

The Performance of Polypropylene Ropes During Static Applications Including Tensioning and Hauling

Written by Dino Heald with thanks to Lyon Equipment and Palm Equipment



Dino Heald is a full time kayak coach at Plas y Brenin, The UK's National Mountain Centre. As well as a level five kayak coach, he is also a BCU Home Nation Advanced White Water Safety Trainer, a Rescue 3 SRT instructor, an active member of the Llanberis Mountain Rescue Team and the North Wales Mountain Rescue Association's Representative Water Officer. Dino's efforts have recently been focused on putting together a new water rescue syllabus and designing a pilot course for the Mountain Rescue Council.



Many folk tales are told comparing water based equipment to mountaineering equipment. Often these tales are conflicting or anecdotal and have little evidence to support the claims.

This article describes some objective testing of water equipment I conducted with the support of Palm Equipment and Lyon Equipment. It is a pilot study of limited scope intended to initiate debate and identify further areas of testing.

Dino Heald Feb '09

Introduction

In the 1980s water rescue started when paddlers with climbing experience, used their improvised mountaineering techniques to rescue their friends and recover equipment from the river. Within the mountaineering world, manufacturers and other interested parties have conducted systems analysis of mountaineering equipment so that the depth of understanding is far greater than those of systems created with water based equipment. The onus of such testing is based on the fact that mountaineering systems comprise of a live load, i.e. a person dangling on the end of the system.

Throw bags containing floating polypropylene line are a common sight on the river, primarily as a way of a safeguard for extracting your mate from the water after departing from the boat, and equally as a rescue tool for recovery of equipment, unpinning rafts, canoes and kayaks, and more recently to safe guard those in steeper ground.

Such situations include a kayak becoming vertically pinned or a canoe becoming broached. The former scenario is when the bow of the kayak becomes stuck in a pocket often during a steep drop. All too often the kayaker in this scenario may be held in the cockpit by the force of water pressing down behind them. The latter scenario is when an open canoe turns sideways to the flow and the boat hits a rock. All too quickly the water piles up on the upstream side, and in an instant the boat is submerged and stuck fast. In both of the situations outlined above, the victim will require rapid intervention to recover their equipment and possibly themselves.

There are many ways to attempt a recovery of such a situation. Good, workable examples can be found in Franco Ferrero's White Water Safety and Rescue (Second Edition). To detail these systems is beyond the scope of this article, suffice to say that all these methods include the generation of mechanical advantage by creating changes of direction around karabiners or pulleys, and the use of rope grabs, especially prusik knots. Three commonly used prusik knots used during these procedures include the French, Kleinheist and the triple wrap knots. The use of polypropylene (throw bag) rope in this context is beyond the intended use of the manufacturer.

It is this application of polypropylene rope that is particularly important to us, especially the progressive tensioning of ropes and how they perform when subjected to this sort of treatment. Below I have outlined some of the slow pull tests that I conducted to represent what would happen in some real world scenarios when a line is tensioned, including:

- Boat recovery
- Tension diagonal
- Steep ground access
- Live bait rescue.

I hope the content will be of equal use to the kayak or canoe coach, recreational boater and rescue practitioner. It is by no means presented as a definitive article; moreover I invite comment upon my findings and will endeavour to make further progress in this area of testing.

Test Facility

Lyon Equipment has a dedicated research and quality control test facility for investigating the performance of textiles and hardware under load. A slow pull test machine was used to pull each sample to destruction, at which point the maximum tensile strength was recorded in kilo Newtons (kN).

Why kN?

Force is a pull or a push. So when a length of polypropylene rope is used to remove a pinned boat, or for that matter placed upon a slow pull test rig, the rope experiences a force. Engineers measure that force in Newtons (N).

A new Palm throw bag for example arrives fresh from the packet with a labelled rating of 1000kg. More correctly the rating would be written as 10kN, which is derived by multiplying 1000kg, by 10m/s (the acceleration due to gravity), which equals 10,000N or 10kN.

Investigations

Palm Equipment supplied new floating Hi-visibility 10.5mm diameter HT Polypropylene cored rope rated as 1000Kg line strength.

- **Rope strength with typical knots (bowline and figure of eight on a bite).**

A well established rule-of-thumb used by the rescue community is that the strength of a low stretch kernmantle (LSK) rope is reduced by a third when a knot is tied in it. For example a 30kN rated rope will break at around 20kN when used within a system containing knots. How will a polypropylene rope perform when a knot is tied in it? We tested samples with a figure of eight an overhand and a bowline.

- **Wet and dry performance**

Polypropylene does not react with water like other fibres. Nylon for example has an unhappy relationship with water that results in a significant reduction of its strength, which is not comforting news when you are climbing a traditional gully route in sporting conditions. Chuck your smelly polypropylene thermals in the washing machine however, and they come out almost dry. How will water soaked ropes perform during slow pull test evaluation?

- **Strength of old ropes that have seen service**

I was able to obtain some samples of rope that were approximately four years old and had seen some use on the river. These samples were identical to the 10.5mm Palm rope used throughout these tests, so I was able to make a direct comparison between a worked line and one straight from the reel.

- **The use of a high strength ring inside a throw bag**

Very often boaters will attach the end of the line into their throw bag via a metal ring. This is useful as it is possible to quickly remove the rope from the bag to create a "clean" working line. How will the ring influence the performance of the rope tied to it?

- **Tape Performance**

Often tape is used to build an anchor, as it is convenient to wrap around a tree, or form a thread as part of a belay. I wanted to test the performance of some commonly used knots when the tape is both wet and dry.

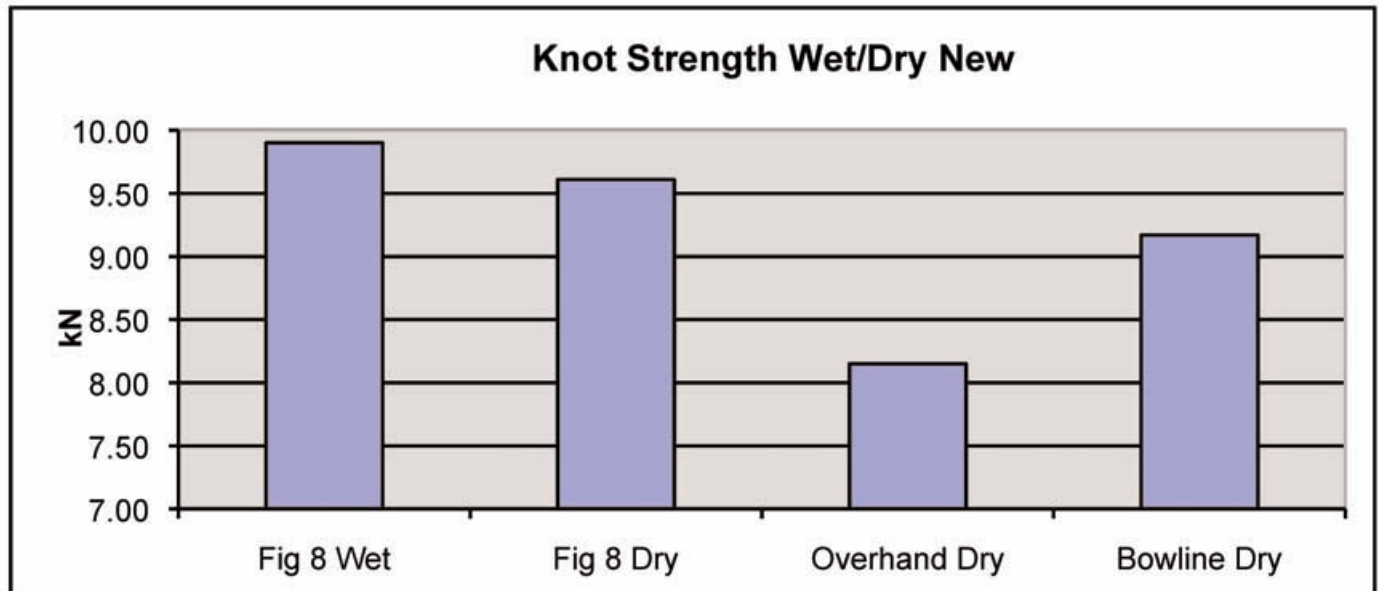
- **The performance of three prusik knots commonly used by boaters**

When we form mechanical advantage systems we use prusik knots to attach travelling pulleys to the main haul line. We also use a prusik at the first pulley to form a ratchet, so when the haul team take a rest, the line connected to the load remains loaded. The French prusik is often cited as being suitable in this application as it is allegedly releasable under load. Triple wrap and kleimheist knots are often used on the travelling pulleys. We subjected these three prusik knots to a slow pull test using 5mm, 6mm accessory cord and tape (for the kleimheist) when attached to Palm 10.5mm polypropylene line.

Results

Knot Strength – New Palm Polypropylene 10.5mm Rope

The chart below represents the sample results for the figure of eight knot (wet and dry samples), overhand (dry) knot and bowline (dry). Each value is an average of three identical tests.



Palm Tape Strength

New 25mm Palm tape was subjected to the following slow pull tests.

Wet/dry	Knot	Strength (kN)
D	Overhand pulled apart (photo)	15 (fig2.1-2.2)
W	Overhand pulled apart (photo)	12
D	Two overhand knots butted together without a gap, pulled apart (photo)	19 (fig2.3-2.4)
D	Tape knot	30 (fig2.5-2.6)
W	Tape knot	23



Fig 2.1



Fig 2.2



Fig 2.3



Fig 2.4



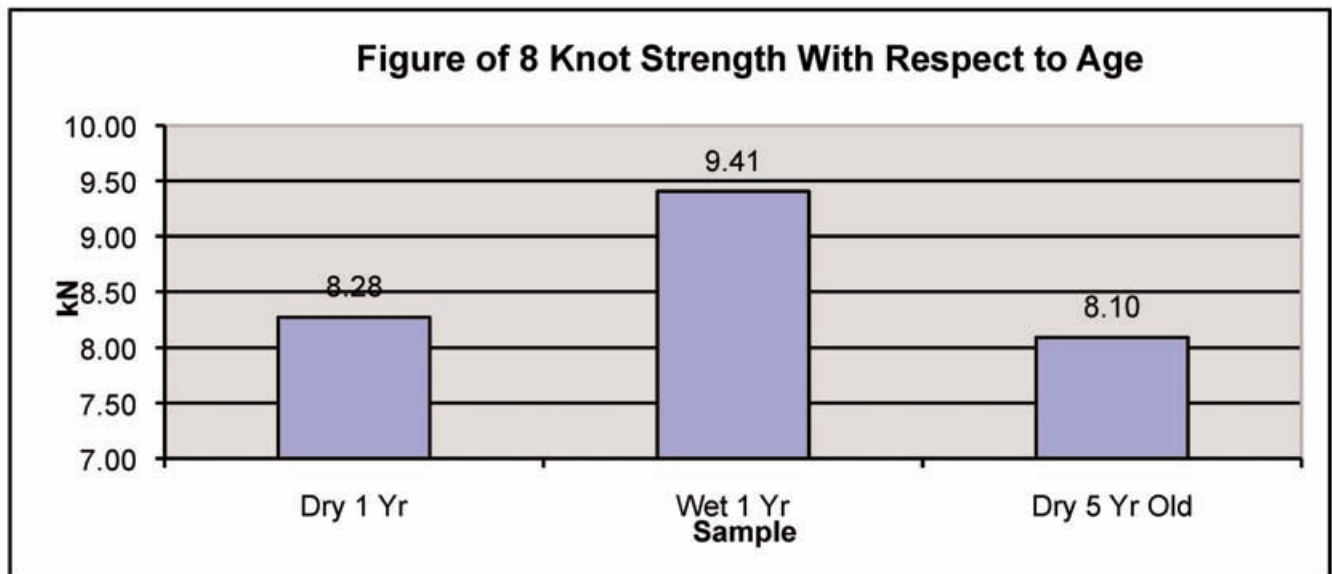
Fig 2.5



Fig 2.6

Knot Strength with respect to age – Palm Polypropylene 10.5mm Rope

The graph below shows the results from new and aged samples with figure of 8 knots



The use of a high strength ring inside a throw bag

The ring and internal webbing of the bag failed at 18.13kN when subjected to slow pull test. The tape failed as apposed to the ring.

The end of the 10.5mm throw line was attached to the ring with a figure of 8 knot and the system subjected to slow pull test. The ring suffered deformation (see photo) and the rope failed inside the figure of 8 knot at 9.7kN.



Prusik Performance

The performance of three prusik knots was evaluated using 4mm, 5mm and 8mm accessory cord. The Kleinheist was tied using 25mm Palm tape. All of the prusiks were applied to new 10.5 mm Palm Polypropylene rope

Prusik Knot	Prusik cord diameter	Wet or Dry	Slip Force (kN)	Comments
3 wrap Classic	5mm	Wet	6.92	Prusik knot stripped the sheath from the rope. (fig3.1)
3 wrap Classic	5mm	Dry	6.58	Sheath intact but very glazed. (fig3.2)
4 wrap French	5mm	Wet	1.37	It was not possible to pretension the French Prusik before the slow test load was applied. Potentially the prusik has slipped prematurely. Some sheath glazing occurred
4 wrap French	5mm	Dry	0.915 (about 1kN)	It was not possible to pretension the French Prusik before the slow test load was applied. Potentially the prusik has slipped prematurely
3 Wrap prusik	8mm	Dry	2.32	Very little glazing
3 Wrap prusik	8mm	Wet	3.15	Very little glazing
Kleinheist 5 wrap	25mm Palm tape	Dry	3.34	Very little glazing
Kleinheist 5 wrap	25mm Palm	Wet	7.74	Very little glazing (fig3.3)



Fig 3.1



Fig 3.2



Fig 3.3

Conclusions

Knot strength

- The samples tested with figure of 8 knots failed at a value very close to the rated value (un-knotted) value of the rope.
- The figure of 8 knot strength remains consistent if the rope is wet or dry. This would indicate that the strength of polypropylene is unaffected by water. I would like to further investigate the overhand and bowline knots on wet samples.
- The bowline is slightly weaker than the figure of 8 knot.
- The overhand knot is about 20% weaker than the figure of eight knot.
- There is a significant loss of strength of a rope that has been in service. The test samples reveal that the worked samples fracture, compared with the new samples that failed by progressive tearing. This would suggest that the samples tested had become brittle with age/service.

Throw bag with high strength ring

- The high strength ring inside a throw bag did not adversely affect the breaking strength of the rope, despite elongation of the steel ring.
- The figure of 8 knot tied inside the bag broke at a value consistent with other test samples.
- The high strength ring does not add a weak link to the rescue – chain.

Prusik knot performance

- The French prusik slipped at approximately 1kN (very low). I need to investigate this further as the testing facility did not represent real world conditions. In use, the prusik would be pre-tensioned before a load was applied (as in a hauling system). I found it impossible to do this at the test facility as the test rig had guards and auto-stopping mechanisms installed for safety.
- The strongest (grip-strength) prusik tested was the triple wrap, but this caused the most glazing to the rope and could strip the sheath.
- The Kleimheist tied with tape, gripped very well and caused the least damage to the rope. I will conduct further testing, adding additional wraps to the knot, which should increase the gripping area on the rope.

Tape performance

The values outlined below give an indication that nylon tape when included in a rescue system will not be the weakest component. However some consideration should be given to the choice of knot. More testing will be necessary to confirm this.

- The overhand knot (dry) rolled over and then continued to slip at a value of 15 kN when orientated such that the knot pulls apart.
- The overhand knot (wet) rolled over and then continued to slip at a value of 12 kN indicating a reduction in the performance of the nylon 20%.
- The tape knot (dry) did not slip and failed at 30kN.
- The tape knot (wet) did not slip and failed at 23kN indicating a reduction in performance of nylon when wet by 23%.
- The butted up double overhand knot configuration did not roll over but failed at a value of 19kN.

Summary

The testing conducted at Lyon has given some clarity to the issues surrounding polypropylene ropes and other components within slow-pull (static) rescue systems.

I would like to build upon these findings and further investigate river-based rescue, recovery and access scenarios. This development will investigate dynamic loadings on river equipment.

Acknowledgements

I would like to thank the follow for their input, support in their feedback and comments, which has helped to define the above work. Lyon Equipment especially Pete Robertson, Dave Ellis and Paul Witheridge, Plas y Brenin for their continued support. Chris Onions, Dave Luke, Franco Ferrero, Loel Collins, Ray Goodwin, Paul O'sullivan, Geriant Rolands. John Evans.



**To download this free document visit:
www.pyb.co.uk/ropetesting**

Test Results - Lyon equipment 09/09/08

The following is what was tested and the results shown below this.

Figure of eight knot

3	09/09/2008	09:47:23	Palm	Dry	New	Fig. 8	9.266
4	09/09/2008	09:51:14	Palm	Dry	New	Fig. 8	9.823
5	09/09/2008	09:54:38	Palm	Dry	New	Fig. 8	9.727
14	09/09/2008	11:43:24	Palm	Wet	New	Fig. 8	9.975
15	09/09/2008	11:49:24	Palm	Wet	New	Fig. 8	9.945
16	09/09/2008	11:52:28	Palm	Wet	New	Fig. 8	9.779

Overhand Knot

6	09/09/2008	09:59:27	Palm	Dry	New	Overhand	7.72
7	09/09/2008	10:01:44	Palm	Dry	New	Overhand	8.163
8	09/09/2008	10:04:35	Palm	Dry	New	Overhand	8.577

Bowline

9	09/09/2008	10:08:04	Palm	Dry	New	Bowline	9.03
10	09/09/2008	10:10:57	Palm	Dry	New	Bowline	9.682
11	09/09/2008	10:13:59	Palm	Dry	New	Bowline	8.808

Fig 8 and webbing ring

12	09/09/2008	10:23:36	Palm	Dry	New	Fig 8 and webbing into ring	9.709
----	------------	----------	------	-----	-----	-----------------------------	-------

Webbing and ring only

13	09/09/2008	10:42:13	Palm	Dry	New	Webbing and ring only	18.13
----	------------	----------	------	-----	-----	-----------------------	-------

Fig 8 old

17	09/09/2008	12:00:38	Palm	Dry	Old 1 year	Fig. 8	7.779
18	09/09/2008	12:05:57	Palm	Dry	Old 1 year	Fig. 8	8.595
19	09/09/2008	12:08:52	Palm	Dry	Old 1 year	Fig. 8	8.451
20	09/09/2008	12:12:44	Palm	Wet	Old 1 year	Fig. 8	8.888
21	09/09/2008	12:15:16	Palm	Wet	Old 1 year	Fig. 8	9.662
22	09/09/2008	12:18:12	Palm	Wet	Old 1 year	Fig. 8	9.668
23	09/09/2008	12:23:28	Palm	Dry	Old 5 years	Fig. 8	8.001
24	09/09/2008	12:26:21	Palm	Dry	Old 5 years	Fig. 8	8.034
25	09/09/2008	12:29:19	Palm	Dry	Old 5 years	Fig. 8	8.25

3 wrap prussic

26	09/09/2008	12:35:06	Palm	Wet	New	3 wrap prusik	6.92
27	09/09/2008	12:41:15	Palm	Wet	New	4 wrap French prusik	1.373
28	09/09/2008	12:46:58	Palm	Dry	New	4 wrap French prusik	0.915
29	09/09/2008	12:50:39	Palm	Dry	New	3 wrap prusik	6.58
30	09/09/2008	13:02:24	Palm	Dry	New	3 wrap prusik (large dia)	2.321
31	09/09/2008	13:07:05	Palm	Wet	New	3 wrap prusik (large dia)	3.145

3 wrap 4 mm diameter

32	09/09/2008	14:23:39	Palm	Dry	New	3 wrap prusik (4mm dia)	4.908
33	09/09/2008	14:28:46	Palm	Wet	New	3 wrap prusik (4mm dia)	3.917

kleimheist 5 wrap

34	09/09/2008	14:36:55	Palm	Dry	New	Klemheist5 wraps	3.342
35	09/09/2008	14:43:56	Palm	Wet	New	Klemheist5 wraps	7.736

Palm tape

48	09/09/2008	15:36:31	Palm tape	Dry	New	Overhand pulled apart	15.087
49	09/09/2008	15:41:58	Palm tape	Dry	New	Double overhand pulled apart	19.39
50	09/09/2008	15:51:58	Palm tape	Dry	New	Tape knot (sling)	30.571
51	09/09/2008	15:57:42	Palm tape	Wet	New	Tape knot (sling)	22.930
52	09/09/2008	16:00:13	Palm tape	Wet	New	Overhand pulled apart	12.176