

# **Cognitions from the Schilthorn Incident Regarding Track Rope Maintenance**

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Max Baumann, born 1955, V.P. Marketing & Sales with a 30 year Fatzer wire rope history, 25 years of which on the market front serving ski lift and ropeway clientele all over the world. Although Max lives and works in Switzerland he is well known in Ski Areas of North America.



# Cognitions from the Schilthorn Incident Regarding Track Rope Maintenance

Max Baumann<sup>1</sup>

The wire rope as both a safety component and an intensely used wear-part influences the ropeway system safety for all phases of the service life. Its great advantages are its redundancy (interacting of a great number of stranded wires that form the rope) and its ability to call attention long before a dangerous condition may arise, thanks to physically recognizable criteria such as corrosion, wire breakage.

An officially called systematic check-up - after the Schilthorn incident - at cableways of identical design unfortunately brought to light an unpleasant scene regarding wire rope maintenance practice: a very dangerous neglect of the appropriate visual inspection and maintenance had sneakily spread out.

This presentation shall address enhanced methodologies, with a focus on track ropes, for the

- prevention of rope damaging in the design phase, during installation and in operation
- due rope preparation (cleaning)
- finding and assessing of impending or existing damages
- skilful restoration, and repair of existing damages
- continued monitoring of both existing and repaired damages

which are essential for the substantiation and evidence of the safety of a ropeway system and which are indispensable premises to declare and ensure safety to operate at any time.

The ropeway design engineers shall be reminded of material and design prerequisites for the prevention of wire rope damage and for the ease of the subsequent rope maintenance. And the procedures of wire rope work (e.g. stringing, rigging, relocating) shall be questioned and optimized continuously, with regard to damage prevention.

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# Cognitions from the Schilthorn Incident Regarding Track Rope Maintenance

Max Baumann<sup>1</sup>

Wire rope is a force transmitting element with moving parts (wires, strands, core), that is exposed to a complex stress collective of tension, flexion and compression. It is subjected to mechanical wear as is any other moving machine element. The wire rope as both a safety component and an intensely used wear-part influences the ropeway system for all phases of the service life.

It's great advantages are it's redundancy (parallel interacting of a great number of stranded wires that form the rope) and it's ability to give plenty of warning long before a dangerous condition may arise, thanks to physically recogniceable criteria such as corrosion, wire breakage etc.

After the 'Schilthorn Incident' (December 2004) an official systematic checkup at cableways of identical design unfortunately brought to light an unpleasant scene regarding wire rope maintenance practice: a very dangerous neglect of the appropriate visual inspection and maintenance had sneakingly spread out.

This presentation shall address enhanced methodologies, with a focus on track ropes, for

- the prevention of rope damage in the design phase, during installation and in operation
- the regular and diligent visual examination<sup>2</sup> in the utilization phase
- the due rope preparation (cleaning)
- the finding and assessing of impending or existing damages
- the spotting of 'new' kind of damages (e.g. HISCC)<sup>3</sup>, the exploration of their onset and propagation mechanisms, and communitywide publication
- the skillful restoration, and repair of existing damages
- the continued monitoring of both existing and repaired damages

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<sup>2</sup> see paper Georg A. Kopanakis: "The Importance of the Visual Inspection of Ropeway Ropes"

<sup>3</sup> HISCC: hydrogen induced stress corrosion cracking

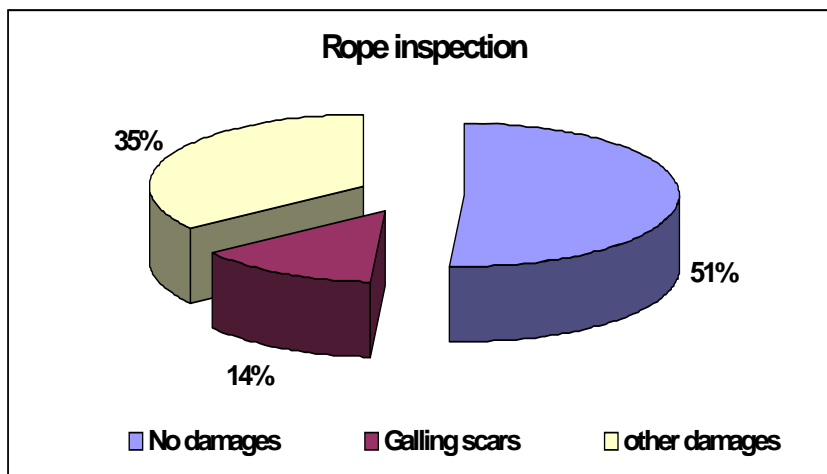


All statements and conclusions herein do reflect the rope manufacturer's view, and are related mainly to exterior damages in 'standing' locked coil ropes (track ropes) of aerial ropeways for public transportation.

The cited incident, without any human injury, was in a way a stroke of luck for the ropeway community, because it has shown that:

- ▶ this kind of damage (hydrogen induced stress crack corrosion) occur in wire ropes, too.
- ▶ dangerous damages have spread unnoticed as a result of neglect visual inspections.
- ▶ both, a thorough visual inspection of the prior 'appropriately cleaned' rope surface and a prompt and professional repair in case of need, are essential preconditions for ropeway safety.

Following the “Schilthorn Incident” the Department of the Environment, Transport, Energy and Communications of the Swiss Federal Office of Transport (FOT) ordered a systematic inspection of all type-similar ropeways in Switzerland, where track rope relocations over deflection saddles had already been conducted . The result for these 104 ropeways is shown in the following chart:



The cases with scars of galling (irregardless of their dangerousness) did represent 14% of all track ropes tested, but 28% of those track ropes found damaged!

It is important to underline that the inspections were limited to rope portions slipped plus rope on the terminal saddle

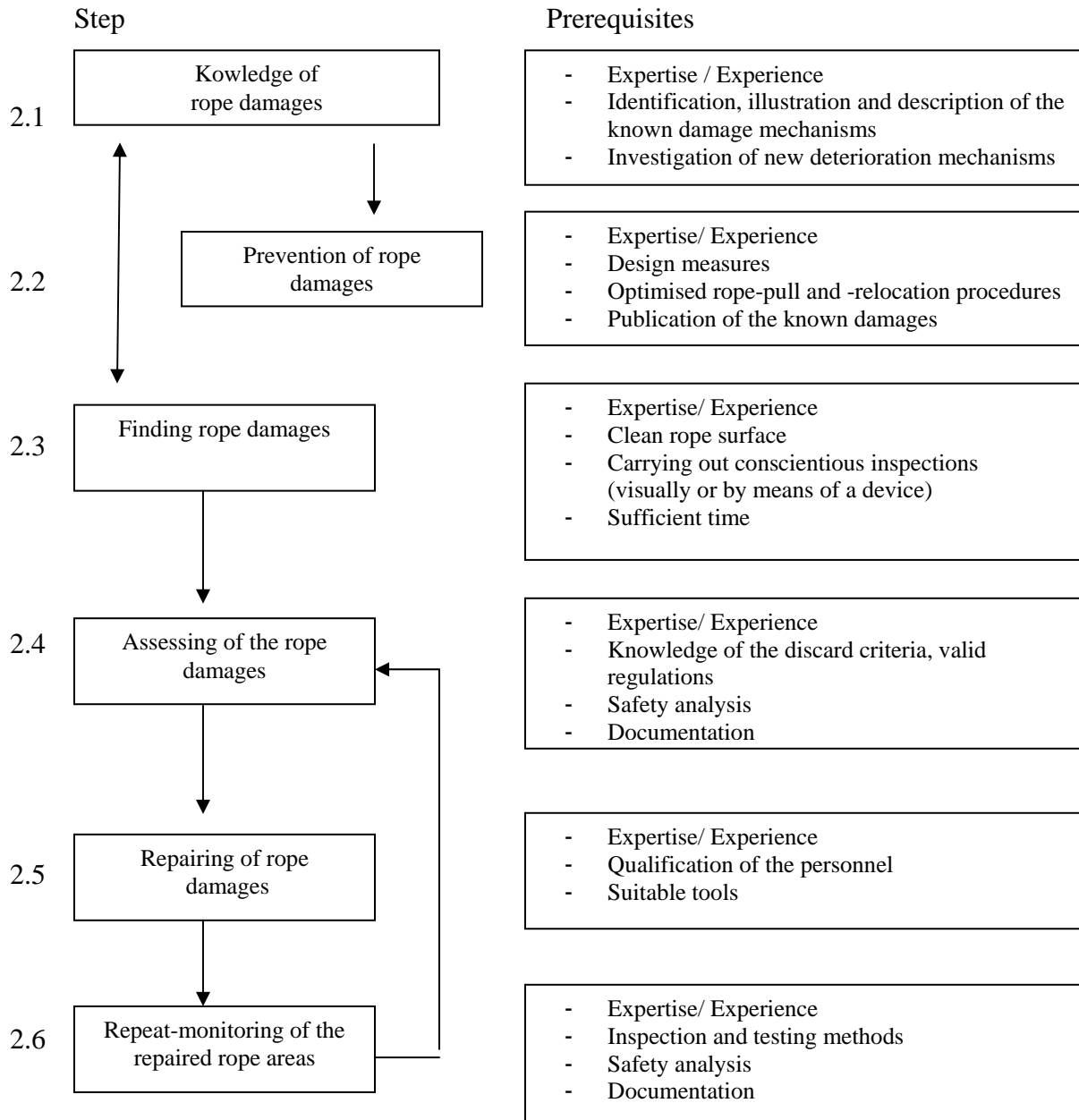
The above results led to the question whether the detected damage patterns must be suspected in other rope sections and in similar ropes in other countries, too. An extensive investigation was therefore initiated, at the tramways we had access to, that unfortunately proved the worst apprehensions. It was found by coincidence, that this particular pattern of damage not only can occur on track ropes of aerial tramways with steel deflection-shoes, but also when a hauling rope flips over the track rope e.g. during an emergency stoppage, and is sliding along it.

So the real potential of danger is by far not affirmed yet and therefore cannot be eliminated.



## 2. Procedural method

The current procedural method for preventing, finding and repairing the existing surface damages on track ropes consists of 6 steps.



The expertise and the experience are evident preconditions ensuring an efficient and correct process. Therefore is the cooperation of all expertise carriers of rope and ropeway manufacturers, authorities, control and testing laboratories etc. inevitable.

The objectives and preconditions for each process step are described in the following paragraphs.



## 2.1. Knowledge of rope damages

Objective: The personnel (maintenance staff, riggers, mechanics and inspectors) involved with locked coil track ropes should be able to recognize, identify and roughly assess exterior rope damages known to date, based on the following example list (from experience - list not exhaustive).

galling scars



track rope jerked over a steel shoe [slid under high pressure]

alien metal build-up



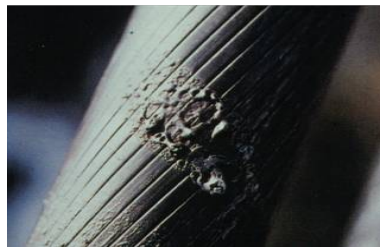
haul rope slid along a track rope after a flip-over

inhibited sliding of the wires



lack of lubrication

fusion traces



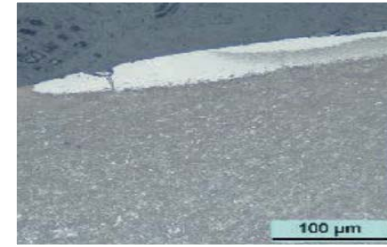
lightning has struck the wire rope

electrical current



welding works in the vicinity of the track rope

martensite formation



e.g. due to a rope derailment, slippage of a rope clamp etc.

deep grooves, scratches



e.g. from detached grease-nipple balls protruded in the saddle shoe

hit marks



unprofessional de-icing by means of steel hammer scale

abrasion



e.g. from clamps continuously scrubbing along the rope

corrosion



inappropriate support material, insufficient protection

corrosion



presence of humidity and lack of lubrication

wire break



e.g. from a slid rigging clamp

## 2.2 Prevention of rope damages

Objective: Prevention of rope damages during the production, transport, installation and operation.

Precondition: Knowledge and understanding of the rope, its function and its operation, of its technical environment and the elements in contact and of the actions taking place during the service period (e.g. rope relocations, renewal of the cast sockets etc.) is inevitable.

### 2.2.1 Design of components in contact with the rope

The function of components holding, guiding, supporting or deflecting wire rope and their assembling process need to be taken into consideration at the very beginning of the design phase. All components in contact with the rope, in addition to their main functional purpose, should at least meet the following requirements with respect to the rope:

- ▶ all the eventual “operating situations” should be taken into account even if they are hardly expected, like e.g. the rope relocation.
- ▶ design should accommodate changing conditions and an eventual movement (e.g. settling, thermal or elastic expansion etc.) as to prevent sliding between the element and the rope that may cause wear.
- ▶ both design and material selection should ensure a “gentle treatment” of the rope. Finally no element should trap or retain moisture.
- ▶ design should enable re-lubrication.
- ▶ design should enable the accessing of it's rope-contacting faces and the rope surface, for inspection and re-adjustment purpose.

### 2.2.2 Optimizing the rope-work procedures

Because of the high risk potential, the “expertise” of the personnel carrying out the rope-pull or -relocation labor, the quality and suitability of the tools to use and the amount of the scheduled time are all essential.

Prior to the rope-pull all the rope guiding elements have to be checked for suitability, functionality and for their eventual potential to cause rope damage. And the path of the slack rope shall be surveyed along the strung pilot line yet before final pull.

After finishing the rope-pull procedure at least all the rope areas subject to potential damage have to be checked prior to starting up regular operation.



## 2.3 Finding of rope damage

Preamble:

- ▶ A clean rope surface is a most important prerequisite for a proper visual inspection, as is also mentioned in the European Code (EN 12927-6, page 7, para. 5.2.2). Cit.: “Ropes shall be discarded if their condition cannot, or can no longer, be assessed with the current methods of inspection”



What is the state of safety of this track rope?

Locked coil ropes usually get heavily soiled over time by a fouling of lubricant, contaminants and corrosion. Therefore they have to be cleaned prior to a visual inspection.

### 2.3.1 Rope cleaning

**Objective:** Soiled rope and its fixing elements must be clean to allow for a reliable visual inspection of its entire surface.

**Precondition:** Longish wire ropes ask for an efficient cleaning device, suitable for all ropeway systems.

A cleaning device should be capable to remove corrosion, encrusted old lubricant and all kind of contaminants from the rope surface in a simple and efficient way. The 'deep' cleaning should preferably be done on a dry and cold rope, and no washing detergents or any other aggressive agents should be used! Solvents may only be used in small quantities and for local spot cleaning on the rope surface! The cleaning procedure must not provoke any wire damage or change of the rope structure!

These requirements have led to the development of new, purpose-built rope cleaning devices which have been tested and analysed.



Deep cleaned ropes shall immediately be inspected, treated and/or repaired, and relubricated to restore corrosion protection.

**a) A flexible rope sling wrapped around the track rope**

The method is utilizing a flexible wire rope sling, wrapped around the track rope and dead-weighted at one end and is pulled along the track rope. It helps to remove encrusted material and in part surface corrosion.

Only slings made of flexible regular lay wire ropes of low grade shall be used.

This cleaning method is however ineffective on heavily soiled ropes, because the amount of dirt is too much to be removed and therefore is just being distributed on the rope surface.

**b) Dry-ice cleaning**

This cleaning method involves ice pellets which are shot by means of compressed air onto the rope surface. The combined cooling effect and light impact of ice pellets cause grease contaminants to crack away from the rope surface.

The dry-ice cleaning method was very effective for fairly new, lubricated yet not soiled ropes. The cleaning effect on heavily soiled ropes however was absolutely insufficient, and inefficient. The required equipment is bulky, expensive, not everywhere available, and the time required for the cleaning procedure is tremendous. Thus, for heavily soiled longish track ropes this cleaning method is suitable to only a limited extent!

**c) Rotary brush cleaner**

Preamble:

- ▶ No mechanical (abrasion) or thermal (frictional heat) influence should adversely affect the rope to be cleaned.
- ▶ Bristle residues can promote surface corrosion, therefore no copper brushes should be utilized!



rotary brush cleaner

The cleaning method with a rotary brush cleaner has been seen most effective.

A device has been designed and built that fulfils the earlier mentioned requirements. The machine ensures a thorough removal of all lubricant residues, contaminants, corrosion products etc. without causing any secondary damage. The track ropes of all ropeway systems, like aerial tramways with single or double track ropes and bi-cable or tri-cable gondolas can be efficiently cleaned. The brushes lift-off at slack carriers and tower saddles.



track rope cleaning device

The effectiveness of the developed method is illustrated in the following pictures of the same rope area before and after cleaning.



soiled rope



cleaned rope with visible damage

### 2.3.2 Categories of potential rope damages and "critical" points

Objective: Make the visual inspection rational and more effective

Preconditions: 'Subdivide' the installed rope into typical sections of increased deterioration potential and where similar kind of damages may be anticipated.

There are certain points along any 'standing' track rope which should receive more attention than others, since some areas will usually be subjected to greater internal stresses, or to greater external forces and hazards. Carefully identify the most critical points for close inspection - points where damaging is likely to be expected. The same critical points on each installation should be compared at each succeeding inspection.

#### a) in bottom station

##### General

- damaging during rope-pull
- corrosion (open or leaky stations and water draining downhill along the rope)

##### End attachments

- cast socket (missing accessibility)
- corrosion (humidity in the bollard area, corrosive agents used for conserving the bollard wood)

##### Roller chain saddle

- scraping against structure components
- defective roller chain



## Terminal saddle

- derogated slide ability (lack of or poor lubrication)
- corrosion (water draining down along the rope, and poor or lack of lubrication)
- sliding against structural components

## **b) at towers**

### General

- damaging during rope-pull (slippage of rigging clamp)
- corrosion (water running down along the rope)

### Track rope derail clips

- abrasion, scars (too small or zero clearance, unnoticed wearing of saddle-profiles, partially deformed by means of touching brake-shoes)

### Tower saddle

- fretting corrosion, restricted movement (slip-stick effect - poor or lack of lubrication)
- scars (detached grease-nipple balls)

## **c) in free rope span**

### General

- lightning strikes
- alien metal build-up caused by haul rope flip-overs
- scars from activated track rope-brakes
- hit marks from hammer scale de-icing

## **d) at suspended haul rope supports (slack carriers)**

### General

- wire breaks (missing displacement, hindered length-compensation)
- corrosion (water draining down along the rope)

### Clamps

- abrasion, scars (deformations from activated track rope-brakes)

## **e) in top station**

### General

- damaging during rope-pull (sliding rigging clamps, twisted ropes etc.)
- corrosion (open stations)

### Buffer mount

- abrasion (rope sliding against structural components sliding)
- corrosion (humidity)



Terminal saddle

- restricted movement / poor lubrication (displacement of layers, corrosion)

Deflection shoe

- lack of or poor lubrication (scars of galling, corrosion)
- sliding against structural components

End attachment (bollard)

- corrosion (missing inspection, rope maintenance)
- corrosion (moist, decomposed wood linings)

Track rope spare length

- corrosion (humidity, lack of or poor lubrication)

### 2.3.3 Visual rope inspection

Objective: The ropes in use and their fixing elements are to be inspected to ascertain their condition, safety and capability to fulfill the assigned task. Eventual damage and misguided developments shall be identified early.

Precondition: Each wire rope must be inspected and assessed individually. Qualified inspectors with proper tools for a safe, rational and effective inspection.

**Every inspection report is of significance with respect to rope safety for the day of inspection conduct! What about rope safety status the day after?**

Please refer to the paper of Georg A. Kopanakis: "The Importance of the Visual Inspection of Ropeway Ropes".

### 2.4 Assessment of the rope damages

Objective: Evaluation of damages, state of safety and level of the risk potential

Preconditions: Knowledge of the existing code limits and expertise to assess the amount of the adverse influence of the identified damage (safety analysis)

Criteria for the potential risk assessment:

- ▶ What is the number of the affected wires and their position in the rope?
- ▶ What is the amount of the detected loss of metallic area, and is it within or beyond the code limits?



- ▶ Is the strength of the remaining wires adversely affected (e.g. by hydrogen induced stress crack corrosion, thermal influence, deep scars, plastic deformation etc.)?
- ▶ What is the load spectrum?
- ▶ Does the damage have a medium- or long-term impact on the rope? What kind of inspections are necessary and how often should they be carried out in the future?

Given that the rope and system data are known, the above questions can be answered easily in most cases, either on the basis of the results of the visual inspection (damages at the rope surface) or on the basis of the results of an NDT (inner and outer wire breaks)

Situations where no specific knowledge of the actual damage is available and where the question; „Is the strength of the remaining wires adversely affected?“ cannot be answered, call for further investigations. And finally, a rope has to be discarded if its condition, for whatever reason, cannot conclusively be assessed.

**Specific information gained from the investigations and the repairs following the “Schilthorn incident”**

It has been proved that the mechanical properties of wires adversely affected by means of HISCC, do entirely recover, if the alien metal build-up is completely removed in time.

**2.5 Repair of rope damages**

- Objective: Eliminating a potential risk
- Preconditions: Expertise in the function principles of the wire rope, and in the onset mechanisms of wire damages  
Suitable tooling for grinding, cutting and welding of Z-shaped wires etc.

Repair and inspection methods were developed in collaboration with an ND-Testing laboratory and with the Swiss Federal Office of Transport (FOT), and optimized.



With the proper treatment of a wire break separation can further damage potential be eliminated.

Suitable grinding & polishing machines have been evaluated, many different abrasives been tested and work procedures established.





Many repairs and their repeated inspections affirmed that micro-cracks can be removed for good.

Critical wire break accumulations can be repaired by means of staggered wire substitution and field welding, dislocating the weld and butt joints to unobjectionable distances.



**The owner/user has to keep written records of any such conducted wire rope repair whereupon it is important to identify the location of the damaged / repaired spot in relation to a fix reference point, for the subsequent monitoring.**

## 2.6 Monitoring of repaired rope damage

- Objective: Early detection of eventual re-occurrence of the repaired surface damage
- Precondition:
- Appropriate inspection and testing methods as well as experienced inspectors
  - Correct and comprehensible record-keeping of damages and repairs, with indication of their exact position, given as distance from a determined fixed point

### Magnetic particle inspection testing

By means of the ferromagnetic particle examination (also called “Magnaflux Test” / well known in other areas) the existence of surface cracks in ferromagnetic materials can be detected.

It is affirmed that cracks, if entirely ground off (removed), can no more be detected by means of magnetic particle examination: Therefore the appropriate repair method can be successful and no re-occurrence of the damage has to be worried.



### 3 The lessons

The understanding of rope damage onset mechanisms - from the “Schilthorn Incident” and other accidental damages and investigations - and the acquired rope restoration and cleaning methodology made evident to conclude:

- ▶ **The various clamping or safety devices for track strands as well as the rope-pull and the slipping procedures have to be reviewed and improved aiming at the prevention of any rope surface damage.** Appropriate tool- and component-design, the provision of rope access-points and the accessibility of critical rope sections during operation are therefore important prerequisites that shall be considered already in the design stage of a new ropeway system.
- ▶ **Conscientious visual rope inspections are inevitable for the rope safety and a long service life.**
- ▶ **A clean rope surface is an inevitable prerequisite for an effective visual inspection.**
- ▶ **Visual inspection and ND-Testing are complementary to each other and can by no means substitute each other.**
- ▶ **Damages detected by NDT methods like the magneto-inductive test, are in the vast majority irreparable broken wire defects, whereas surface damages detected by visual inspections can be repaired in most cases. Visual inspections therefore help extend the wire rope service life.**
- ▶ **It is indispensable to communicate and share the know-how from incidents, about the onset mechanisms of eventual damages and their background, with the rope and ropeway industries, trans-nationally.**
- ▶ **Lack of time and cost pressure are deadly enemies of a due rope maintenance!**
- ▶ **Wire rope used properly will serve well; used carelessly or ignorantly it can injure or even kill!**

### References

- 1 Kopanakis G.A: *The Importance of the Visual Inspection of Ropeway Ropes.*
- 2 Anon. (-) Untersuchungsstelle Bahnen und Schiffe: *Untersuchungsbericht über den Schaden am Tragseil “B” der Luftseilbahn Mürren Birg*, www.uus.admin.ch
- 3 Oplatka, G: *Track Rope Incident at the Schilthornbahn*, OIPEEC Conference Athens, March 2006



