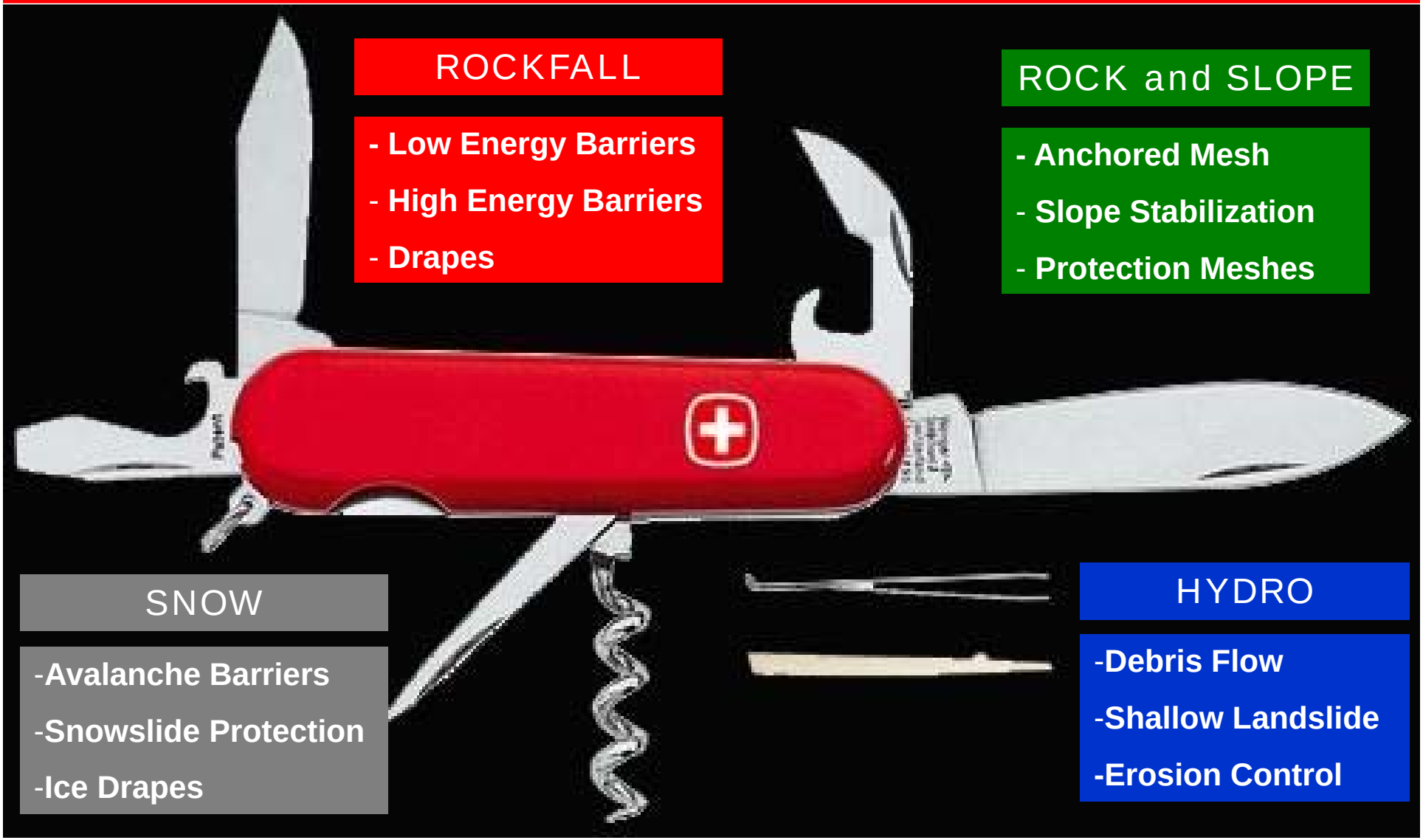
GEOBRUGG
BRUGG
Safety is our nature

GEOHAZARD SOLUTIONS

GEOHAZARD SOLUTIONS

GEOBRUGG
BRUGG
Safety is our nature

The Use of Flexible Systems for Natural Hazard Mitigation



ROCKFALL

- Low Energy Barriers
- High Energy Barriers
- Drapes

ROCK and SLOPE

- Anchored Mesh
- Slope Stabilization
- Protection Meshes

SNOW

- Avalanche Barriers
- Snowslide Protection
- Ice Drapes

HYDRO

- Debris Flow
- Shallow Landslide
- Erosion Control

NATURAL HAZARD PROTECTION SYSTEMS

GEOBRUGG BRUGG
Safety is our nature

Geobrugg Protection Systems

SNOW Avalanche Protection Structures

NATURAL HAZARD PROTECTION SYSTEMS

GEOBRUGG®
BRUGG
Safety is our nature

Geobrugg Protection Systems

ROCKFALL - Barriers and Catchfences

NATURAL HAZARD PROTECTION SYSTEMS

GEOBRUGG BRUGG
Safety is our nature

Geobrugg Protection Systems

ROCKFALL – Barriers and Catchfences

NATURAL HAZARD PROTECTION SYSTEMS

GEOBRUGG
BRUGG
Safety is our nature

Geobrugg Protection Systems

ROCK & SLOPE – Drapes and Attenuators

SLOPE STABILIZATION

GEOBRUGG
BRUGG
Safety is our nature

Geobrugg Protection Systems

ROCK and SLOPE – Anchored Mesh Solutions for Unstable Slopes

SLOPE STABILIZATION

GEOBRUGG
BRUGG
Safety is our nature

Geobrugg Protection Systems

ROCK and SLOPE – Anchored Mesh Solutions for Unstable Slopes

NATURAL HAZARD PROTECTION SYSTEMS

GEOBRUGG BRUGG
Safety is our nature

Geobrugg Protection Systems

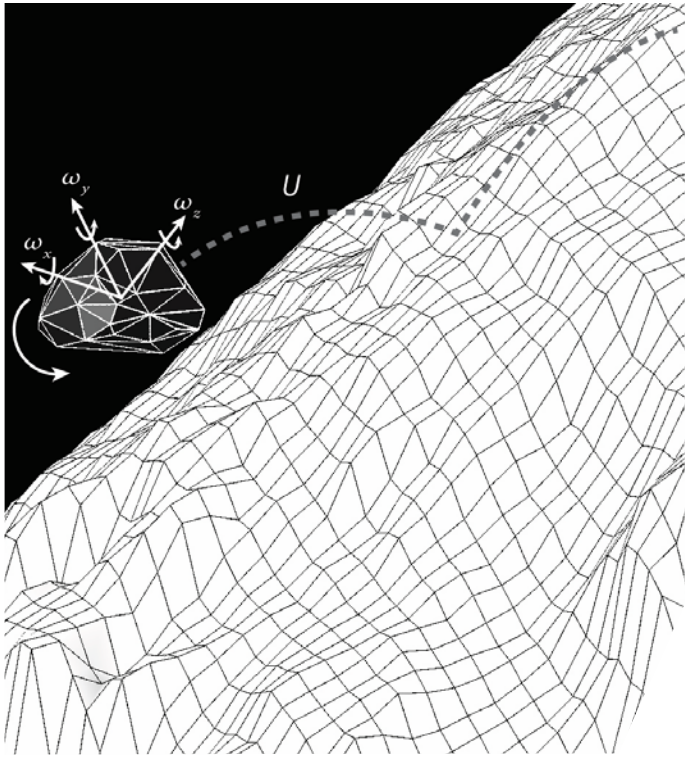
HYDRO - Debris Flow Barriers

GEOBRUGG
BRUGG
Safety is our nature

Presented by Bob Lyne

ROCK | high tensile ringnet canopies and the behavior to self-cleaning effects together to alternative systems

AGENDA

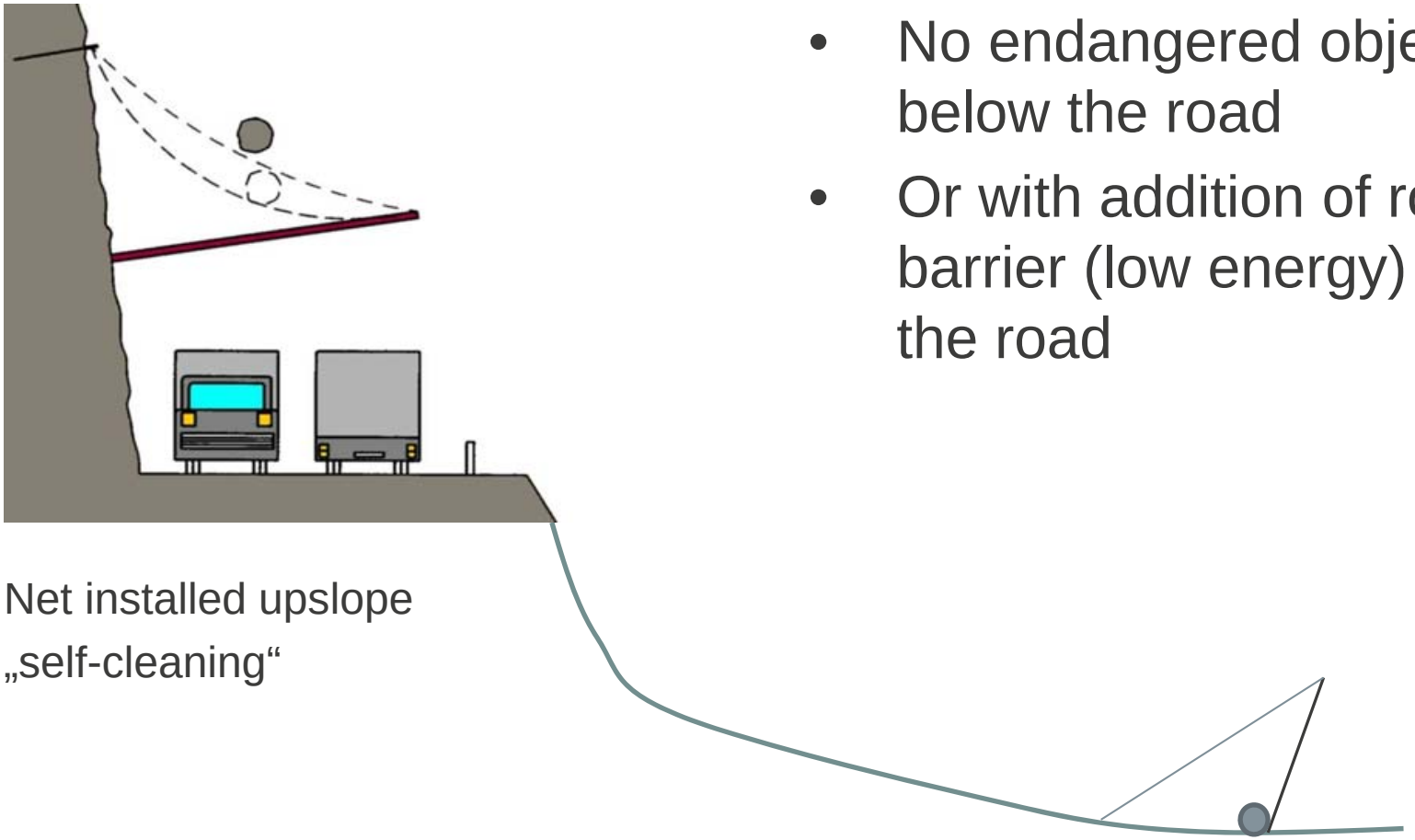


1. HISTORY AND EXECUTED PROJECTS IN THE PAST
2. NEW GENERATION OF CANOPIES
3. FULL-SCALE TESTS
4. PARAMETER STUDY WITH FARO
5. COMPARISON TO CONCRETE GALLERY

CANOPY SYSTEM

GEOBRUGG
BRUGG
Safety is our nature

When and why is self cleaning necessary?



Net installed upslope
„self-cleaning“

- No endangered objects below the road
- Or with addition of rockfall barrier (low energy) below the road

GEOBRUGG
BRUGG
Safety is our nature

01

HISTORY AND EXECUTED PROJECTS IN THE PAST

SEEWIS (SWITZERLAND). 198..

GEOBRUGG BRUGG Safety is our nature

One early attempt to divert rocks with wood and springs

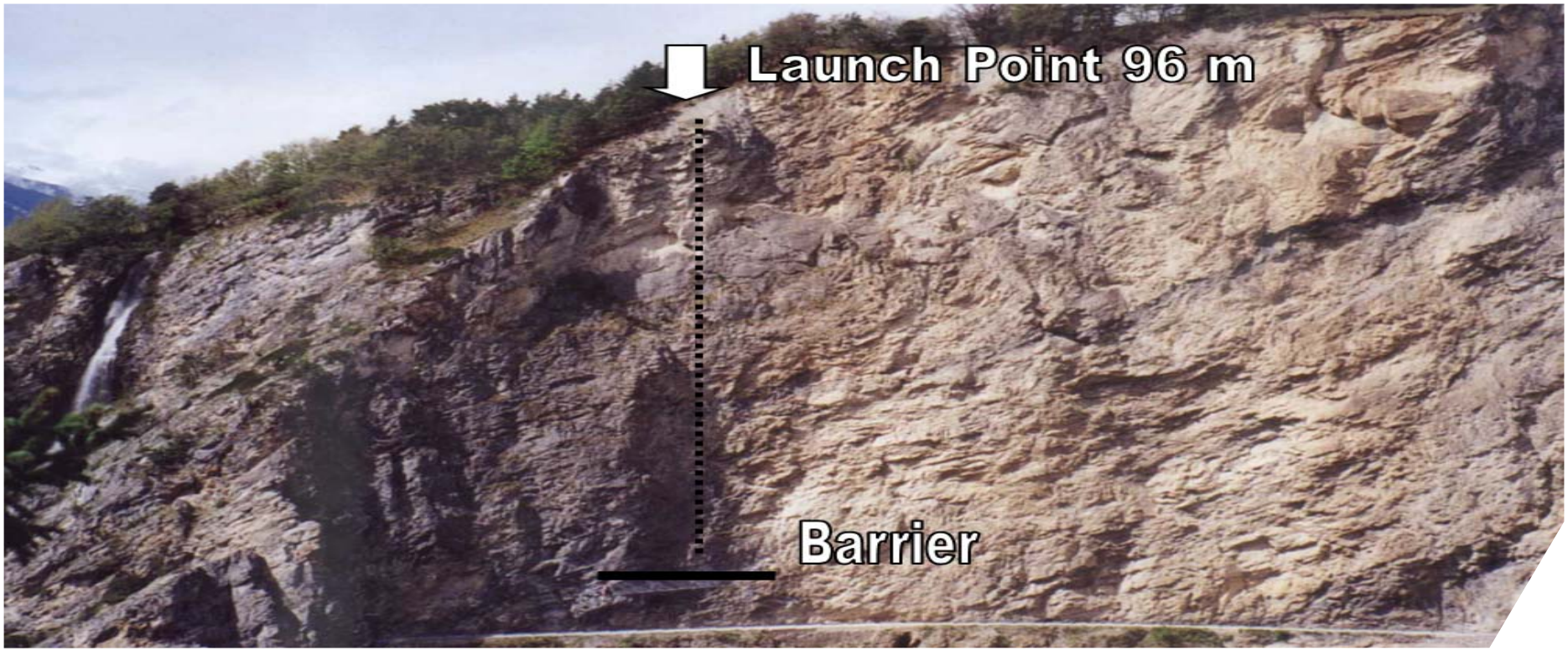
MONTSERRAT (SPAIN), 1992

- Energy rating: 500kJ
- Width: 4 – 8m

VARNERFLUH (SWITZERLAND), 2000

GEOBRUGG
BRUGG
Safety is our nature

Real Scale Testing with high velocity up to 43m/s and 700kg



VARNERFLUH (SWITZERLAND), 2000

GEOBRUGG
BRUGG
Safety is our nature

Real Scale Testing with high velocity up to 43m/s and 700kg

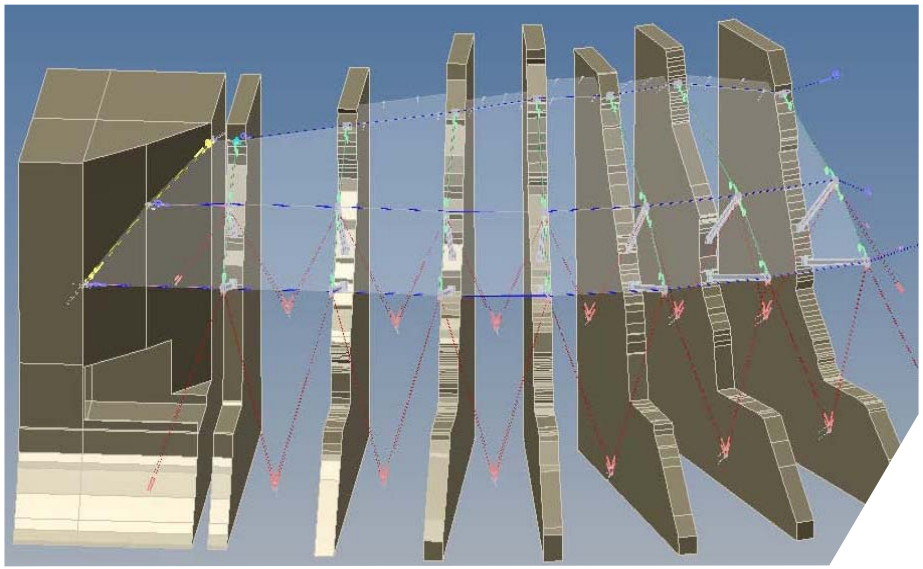
VARNERFLUH (SWITZERLAND), 2000

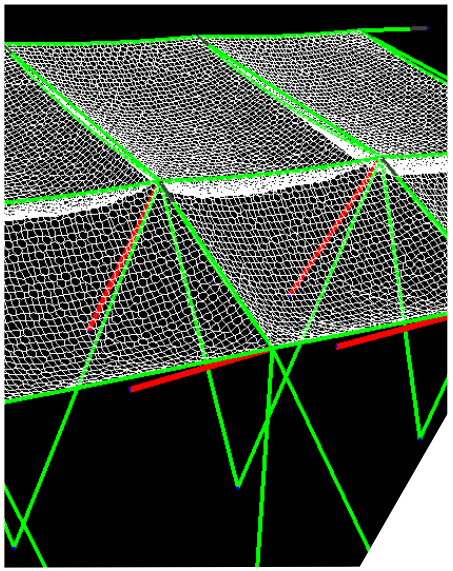
Full-scale Testing movie

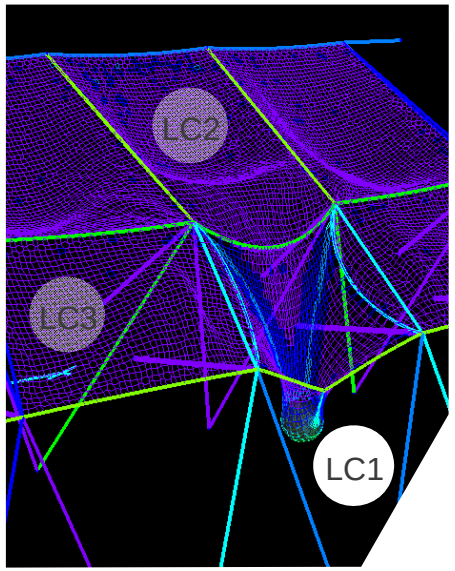
1. Length of barrier : l=22m
2. Height of barrier : h=4m
3. Post spacing : s=5/10/7m
4. Post inclination : α=10-15°
5. Post profile : HEB-140
6. Net angle : β=45°

PONTIS SUD (SWITZERLAND), 2008

Validation with simulation up to an energy of 2000kJ







Load case	LC1	LC2	LC3	LC1+S
ROCK z-disp	-5.7 [m]	-6.7 [m]	-5.8	-4.8
Vertical displ rel. to bottom post level	-1.9 [m]	+1.4 [m]	-1.9 [m]	+1.8[m]

PONTIS SUD (SWITZERLAND), 2008

Studied options:

- Option 0: Rockfalls of up to 2’000 kJ every 10 years
- Option 1: Extension of existing tunnel: 8.0 Mio. CHF
- Option 2: Concrete rockfall canopy: 3.5 Mio. CHF
- **Option 3: Flexible gallery: 1.1 Mio. CHF**

GEOBRUGG
BRUGG
Safety is our nature

NEW GENERATION OF CANOPY

2. SCC-500

GEOBRUGG
BRUGG
Safety is our nature

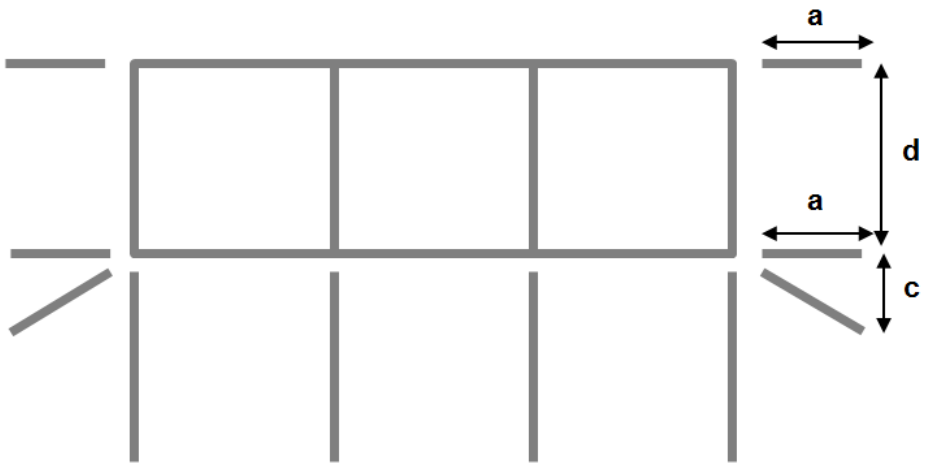
Self cleaning canopy up to 500kJ

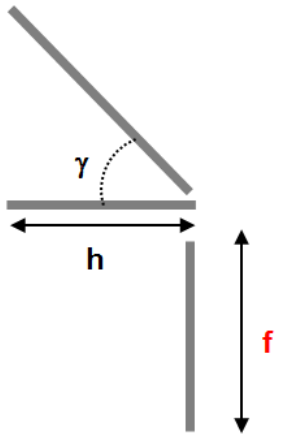
- Developed with experience of rockfall system
- Self-cleaning effect till 500kJ
- Maximum energy level 1000kJ
- Low maintanance
- Easy installation

NEW GENERATION OF CANOPY

GEOBRUGG
BRUGG
Safety is our nature

Staking out – flexible in all directions





γ : appr. 45°, depends on ground geometry

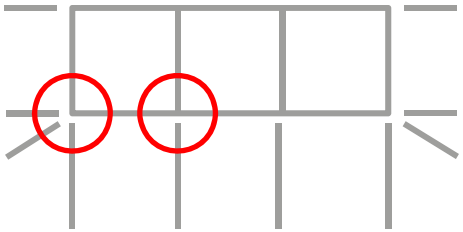
f : depends on installation height. In minimum 10m

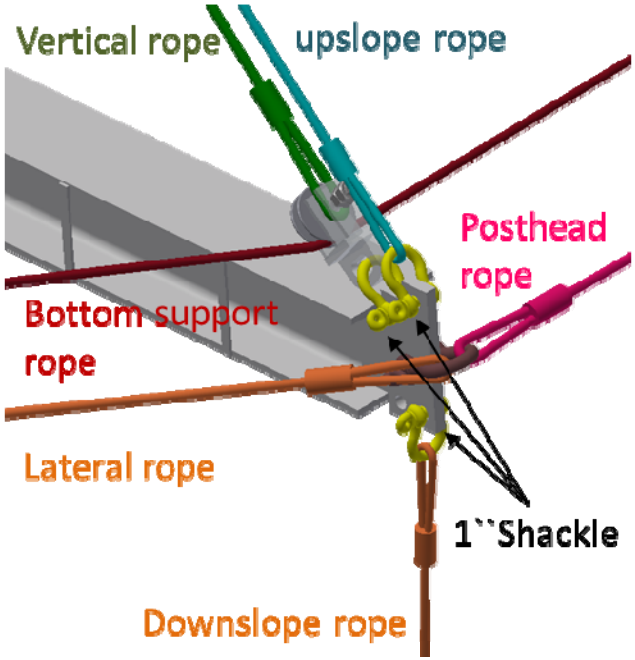
H – Post Length	a	c	d
6.00	5.50	1.30	6.00
7.00	6.50	1.50	7.00
8.00	**7.50**	**1.50**	**8.00**

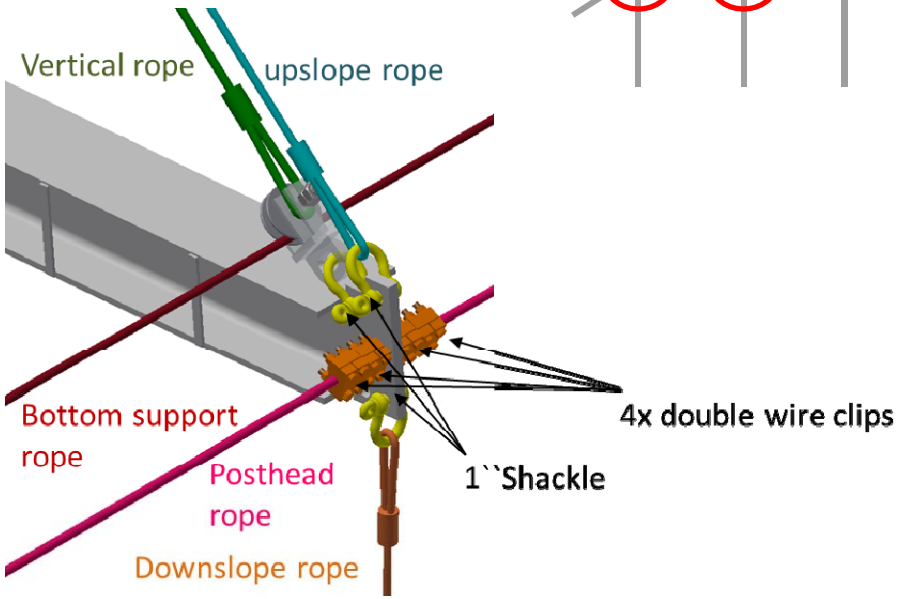
NEW GENERATION OF CANOPY

GEOBRUGG
BRUGG
Safety is our nature

Installation Assembly – very easy and clear







GEOBRUGG
BRUGG
Safety is our nature

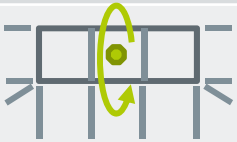
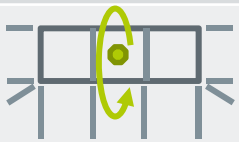
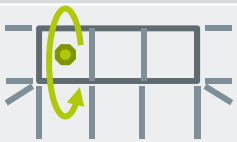
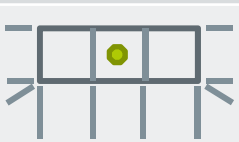
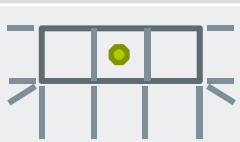
03

FULL-SCALE TESTS

TESTS EXECUTED WITH FLEXIBLE CANOPIES

GEOBRUGG BRUGG Safety is our nature

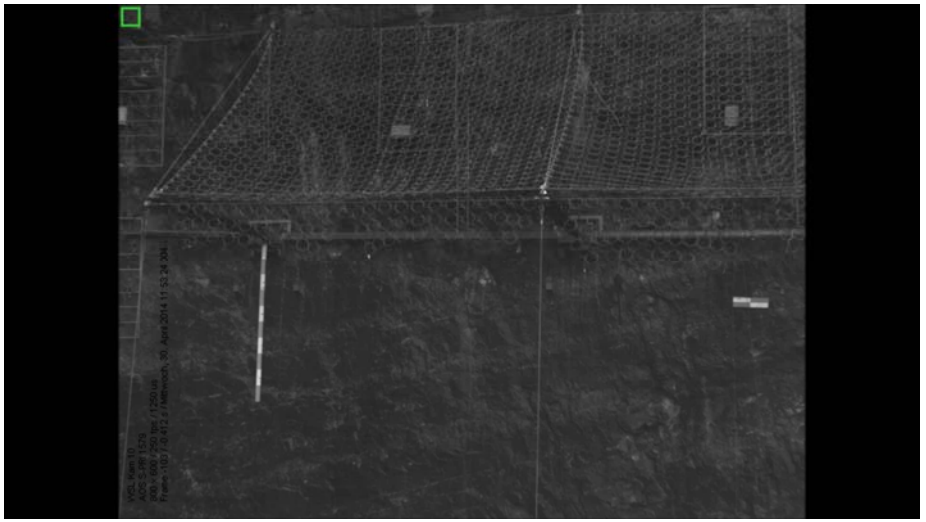
Flexible canopy system with different load cases

	TEST 1	TEST 2	TEST 3	TEST 4	TEST 5
Energy	500 kJ	500 kJ	500 kJ	1000 kJ	500 kJ
Position	Middle field	Middle field	Border field	Middle field	Middle field
Serie	1st impact	2nd impact	3rd impact	1st impact	2nd impact
Post length	8m	8m	8m	8m	8m
ROCK	rotation	rotation	rotation	-	-
					
Self-cleaning	YES	YES	YES	NO	YES
Deformation	6.10m	5.40m	5.80m	6.70m	5.30m

TEST 3 BORDER FIELD – 500KJ

Full-scale test according to ETAG 027 guideline

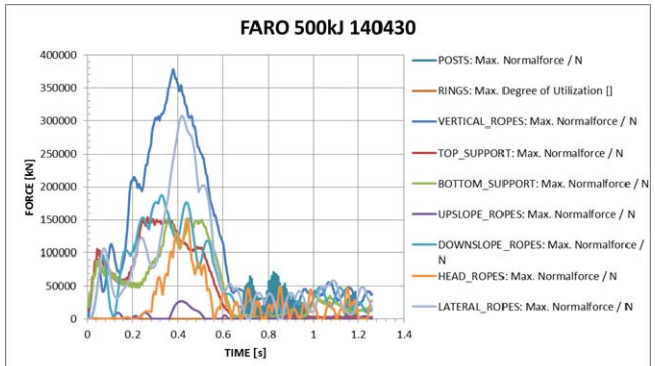
- Mass m=1600kg
- Velocity v=25 m/s
- Energy E=500kJ



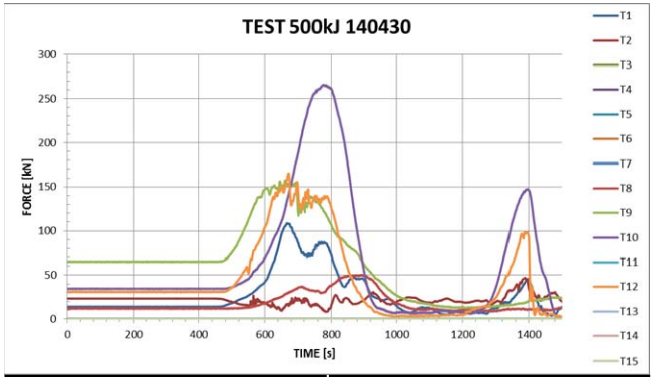
TEST 3 BORDER FIELD – 500KJ

GEOBRUGG
BRUGG
Safety is our nature

Comparison of FARO simulation with test



	FARO 500kJ
Top support rope	150 kN
Bottom support rope	155 kN
Vertical rope	375 kN
Upslope rope	30 kN
Downslope rope	185 kN
Lateral rope	305 kN
Posthead rope	150 kN



TEST 500kJ	
160	Top support rope
165	Bottom support rope
No data	Vertical rope
45 kN	Upslope rope
110 kN	Downslope rope
265 kN	Lateral rope
No data	Posthead rope

GEOBRUGG
BRUGG
Safety is our nature

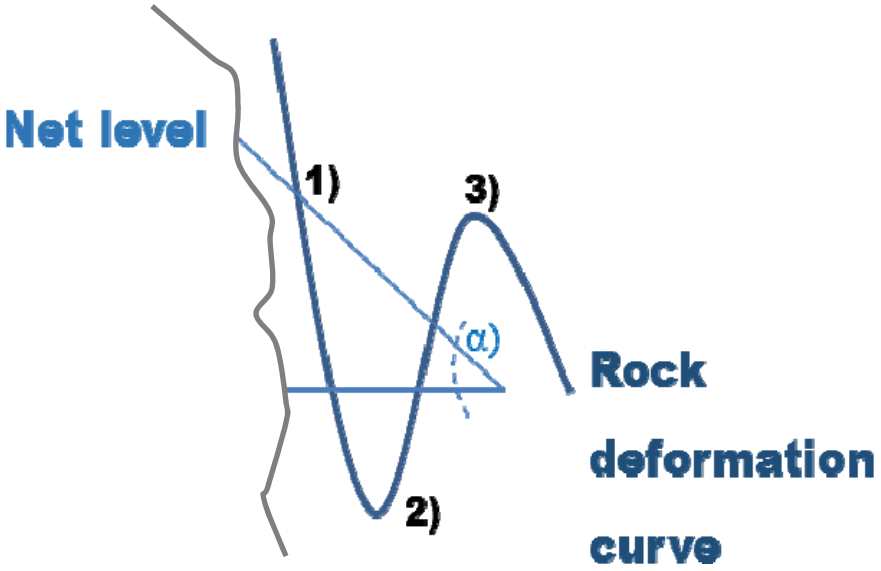
04

PARAMETER STUDY WITH FARO

PARAMETER STUDY WITH FARO

GEOBRUGG
Safety is our nature

Self-cleaning effect and the energy distribution



First net contact	Stopped block	Block moved out
$E_{pot} = 0$	$E_{pot} = 0$	$E_{pot} = max.$
$E_{kin} = max.$	$E_{kin} = 0$	$E_{kin} = 0$
$E_{ten} = 0$	$E_{ten} = max.$	$E_{ten} = 0$

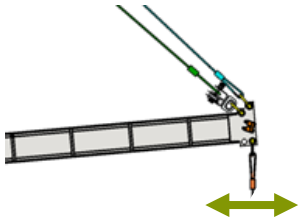
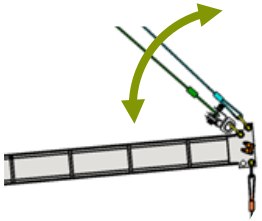
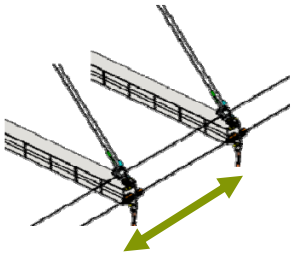
α = net angle

1) E_{kin} = max., kinetic energy is maximum by first contact rock and net
2) E_{ten} = max., deformnation energy is maximum, velocity of rock is zero, v=0 m/s
3) E_{pot} = max. defornmation, rebound point of the rock, velocity is negative (rebounding rock)

PARAMETER STUDY WITH FARO

GEOBRUGG BRUGG Safety is our nature

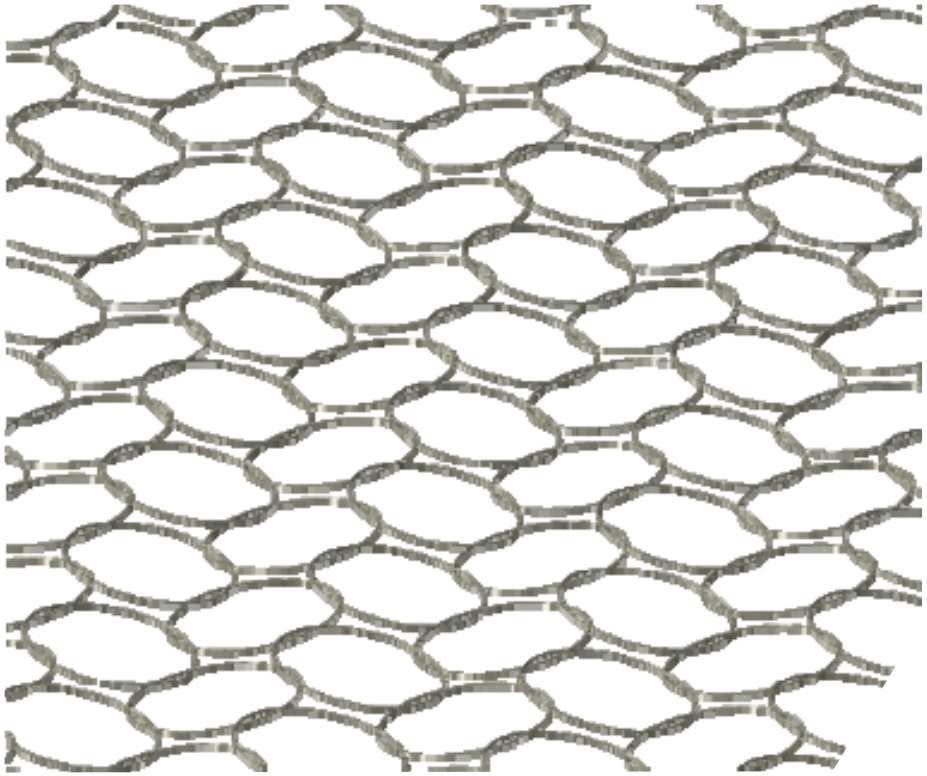
Parameter and influence for the canopy system to self-cleaning effect

A1 - Post length		L= 6.0m – 10.0m
B1 - Net angle		α= 30° – 50°
C1 – post spacing		S= 6.0 – 12.0m

PARAMETER STUDY WITH FARO

GEOBRUGG
BRUGG
Safety is our nature

Ring Net



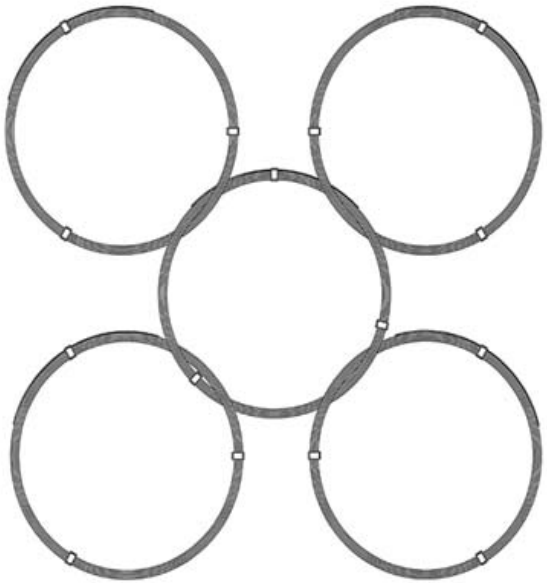
- Elastic properties
- Plastic properties
- Damage
- Ring-to-ring contact (friction)
- Diameter
- **# Winding number**

PARAMETER STUDY WITH FARO

GEOBRUGG® BRUGG Safety is our nature

Winding number

ROCCO® 7/3/300
ROCCO® 12/3/300
ROCCO® 16/3/300
ROCCO® 19/3/300

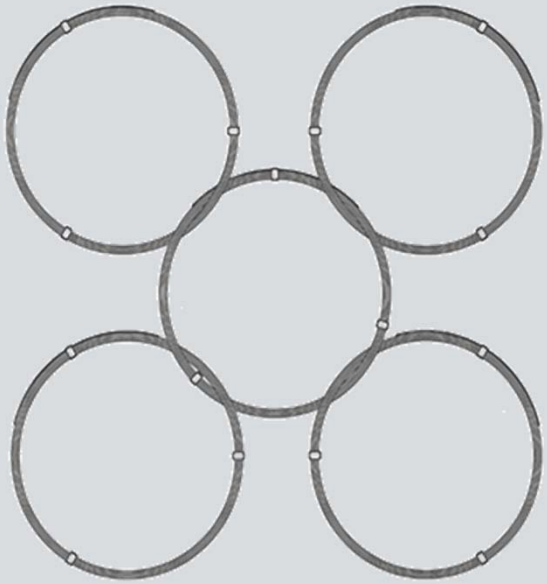
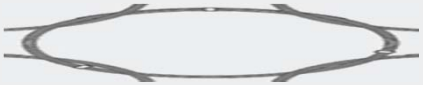
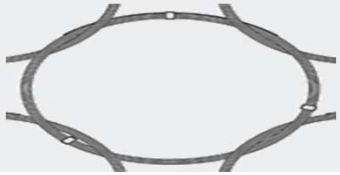


- Increasing load capacity with increasing winding number
- 7/3/300: 50 kN / Ring
  12/3/300: 100 kN / Ring
  16/3/300: 140 kN / Ring
  19/3/300: 180 kN / Ring

PARAMETER STUDY WITH FARO

GEOBRUGG
BRUGG
Safety is our nature

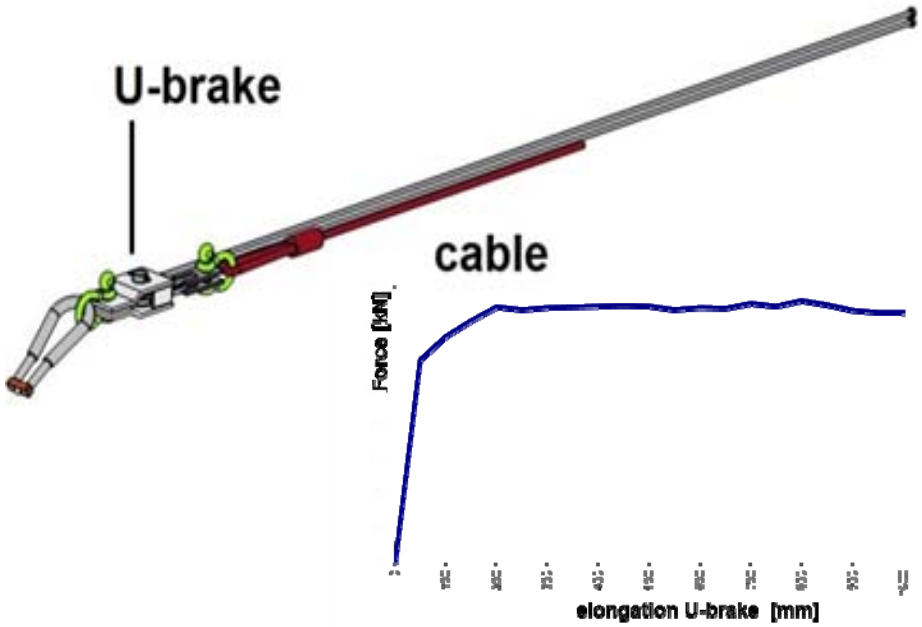
Ring Properties

1. Ring Net Before Impact/ Deformation	2. ROCCO Ring Net During Impact	3. ROCCO Ring Net After Impact
	Elastic & plastic behavior	Permanent plastic deformation
		
	Elastic behavior	Elastic Rebound
		

PARAMETER STUDY WITH FARO

GEOBRUGG
BRUGG
Safety is our nature

System Brakes – Energy Dissipating Devices

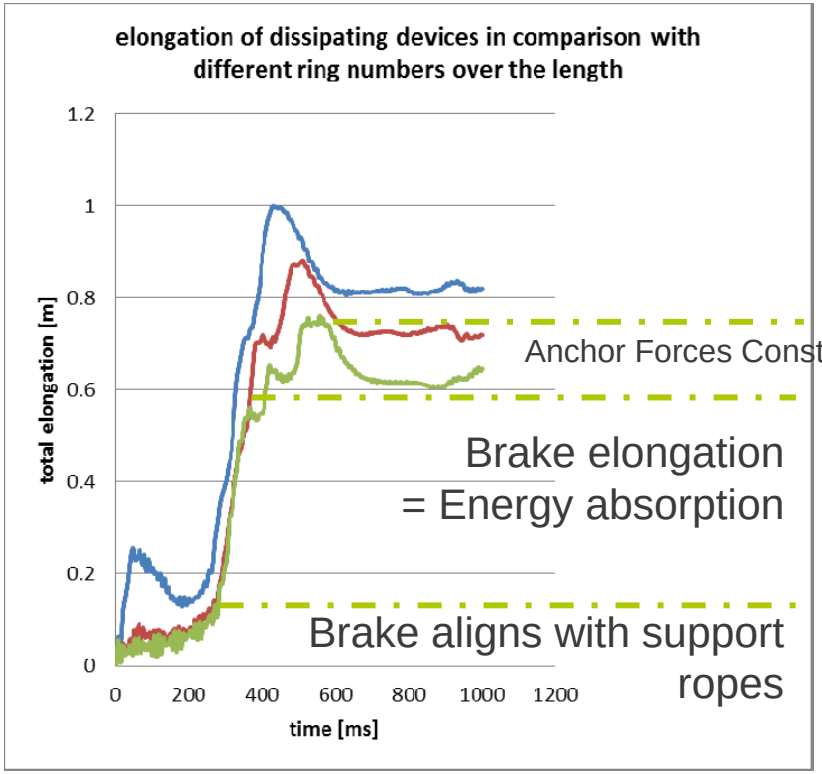


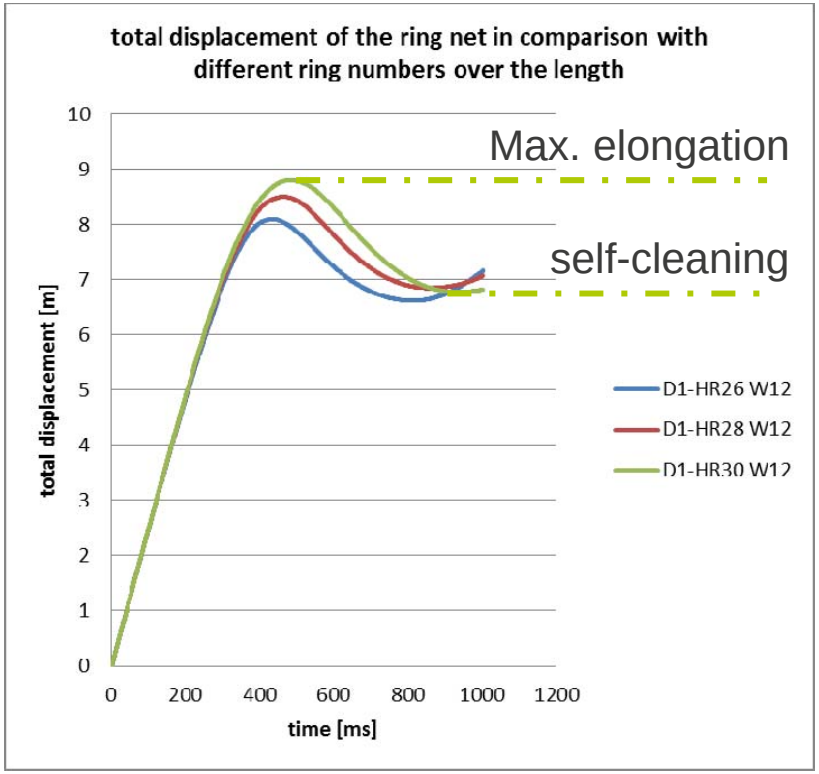
- High activation force
- Barrier reacts mostly elastic
- Controlled anchor forces

PARAMETER STUDY WITH FARO

GEOBRUGG
Safety is our nature

Explanation of the FARO results

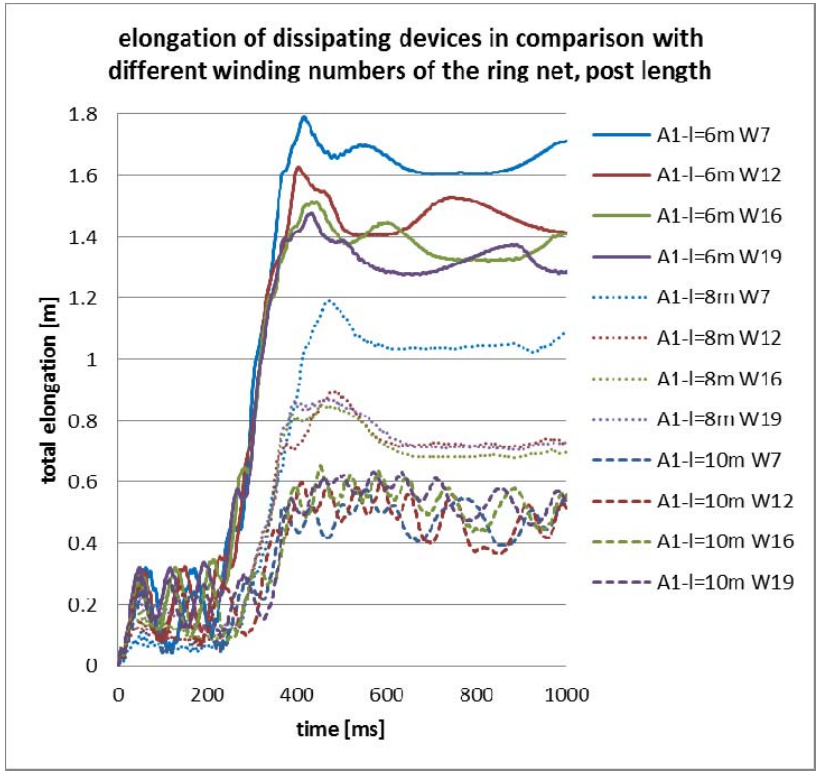


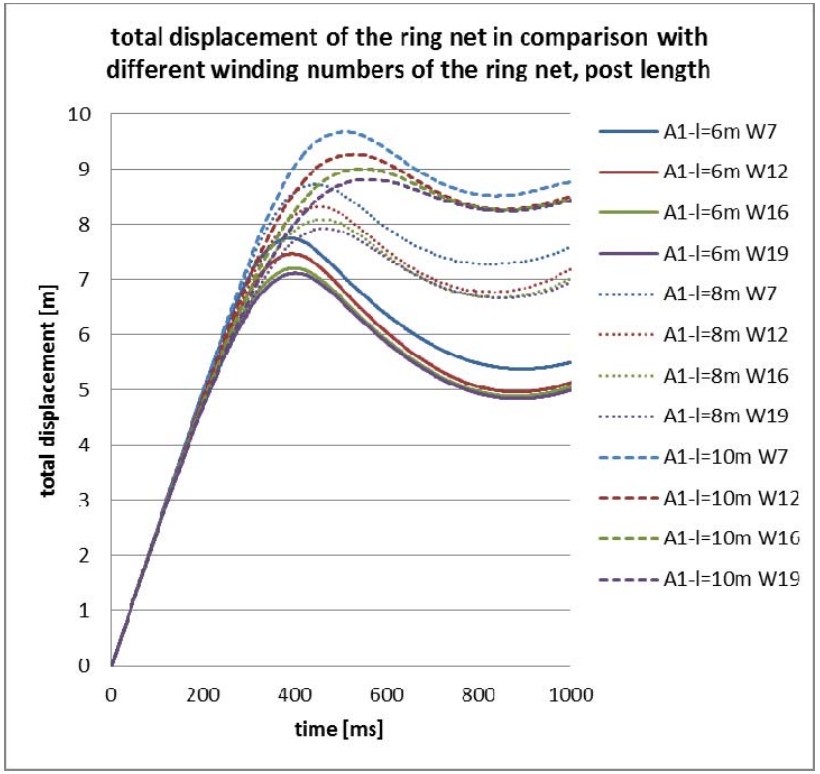


PARAMETER STUDY WITH FARO

GEOBRUGG
Safety is our nature

Self-cleaning behavior depending on post length

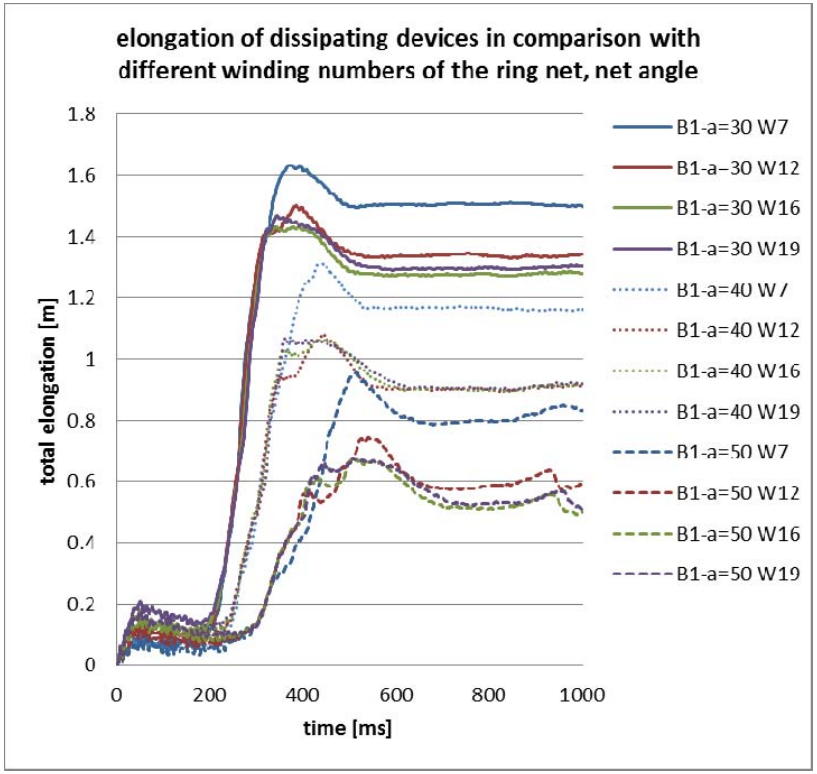


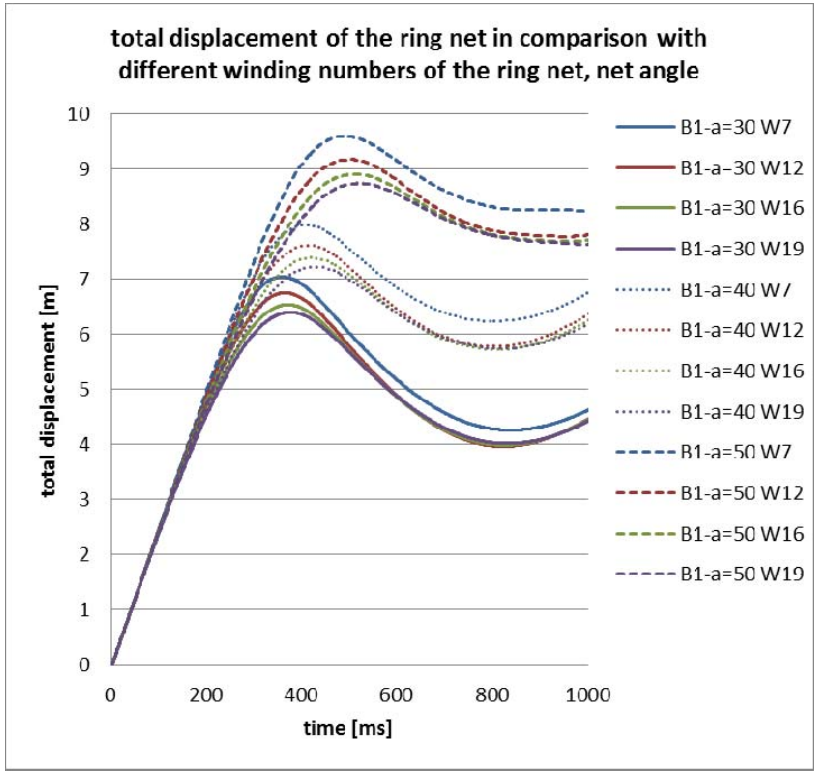


PARAMETER STUDY WITH FARO

GEOBRUGG
Safety is our nature

Self-cleaning behavior depending on net angle

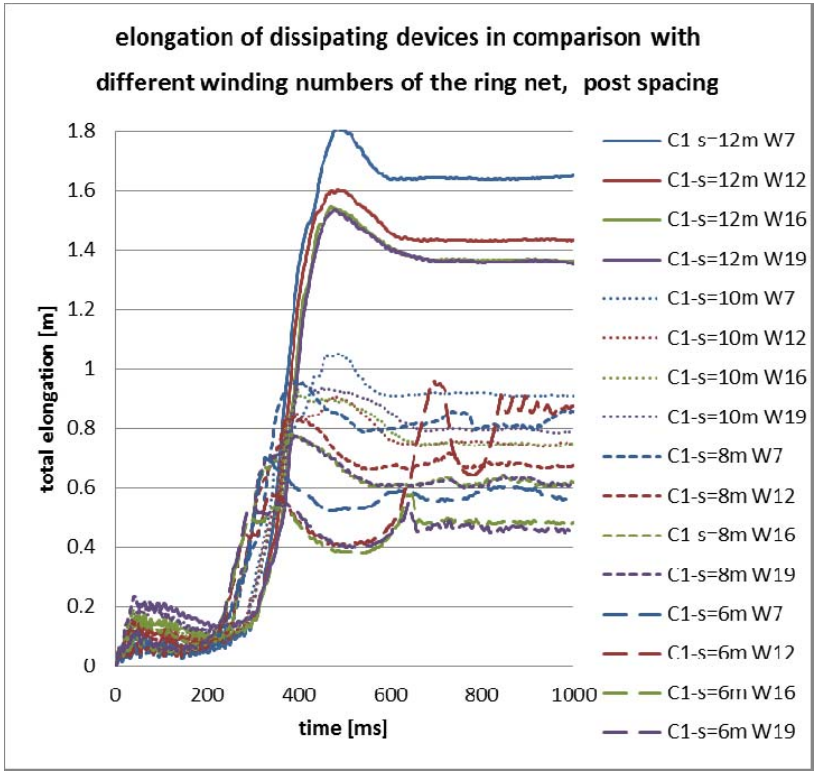


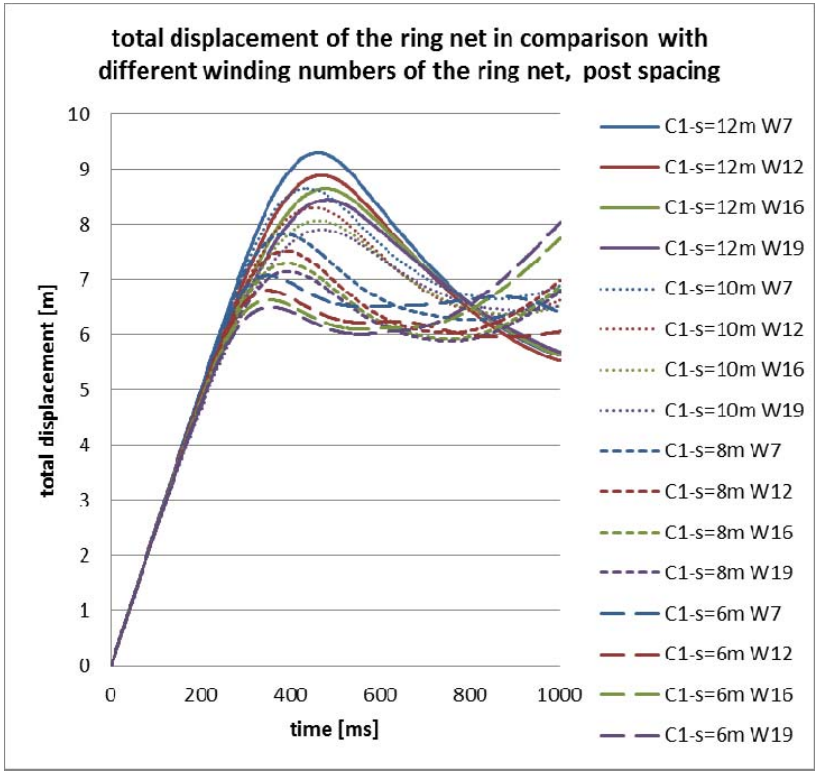


PARAMETER STUDY WITH FARO

GEOBRUGG
BRUGG
Safety is our nature

Self-cleaning behavior depending on post spacing





GEOBRUGG
BRUGG
Safety is our nature

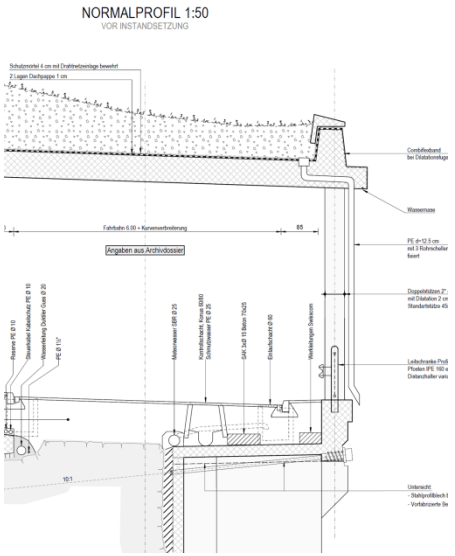
05

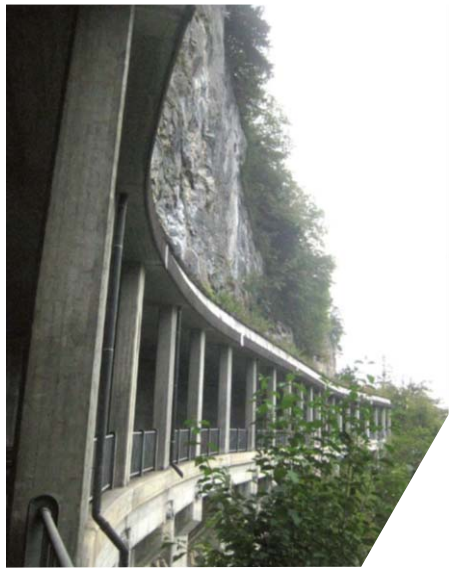
ALTERNATIVE TO CONCRETE GALLERY

CONCRETE GALLERIES IN COMPARISON

GEOBRUGG
BRUGG
Safety is our nature

Mattstock, Churfirsten, Switzerland



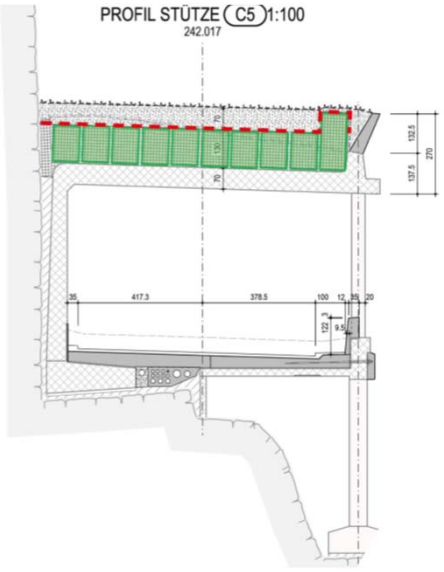


Concrete width	: 9.95m
Gallery length	: 110m and 155m
Roof thickness of concrete	: 0.70m + appr. 1.00m damping material (gravel, soil)
Energy level	: 300 – 500 kJ

MODIFICATION ROCKFALL-X®

GEOBRUGG BRUGG Safety is our nature

Mattstock, Churfirsten, Switzerland

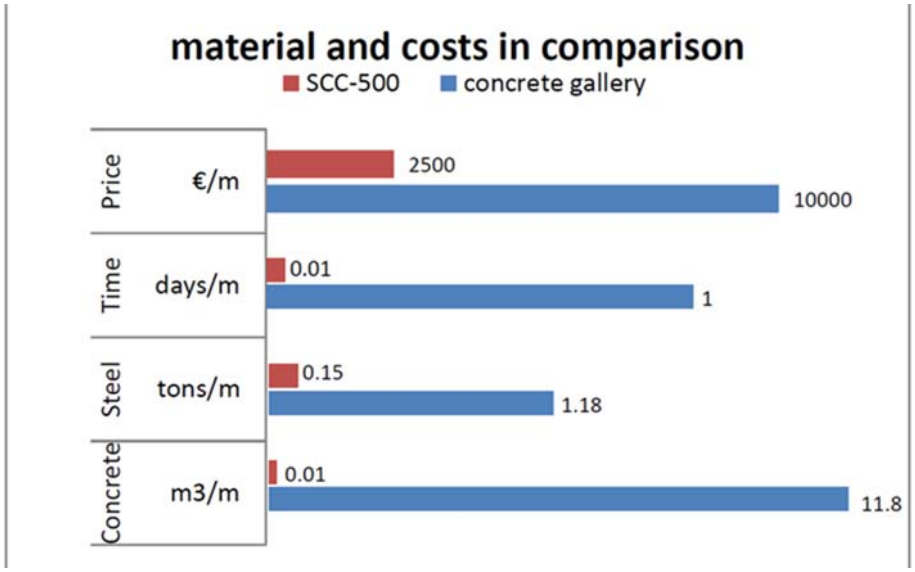


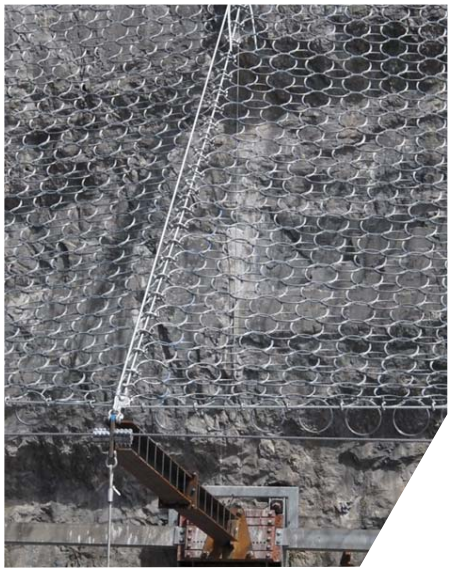
Energy level	: 200 – 1900 kJ
Rockfall-X® bags	: 1300 pcs à 1.30m and 575 pcs à 2.00m

CONCRETE GALLERY VS. CANOPY

GEOBRUGG
BRUGG
Safety is our nature

SCC-500kJ cost effective and less installation time





Flexible systems reduce the impact force. This fact allows a very economic use of material. Additionally, the forces in the foundation and wire rope anchors are reduced.

GEOBRUGG
BRUGG
Safety is our nature

THANK YOU