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TECHNICAL COMMITTEE MEMORANDUM TCM 11/01

Low-stretch rope, Snapped rigging rope for Tyrolean

Incident Ref. 01/11/B.KIN

SUMMARY

The BMC was contacted by an advisor to an outdoor centre. It was reported that a postman's walk set up had failed at the pursuits centre, and that they wished the BMC TC to examine a sample of the rope. A piece of rope was sent to the BMC, shown in Figure 1. Information regarding the set up and loading circumstances were received by email (see Appendix I).

It appears that failure of the anchor had occurred from a combination of mal-practise and a poor set up of the postman's walk. Failure of this anchor rope (refered to as "tree anchor rope") had occurred from mechanical over loading and environmental degradation of the rope. Although chemical damage could not be discounted, given the circumstances, it seems unlikely. This report outlines the findings from information received, to confirm that mechanical overloading seems the most reasonable cause of failure of the system. Thankfully, the climber was not injured during the failure of this set up.

Author:	**Kunal Masania**
Checker:	**Alan Huyton**
Draft:	
Approved for issue by the EIP:	

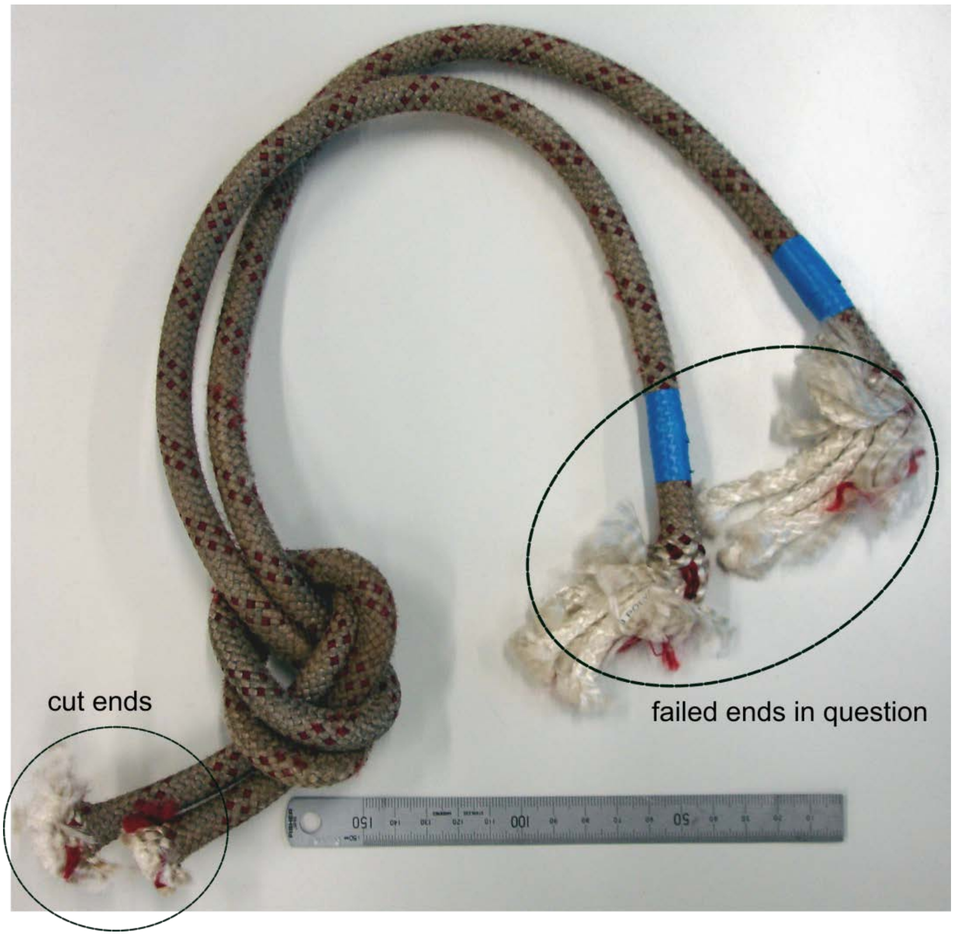


Figure 1. Image of the received section of rope.

1. INTRODUCTION

A sample of failed low stretch rope (semi static 10.5 mm PA Beal, see Appendix II) was received from an advisor to the outdoor centre. The advisor had been appointed to investigate a rigging failure at an outdoor pursuits centre.

The piece of rigging formed part of the anchor on a Tyrolean traverse Postman's walk set up, see Figure 2.

Figure 2. Image of a typical Postman's walk [1].

The system appeared to be over tensioned. Whilst also re-training the instructors at the centre, the advisor wished for the BMC TC to evaluate the set-up and a sample of rope in order to confirm this hypothesis.

Setup

This 11m section was slung around a tree with a single loop, see Figure 2. The broken region was in contact with a ∅10mm DMM carabiner at a 50/60° angle to the tree. Hence the tension in the tree anchor rope is about 0.58* (tension, T, in main line).

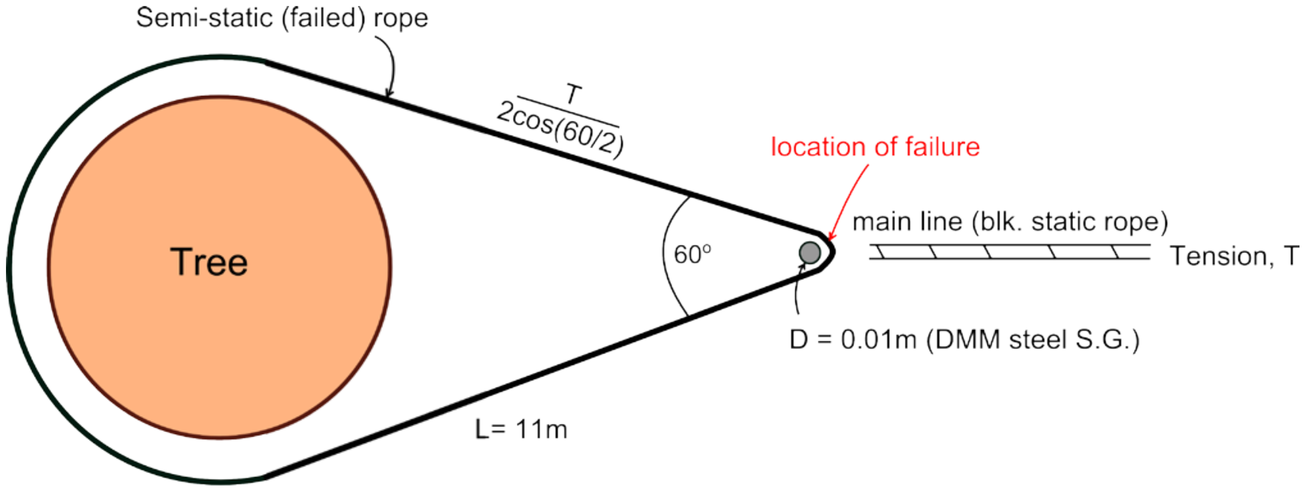


Figure 3. Schematic of the set up that was described.

A 3:1 pulley system was created using a Croll and Fixe pulley attached to a Gri Gri, see Figure 3. All participants pulled on the rope to pre-tension the system before and after each Postman's walk. Hence loading could be assumed to be around 7.5 kN* in the system, before the climber crossed the rope.

* assuming that five participants pull about 600 N each, with a three to one pulley system – with friction reducing this ratio to 2.5.

* acknowledging Mr A. Huyton's valuable contribution of hand forces data, and friction information for the Fixe pulley and Gri Gri.

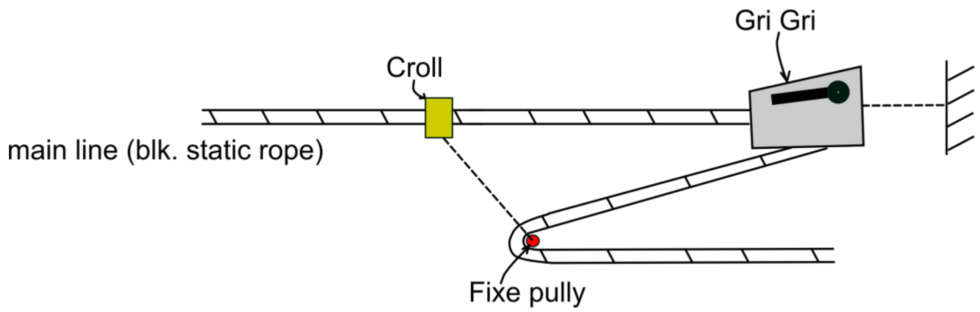


Figure 4. Three to one pulley system that was described.

The figure of eight-on-a-bight on the fixed end was so tight, that they were left on the rope and **could not be opened** between times of rigging of the traverse use – verifying that the pretension in the system was likely to be very high.

Loading

The climber's hands held on black low stretch upper rope, whilst they walked along a second rope. Often the climber would fall on to sling lanyards attached to the black low stretch upper rope. The failed rope was a semi static 10.5 mm PA Beal rope that was used for rigging the static rope to an anchor point (tree).

In this incident, the system failed after the fourth loading on this occasion of use. A larger than average client (assuming 100 kg) fell very close to the tree anchor onto the black static rope (assuming 1 m away). The climber fell onto lanyards that were made from slings (static tape, assuming 1m).

It is entirely possible that the ropes dynamic safety limit was exceeded. The specification data states that the rope is capable of 15 falls exceeding 100kg (1 kN of force, see Appendix II). With a highly tensioned rope, it is possible to produce very high tensions in the main line as the angle of the rope approaches 180°, shown in Figure 5.

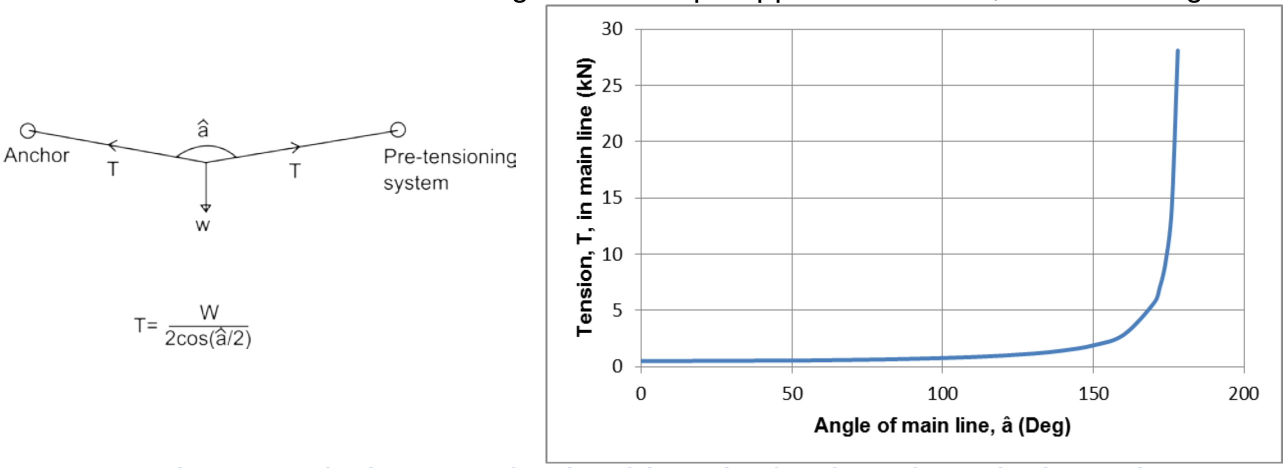


Figure 5. Tension in rope as a function of the angle – for a force of 981 N (100kg mass).

* acknowledging Mr A. Huyton's input of tensions in the main line.

This repeated fatigue loading at the pursuits centre, combined with environmental fatigue (the rope appears to be very dirty and old, see Figure 4 and [2].), and the stress concentration of the small radius of the screw gate all contributed to the failure of the rope. Given that the rope failed at the stress concentration caused by the screw gate, rather than the knot, one could postulate that the rope will have failed at somewhere between 30-70% of the maximum strength of the rope [3]. It is interesting to note that the tree anchor rope failed rather than the black main line despite the rope diameters being similar (10.5 mm versus 11 mm). The tension in the tree anchor rope being estimated as 0.58 times the main line tension. It is possible that this was due to the tree anchor rope being left outside between seasons, whilst the black main line was packed away during the winter.

Given the information that was received, unfortunately, it is not possible to conduct an accurate stress analysis. However, it can be shown that with this set up, and the basic assumptions that were outlined, that the climber could easily apply a load in excess of 10 kN on to the system, and thus contribute to the failure of this set up [4].

Figure 6. Image showing signs of environmental damage and dirt on the sample rope.

Signs of bad practice/Mis-use

- 3:1 pulley system (actual mechanical advanrtage of 2.5 when friction is considered), using all participants to remove slack in the rope.
- Unable to open knots between use.
- Repeated re-tensioning after every crossing.
- Very dirty, old rope: possible signs of environmental degradation.
- After questioning by the advisor, it was found out that a month previously; a Gri Gri had had its handle spring broken when trying to release this system -such was the pre-tension in the system.
- A local Instructor had also previously needed to cut the rope in order to release tension in the system for dismantling.

2. EXAMINATION

The rope in question is a Beal 10.5mm Spelenium semi static (see Appendix II for rope specifications). Optical microscopy was conducted on the cut end of the rope, and a sample from the failed end of the rope. There are obvious differences between the two samples of rope, shown in Figure 5.

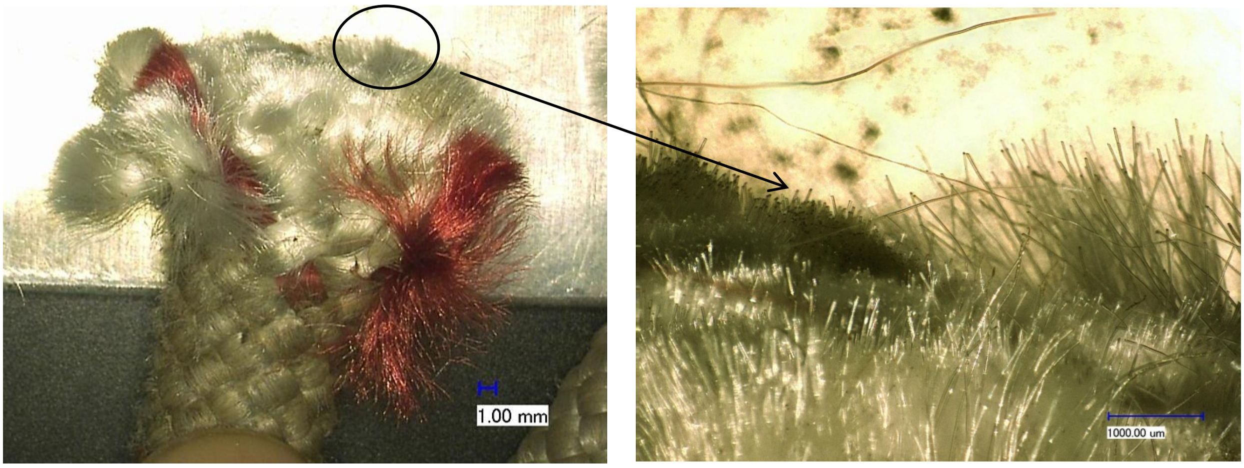
(a) (b)

Figure 7. Images of (a) a cut end and (b) the failed end of the semi static rope.

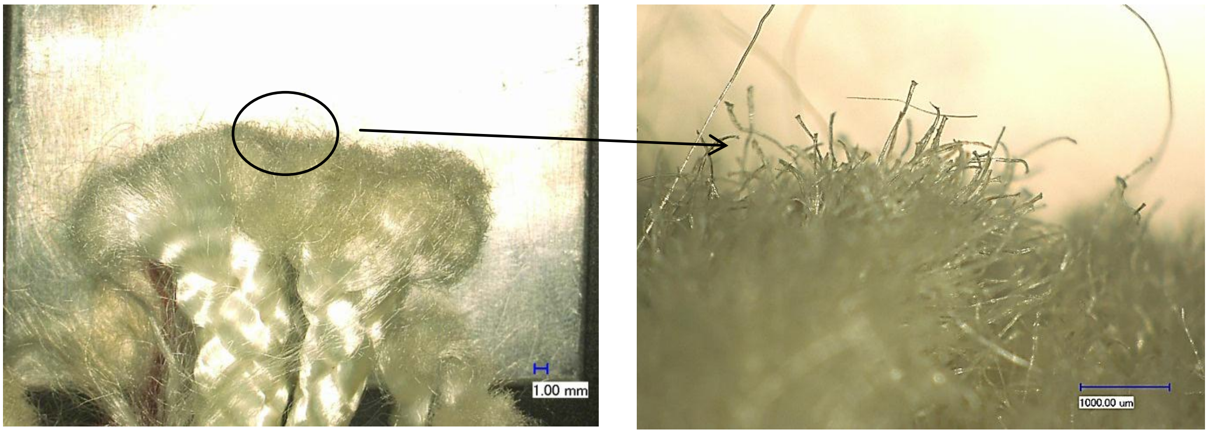
The failed end of the rope shows that the core is exposed a reasonable length down the rope, about 40 mm at each end, shown in Figure 6. It is clear from the image that the cores are kinked to the left (in the images), hence indicating plastic deformation having occurred in the polyamide (PA) core of the rope. When the rope was examined, no evidence of failure due to cutting or abrasion could be identified.

Figure 8. Close up images of the failed end of the rope.

There was significant evidence of necking of the fibre ends close to the failed region. This is indicative of a quasi-static or fatigue type loading from the applied tensile load. Final failure obviously occurred via a dynamic load applied to the system; however, it seems that damage had already occurred to the rope from the rigging.



(a)



(b)

Figure 9. Microscopy images of (a) a cut end and (b) the failed end of the semi static rope.

If one compares the failed fibres and cut fibres at high magnification (Figure 6), distinct differences can be seen. The cut fibres are straight, aligned, and have clean ends at the point of cut. The failed fibres show evidence of fibrillation and tensile drawing, indicative of a tensile loading failure. It is most likely that this initiated at the core, on the outside of the rope (side not in contact with the carabineer), and progressing through cross section of the rope.

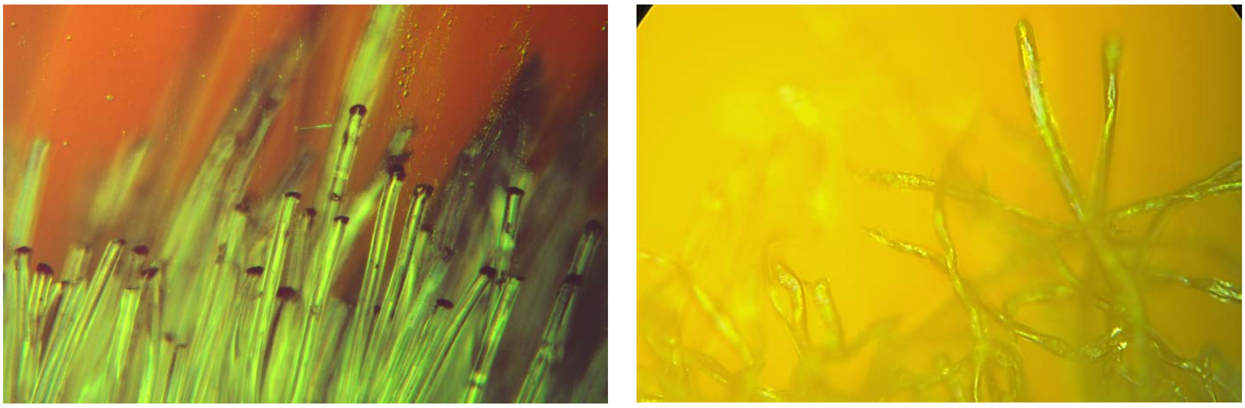


Figure 10. High magnification microscopy of the rope, showing (a) a cut end and (b) the failed end of the semi static rope.

* with thanks to Fachochschule Nordwestschweiz for use of optical microscopy facilities.

Chemical analysis of the rope was attempted to eliminate any solvent related damage to the rope by chemistry researchers at the ETH-Zürich. Please refer to Appendix III, explaining their attempts and reasoning for lack of evidence of any chemicals – had they been present.

* acknowledging Mr M. Roggen's help with the analysis.

3. DISCUSSION

It appears that the advisors initial evaluation is correct, and that the rope failed due to mechanical overloading and environmental degredation.

The instructors believed that a very tight rope was the best practise for a Tyrolean traverse set up. Re-training of the instructors at this centre is already in place.

Perhaps a short article on best practises when working with tensioned systems should be considered i.e. Tyrolean traverses or slack lines? Perhaps such a document exsists and a reminder is needed if some time has passed since publication.

4. REFERENCES

1. *Image of a Postman's walk,* 2012. Available from: ://www.kingswaycentre.co.uk/index. .
2. Nikonov, A., I. Saprunov, B. Zupancic, and I. Emri, *Influence of moisture on functional properties of climbing ropes.* International Journal of Impact Engineering, 2011. 38(11): p. 900-909.
3. Sterling_Rope, *Guide to Rope Engineering, Design, and Use,* Available from: .sterlingrope. .
4. Attway, S.W., *Rope System Analysis,* 1996. Available from: ://lamountaineers.org/xRopes. .
5. Beal_Ropes, *Spelenium 10.5mm rope,* 2012. Available from: bealplanet.comsportanglaisall-semi-statiques.php.

Appendix I - Original Correspondence

From:
Sent: *24 March 2011 18:27*
To: *Dan Middleton*
Subject: *RE: Testing of a rope - from Edward Kinnear*

Helllo Dan
Thanks for the reply.
I visited the site and had it rigged by the member of staff on 'incident' day and spoke to him and others about how the system is used (or should I say abused?)

Iam confident now that the cause of the failure was due to excessive mechanical over tensioning, due to the misbelief that a tight rope was a better rope.
As i described on the paper it was used as a postman's walk (hands held onto this rope as the support and safety line) and falls were taken off the lower foot rope onto this line.

This main line was black 'static rope' and the bit that broke was the evidently semi-static single anchor rope, tied as a single loop round the tree. the angle at the breaking point (a 10mm dmm steel krab - clean inner radius) was 50-60 degrees.

It was the practice to use a Gri Gri as a tension capture device (with a Croll and Fixe pulley attached to the line to create a basic 3:1 pulley) ALL participants pulled on the rope to tighten and then a client crossed - inevitably falling - and everything retensioned again and again etc etc. After the fourth tension a larger client went out and fell onto sling lanyards (with an almost certain dynamic fall) nearer to the broken end rather than in the middle of the lines.

There are other indicators that have led me to believe that over tensioning (and removing quite literally all stretch out of this short section of 11 metres of rope) is the reason for the failure. After questioning it was found that a gri gri a month before had had its handle spring broken when trying to release the tension on it and that there was talk of a local instructor using the same system having to cut the mainline to release tension.
Also found in the black mainlines were fig 8 on a bight knots that were so tight (it was these that were clipped into the anchor at the non tension end) that they had not been undone after use and just left there in stores.

Due to the work load of the centre I could not wait for your conclusions (although I am obviously still very interested) and have implemented retraining in using a system that adopts current best practice when using tensioned ropes (and hopefully retrained the attitude of some of the instructors towards tight ropes!).
I can ask whether any of the ropes exist, but they have all been gashed due to the tensions involved. How much do you need for tensile testing? as I can ask.

I hope this all helps

Regards

Appendix II – Rope specifications

*Available from Bealplanet [5].

Appendix III - Chemical analysis

***From**: Markus Roggen [mailto:markus.roggen@org.chem.ethz.ch]*
***Sent**: 29 June 2011 09:02*
***To**: Masania Kunal*
***Subject**: Rope analysis*

Dear Dr. Kunal Masania

After a long debate with the specialist (also a mountaineer) from the mass spectroscopy group at the chemistry department of ETH Zürich, CH, we came to the conclusion that a chemical analysis of the piece of rope in question would not yield any conclusive results to confirm or deny chemical damage.

The piece of rope in question shows already strong signs of use and the broken as well as the cut end of the rope have been contaminated due to its transport and handling. If a chemical analysis of material from the breaking point would be undertaken, a multitude of chemicals would be found, and due to the limited sample and recourses some compounds would not be identified.
Chemicals that are expected to be found on the rope are aside from the organic material of the rope, process chemicals involved in manufacturing the rope, additives to improve the performance of the rope (often patent protected, therefore difficult to identify), substances from previous use of the rope (mood, organic material) and most important all the substances present on the fingertips of people who have handled the rope after breaking.

With all these substances present on the rope, a conclusive analysis of any chemicals that might have contributed to the failure of the rope cannot be given.

Regards
Markus Roggen

Department of Chemistry
ETH Zürich
Switzerland