Light Anchors, Heavy Loads

Suitability of Dyneema in Rope Rescue Anchors

Zephyr Feryok

4/3/2015

www.verticultural.com/testing

Background and Introduction

As climbers, we strive for better, lighter equipment. We find ways to shave ounces off our racks, and we eagerly grab the latest “alpine” products. As rescuers, we find safety in the tried-and-true. We act conservatively, often using older equipment and techniques because we know they work. Each high-angle discipline benefits, however, from looking to the other.

Both climbing and rescue anchors are expected to be strong, but while a bombproof anchor is advised for all systems, it is absolutely required in a rescue scenario. Existing methods often use bulky cord and tubular nylon webbing to achieve high-strength, multipurpose anchors. These methods have been systematically tested and studied, principally in Tom Moyer’s work *Comparative Testing of High Strength Cord*, and in *A Look at Load-Distributing and Load-Sharing Anchor Systems* by McKently et al. It is agreed that quantitative data are important when evaluating the choice of one system over another in rope rescue, and with this principle in mind, a wide variety of testing was completed on Dyneema anchor configurations.

Dyneema slings are commonly manufactured in loop lengths of 60cm, 120cm, and 240cm, with bar-tacked connections forming a loop. For anchor-building purposes, the 120cm and 240cm slings are the most useful, as they provide enough material to link together several anchor points, or to wrap around a large diameter object. In climbing systems, a “cordelette” method is often employed, which involves clipping the sling through each anchor point, drawing the sling together as to create a loop of material leading to each anchor, and tying a “master-point” knot to provide redundancy to the system. The load-sharing capabilities of this type of system have been addressed previously, but this study tests whether the ultimate strength of the anchor system is affected by use of knotted Dyneema slings.

Other common anchor configurations in rescue are the basket hitch and the wrap-3 pull-2. These use tied cord or webbing to achieve a high-strength connection to an object such as a tree or boulder. The chief concern of these anchors is the time that it takes to build them and the weight and bulk of the material required. Use of Dyneema slings seeks to address all of those concerns, as a pre-sewn loop requires no knots to be tied, and is far lighter and smaller than equivalent lengths of cord or tubular nylon webbing.

The biggest drawback with using pre-sewn slings is the loss of versatility and cost. For optimal strength, Dyneema is sewn, which means the sling length cannot be adjusted without loss of strength, unlike nylon webbing. The sling can, however, be doubled or tripled up to reduce length. The second issue, cost, can be prohibitive for teams with limited resources.

Material

Dyneema is formed through spinning Ultra-High Molecular Weight Polyethylene fibers. It has an extremely high strength-to-weight ratio, rendering it an excellent choice for climbers. Dyneema exhibits a very low elasticity and melting point, in addition to good wear-resistance and low water absorption capabilities. Concern has been raised towards major strength loss when knots are present in Dyneema slings, with knot efficiencies sometimes quoted as less than 40% of the original sling strength. There has been little comprehensive testing to verify or dispute these claims.

Testing

In the interest of providing a greater source of quantitative test data for Dyneema slings, specific testing was designed to evaluate the appropriateness of certain anchor configurations for use in high-angle rescue and climbing.

The configurations tested include the following:

- Cordelette Style
  - Two leg with overhand master-point, carabiner present and absent in knot
  - Two leg with fig. 8 master-point, carabiner present and absent in knot
  - Three leg with overhand master-point, carabiner present and absent in knot
  - Two leg with clove hitches on anchors, overhand master-point, carabiner present in knot
  - Three leg with two anchors clove hitched and a loop on the third, overhand master-point, carabiner present in knot
- Girth Hitch
  - 4.75 inch diameter post, one wrap
  - 4.75 inch diameter post, two wraps
- Basket Hitch
  - Open basket hitch on 4.75 inch diameter post
  - Overhand basket hitch on 4.75 inch diameter post
- Wrap 2 Clip 4
  - Wrap two clip four on 4.75 inch diameter post

All anchors are half-inch steel pins, simulating carabiners, except when specified as a post. The sample material is the Sterling Rope 10mm Dyneema Sling, with an advertised material breaking strength of 23kN. This strength was confirmed through open-loop tensile testing. The slings are bar-tacked, and have yellow nylon edging. The master-point is connected to a 100kN load cell, and the anchor pins are connected to a steel jig attached to the moving crosshead of the Instron tensile tester.

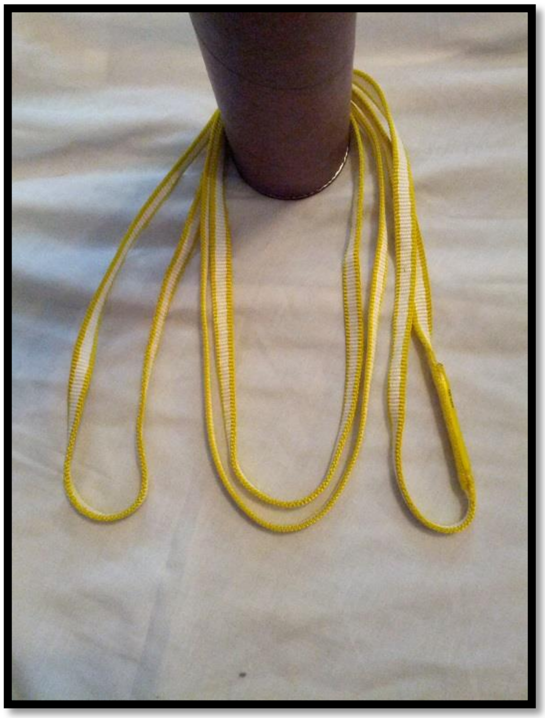
Pictures of the anchor configurations follow:

Two leg with master-point

Two leg, clove hitches on anchors, with master-point

Three leg with master-point

Wrap Two Clip Four (Setup)



Wrap Two Clip Four (Complete)

Three leg, two anchors clove hitched, loop on third anchor, tied master-point

Carabiner in overhand knot

Carabiner in fig. 8 knot

Basket

Overhand Basket

Girth

Two Wrap Girth

Results

In general, all two-leg anchor configurations without clove hitches failed at around the material breaking strength (MBS) of the Dyneema loop (23kN). The failures happened at the knot in all cases, with a fairly even split between leg and loop failure. The three-leg anchor tested to a higher strength, around 30kN.

Clove hitches began to slip at around 4.5kN, and would continue slipping without cinching down. To test the strength of the hitch itself, an overhand was tied above the clove hitch as a lock-off. In this configuration, the two-leg cloved anchor failed at the clove hitch at around 13kN. The three-leg clove anchor first failed at the single looped leg at around 20kN.

Girth hitches showed a minimal strength reduction, with mean failure at 22kN, though the two-wrap girth gave more consistent failure results and a slightly higher breaking strength that approximately equaled the MBS. All girth hitch configurations failed at the point where the sling passed through itself. The overhand basket tested at around the same strength as the girth hitch (24kN), with failure occurring at the knot. The open basket proved the second strongest configuration, with a breaking strength of 45kN. Failure of the open basket was at the half-inch test pin.

By far the strongest configuration was the wrap-two clip-four. The Instron was unable to break this configuration, with loads peaking at 64kN. One sample was cycled repeatedly to this load, with no apparent failure.

Conclusions

- Clipping a carabiner through knots in Dyneema seems beneficial; no apparent strength reduction was found, it makes the knot far easier to untie, and visual observation indicated that it might allow the knot to shift and distribute the load a little better. In all samples pulled to failure, the carabiner was removable, and the knot was easily untied after.
- When attaching a single sling to a post, there appears to be no reason to use an overhand basket knot over a girth hitch. It results in the same material strength, and leaves less material to work with. The open basket is most ideal, but if improper carabiner loading would occur, the girth hitch should be the next choice over the overhand basket. If there is sufficient material to do a second wrap with the girth hitch, it may prove slightly stronger, but these data indicates the difference is negligible.
- No apparent difference was seen in master-points tied with an overhand versus figure 8 knot. The overhands were still easily untied when a carabiner was clipped through them, and they took up far less material.
- For absolute strength, the basket hitch and wrap 2 clip 4 appear to be the most ideal. Both are not inherently redundant, but as always, redundancy in a single anchor often comes with a loss of strength.
- Clove hitches were shown to be inappropriate in Dyneema slings, with failure loads far lower than any other anchor configuration. There was significant slippage when not tied with an

overhand above the clove, and the ultimate failure strength was unreasonably low even with the overhand.

Discussion

The wrap-two clip-four anchor configuration could easily replace the wrap-three pull-two that is commonly tied in webbing. Not only is it apparently stronger than the W3P2 (Evans & Stavens, 2012), it uses lighter material, is faster to build, and does not absorb water as readily. Reducing the amount of webbing carried could certainly be assisted by using the wrap-two clip-four.

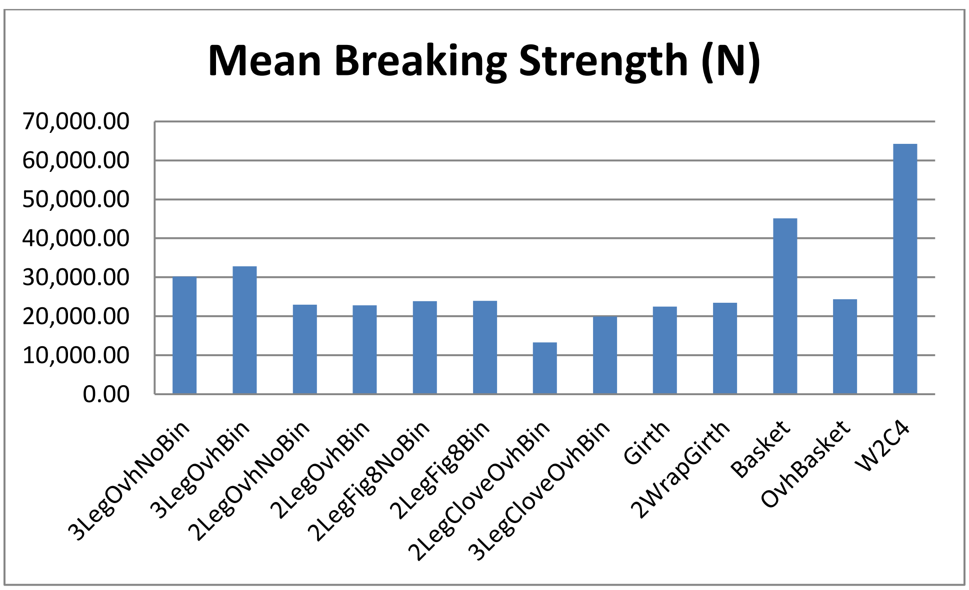
The basket hitch and three-leg configurations (except the clove hitched version) tested to fairly high loads, warranting further research on their usefulness in rescue situations.

Considering a 2kN load, all of the two-leg configurations except the clove hitch provided a greater than 10:1 static safety factor. The suitability of these anchor configurations to drop-testing and shock loading has not been investigated by this study, and as such, further research is necessary.

Appendix A

Tabulated Test Data

Max. Load Before Failure (Newtons)					
Test	Sample 1	Sample 2	Sample 3	Mean	Std. Dev.
Three-Leg|Overhand|No Biner	32,206.52	31,141.63	27,208.22	30,185.46	2632.763
Three-Leg|Overhand|Biner	31,965.88	33,221.61	33,201.11	32,796.20	719.1513
Two-Leg|Overhand|No Biner	22,467.38	23,283.61	23,253.27	23,001.42	462.7409
Two-Leg|Overhand|Biner	22,739.34	23,370.50	22,438.49	22,849.44	475.6603
Two-Leg|Fig. 8|No Biner	23,434.18	23,512.51	24,784.50	23,910.40	758.0082
Two-Leg|Fig. 8|Biner	23,463.00	22,721.34	25,801.80	23,995.38	1607.756
Two-Leg|Clove|Overhand|Biner	13,770.31	13,630.01	12,487.68	13,296.00	703.5318
Three-Leg|Clove|Overhand|Biner	19,232.59	20,568.46	20,006.47	19,935.84	670.7299
Girth	23,956.30	21,176.85	22,225.97	22,453.04	1403.569
Girth|Two-Wrap	23,385.10	23,166.82	23,863.45	23,471.79	356.3141
Basket|Open	46,189.31	45,412.72	43,650.33	45,084.12	1300.995
Basket|Overhand	27,432.64	22,162.31	23,447.86	24,347.60	2747.953
Wrap 2 Clip 4	63,289.09	64,609.42	64,837.24	64,245.25	835.857



Appendix B

Testing Specifications

Instron Tensile Tester

Model: 4505 / 5800R

Serial: C2152

Crosshead Speed: 0.5 inches per second

Load Cell

Manufacturer: Instron

Capacity: 100kN

Sling

Item Number: SW100DYSL024

MBS: 23 kN

Bibliography

Evans, T., & Stavens, A. (2012). Empirically Derived Breaking Strengths for Basket Hitches and Wrap Three Pull Two Webbing. *Nylon Highway*.

McKently, J., Parker, B., & Smith, C. (2007). *A Look at Load-Distributing and Load-Sharing Anchor Systems.* CMC Rescue.

Moyer, T. (2000). *Comparative Testing of High Strength Cord.*