Testing Tensile Strength of Accessory Cord and Hand-Crimped Cable for Use as Homemade Slings

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I. Introduction

When participating in inherently dangerous activities, risk mitigation and safety are of utmost priority. Select companies specialize in producing and manufacturing safety products that are certified by governing bodies of safety standards. The professional procedures and standards they must follow are widely accepted to be trustworthy, however many consumers take the certifications at name value without understanding how or why they are received. This creates distrust in products that are sufficient for certain applications, but do not have the brand name and safety certifications stamped on it. Our belief is that a strong understanding of the limits of safety gear can allow for cheap, effective, and accessible alternatives to existing products. In this report, we will explore three types of loops that could be used as homemade slings in heavy-load applications. This report is intended to provide testing information that is not typically released for the products we tested under the specified conditions. As previously mentioned, risk mitigation and safety are of utmost importance in potentially dangerous situations, and anyone choosing to use this information in their own applications should do so at their own risk.

II. Background

We set out to determine what kind of homemade loops could be used in heavy-load applications, with an emphasis on being used as replacements for webbing in climbing cams. We considered factors such as strength, consistency, accessibility, and cost in choosing a method for a homemade sling. Typically, manufacturing companies sell slings that receive UIAA and EN566 certifications. The EN566 certification requires that a sling has a minimum breaking strength (MBS) of 22kN and does not unravel when individual strands are cut while holding a 150g load.[1] However, forces as high as 22kN are virtually impossible in any climbing scenario. Petzl has conducted several tests of varying degrees of falls and recorded the impact forces on the belayer, anchor, and climber.[2] A factor 1 fall is the most serious fall test recorded, in which the climber falls the full length of the rope, which produces high forces throughout the system. The force on the anchors and climber is reported to be 6kN and 4kN respectively. OSHA standards require that forces on a person through a harness should not exceed 8kN[3]. It should be noted these are worst-case scenario falls in which there is minimal rope and friction in the system to absorb the load.

Considering Black Diamond, a renowned outdoors and climbing gear company, sells several small cams rated as low as 5kN[4], and the maximum achievable forces in a realistic climbing scenario mentioned above, we will consider a loop of 8kN or above to be sufficient as a temporary replacement for a climbing cam sling, assuming proper manufacturing, installation, and inspection.

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[1] https://www.satra.com/ppe/EN566.php
[2] https://www.petzl.com/US/en/Sport/Forces-at-work-in-a-real-fall
[3] https://www.fallprotect.com/blog/techtalk/what-is-maximum-arresting-force
[4] https://www.rei.com/product/169038/black-diamond-camalot-z4-cam

III. Procedures

For our testing apparatus a tensile test was conducted on an Exceed E43 UTM at room temperature. Specifically in our setup, we used a 50KN load cell with rope test attachments rated to 5000LBF, and two aluminum Black Diamond climbing carabiners with a closed gate rating of 18KN to attach our samples. It should be noted that the carabiners will elastically deform during the test which will add a degree of inaccuracy to the measurements from the crosshead, but across all tests this deformation should be nearly the same and thus the tests are comparable to each other.

To prepare our rope samples (6mm & 7mm Polyester Accessory Cord) six uniform lengths of material were cut and the ends melted to prevent fraying. These sections were each identified from one to six and then tied in loops using a double fisherman knot. To prepare the steel cable six uniform lengths were cut, and then crimped in a loop, with each sample being identified from one to six. The loops were each tied or crimped to a circumference of about 260mm. Specimens one, two, and three of each material were then attached to the UTM between the carabiners and tested until failure/break detection from the UTM at a rate of 0.8mm/s. We chose .8mm/s because it was on the higher speed we saw for ropes and the normal testing we saw done on steel cable, which to use felt somewhat more representative of the quick loading experienced during normal use. Our initial crosshead values were taken to be just before the sample experienced any meaningful(greater than zero load fluctuation) tension. Specimens four, five, and six prior to testing were soaked overnight in water and then tested using the same procedure as the first three.

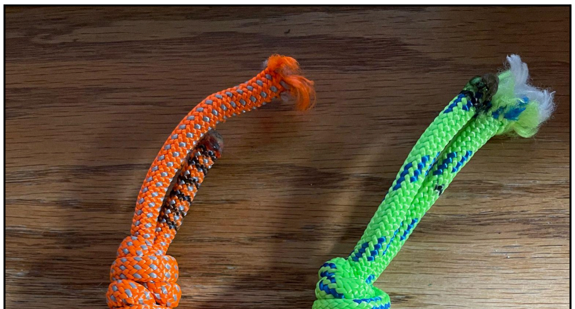
Material (Parameters being varied)	Test 1-3(Dry)	Test 4-6(Wet)
6mm Polyester	Initial length Ultimate yield strength Final length	Initial length Ultimate yield strength Final length
7mm Polyester	Initial length Ultimate yield strength Final length	Initial length Ultimate yield strength Final length
3/8in Steel Cable	Initial length Ultimate yield strength Final length	Initial length Ultimate yield strength Final length

The post-test overall length of the specimen was measured with a tape measure, measuring to and from the edge of the "solid section" of each break. The area of the sample post-break was calculated from the diameter of the "solid section" of each break. In the case of the cable, measurements were estimated to be the same as the original due to the crimp failing to hold until failure of the cable itself instead allowing slipping. This made it impossible to correctly determine the points of the cable to measure to and from, in the case of the samples that fully slipped out, and for the ones that were still partially crimped their interior loop length would also not correctly reflect the part of the sample placed under tension. Additionally when the samples were measured no noticeable difference could be found for their length.

IV. Results & Analysis

	3.175mm Galvanized Aircraft Cable	6mm Orange Polyester paracord	7mm Green Polyester paracord
Average Ultimate Strength	224.38	333.7225	282.0285
Average Yield Strength (Mpa)	631.67	350.7745	349.9355
Average Ductility	0%	43%	44.65%
Average Strength per Dollar	779.839	216.495	183.212
Average Saftey rating/Actual Strength	N/A	72.20%	75.70%

In the table we have the summary of the values we were interested in comparing including how



our tests compare to the safety rating given to the ropes as well as the best performance for price. The Cable wasn’t as strong but had the best price for its strength. However, this varied quite a bit across the cables. The failure point was always how well crimped the cable was, not the strength of the steel itself. This also meant we had no ductility or deformation due the slippage happening before the steel deforming. So we had a wide range of results. pictures of the 6mm and 7mm samples post-break. We had assumed that they would snap at the knot but instead they broke where the ropes were attached to the carabiner. Most likely due to the compressive stress at that singular point with high tension forces on either side.

Dry test graphs

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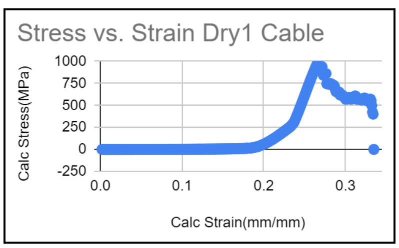
<td>
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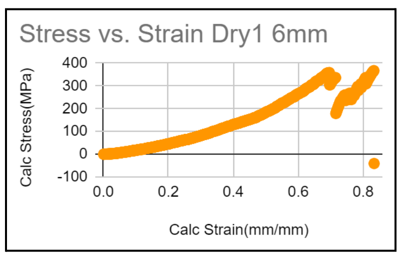
<td>
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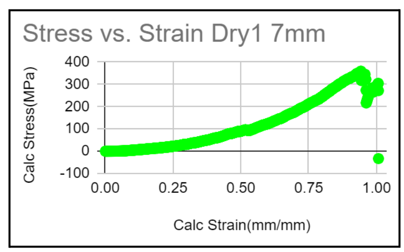
<td>
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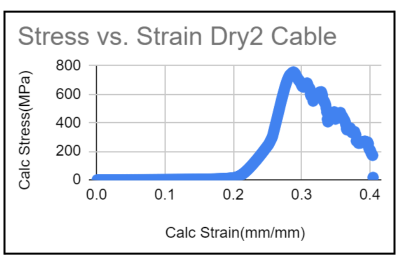
<td>
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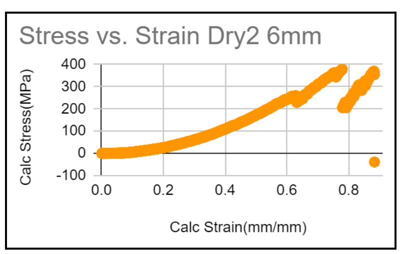
<td>
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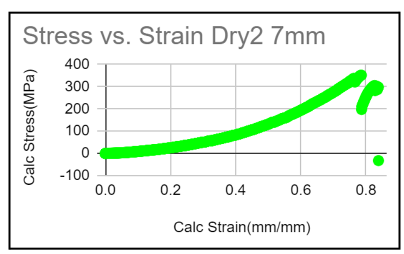
<td>
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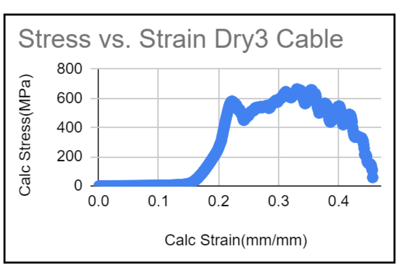
<td>
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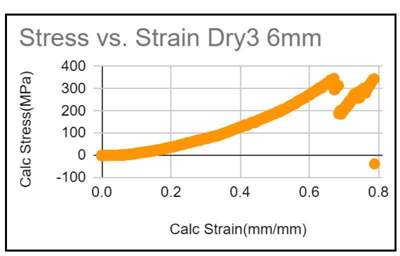
<td>
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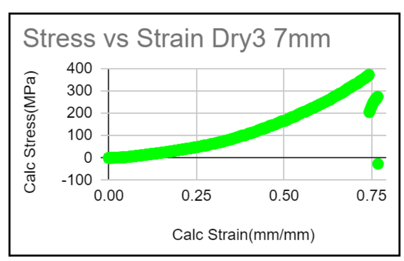
<td>
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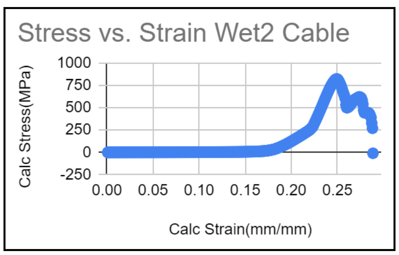
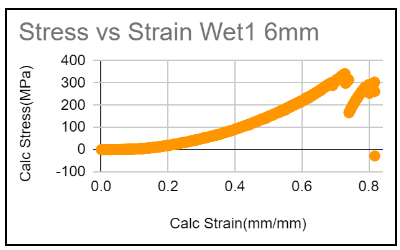
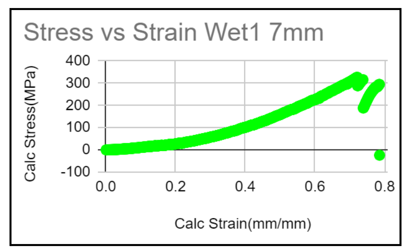
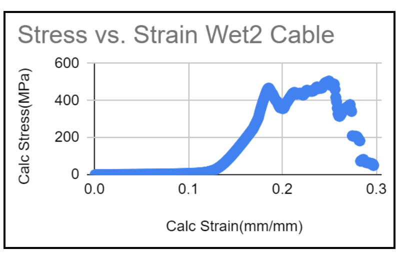
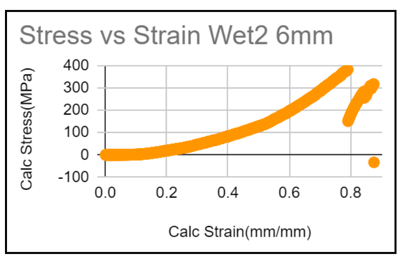
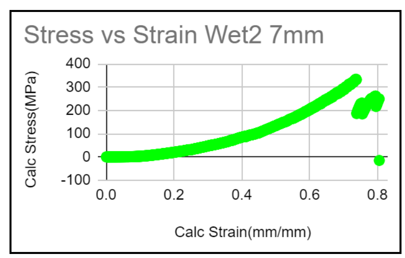
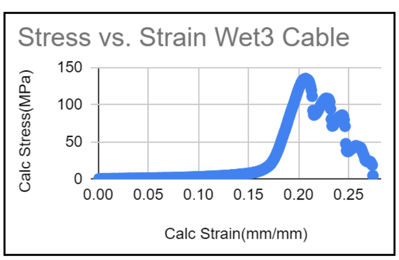
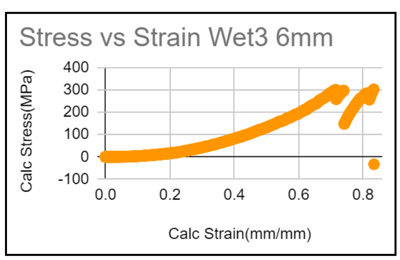
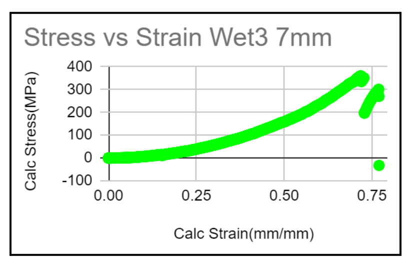
Looking at the dry tests gives us a good idea of the reliability and absolute maximum forces these ropes can withstand as opposed to the cable which is far more unreliable. After the initial peak (where the cable finally started to slip) the graph descends in a bumpy manner as the cable slides and then catches again within the crimp.

Looking at the rope graphs, each break in the graph is a point where we started to hear popping as the interior started to split and give.

Wet tests

Cable	6mm	7mm
		
		
		

Looking at the wet graphs we see even more variation for the cables. This may be due to water being able to get into spots where the crimp wasn't as tight and lubricate it even more. The wet tests for the rope are also very consistent and not incredibly dissimilar to the dry graphs as we thought they might be. This may be due to water not fully being absorbed into the rope in 24 hours. However, the short soak in water did make a difference.

	Cable	6mm	7mm
AVERAGES (Wet&Dry)			
Ultimate Strength (Mpa):	224.38	333.7225	282.0285
Yield Strength (Mpa):	631.67	350.7745	349.9355
Ductility:	0%	43%	44.65%
Max load (N)	6257.276449	9966.085	13477.955
AVERAGES (Dry)			
Ultimate Strength (Mpa):	226.62	359.697	293.318
Yield Strength (Mpa):	776.168	360.492	360.593
Ductility:	0%	41.10%	49.70%
Max load (N)	6367.298503	10271.97	13875.63
AVERAGES (Wet)			
Ultimate Strength (Mpa):	222.14	307.748	270.739
Yield Strength (Mpa):	487.172	341.057	339.278
Ductility:	0%	44.90%	39.60%
Max load (N)	6147.254395	9660.2	13080.279
Strength per Dollar (dry):	958.232	222.53	188.792
Strength per Dollar (wet):	601.447	210.53	117.632
Saftey rating/Actual Strength (d):	N/A	70%	73.51%
Saftey rating/Actual Strength (w):	N/A	74.50%	78%
Strength per Dollar (both):	779.839	216.495	183.212
Saftey rating/Actual Strength (both):	N/A	72.20%	75.70%

Looking at our averages for each material for each condition we can see that the average yield and ultimate strength for the ropes soaked in water is lower. This is also seen in the maximum loads recorded. These results show wet ropes do end up performing worse under high loads and probably will not last as long under traditional loads. We think this may be due to some water seeping into the rope fibers and causing them to expand from each other a tiny bit, losing some strength. All of our raw data and results can be accessed here.

V. Conclusion

After testing these materials under different conditions we learned that there is a significant difference between materials and conditions. Hand-crimping cable may not be the most reliable process according to our results. Humans are just not consistent enough to ensure the same force and placement of the crimp across multiple loops. However, steel is incredibly strong and the only weak point in those loops were the crimps. If the home manufacturing process could be perfected these would make excellent, cheap anchors.

The most relevant result was the difference one millimeter in diameter can do for rope loads as well as what prolonged moisture can do to overall load resistance. The one millimeter difference added about 4000N of load capacity for the rope which is significant. However, this does come with a higher price. Moisture also decreased the load bearing capacity by about 700N. This isn’t much compared to the overall load, but if these ropes are used in the rain consistently we can expect them to fail much sooner than dry ropes.

Overall, climbers need to watch the condition their ropes are in to be safe while climbing. Moisture can cause rope failure sooner than expected. Additionally, shelling out a bit more money for a slightly larger rope isn’t a bad idea considering the additional load capacity. However, making your own climbing materials that are used to save lives may not be ideal.

REFERENCE SITES

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