

**ONR 24810 – A Comprehensive Guideline for Building Better Rockfall Protection Structures**

**Gernot Stelzer**

Trumer Schutzbauten GmbH  
Weissenbach 106  
5431 Kuchl  
Austria

**Ahren Bichler**

Trumer North America Inc.  
14900 Interurban Ave S., Suite 271 #19  
Seattle, Washington 98168  
United States  
1(855)-732-0325  
a.bichler@trumer.cc

Prepared for the 64<sup>nd</sup> Highway Geology Symposium, September, 2013

## **Acknowledgements**

The authors would like to thank all of the members of the ONR 24810 working group that contributed to this valuable document.

## **Disclaimer**

Statements and views presented in this paper are strictly those of the author(s), and do not necessarily reflect positions held by their affiliations, the Highway Geology Symposium (HGS), or others acknowledged above. The mention of trade names for commercial products does not imply the approval or endorsement by HGS.

## **Copyright Notice**

Copyright © 2013 Highway Geology Symposium (HGS)

All Rights Reserved. Printed in the United States of America. No part of this publication may be reproduced or copied in any form or by any means – graphic, electronic, or mechanical, including photocopying, taping, or information storage and retrieval systems – without prior written permission of the HGS. This excludes the original author(s).

## **ABSTRACT**

The influence of the ETAG 27 Guideline for European Technical Approval of Falling Rock Protection Kits, published in 2008, has been relatively far reaching, including here in North America. ETAG 27 makes it possible to compare products, from different material suppliers, through standardized reporting of testing and material data. However, it does not consider best practices for the implementation or the evaluation of safety and maintenance requirements.

A new document published by Austrian Standards Institute – the Austrian national standards body, similar to ASTM and CSA – goes beyond ETAG 27, though in a much more broad spectrum including stabilization with anchoring and mesh/nets, embankments, and galleries. The document is entitled “ONR 24810, Technical protection against rockfall – Terms and definitions, effects of actions, design, monitoring and maintenance”, published in January of 2013.

Herein, the authors focus on summarizing the parts of the ONR specific to catchment fences beginning with the initial site investigation, which results in the input parameters for the numerical rockfall analysis. The semi-probabilistic verification of the design is then explained by the comparison of the impact parameters, such as energy and bounce height, with the resistance parameters of the catchment fence. Furthermore, helpful design and constructive rules regarding anchor design and fence layout are given. Lastly, maintenance and inspection schedules are presented.

## INTRODUCTION

The publication of the ETAG 27 Guideline for European Technical Approval of Falling Rock Protection Kits in 2008 (1) was in response to the increasing use of flexible net catchment fences for mitigating rockfalls throughout Europe and the need for a unified standard. The document covers only the methodology by which systems are tested and how manufacturers must report material properties and system characteristics. It replaces national standards that had until then been enforced differently from country to country (e.g. 2, 3). Since similar national standards were not in existence in North America, the ETAG 27 guidelines have also become increasingly cited for projects that use rockfall catchment fences both in Canada and the USA.

A new tool for agencies, consultants and construction companies involved with rockfall mitigation was recently published by the Austrian Standard Institute, the Austrian national standards body similar to ASTM or CSA. This comprehensive document is entitled: “ONR 24810, Technical protection against rockfall – Terms and definitions, effects of actions, design, monitoring and maintenance” (4). Unlike ETAG 27, it focuses not only on rockfall catchment fences but also on many other forms of mitigation including, stabilisation with anchoring and mesh/nets, embankments, and galleries. It does not cover system testing or material properties but instead concentrates on how mitigation structures are implemented, in particular the standardization of site investigation, design, construction and maintenance.

Only those sections of the ONR 24810 that pertain to rockfall catchment fences are discussed herein. The following themes will be summarized: Site Investigation, Semi-probabilistic Design, Anchor and Foundation Design, Constructive Rules, and Maintenance and Inspection.

### Consequence Classes

A fundamental part of the ONR 24810 is its dependency upon consequence classes detailed in the European Norm EN 1990:2003 “Eurocode: Basis for structural design” (5). The consequence class is a qualitative rating in the case of failure of the system or component being classified with regards to the degree of loss of human life, and economic, social or environmental impacts. Three levels of consequence are defined as high, medium or low as per Table 1. They are arrived at by considering both the effects on the area of protection as well as the effects on the mitigation system’s integrity which yield a global consequence class.

<b>Table 1 - Consequence Classes</b>		
<b>Consequences Class</b>	<b>Description</b>	<b>Examples of buildings and civil engineering works</b>
CC3	<b>High</b> consequence for loss of human life, or economic, social or environmental consequences <b>very great</b>	Grandstands, public buildings where consequences of failure are high (e.g., a concert hall)
CC2	<b>Medium</b> consequence for loss of human life, economic, social or environmental consequences <b>considerable</b>	Residential and office buildings, public buildings where consequences of failure are medium (e.g., an office building)
CC1	<b>Low</b> consequence for loss of human life, and economic, social or environmental consequences <b>small or negligible</b>	Agricultural buildings where people do not normally enter (e.g., storage buildings), greenhouses

In the ONR 24810, consequence classes are used to determine the required level of safety of components and characteristics of the planned mitigation structures, e.g. the factor of safety applied to forces used during design, a geometric coefficient applied to bounce heights, or the allowable opening of gaps in a fence after an idealized event. As the consequence level increases, so does the level of safety applied.

## **SITE INVESTIGATION**

Site investigation requires both a desk and field investigation. The primary goal of the site investigation is to verify the hazard and collect information pertinent to the semi-probabilistic design parameters for the mitigation structures. The ONR 24810 explicitly notes that there should be no design of mitigation measures without conducting a thorough site investigation.

The desk investigation collects baseline information and identifies elements at risk and the areas of interest to protect prior to entering the field. It includes the review of historical data, databases, maps (e.g., topographical, geological, infrastructure, etc.) and other sources that help focus field investigations.

The field investigation is subdivided into three zones: initiation, transition and deposition. Each zone is investigated in an attempt to verify and expand information obtained during the desk investigation. Some examples of information collected for each zone are:

### *Initiation zone*

Rock mass characterization, joint and discontinuity patterns and analysis, failure mechanisms, etc.

### *Transition zone*

Morphology, dampening buffers, evidence of frequency, bounce height indicators, etc.

### *Deposition zone*

Site morphology, relief (relative to initiation zone), identification of debris from previous events, evidence of frequency, bounce height indicators, accessibility (in particular for construction and maintenance), location of elements at risk, etc.

Using the information obtained, some preliminary analysis of the data is carried out in order to meet the goal of the site investigation, i.e. block size distribution, event frequency distribution, and bounce height distribution. Homogeneous areas are identified and a pre-selection of locations for mitigation measures are defined.

## **SEMI-PROBABILISTIC DESIGN PARAMETERS**

After obtaining the necessary data, a series of steps are undertaken to perform a semi-probabilistic design of the catchment fence.

## Design Block Selection

The selection of the design block is made in one of two ways: a simplified approach or standard approach. The simplified approach is used in the case that at least one of the following applies:

- Less than 100 blocks present in the deposition zone
- Less than 100 jointed rock bodies present in initiation zone
- Consequence class defined as CC1
- Event frequency falls under EF1 or EF2 (Table 2)

In this case, an expert can define the block based on their experience and information obtained during the site investigation.

<b>Event Frequency Class</b>	<b>Event Frequency n</b>	<b>Fractile for Design Block Size</b>
EF 4 (very high)	$n \geq 10$ ( $\geq 10$ events per year)	$V_{98}$
EF 3 (high)	$1 \leq n < 10$ (1 to 10 events per year)	$V_{97}$
EF 2 (low)	$0.03 \leq n < 1$ (1 event per year to 1 per 30 years)	$V_{96}$
EF 1 (rare)	$n < 0.03$ ( $< 1$ event per 30 years)	$V_{95}$

In contrast, if none of the criteria for the simplified approach apply, then a standard approach to the block size design is required. This implies that the design block is the 98<sup>th</sup> fractile of the block size distribution recorded during the site investigation when the frequency class is rated as very high, or the design block is the 97<sup>th</sup> fractile in the case of a high frequency (as per Table 2).

## Modelling of Energy and Bounce Height

State-of-the-art modelling techniques for trajectory analysis are employed using the data obtained from the site investigation and the design block. The results are verified with the site data to ascertain the realism of the model. The distributions of the modeled energy and bounce heights at the pre-selected location for the mitigation structures are reported and used for the verification of the mitigation design.

## VERIFICATION OF DESIGN PARAMETERS FOR CATCHMENT FENCE

The basis for the verification that a particular catchment fence is an appropriate mitigation measure for a site follows the basic principle that the design values for the event are less than or equal to the design values of the resistance of the structure (i.e.,  $E_d \leq R_d$ ). Keeping to this, the verification of the energy

capacity and bounce height are carried out independently. In addition, special performance criteria can also be implemented.

### Energy

The verification of the energy capacity of a structure is carried out by comparing the design impact energy ( $T_{E,d}$ ) to the resistance capacity of the structure ( $T_{R,d}$ ). The design impact energy is given as Equation 1 and is equal to the 99<sup>th</sup> fractile of the energy distribution obtained for the location of interest ( $T_{E,k}$ ) with a partial factor of safety ( $\gamma_{E,kin}$ ), that is defined by the consequence class as shown in Table 3.

$$T_{E,d} = T_{E,k} \cdot \gamma_{E,kin} \quad \text{Equation 1}$$

<b>Table 3 - Partial Safety Factor for Impact Energy</b>			
	<b>CC1</b>	<b>CC2</b>	<b>CC3</b>
$\gamma_{E,kin}$	1.00	1.05	1.15

The resistance capacity is defined by the Maximum Energy Level (MEL) reported for a system by the manufacturer as per ETAG 27 ( $T_{k,MEL}$ ) with a reduction factor ( $\gamma_{T,R}$ ) applied as in Equation 2. The reduction factor is dependent on the consequence class given in Table 4.

$$T_{R,d} = T_{k,MEL} / \gamma_{T,R} \quad \text{Equation 2}$$

<b>Table 4 - Partial Safety Factor for Resistance Energy</b>			
	<b>CC1</b>	<b>CC2</b>	<b>CC3</b>
$\gamma_{T,R}$	1.00	1.05	1.15

The suitability of a system with regards to energy requirements is verified when Equation 3 holds true, i.e. the design impact energy is less than or equal to the resistance capacity. If the statement is false, a system with a higher capacity must be considered.

$$T_{E,d} \leq T_{R,d} \quad \text{Equation 3}$$

## Bounce Height

The verification of the bounce height requirement is made by comparing the design bounce height ( $h_{E,d}$ ) with the resistance height of the structure ( $h_{R,d}$ ). The design bounce height is defined in Equation 4 as the 95<sup>th</sup> fractile of the bounce height distribution ( $h_{E,k}$ ), taken at the upper surface of the block (i.e., **a half block height must be added**), for the location of interest with a geometric coefficient ( $\alpha_1$ ) applied that is given by the consequence class found in Table 5.

$$h_{E,d} = h_{E,k} \cdot \alpha_1$$

Equation 4

<b>Table 5 - Coefficient of Bounce Height</b>			
	<b>CC1</b>	<b>CC2</b>	<b>CC3</b>
$\alpha_1$	1.05	1.10	1.30

The design bounce height is then compared to the available nominal heights of the system identified as a plausible system during the energy verification. Available nominal heights are governed by ETAG 27 and are based on the height of the system as tested, whereby:

1. The system cannot be manufactured below the tested height.
2. The system height can only be increased by 0.5 m if tested with a nominal height below 4 m.
3. The system height can only be increased by 1.0 m if tested with a nominal height greater or equal to 4 m.

The resistance height of the system is calculated in Equation 5, where the allowable nominal height of the system according to ETAG 27 ( $h_{R,k}$ ) is reduced by a reduction coefficient ( $\alpha_2$ ) according to the consequence class in Table 6.

$$h_{R,d} = h_{R,k} / \alpha_2$$

Equation 5

<b>Table 6 - Coefficient of Structure Height</b>			
	<b>CC1</b>	<b>CC2</b>	<b>CC3</b>
$\alpha_2$	1.00	1.05	1.10

The verification of the system with respect to height is then validated if the design bounce height is less than or equal to the resistance height as per Equation 6.

$$h_{E,d} \leq h_{R,d}$$

Equation 6

## Performance Criteria

A last set of criteria is defined related to the effects of the MEL impact on the catchment fence. Where, for example, the residual height of a fence is reported and classified under the ETAG 27, the opening of

gaps in the net near post locations are only reported but not evaluated. Gap openings such as this are a common occurrence in systems as elasticity of the net is limited in this area. These openings can allow subsequent material to pass through the system, and indicate a general elastic behaviour of the system. As such, the amount of allowable opening is defined according to the consequence class as indicated in Table 7. Other criteria under this category include what components are allowed to fail/rupture. This extends beyond ETAG 27 where elements such as nets, ropes or strands within ropes are allowed to fail, though they must be reported.

<b>Table 7 - Optional Requirements for Rockfall Catchment Fences</b>	
<b>Consequences Class</b>	<b>Unacceptable Damages During an MEL Test</b>
CC3	<ul style="list-style-type: none"> <li>- No opening of nets greater than or equal to <b>0.2 m</b> below the residual height, between the lower bearing rope and net.</li> <li>- No openings between the end posts and the net greater than or equal to 10% of the nominal height if the end fields are located within the hazardous area.</li> <li>- No rupture of the main nets, bearing ropes or retaining ropes <b>or the strands</b>. Single wires are allowed to break (as long as it is not through the entire strand).</li> <li>- A rupture of the sewing rope or component used to attach the primary net to the bearing ropes is <b>not allowed</b>.</li> </ul>
CC2	<ul style="list-style-type: none"> <li>- No opening of nets greater than or equal to <b>0.4 m</b> below the residual height, between the lower bearing rope and net.</li> <li>- No openings between the end posts and the net greater than or equal to 10% * of the nominal height if the end fields are located within the hazardous area.</li> <li>- No rupture of the main nets, bearing ropes or retaining ropes.</li> <li>- A rupture of the sewing rope or component used to attach the primary net to the bearing ropes is allowed if a new load bearing net border develops as non-positive connection to the bearing rope.</li> </ul>
CC1	<ul style="list-style-type: none"> <li>- No additional requirements. ETAG 27 certification sufficient.</li> </ul>

\* If the lateral openings are greater than or equal to 10% of the nominal height, the length of the line has to be extended by a half module length. If the end module lies outside of the hazardous area this condition can be neglected.

As an example, rockfall catchment fences tested that experienced either a rupture of the net or an opening of greater than 20 cm around the posts would receive full certification but would not be allowed to be used for projects having a high consequence class.

## **VERIFICATION OF ANCHOR AND FOUNDATION DESIGN**

The design of foundation components is a somewhat contentious issue dependent on the project engineer's experience and local regulations. For our purposes, the design of anchor components is limited to rock and soil anchors that are bearing elements which apply both compression and tension forces into the ground and are hereafter referred to as micropiles.

Micropiles are further defined as having a borehole diameter of less than 300 mm and a reinforcement element (e.g., monobar anchor) diameter less than 150 mm. In Austria, the reinforcement element must have a national, i.e. Ministry of Traffic, Innovation and Technology (BMVIT), or a European, i.e. EOTA, approval. In addition, the following requirements apply when using micropiles:

- Minimum borehole diameter of 90 mm except in solid rock, with minimum 20 mm coverage of reinforcement element
- Minimum distance between micropiles is 1 m with the exception of base plate anchors
- Reinforcement element is centred in hole
- Minimum inclination 15 degrees from horizontal
- Injection begins from bottom of hole
- Micropiles that undergo primarily compression must use reinforcement tubes or concrete blocks or similar in the first 0.5 m for weathered or fractured rock or 1 m in soils
- The micropile is oriented to minimize shear loading on the anchor

As with the catchment fence, the verification is divided into two components: an effect side and resistance side.

On the effect side, the maximum force monitored during an ETAG 27 MEL test ( $E_k$ ) is used for determining the design force ( $E_d$ ). If multiple ropes are connected to a single anchor, then **the maximum forces from each rope are added in a scalar fashion**. A partial factor of safety ( $\gamma_E$ ) equal to 1.5 is applied to this force (Equation 7).

$$E_d = E_k \cdot \gamma_E$$

Equation 7

This method of adding forces is extremely important and often neglected resulting in under designed anchors. In many instances forces are added as vectors. If such a summation is used, then every anchor point must be considered individually with regards to the geometry of ropes and anchor positions. This is impractical, unrealistic and normally inefficient with regards to costs. If summed forces are given by manufacturers, they should clearly state how these forces were determined.

On the resistance side, two verifications are necessary: the cross section of the steel reinforcement element, and the verification of the surface between anchor grout and underground.

### Verification of Steel Cross Section of Micropile

The resistance force ( $R_{d,t}$ ) of the steel cross section of the micropile is determined by the product of the cross section of the element and the characteristic yield strength divided by the product of a partial factor of safety ( $\gamma_{s,t} = 1.15$ , as per OENORM B 1997-1-1:2010 (5)), and a model parameter ( $\eta_{Mod} = 0.95$ ) as shown in Equations 8 and 9.

$$R_{d,t} = R_{k,t} / (\gamma_{s,t} \cdot \eta_{Mod}) \quad \text{Equation 8}$$

$$R_{k,t} = A_s \cdot f_{y,k} \quad \text{Equation 9}$$

### Verification of Surface Between Anchor Grout Body and Underground

For the case that pre-production anchor pull tests are conducted, the characteristic value of pull out force ( $R_{t,d}$ ) is defined by Equations 10 and 11. The value of pull out force is the lesser of the average pull out force ( $(R_{t,m})_{mitt}$ ) divided by a distribution coefficient ( $\xi_1$ ) or the minimum pull out force ( $(R_{t,m})_{min}$ ) divided by a second distribution coefficient ( $\xi_2$ ), where the distribution coefficients are defined based on the number of pretests as per Table 8. In both cases a partial factor of safety ( $\gamma_{s,t}$ ) is applied.

$$R_{t,d} = R_{t,k} / \gamma_{s,t} \quad \text{Equation 10}$$

$$R_{t,k} = \min[(R_{t,m})_{mitt} / \xi_1, (R_{t,m})_{min} / \xi_2] \quad \text{Equation 11}$$

<b>Table 8 - Distribution Coefficient Depending on Number of Pretests</b>					
<b>n =</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>≥ 5</b>
$\xi_1$	1.40	1.30	1.20	1.10	1.00
$\xi_2$	1.40	1.20	1.05	1.00	1.00

When no anchor pull tests are performed and values for the skin friction of the anchor grout surface are obtained from literature, then a model factor based on the consequence class is applied as per Table 9 in Equation 12.

$$R_{t,d} = R_{t,k} / (\eta_{P,t} \cdot \gamma_{s,t}) \quad \text{Equation 12}$$

<b>Table 9 - Modell Factors for Resistance of Foundation of Rockfall Catchment Fences</b>				
<b>Resistance</b>	<b>Symbol</b>	<b>CC1</b>	<b>CC2</b>	<b>CC3</b>
Micropile under axial pressure	$\eta_{p,c}$	1.25	1.25	1.30
Micropile under axial tension	$\eta_{p,t}$	1.25	1.25	2.50

The results of the verification are compared to available anchors and an appropriate selection and subsequent design is conducted.

## **CONSTRUCTIVE RULES**

Some basic rules for the layout and construction of rockfall catchment fences are also defined by the ONR 24810. They are based on expert opinion and field experience, as described below.

### *Distance between catchment fence and object of protection*

To ensure that the elements at risk are sufficiently far from the rockfall catchment fence, a factor of safety of 1.2 is applied to the maximum elongation distance as reported for the MEL test in the ETAG 27 documentation but where a minimum of the maximum elongation plus 1 m is observed.

### *Post spacing*

It is not recommended to deviate from the approved tested post spacing for a system by more than  $\pm 2$  m.

### *Row length without internal anchor*

The length of a catchment fence without internal anchoring (i.e., directing the forces of the bearing ropes into the ground) shall not be more than 60 m.

### *End field placement*

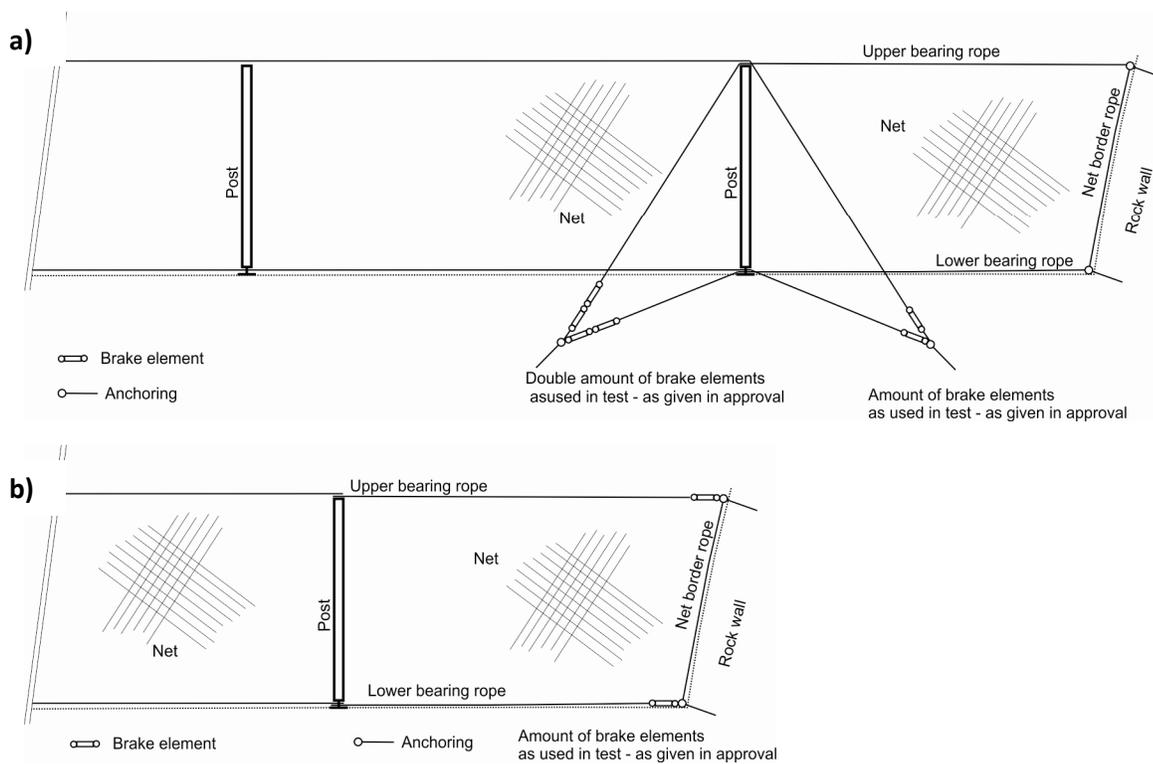
Since end fields are not tested for impacts, the last module should extend beyond the primary hazardous area. If the system has a tendency for the net to pull away from end post  $\geq 10\%$  of the residual height, then this is absolutely necessary.

### *Direct rock wall connection*

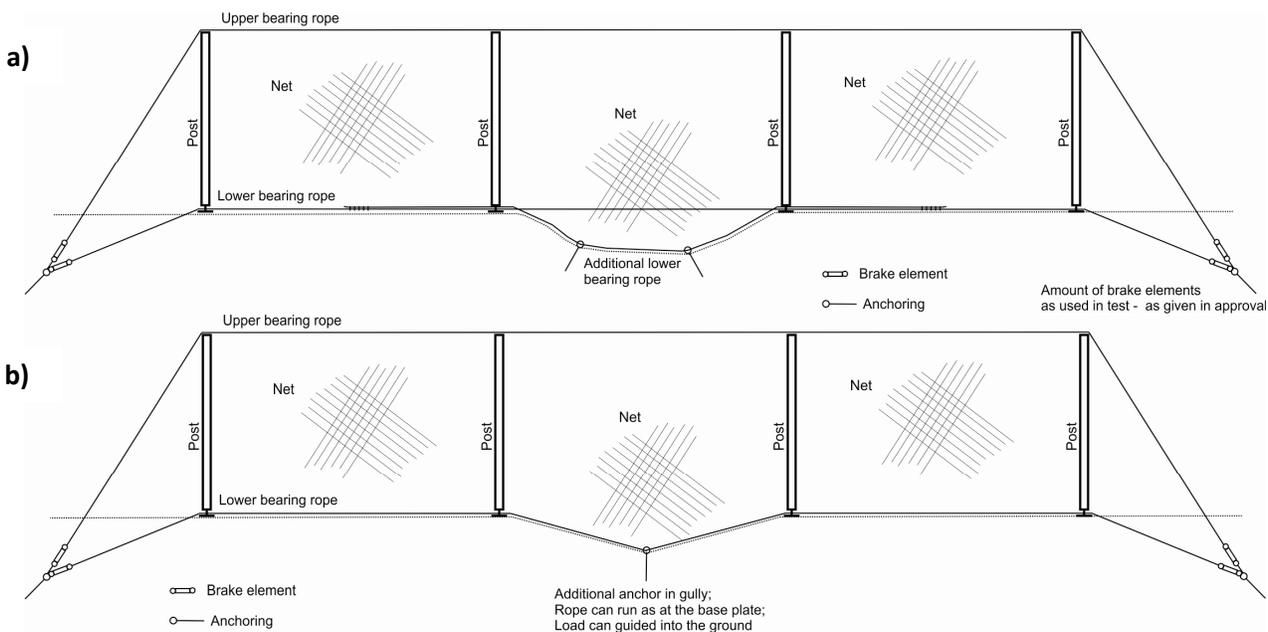
There are two accepted scenarios for terminating a fence into a rock wall that differ in how the fence reacts to impacts in the end field, specifically the degree to which the net is pulled away from the wall. The accepted configurations are shown in Figures 2a and 2b.

### *Gully nets*

Where gaps are present below the lower bearing rope due to undulating topography, the same net type must be used to fill the gap. No influence on the primary system is allowed (e.g., shortening of the elongation path, blocking of brake elements, etc.). Figures 3a and 3b show schematics of two potential solutions for gullies.



**Figure 2 - Accepted solutions for the termination of a system into a rock wall where a) extra internal anchoring is used, and b) direct connection is used.**



**Figure 3: Solutions for gully nets where a) additional anchoring and an additional bearing rope are used, and b) additional anchoring with no additional bearing rope is used.**

## MAINTENANCE AND INSPECTION

Once a mitigation measure has been implemented, detailed documentation is required to establish a baseline of the structures. From this, the status of the system can be evaluated during future inspections in order to determine necessary maintenance.

The ONR 24810 covers the topic of maintenance and inspection in a general way that can be applied to all mitigation measures described in the document. The general methodology is laid out in Table 10 and consists of three primary inspection protocols: On-going inspection (LU-protocol), Control inspection (K-protocol) and Test inspection (P-protocol). A fourth type of inspection, Post-event inspection (SK-protocol) is a special case after an event has impacted the system. Examples of components of these protocols are limited to rockfall catchment fences herein.

<b>Inspection type</b>	<b>Frequency</b>	<b>Responsibility</b>	<b>Execution</b>	<b>Result</b>
On-going inspection	yearly	obligated to maintain	by experts or trained personnel	LU-protocol
Control inspection	every 5, 7 or 10 years depending on consequence class	obligated to maintain	by experts	K-protocol
Test inspection	as needed	obligated to maintain	by experts or team of experts	P-protocol

### *LU-protocol*

The on-going inspection is a yearly inspection conducted by experts or trained personnel. It includes checking brake functionality, elongation and residual capacity, net deformation and damage, damages to ropes, verification of nominal height, evaluation of debris in the system, etc.

### *K-protocol*

The control inspection is conducted only by an expert on a schedule determined by the consequence class: every 10, 7 or 5 years according to a consequence class of low, medium and high, respectively. This protocol includes the LU-protocol but also evaluates possible corrosion of components such as brake elements, nets, ropes, posts and base plates, or any connecting elements. An evaluation of the foundation is also required where corrosion and deformation of micropiles are evaluated, as well as the state of erosion surrounding them along with the general condition of concrete foundations (e.g., evidence of cracking, spalling, flaking, corrosion of reinforcement elements if visible, etc.). Finally, a general evaluation of the state of the system compared to the most recent inspection report is conducted. Table 11 summarizes qualitative levels of system conditions with suggested actions and appropriate timeframes.

<b>Table 11 - Qualitative Levels of System Status</b>				
<b>State Class</b>	<b>Structural Safety</b>	<b>Fitness for Use</b>	<b>Time to Start Measure</b>	<b>Examples at Rockfall Catchment Fences</b>
1	given	given	long-term	no damage visible
2	given	given	long-term	minimal corrosion, minimal wear and tear
3	given	given	middle-term	plastic deformation of net, visible deformation brake element
4	limited	very limited	short-term	eroded or buckled micropiles, deformed posts, strongly deformed brake elements, decreased nominal height, rope ruptures, deformed shackles and wire rope clips, pulled micropiles, filled nets, broken welds
5	not given	not given		completely destroyed

*SK-protocol*

The post-event inspection is conducted by an expert and is in response to an event. It is independent from scheduled inspections and is used to determine the status of the system. It can result in the request for a test inspection.

*P-protocol*

This test inspection is conducted by an expert or possibly by an inter-disciplinary expert team. It is conducted on an as-needed basis when the status of a system or system component is identified by a previous inspection as indeterminable and which deems further, more detailed inspections are necessary. The nature of the test inspection will depend on the component(s) being inspected and may include more intrusive/involved test procedures to help determine the overall safety or state of the system (e.g., anchor pull tests).

**SUMMARY**

The ONORM 24810 describes a framework for the planning, implementation, construction and subsequent maintenance of rockfall mitigation measures. It includes methodology for the verification of suitability of a particular measure with respect to predicted event characteristics. Specifically regarding rockfall catchment fences, it draws on ETAG 27 documentation provided by catch fence manufacturers for the purpose of verifying that a particular system meets requirements determined during the site investigation and the engineering design. Constructive rules and maintenance routines are presented that help ensure a proper installation and the continued safe upkeep of the system.

## REFERENCES

1. EOTA. *Guideline for European technical approval of falling rock protection kits (ETAG 027)*, February 2008.
2. Austrian Service for Torrent and Avalanche Control WLW. *WLW-Richtlinie für den Eignungsnachweis und risikobezogene Zusatzkriterien für Steinschlagschutznetze*, July 2010.
3. Gerber. *Swiss Guideline for the Approval of Rock-Fall Protection Kits*. WSL & Swiss Agency for the Environment, Forests and Landscape (SAEFL), 2001.
4. Austrian Standards Institute. *ONR 24810, Technical protection against rockfall - Terms and definitions, effects of actions, design, monitoring and maintenance*, 2013.
5. CEN. *EN 1990:2003, Eurocode – Basis of structural design*. 2005.
6. Austrian Standards Institute. *OENORM B 1997-1-1:2010, Eurocode 7: Geotechnical design – Part 1: General rules; National specifications concerning OENORM EN 1997-1 and national supplements*, 2010.