ROPE WEAR IN CLIMBING AND IN LABORATORY

Decay in dynamic performance of ropes due to wear

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Introduction

Research on rope wear is a very difficult task; the efforts devoted to it by the UIAA Associations up to now are by far inadequate. In addition, it was not possible to rely on a consistent support by yarn and rope manufacturers. For these main reasons not much has been accomplished, though the subject has been studied for more than thirty years now.
The Materials and Techniques Commission (CMT) of the Italian Alpine Club has programmed a wide range of experiments, both in laboratory and in real mountaineering and climbing. The first results are reported here.
First of all let's make it clear that it's improper to talk about "rope ageing"; it's only **wear** (or more rarely environmental effects) that causes rope degradation: in fact, contrary to all expectations, the performance of a properly stored rope does not decay with time. This has been proved by testing dynamic performances - measured at the Dodero - of several ropes kept in-house for more than 15 years without using them. Tests results (impact force, number falls etc.) were equal to the values quoted by the manufacturer[9]; this behaviour is confirmed by all rope manufacturers.

Environmental effects

A companion paper by Gigi Signoretti deals with the effect of ***sunlight and water/ice*** on rope resistance.
Other ***natural atmospheric agents*** could be mentioned as possible causes of deterioration of rope performance. However, the effects of oxidation, heating due to sun exposure, air humidity and pollution are definitely negligible[3] compared to sunlight effects on polyamide. Pigments and additives used by manufacturers to reduce the effects of UV radiation act as stabilizers against other atmospheric agents as well.
It's very difficult to give a valid information concerning damages caused by non-natural and natural agents. It is only possible to mention the most dangerous ones: chemical solvents, acids, esters, amides, saline solutions, oil products (petrol, diesel oil, liquid fuels, hydrocarbons etc.), stickers and glue, biological agents (fungus and moulds). The effects of these agents can largely be avoided by careful use and correct maintenance of the rope.
Concerning natural agents, the ropes are able to absorb a great deal of dirt, particularly as crystals picked up from the ground or produced by water evaporation. However, this can only to a small extent explain rope wear: dirt remains mainly on the sheath of the rope, unless its penetration is enhanced by mechanical stress.

Wear

Wear is the real "enemy" of a rope. Its effects, particularly intense in abseiling and top roping, are increased by dirt (abrasive dust penetrating rope, crystals produced by water evaporation, other unknown causes). This phenomenon is enhanced by friction in belaying and abseiling devices, which causes a greater

Photo 1 A - Abrasion of sheath

Photo 1B: Zoom into 1A

attraction of particles towards the rope, charged by static electricity. Damage due to wear occurs primarily on the surface of rope, the ***sheath.*** A study performed by the CMT has shown[7] that the sheath plays an important role in the whole resistance of the rope. In fact, both components (sheath and core) contribute to energy absorption, though their elongation under load is different, depending on construction. The sheath, whose weight is about 30% of the rope, contributes by about 30% to the static breaking load. Dodero tests carried out after cutting the sheath of the rope showed a dynamic resistance decrease from, typically, 8-9 falls to only 1 fall. The reduction in the peak force during the first fall arrest was moderate, but the corresponding increase in elongation was obviously large enough to cause permanent deformations which piled up during subsequent falls. Therefore, to weaken the sheath means to seriously reduce the dynamic performances of the rope. It is plain that superficial abrasions of rope, easily noticeable with naked eye, correspond to breakage of part of the filaments (**PHOTOS 1A and 1B**). The reduction of the static breaking load of a rope can be fairly well correlated to the total number of broken filaments.

Wear due to abseiling

Another study, to some extent related to the one on the role of the sheath , was carried out on the CMT Tower at Padua. Research purpose: quantify the effect of the number of abseil descents and of the type of abseiling device on the decay in dynamic resistance of a rope. For this purpose, a member of CMT weighing about 80 kg (UIAA standard) made 114 descents. He used a popular type of rope, diameter 10.5 mm; the abseiling devices were Figure-of-Eight and Robot. In both cases 1-7-49 descents were made. The rope specimens were observed both with the naked eye and with an optical microscope; standard Dodero tests were performed.

By visual inspection, only the specimens related to 49 descents with Figure-of-Eight were noticeably damaged. In fact, even with the naked eye

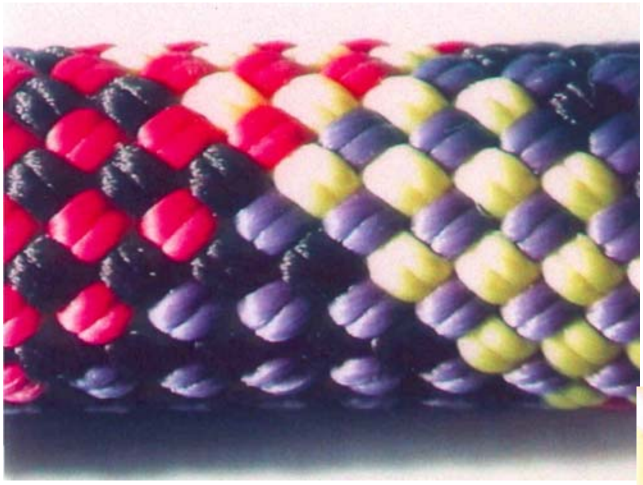


Photo 2A: After 7 rappels with fig-of-eight

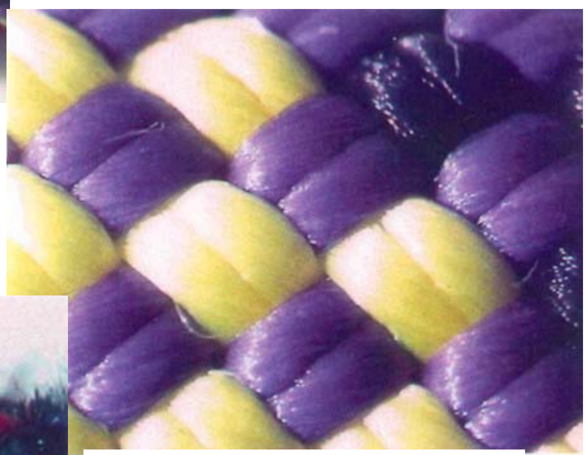


Photo 2B: Zoom into 2 A

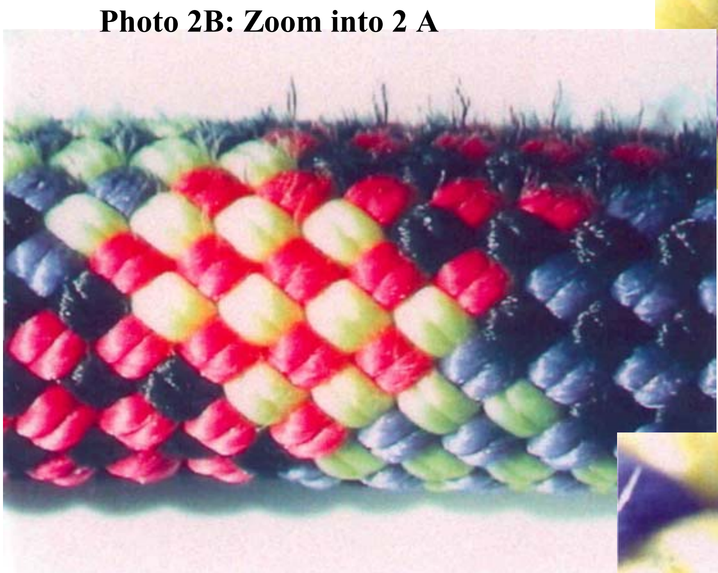


Photo 2C: After 7 rappels with fig-of-eight

Photo 2D: Zoom into 2 C

the presence of broken

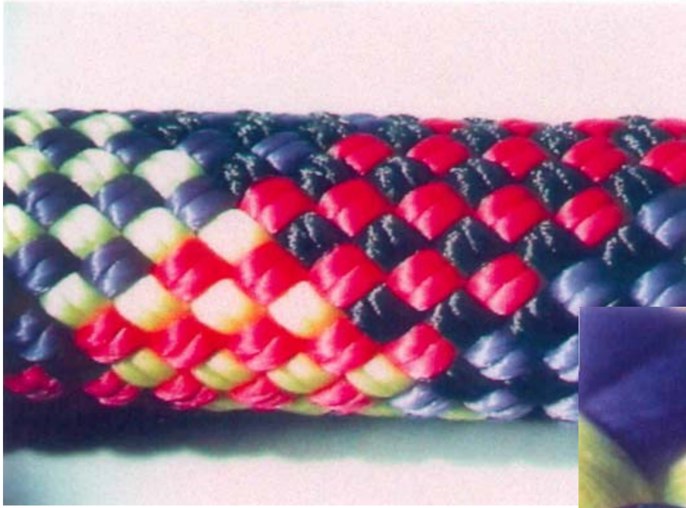


Photo 3A: Sheath of a new

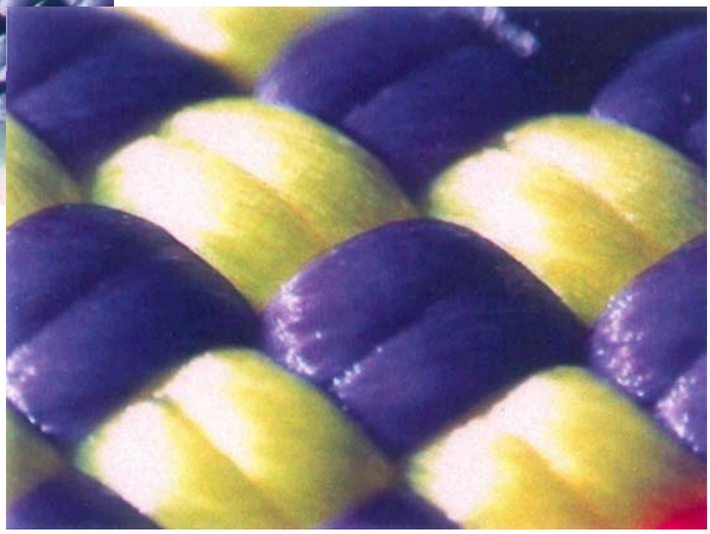


Photo 3B: Zoom into 3 A

Photo 3C: After 49 rappels with ROBOT

Photo 3d: zoom into 3c

filaments causing the characteristic superficial down of the sheath was well visible (**PHOTOS 2A,2B,2C,2D**). Breaking tests done on several strands showed a reduction in breaking strength of about 35%, in very good agreement with the percentage of broken yarns counted on the strands. This result caused concern, due to the important contribution of the sheath to the total rope strength; this concern was confirmed by tests on the Dodero. Indeed **(TABLE.1),** after about fifty descents with Figure-of-Eight the dynamic resistance of the rope (that is the number falls sustained at the Dodero) is reduced by about 1/3.
As can be seen from (**PLOT 1, see annex power point presentation)**, this decay is much faster at the beginning than after continual use (an almost straight line on a logarithmic scale).
This remark is to some extent comforting. Indeed it shows that even after thousands of rappels [*rappel* is the French word for the German *Abseil*] (a hardly imaginable number during the life of a rope) the rope performance could still be considered good. However, it points out the effect of the type of abseiling device used. In fact tests done with the abseiling device Robot (**PHOTOS 3A,3B,3C,3D**) don't seem to seriously affect the dynamic performance of the rope.
It's important to underline that the descents were done about every 3 minutes and the operator always descended with extreme care. In case of fast and/or jerky descents, higher temperatures can be generated and cause considerable damage to the sheath, almost like that produced in holding a fall with a belaying device (**PHOTOS 4A,4B**).

Wear in laboratory and on the field (mountaineering and/or climbing)

Is it possible to quantify rope decay with use? It's not easy to give a

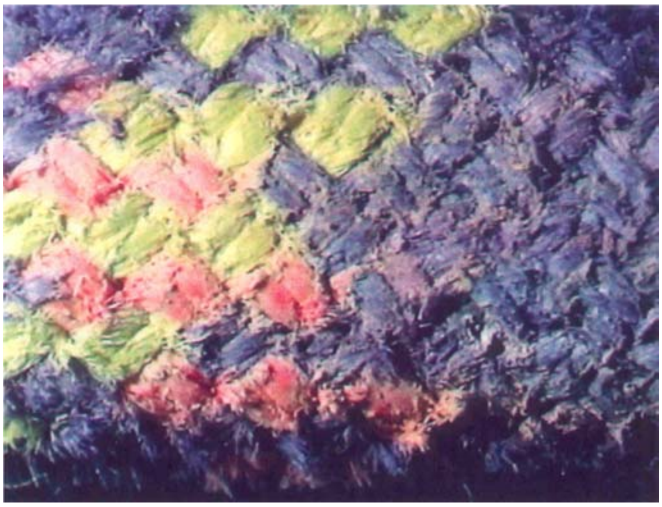
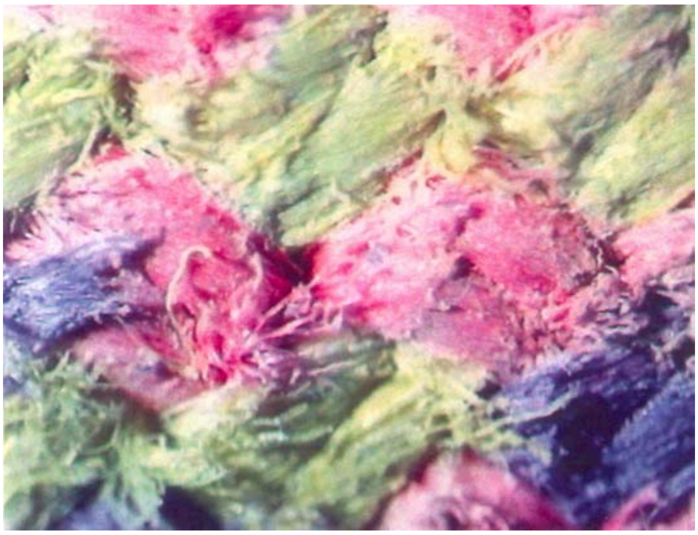


Photo 4A: Fusion of sheath filaments

Photo 4B: Zoom into 4 A



definite and plai
n answer to this question. Ropes are used in various ways: in climbing sites (and subjected to a few or a lot of falls), in mountaineering with different rocks and soils (granite, limestone, ice, mixed etc.); in addition, the speed in abseiling and top roping varies from slow to very fast.

One thing we clearly know: the main cause of rope wear is the combined effect of the rubbing against rocks, mechanical stresses (carabiners and belaying devices), dust and small crystals that penetrate the sheath. The number of metres climbed matters, not the age of the rope.

Research carried out by the CMT[1] [2] and elsewhere[4] has provided an interesting contribution to the understanding of the complicated mechanisms that produce the decay of rope performance. However, it hasn't produced enough information to improve the evaluation of rope deterioration in quantitative terms. At present, the only valid information in this context is given by the research carried out during the '90s by Pit Schubert[5] [6]. By testing ropes used in climbing and mountaineering, Schubert was able to quantify the decay in dynamic performance of a rope as a function of the length of its run in climbing sites or in the mountains.

In the first research, the *static breaking load on an edge* was reported as a function of use (expressed in metres) in different conditions, the way it was used (climbing, abseiling, both) and the environment (limestone or granite). The use of an edge corresponds to the way the ropes really break in mountaineering; the use of static tests instead of dynamic tests is still under evaluation today, however the results clearly showed the dominant effect of abrasion and mechanical stress (abseiling, friction on rock and carabiners) on the deterioration of a rope. The importance of the environment was also shown: different decay curves can be plotted for ropes used in granite and limestone.

In the second research, the *decay of the dynamic performance* of the rope was evaluated, based on the analysis of about thirty ropes used by climbers and mountaineers in different conditions. It's interesting to point out that these tests were done on the Dodero, using classical and sharp orifice edges with different curvature radii: the relative reduction of the number of sustained falls was about independent of the type of edge used (**PLOT 2 see annex power point presentation**).
The plot shows that after climbing 5.000 metres (equivalent to about one year of *average* (?) use) the dynamic resistance is reduced by 50%. After climbing 11.000 metres (one year of intense use) the residual resistance goes down to 30%. A remarkable and perhaps unexpected decay, however in a fairly good agreement with other results[1] [4].

<u>Present work of the CMT</u>
The CMT is now engaged in a research on this subject. We hope to get significant results in the near future. The research is carried out with artificial wear as well as with real use in climbing and mountaineering.
In the artificial wear machine, a long annulus of rope is pulled trough a braking device, simulating an abseiling device; the rope can be dry or wet, clean or made dirty with granite or limestone particles of controlled size. One cycle of the annulus is considered equivalent to one abseil or 50 m climbing length.
The second working area, like Schubert's study, is based on results obtained by rock climbing with various types of rope (single rope, half ropes or twin ropes*)* of different makes, used by skilled climbers.
The work is expected to continue for a few years, with both artificial and "real" wear. ***The first results***, where real use by experienced climbers is extended up to 30,000 metres, are presented in **<u>Tables 2 to 6 (</u>see annex power point presentation**).

The results of the dynamic tests, made on the Dodero according to UIAA standards, show that new and used ropes generate about the same holding force on the first fall. This means that wear does not affect elongation on the first fall, but leads to plastic deformation and/or breakage of filaments, which produce cumulative effects in the subsequent falls.

It's important to point out that the results - particularly those referring to artificial wear - are in a very good agreement with Pit Schubert's (**PLOT 3,**

see annex power point presentation). This seems to confirm the validity of procedure adopted by the CMT for artificial wear. This comparison is possible because Schubert's curve is valid for standard Dodero as well as for sharp- edge Dodero tests.

In conclusion, may we remind the reader that our data refer to numbers of falls held on the Dodero, that is in a test where the rope is clamped at one end. In real life, dynamic belay normally occurs in holding a fall; this means that the characteristics of a rope are less important than on the Dodero
However, the Dodero test is extremely important in evaluating rope performances, because it is clearly reproducible and provides critical conditions that could occur in practice, in case the dynamic belay fails (for instance: badly working belaying device, rope caught in a crack etc.).

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Annex po power poitn presentation.

TABLE 1 – Number of rappels and rope strength
PLOT 1 - Dynamic strength of rope vs. number of rappels and device
PLOT 2 - Dynamic strength of rope vs. rope run in climb/abseil (Pit Schuberts's data)
TABLE 2 - Artificial wear and dynamic strength
TABLE 3, 4, 5, 6 - Dynamic strength vs. rope run in climbing / Various ropes
PLOT 3 - Artif. wear and rock climbing. Comparison with Pit Schubert's data