



Säkring av bergslänter | Jonas von Wartburg

ADVANCEMENTS IN ROCKFALL PROTECTION

Advancements in Rockfall protection



1. OVERVIEW OF ROCKFALL PROTECTION SOLUTIONS
2. HISTORY OF ROCKFALL TESTING
3. RESEARCH PROJECT INNONET
4. OTHER ADVANCEMENTS

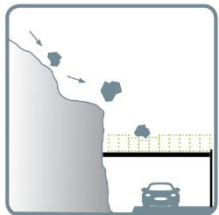


OVERVIEW OF ROCKFALL SOLUTIONS



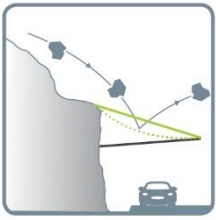
ROCK CATCH FENCE – PASSIVE PROTECTION





ROCKFALL GALLERIES – PASSIVE PROTECTION





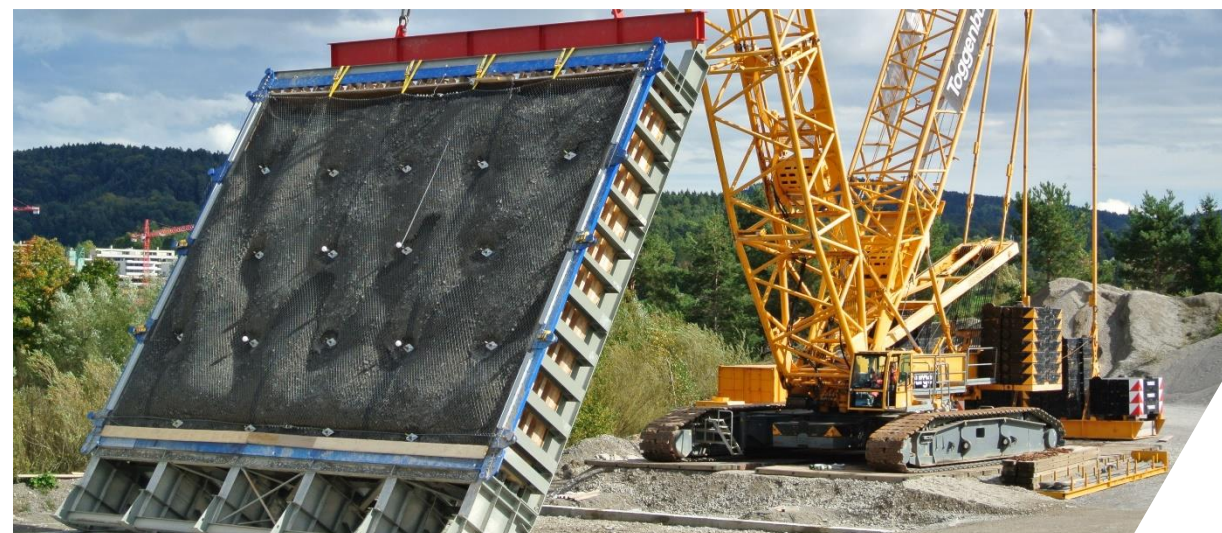


ATTENUATORS & DRAPES – PASSIVE PROTECTION





NAILED MESH COVER – ACTIVE STABILIZATION



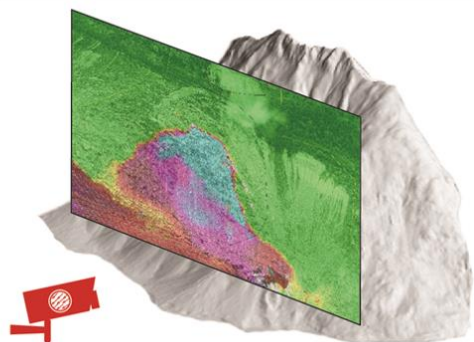
NAILED MESH COVER – ACTIVE STABILIZATION



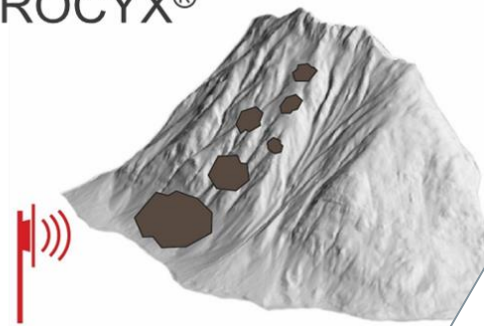


MONITORING AND ALERTING – PASSIVE PROTECTION

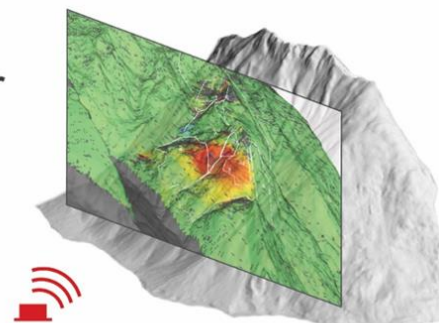
DEFOX®



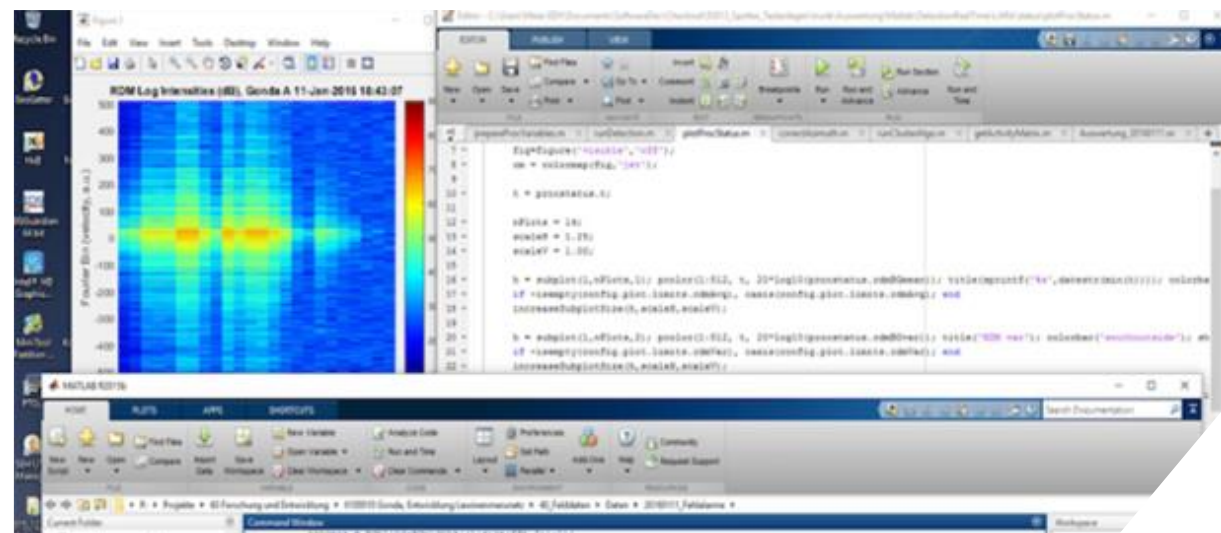
ROCYX®



Georadar



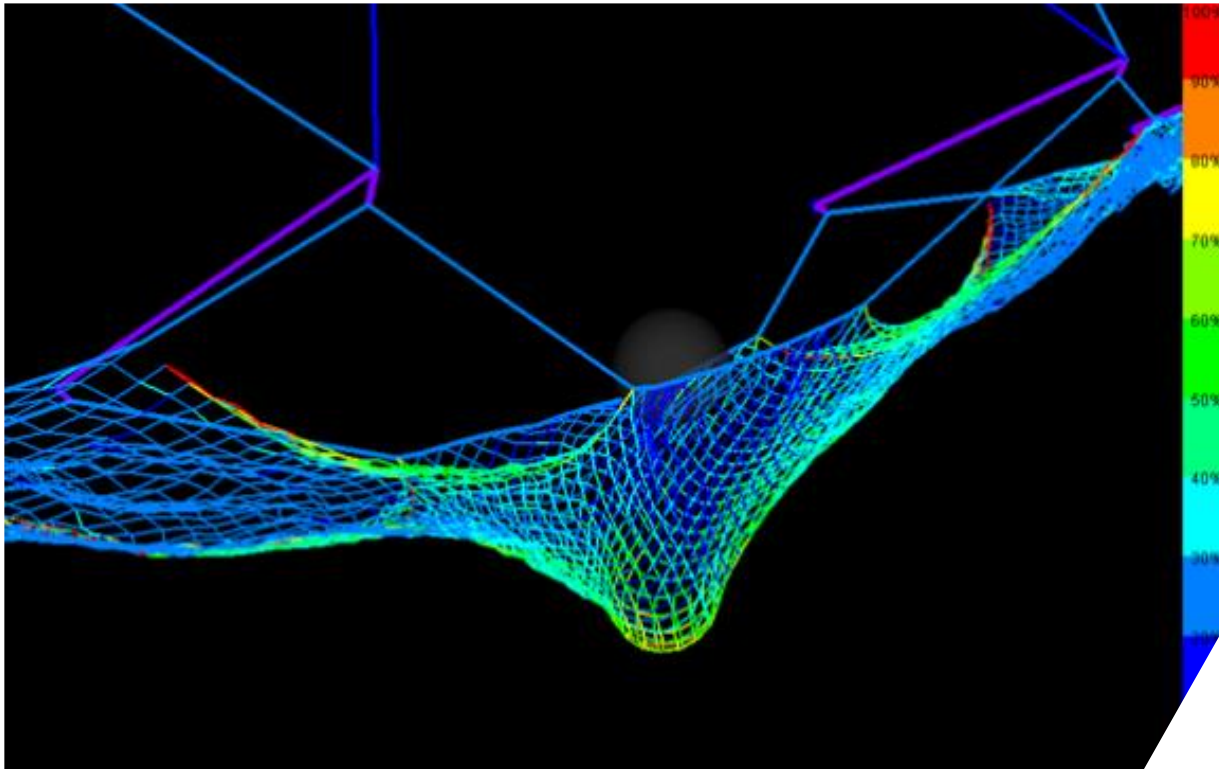
AVYX®



HISTORY OF ROCKFALL TESTING

WHY TESTING?

Why testing and not calculating or modelling?



- ▶ Development of Barriers were always based on testing / experiments to learn about the behaviour / performance
- ▶ Tools for calculation / Simulation not accurate enough
- ▶ Friction simulation and large deformations are the problem
- ▶ Testing for final verification of calculations and modelling

HOW FLEXIBLE PROTECTIVE STRUCTURES STARTED

First approach with snow barriers based on steel wire rope nets in the 50's



First tests of components, systems and brake elements 1970 - 1987/1988

- ▶ In the 60's very simple test were executed pushing rocks into avalanche barriers
→ first approach to use flexible barriers for rockfall protection
- ▶ Till 1988 testing of components / combination of parts of barriers
→ step by step knowledge about behaviour of barriers
- ▶ 1988 First field tests by CALTRANS under natural conditions – rolling rocks

FIRST TESTS OF DIFFERENT BARRIER DESIGNS

Repeatable testing with inclined rope way since 1993 1500 kJ



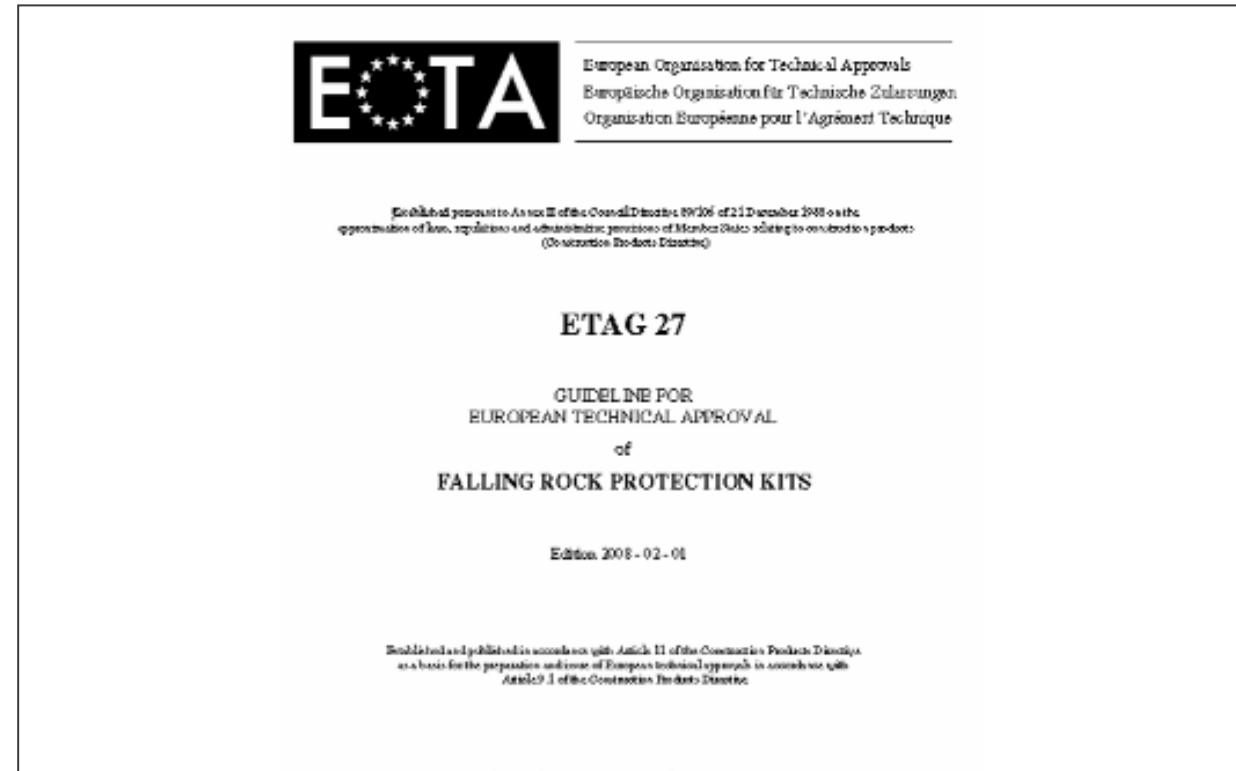
Repeatable and accurate **vertical testing** according CH-Guideline 2001, → 3000 kJ



- ▶ The Guideline specifies the test procedure and a minimum performance
- ▶ A specific test site was defined
- ▶ Test procedure is a compromise:
 - ▶ Type testing
 - ▶ Not reflecting the real case
 - ▶ Making products comparable under specific testing conditions
- ▶ First barrier acc. to guidelines with approval of BAFU/FOEN

TESTING ACCORDING TO GUIDELINES

EOTA guideline published in **2005** → **ETAG-027**

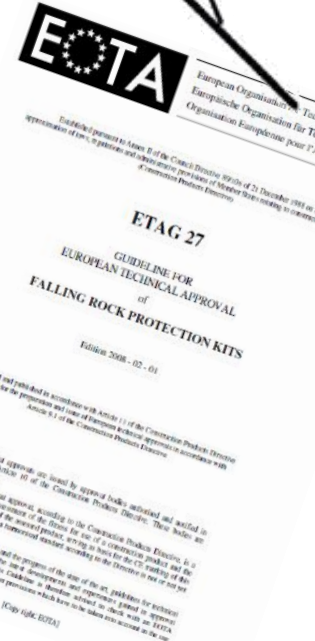
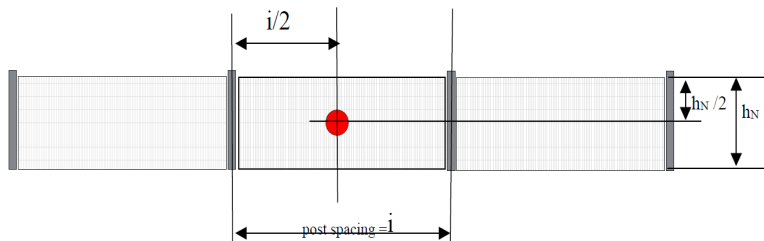


ETAG 027 (2008 / 2013) → EAD 340059-00-0106 (2018)

more than 50 Barriers tested and approved...

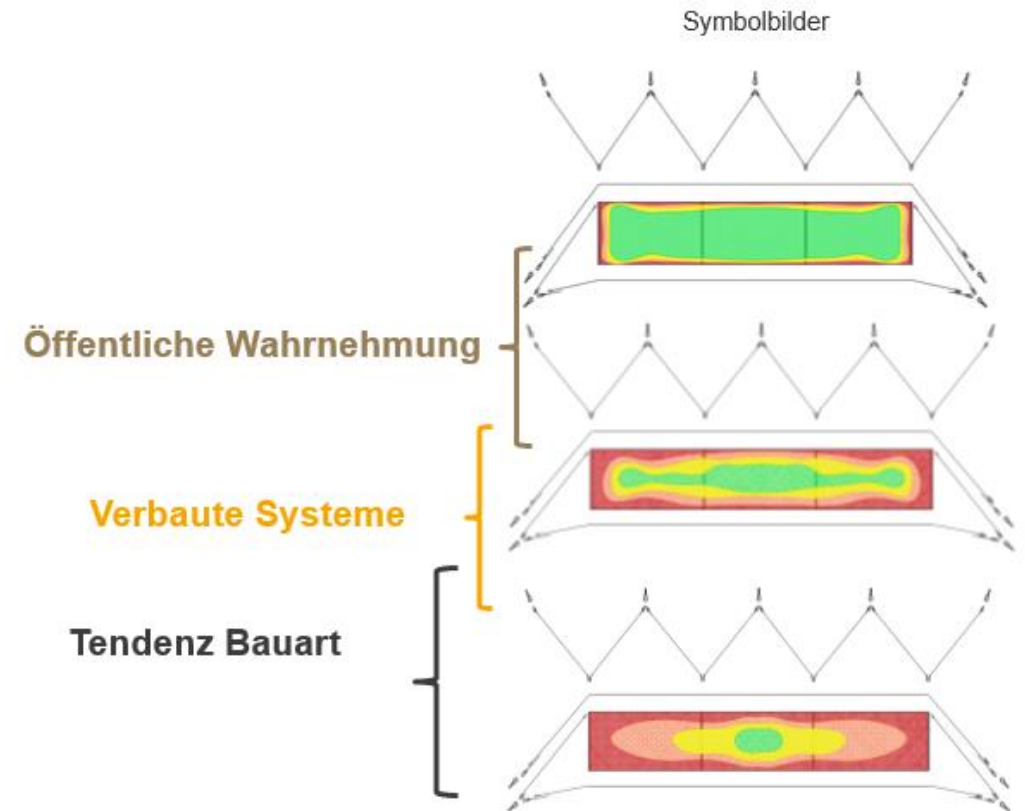
- ▶ One Multi-National Guideline
- ▶ Factory production control
- ▶ Tests repeatable and comparable with defined test criterias
 - ▶ (SEL 1, SEL 2, MEL)
- ▶ Easy to describe in a tender

- ▶ Minimum Standard with Compromise
- ▶ Competition results in lighter, more optimized to the standard on the cost of residual capacity



Public perception vs. Actual guaranteed protection surface

- ▶ Optimizing the barrier on the EAD standards often lead to compromises in the residual safety
- ▶ Compensation often took place through over dimensioning, which doesn't always result in what is expected
- ▶ → Research project "InnoNet" for more robust systems



IOIB

RESEARCH PROJECT INNONET

Real scale rockfall tests in natural environment

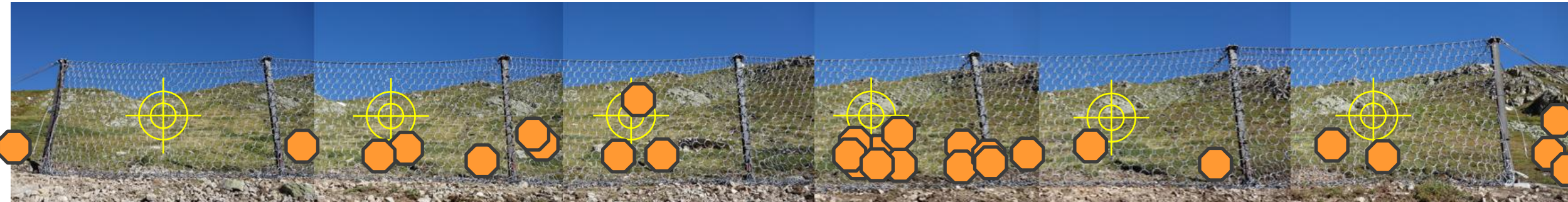



- ▶ Innosuisse Projekt: WSL + Geobrugg
- ▶ Investigation of natural load cases
- ▶ Excentric hits, rotation, different shapes, different sizes
- ▶ Goal: Better understanding and design for natural load cases.

RESEARCH PROJECT: INNONET → WSL + GEOBRUGG

A view into reality of rockfall testing:

Total 30 tests of which 25 hit the fence → «nearly everything is possible»



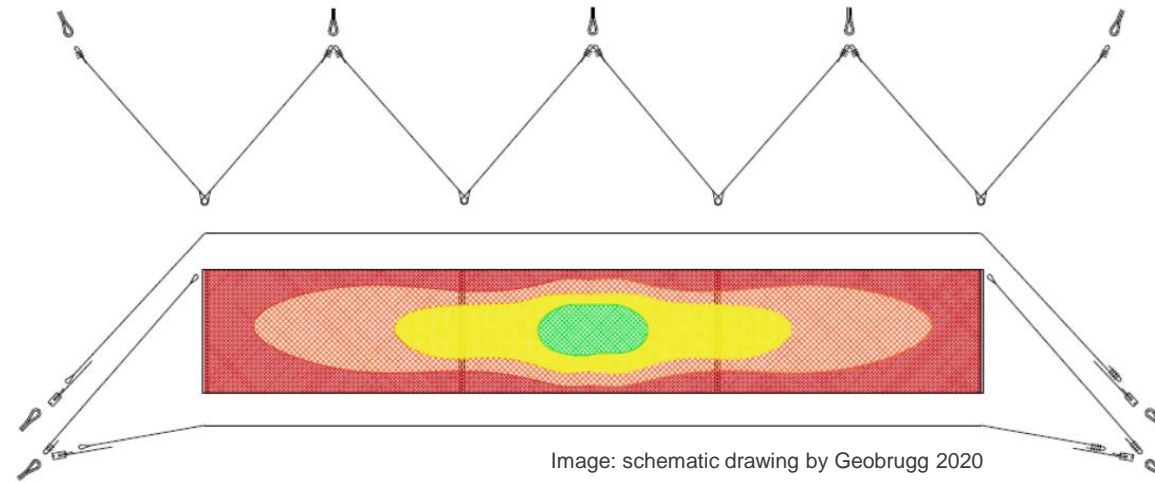
 impact locations in a 60 m long rockfall protection system

WSL: Swiss Federal Institute for Forest, Snow and Landscape

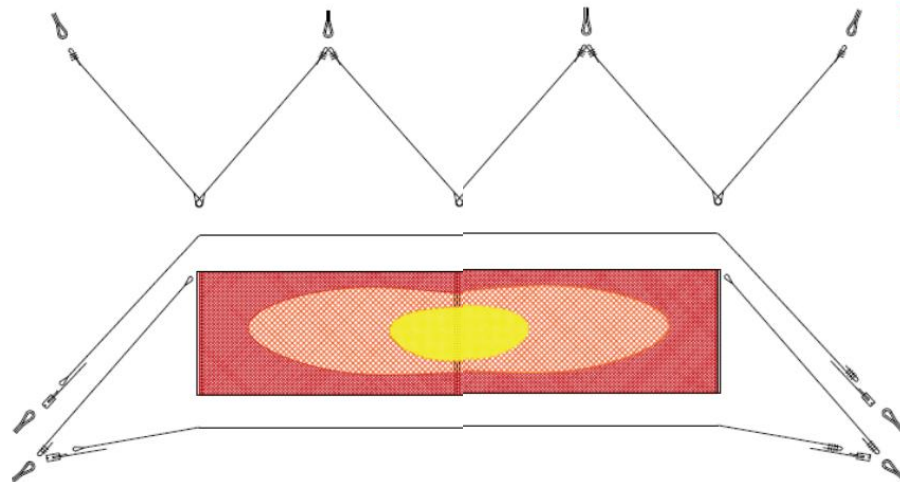
CURRENT BARRIER TESTING

Assumption what a standard tested rockfall protection system can guarantee:

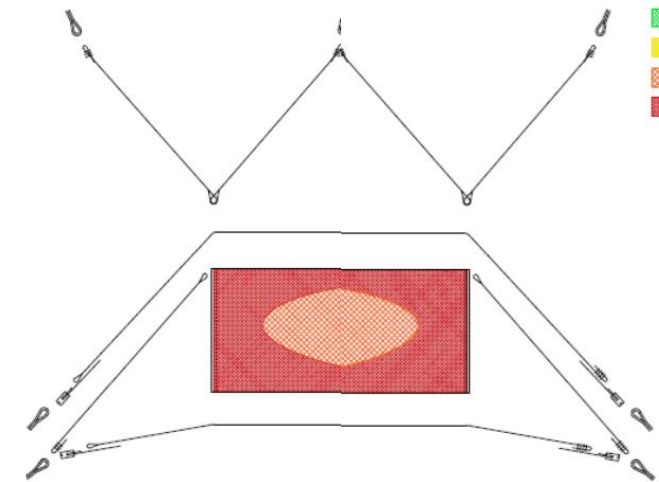
Three and more fields



Two fields



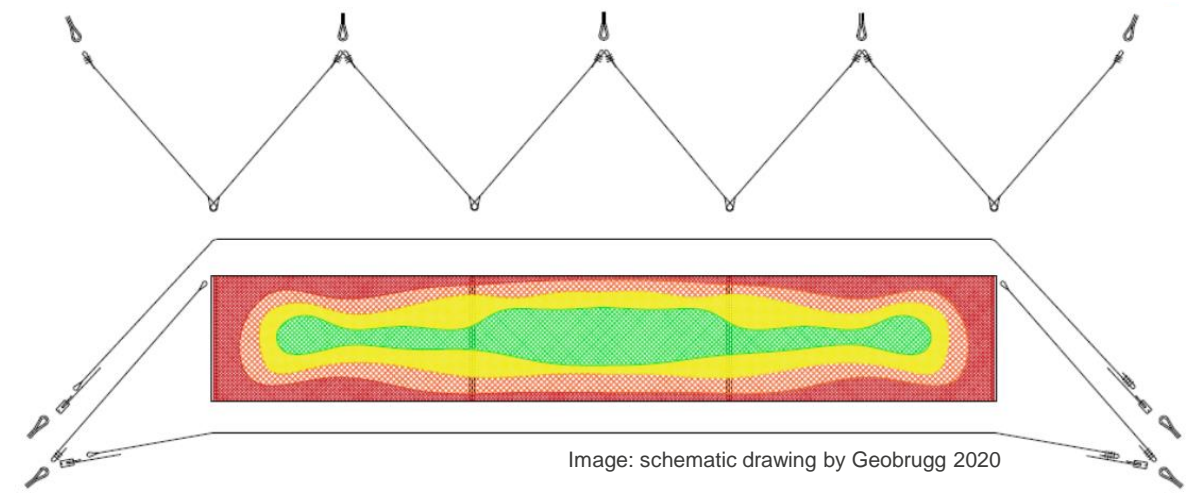
One field



WHAT ARE THE IMPROVEMENTS OF THE NEW TESTS

Proof of performance of a ROCCO type tested rockfall protection system:

Three and more fields



Two fields

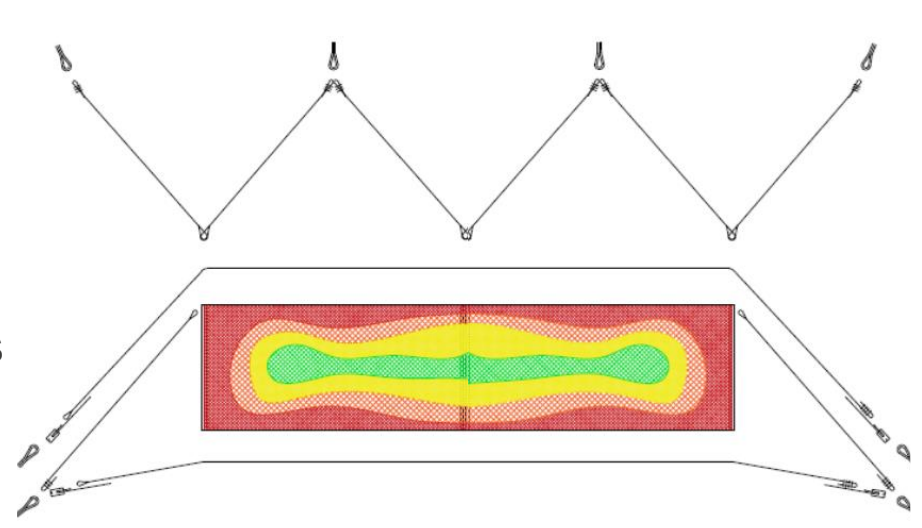
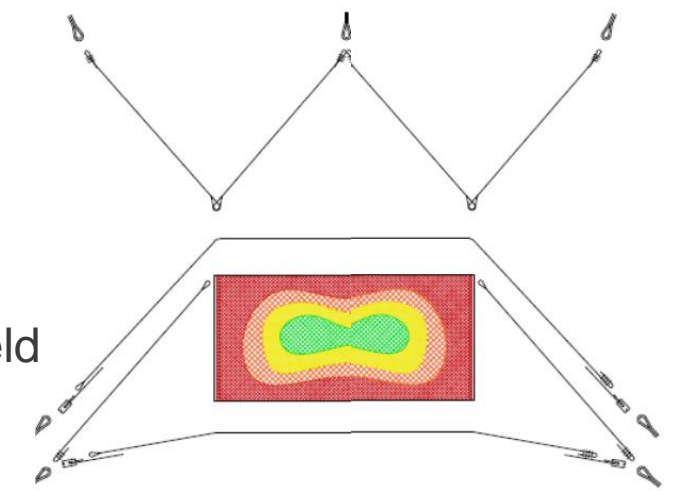


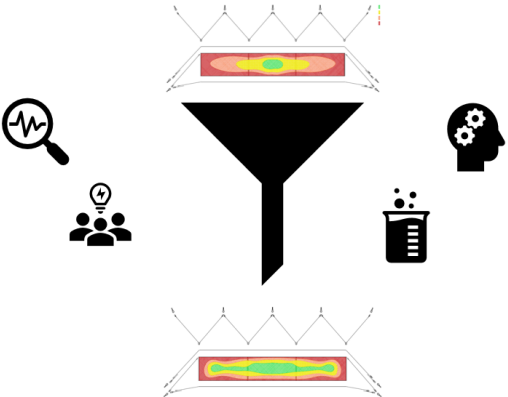
Image: schematic drawing by Geobrugg 2020

One field



TESTING OF ROCCO BARRIER

Tests at Flüela and additional Tests at Walenstadt



TESTING OF ROCCO BARRIER

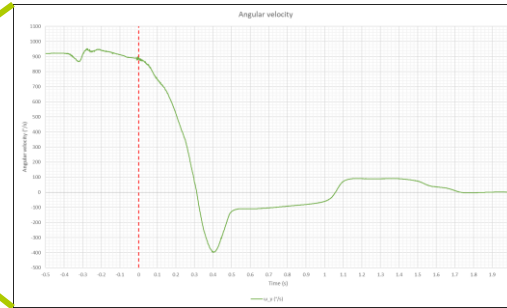
Additional Tests at Flüela



- ▶ Innosuisse Project: SLF (WSL) + GB
- ▶ Investigation natural load cases
 - ▶ Eccentric impacts
 - ▶ Rotation
 - ▶ Shape and block size

TESTING OF ROCCO BARRIER

Additional Tests at Flüela



- ▶ Barrier: ROCCO-2000 H=5 m
6 x 10 m
- ▶ 30 Tests 25 Impacts (2019, 2020)
- ▶ 840 kg ... 3200 kg
- ▶ Velocity: ...18.5 m/s (225 rpm)
- ▶ Translational Energy: 550 kJ
- ▶ Rotational Energy: 115 kJ

TESTING OF ROCCO BARRIER

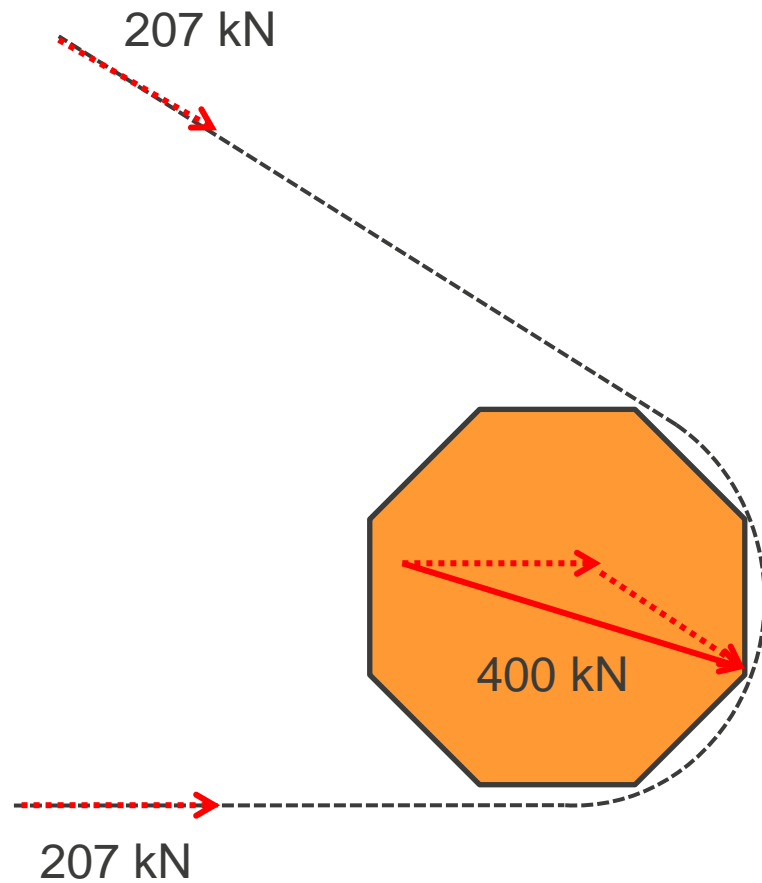
Comparison Flüela vs. vertical drop Test (SEL2)



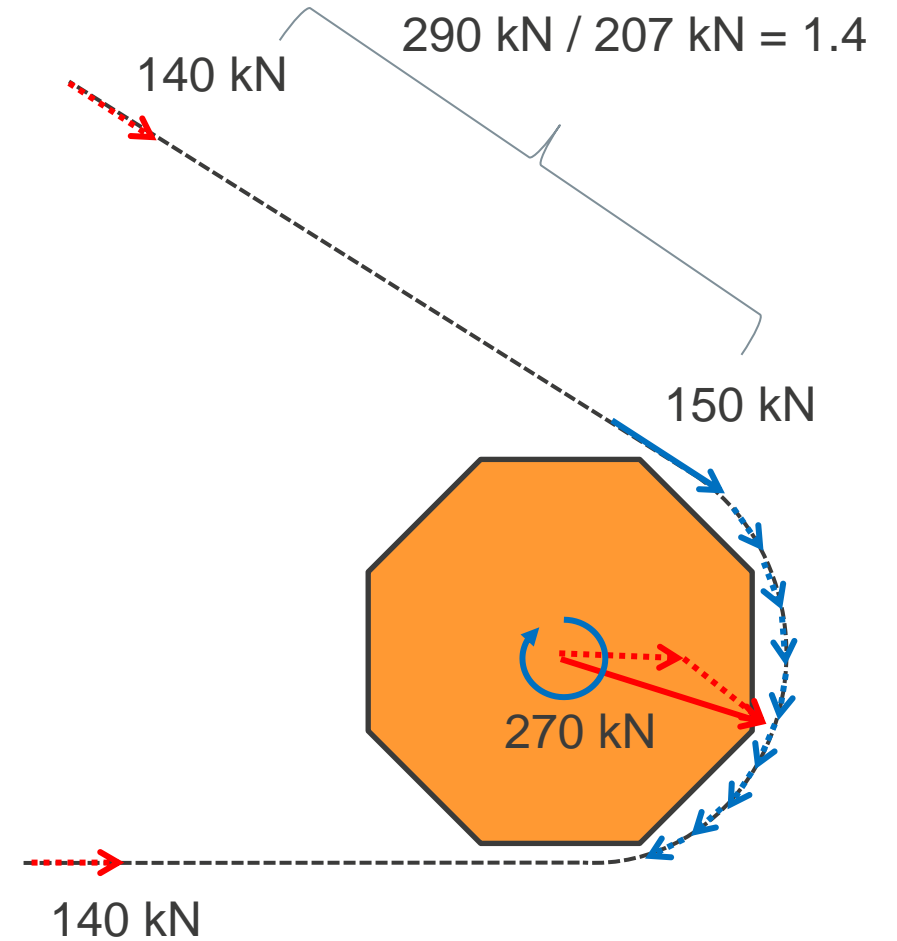
Findings: Rotation + eccentric impacts -> high forces at post head
 $\frac{2}{3}$ kinetic energy on field results in $\frac{4}{3}$ forces in upslope anchors

Rotation causes higher forces in the post head area

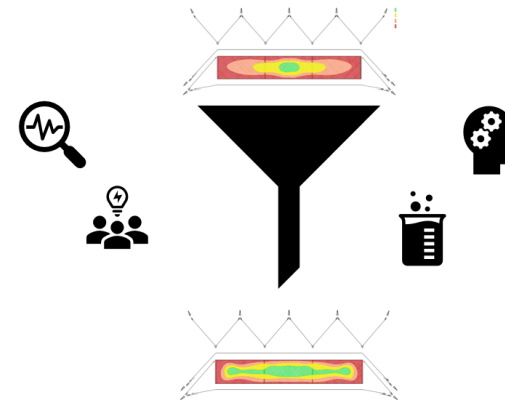
► SEL 2



► Feld



TESTING OF ROCCO BARRIER

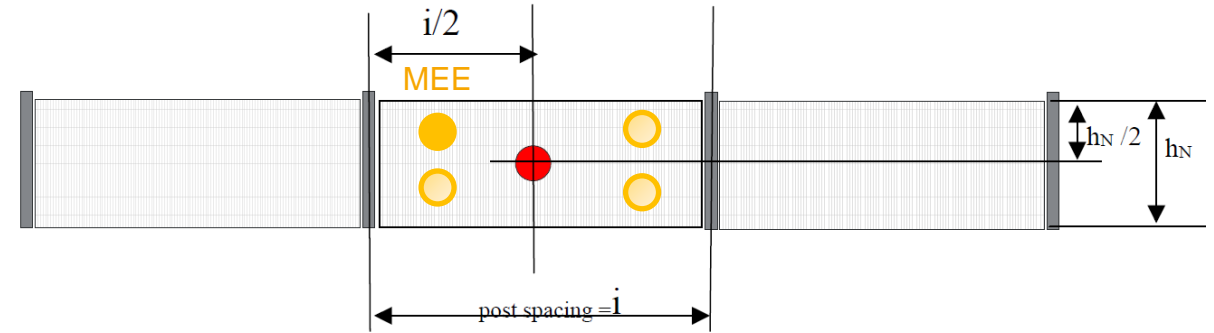
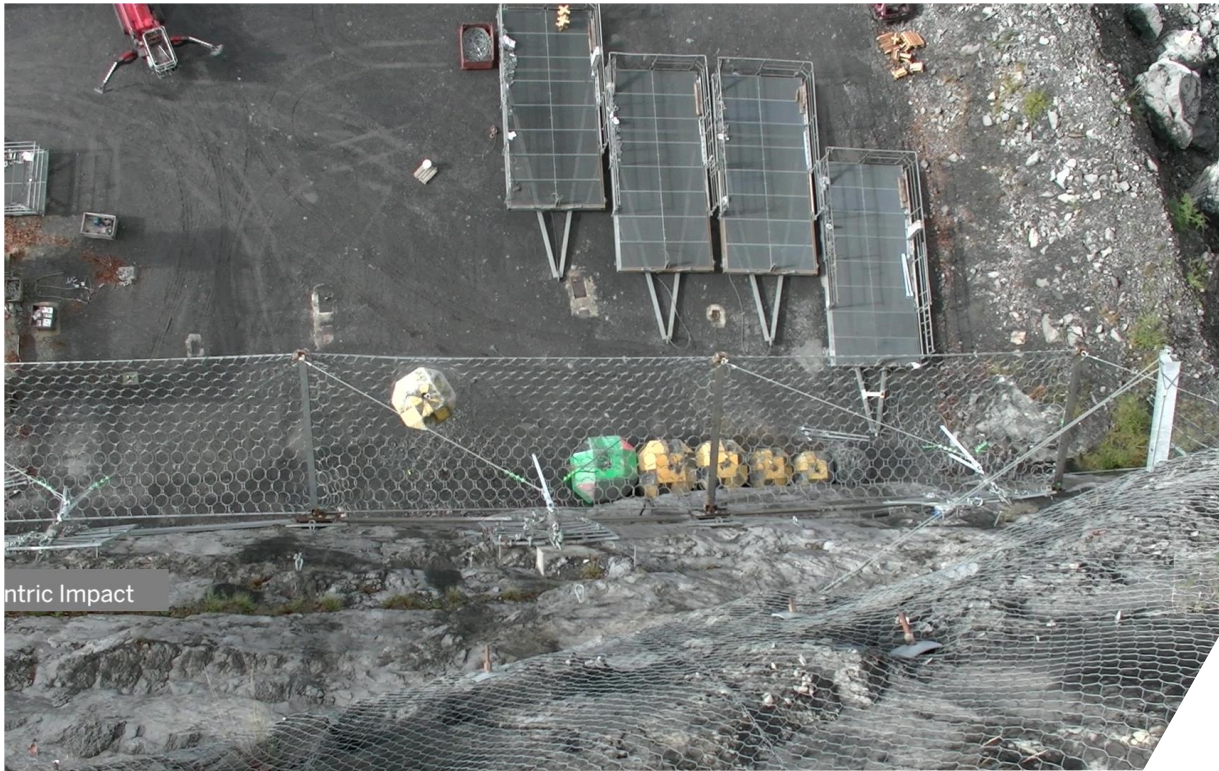


Additional tests to proof the robustness:

- ▶ **MEE*** (100%) =
Maximum Energy Eccentric (eccentric in middle field)
- ▶ **MEF*** (100%) =
Maximum Energy Field (one, two field and border field)

TESTING OF ROCCO BARRIER

MEE* (100%) = **M**aximum **E**nergy **E**ccentric (eccentric in middle field)



- ▶ Asymmetric loads
- ▶ Proof of net resistance

TESTING OF ROCCO BARRIER

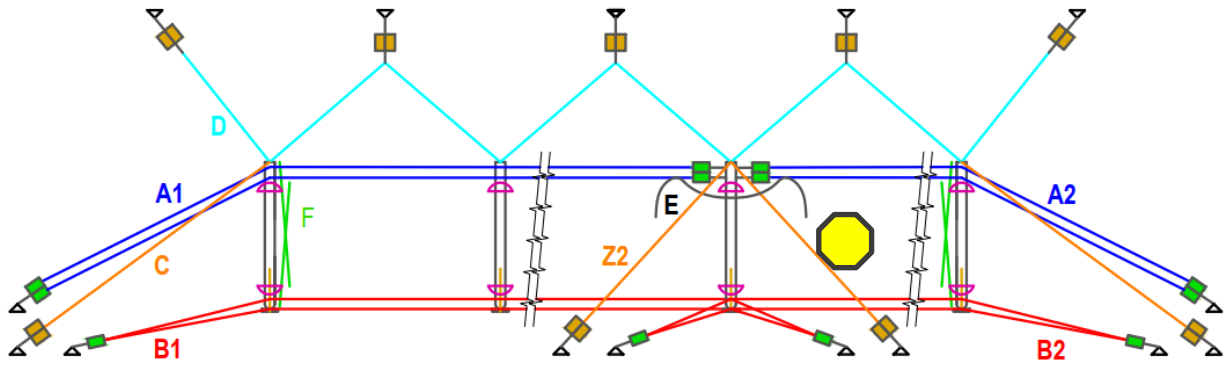
MEF* (100%) = **M**aximum **E**nergy **F**ield (one, two field and border field)



- ▶ MEL in one field
- ▶ 1/3 higher forces in upslope anchors
- ▶ 50% more energy absorption in U-Brakes

TESTING OF ROCCO BARRIER

(MES* (100%) = Maximum Energy Separation (centric in middle field with support rope separation))



Only ROCCO-2000!

Certification, evaluation report and technical report from the same body.

Page 3 of 51 of Evaluation report for assessment of ETA 19/0568, Falling rock protection barrier ROCCO 2000

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1 INTRODUCTION

This report describes the methods used to assess the the Falling Rock Protection Kit "Falling rock protection barrier ROCCO-2000", introduced by GEOBRUGG AG, according to the essential characteristics in European Assessment Document EAD 340059-00-0106 Falling rock protection kits, July 2018. These evaluation and assessment include results of tests carried out in accordance with the EAD 340059-00-0106.

The impact tests were performed at the test site in Walenstadt, Switzerland (SG) by WSL testing laboratory under supervision of TSÚS Technical Assessment Body.

2 REFERENCES

- [1] European Assessment Document EAD 340059-00-0106 Falling rock protection kits, July 2018
- [2] pSi_19_ 1286 ROCCO-2000, Test report about impact tests of Falling Rock Protection Barrier ROCCO-2000. Dynamic Test Center, Vauffelin, Switzerland, November 2019
- [3] pSi-19-1575 ROCCO-2000 Additional tests. MEL eccentric, MEL single field, MEL rope separation, Dynamic Test Center, Vauffelin, Switzerland, November 2019

Order No.: **from date 03.03.2020**

Job No.: **70200042/1**

Print Number: 2

Technical Report No. 70200042/1

Evaluation and assessment of eccentric, single field and support rope separation impact tests on Falling Rock Protection Barrier ROCCO-2000

ADDITIONAL INFORMATION

robust barrier / best safety level:

- ▶ ROCCO additional tests:
 - ▶ SEL3: border field
 - ▶ SEL4: border field
 - ▶ SEL5: post hit
 - ▶ SEL6: middle field
 - ▶

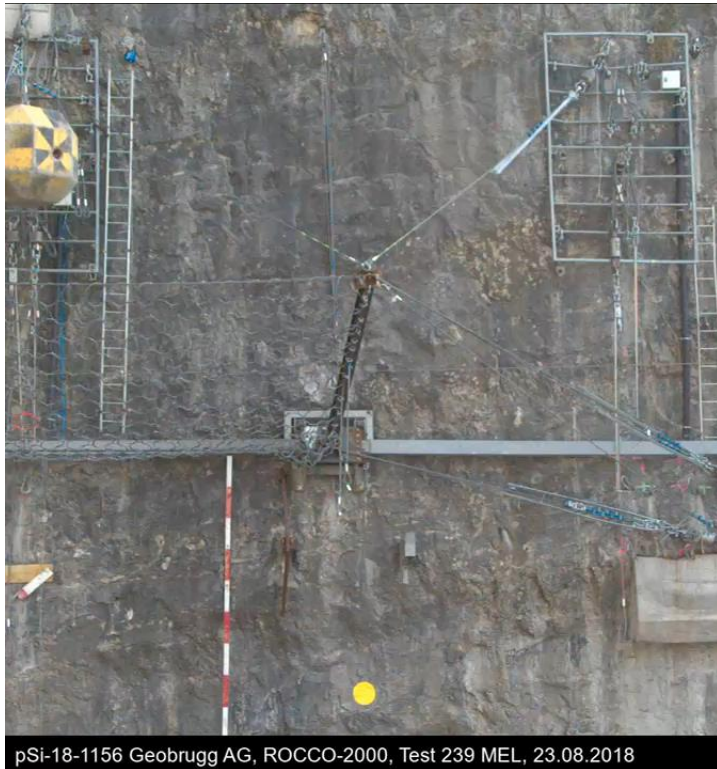




OTHER ADVANCEMENTS

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Structural health monitoring with Geobrugg GUARD



pSi-18-1156 Geobrugg AG, ROCCO-2000, Test 239 MEL, 23.08.2018

- ▶ Continuous rope force measurement
- ▶ Corrosivity measurement
- ▶ Impact detection
- ▶ Inclinator
- ▶ Temperature and Humidity
- ▶ Battery status

YOUR CONTACT AT GEOBRUGG



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<https://www.geobrugg.com/en/Contacts-8098,7847.html>



THANK YOU!