edge, but it is *much* sharper than anything we would ever deliberately set a rope on without padding. Five trials were done on each rope and the results were averaged.

Prusik testing was done with three wrap, 8mm prusiks. The load was measured as the prusik was pulled until it slipped on the rope. Four trials were averaged for the two ropes we have in service.

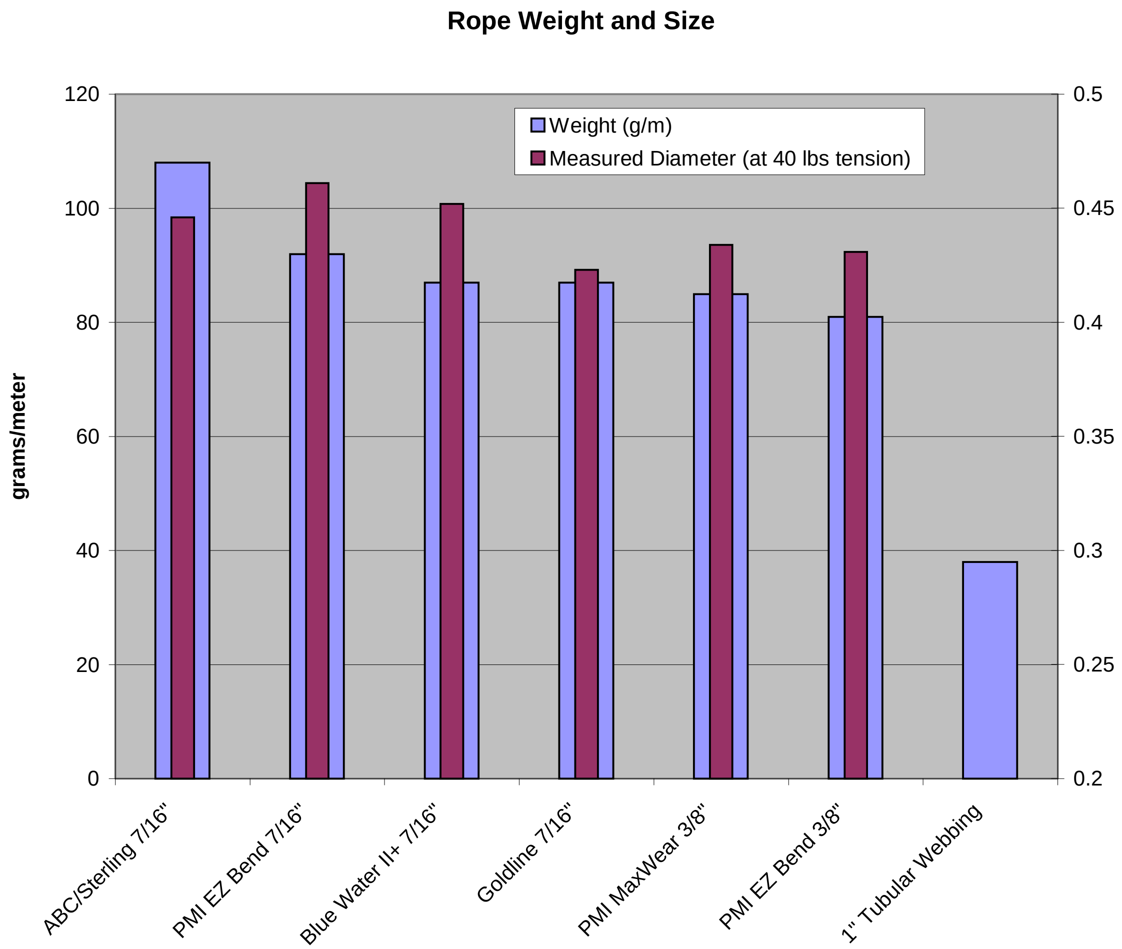
Abrasion *along* the rope was tested at a local granite boulder. The edge chosen was not at all unusual for one the rope might encounter on an evacuation. Because a very high load is needed to break a rope this way in a reasonable amount of time, the load I pulled was not a weight, but a stretched piece of retired dynamic rope. A short piece of the test rope ran across the rock edge, and was connected with a prusik to a long piece of dynamic rope. This arrangement was pulled to a preload of 1,000 pounds, and then cycled back and forth with the cable puller until the rope failed. The force on the static side of the system over a pull-release cycle varied between 600 and 1000 pounds. The distance moved by the rope in a cycle was about one inch. To control for changes made to the rock edge over repeated tests, I put each rope in exactly the same spot on the rock. Ropes were tested in the same order on each set of trials. The fact that the rock edge *did* become smoother over four sets of trials is visible in the data. The treatment of the data is discussed more in the Results section of this paper.

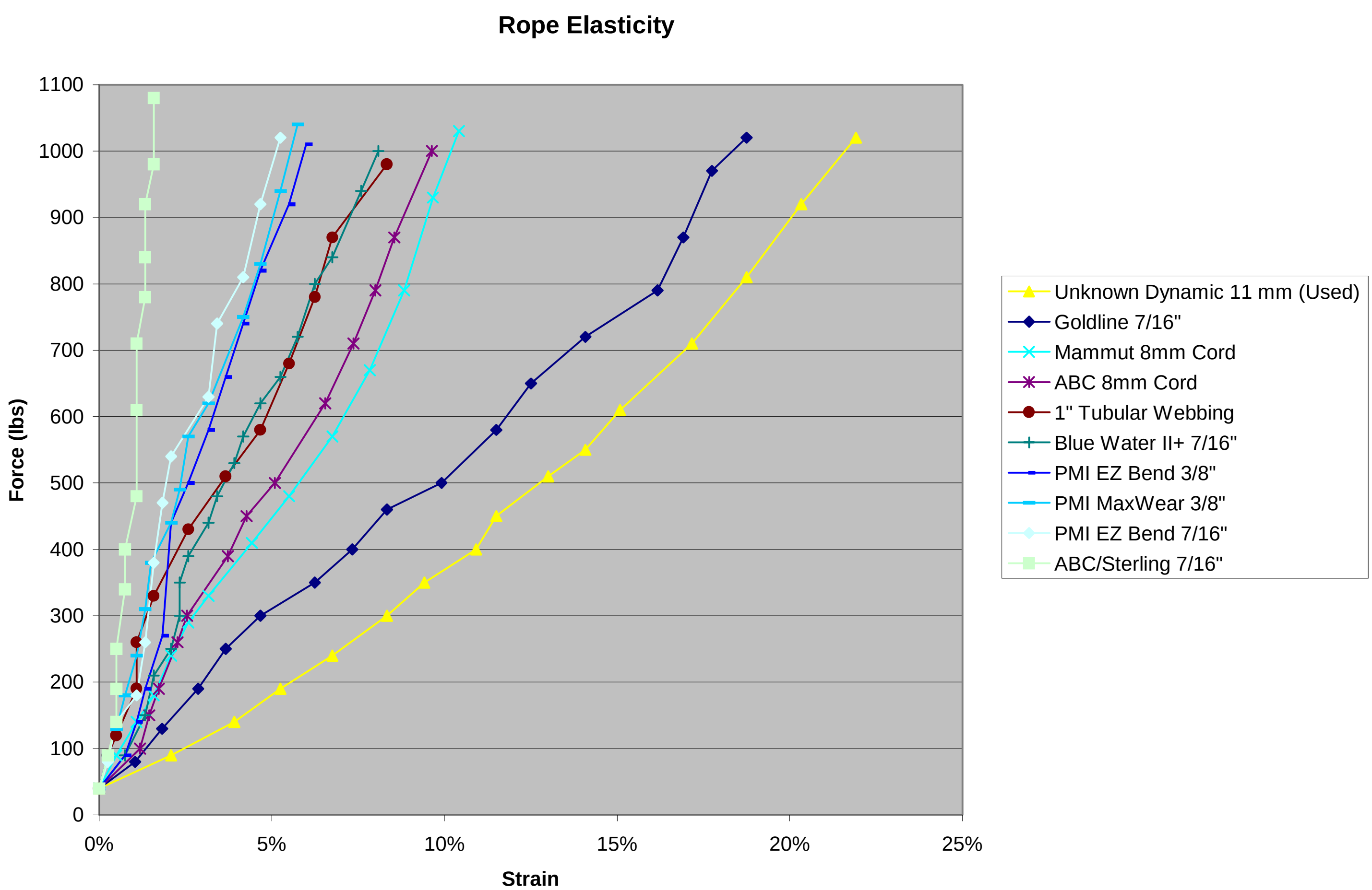
Abrasion across the rope was tested on the sharp concrete edge of a building. We chose a man-made edge deliberately for this test, since it was mostly consistent along its length. The rope to be tested was loaded over the edge with a 160 pound weight (me!), and moved back and forth over a 24" section until it failed. The distance to failure was measured. To check for changes in the edge caused by the testing, we followed the same procedure as in the previous test, but no change was apparent in the data for this test. Four trials were averaged.

Uncontrolled factors which could contribute to variability in the data include temperature, humidity, rope color, and variation in the rope manufacturing process. I recorded temperature and humidity for each abrasion test, but could see no trend in the results. Both varied only in a narrow range over the course of the tests. Both dyed and uncolored ropes were included in the testing, but no single rope was tested in both a dyed and uncolored model to check this.

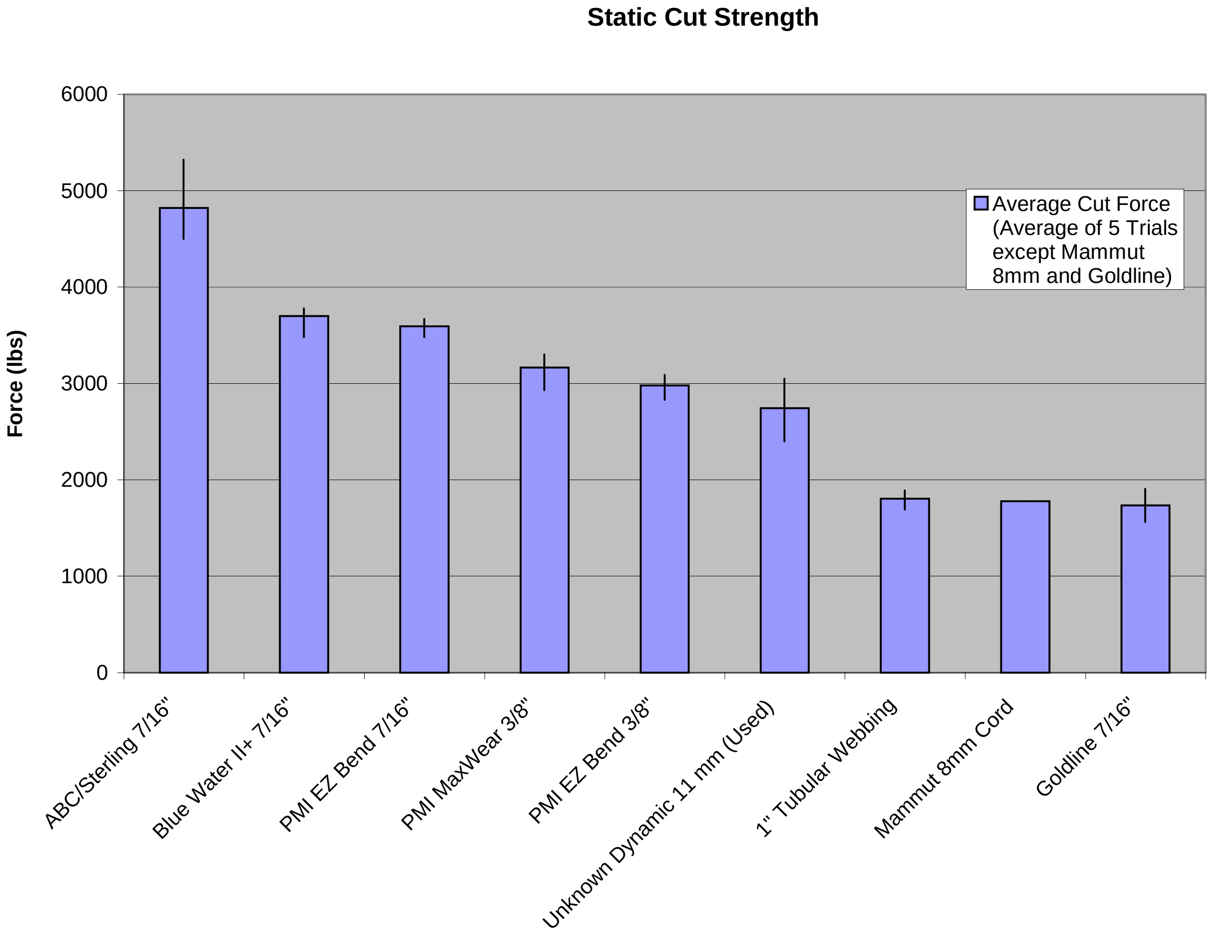
### *Results*

The results of the elasticity test were definitely a surprise. I had not expected to learn much from this. Although both of the two ropes we currently use are considered static ropes, the elasticities differ by a factor of five! This is definitely an issue for us to be aware of. Neither one is a safety problem unless it is misused. The application with a potential for error is in the rigging of highlines. If the highline is preloaded excessively before the litter is attached to it, the stiffer rope will see a much higher tension and may fail. A very stiff rope, like a steel cable, must be set up with some sag to keep the tension low enough. A more elastic rope will sag some when the weight is applied and reduce the potential problem.

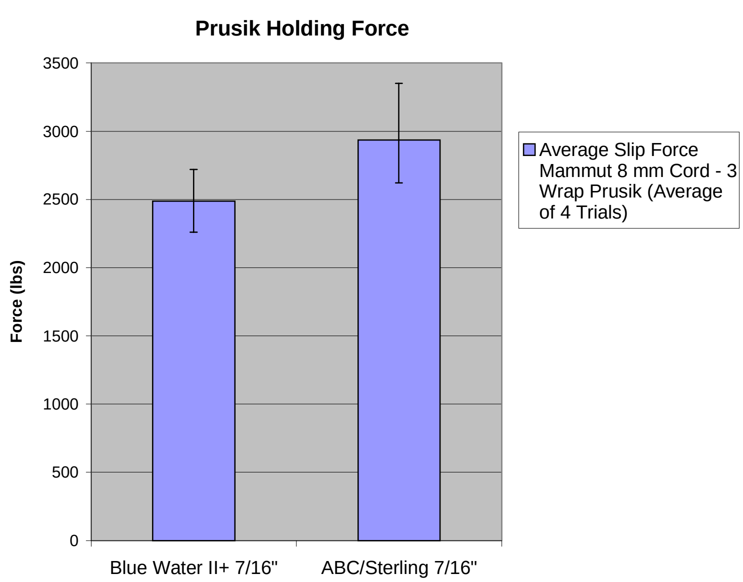

Rope Weight and Size
Weight (g/m)
Measured Diameter (at 40 lbs tension)
grams/meter
inches
0
20
40
60
80
100
120
0.2
0.25
0.3
0.35
0.4
0.45
0.5
ABC/Sterling 7/16"
PMI EZ Bend 7/16"
Blue Water II+ 7/16"
Goldline 7/16"
PMI MaxWear 3/8"
PMI EZ Bend 3/8"
1" Tubular Webbing


Rope Elasticity
Force (lbs)
Strain
0
100
200
300
400
500
600
700
800
900
1000
1100
0%
5%
10%
15%
20%
25%
Unknown Dynamic 11 mm (Used)
Goldline 7/16"
Mammut 8mm Cord
ABC 8mm Cord
1" Tubular Webbing
Blue Water II+ 7/16"
PMI EZ Bend 3/8"
PMI MaxWear 3/8"
PMI EZ Bend 7/16"
ABC/Sterling 7/16"

Cut testing was extremely informative, as always. The standouts are clearly the ABC/Sterling rope on the high side, and webbing and Goldline on the low side. Error bars on the chart show the maximum and minimum failure loads for each rope tested. Be careful to pad edges well when using webbing for rock anchors!

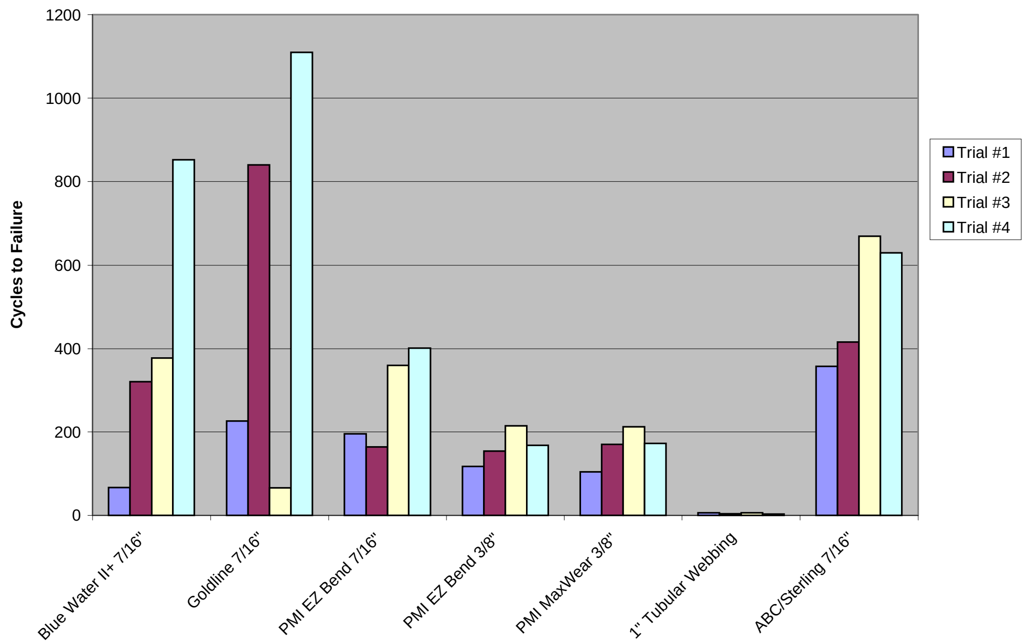



The prusik test is, in my opinion, not very informative. We don't care much what the failure load is, as long as it is consistently greater than 1000 pounds - the maximum load we should ever see on a rescue, and consistently less than the failure load of either the prusik or the rope. In other words, the prusik should ideally always fail by slipping, not by breaking. Measuring the exact slip force for a given rope is affected by the test method. It varies with the speed of the pull and with the subjective definition of what point exactly to call "slipping". I recorded peak forces when the whole prusik slipped at once. For both of the ropes I tested, every failure was by slipping.

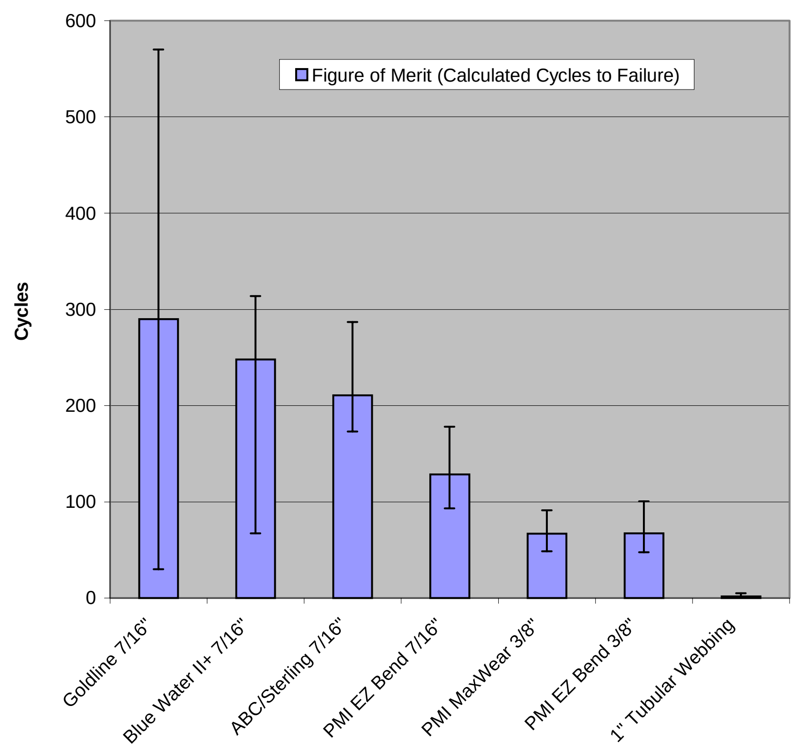


The abrasion *along* the rope test is the most like the real-world rescue situation.  Like the real world, there is a fair amount of variability in the results.  There is, however, enough consistency to consider this a very useful test.  The most obvious thing in the raw data is a clear upward trend in the number of cycles that were required to break each rope on each successive round of testing, as the rock became smoother.  The effect of the wear on the rock is that the ropes which were tested first in each round suffer by comparison to the ropes which were tested last, because they were tested on rougher rock.  To compensate for this, I have calculated a figure of merit for each rope, which roughly approximates the average number of cycles that would be required to break a rope - if it were tested with *no* previous wear on the rock.  The error bars on the chart show the deviations of the actual tests from the results which would be predicted by the figure of merit and the amount of previous wear on the rock.

**Abrasion Along the Rope - Raw Data**



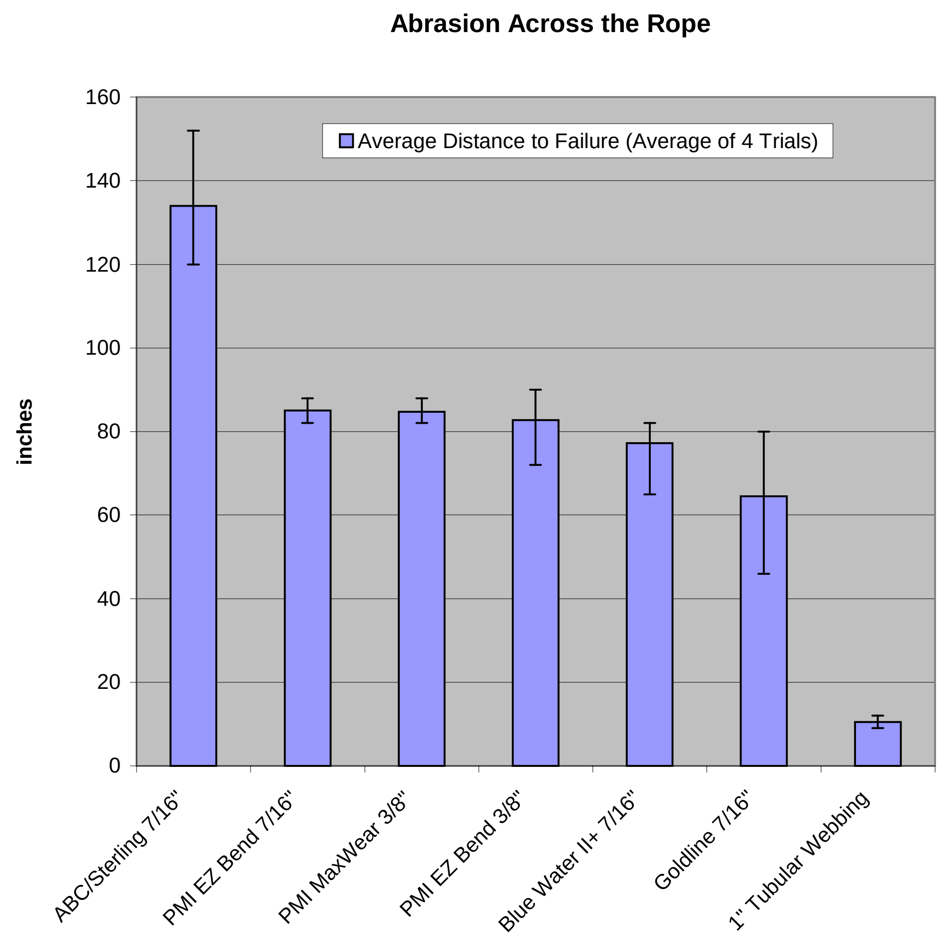

**Abrasion Along the Rope**



This test was done over the course of two days. The two data points which stand out as anomalously low are the first round test on the Blue Water rope, and the third round test on Goldline. These two data points were the first ones taken on each day. The first one is clearly the effect of a rougher rock - which doesn't really abrade as linearly as my equation says. The second one I do not understand. Including or eliminating these two points in the data does not change the relative rankings of the figures of merit for the ropes. Their effect is visible in the giant error bars for these two ropes. The results presented here include every test I did. No outlying points were eliminated.

Looking at the data, the one thing that stands out as blindingly obvious is that webbing is awful! For a round rope, only a few fibers at a time are exposed to the rock edge, and the rope wears a few fibers at a time. For webbing, almost all the fibers are abraded on every cycle, and it fails very quickly.

The abrasion *across* the edge test is, in my opinion, one of the best for evaluating ropes. The test was quite consistent - see the small error bars on the chart, and this is the type of failure that worries me the most on actual rescue operations. Where abrasion *along* the rope should be seen at the next rope inspection, abrasion *across* the rope can produce immediate catastrophic failure - even at low loads like body weight. This test again clearly demonstrated that webbing is awful in abrasion.




### ***Conclusions***

For the most part, readers can draw their own conclusions from the test data, or better yet, repeat these or other tests on their own equipment. For our group, we found nothing that scares us away from either of the brands of rope we currently have in service. The primary difference we will focus on in our training is the difference in elasticity. The test results for webbing make very clear what we have known for a long time. For rock anchors, if there is any possibility that an anchor could shift when it is loaded, webbing should not be used. If it is used on rock, edges should be well padded.