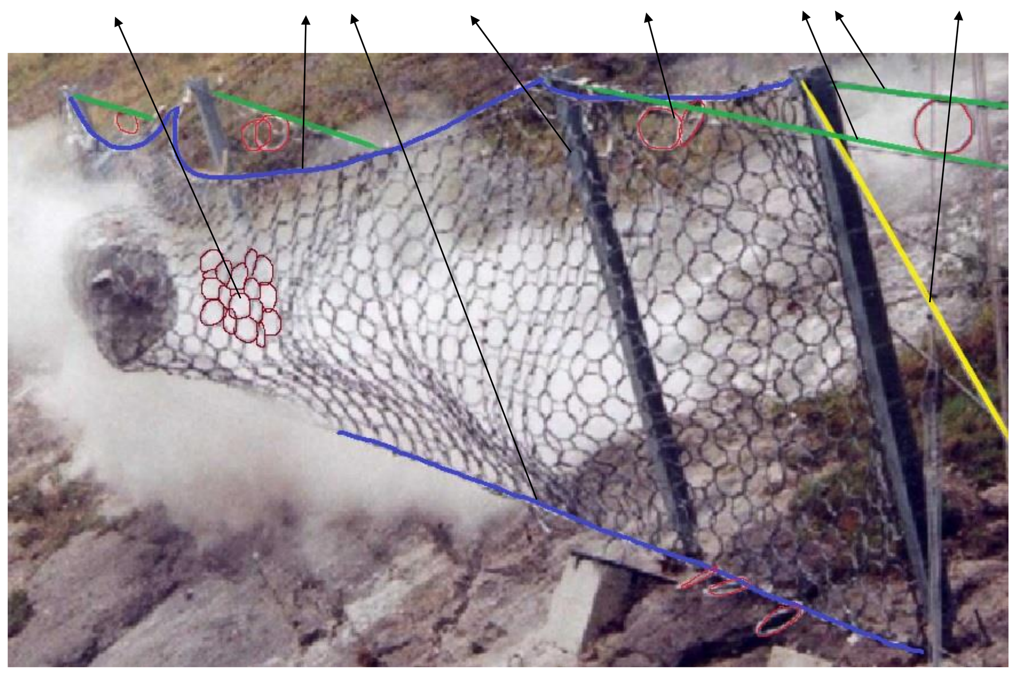
EXPECTED WORKING LIFE AND MAINTENANCE OF ROCKFALL FLEXIBLE PROTECTION SYSTEMS

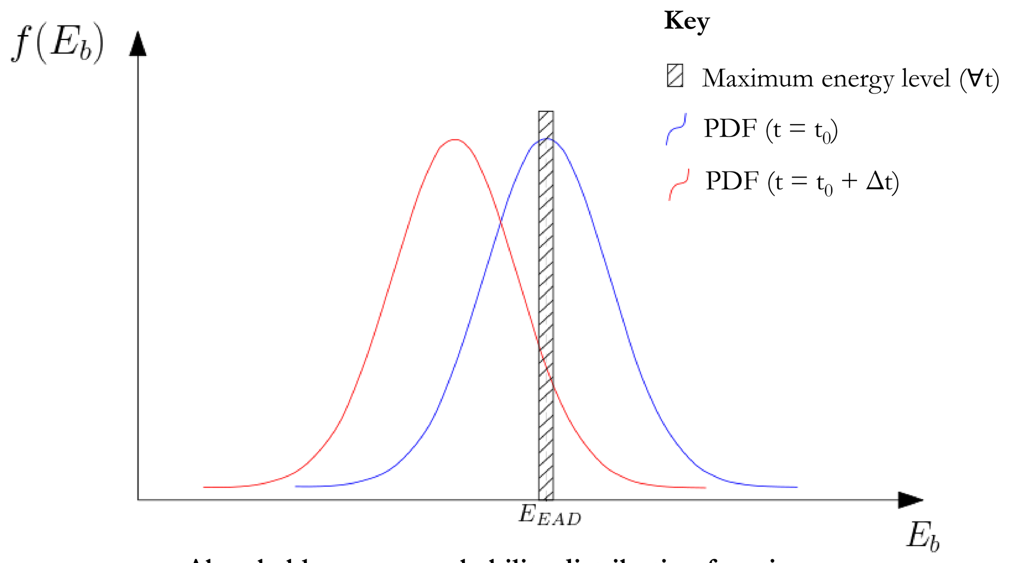
Scientific Supervisors: Prof. Valerio De Biagi, Dr. Maddalena Marchelli

PhD Student: Eng. Francesco Pimpinella

Outline of the research



Flexible rockfall barrier subjected to impact, Fatzer



Absorbable energy probability distribution functions

Flexible rockfall barriers are effective structures for protection against rockfall events. However, a codified design procedure has not been defined yet, and only the performance assessment for placing a product on the European market is defined through EAD 340059-00-0106 (2018)

The aim of the research is to provide a trustworthy evaluation of the system capacity during its service life, which would allow the definition of efficient maintenance procedures. It is thus required to estimate the performance threshold time and understand which are the factors that are critical for reaching this performance threshold

1.Development of a complete analytical model (adaptable to a wide variety of existing tecnhologies) by:

- studying the single structural components
- proposing for them partial analytical models
- assembling the parts into a complete model

2.Execution of corrosion tests on critical parts in order to evaluate the material degradation under different exposure site conditions

3.Realization of numerical models mainly related to single components, so that it is possible to validate analytical models or extend the results of impact tests to different system typologies

Analytical models for energy dissipating devices

1. Double tube crushing dissipator

2. Squared thin-walled tube dissipator

3. U-brake

4. Brake ring

Analytical models and small scale experiments

1. $E_d(x) = F(A, A_1, f_y)\ x \cong 1.17\ P_{a,1}\ x$
2. $E_d(x) = F(A, A_1, f_m)\ x \cong \dfrac{2\ P_{a,2}}{1 + e^{-\mu_1 \pi}}\ x$
3. $E_d(x) = F(\mu_2, M_{res}, R, b_1, b_2, M_p)\ x$

Validation through literature data or small scale experiments

Key

- E_d → Dissipated energy
- x → Brake travel length
- F → Mean force causing movement
- A → Brake cross sectional area
- A_1 → Area enclosed by the cross section
- f_y → Material yielding stress
- f_m → Material mean stress in plastic phase
- μ_1 → Rope - guide friction coefficient
- μ_2 → Roller - case friction coefficient
- M_p → Metallic ribbon plastic moment
- R → Roller radius
- $b_{1,2}$ → External case position
- $P_{a,1}$ → Buckling load for circular thin-walled sections
- $P_{a,2}$ → Buckling load for squared thin-walled sections (Abramowicz et al., 1984)

Small scale test on squared tube dissipator

Small scale test on U-brake

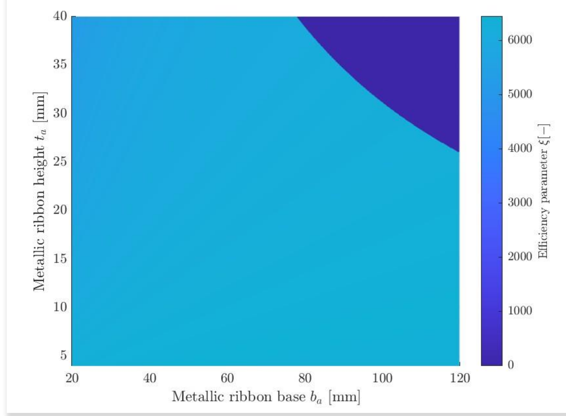
Efficiency sensitivity analysis

$$\xi = \frac{E_{d,1}}{W}$$

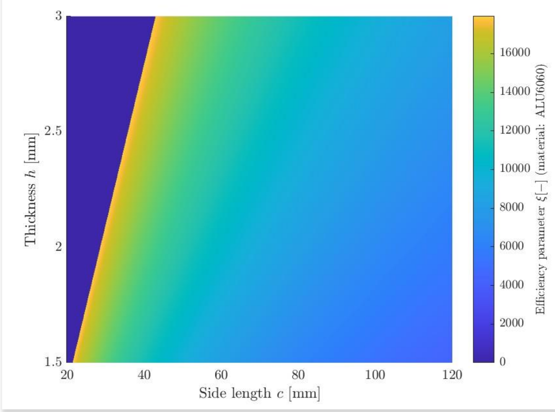
$E_{d,1}$ → Dissipated energy for unitary brake travel length

W → Weight

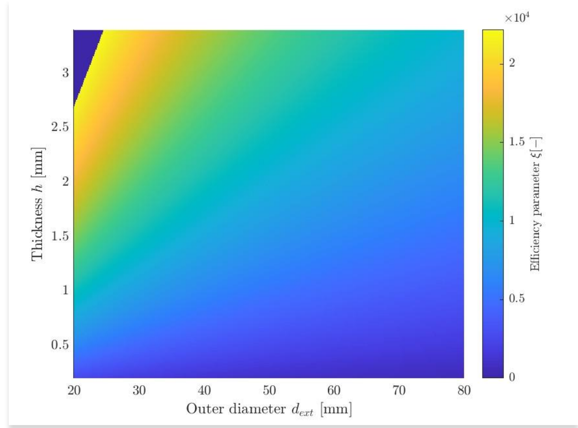
For different energy dissipators, ξ is computed and its sensitivity towards geometrical properties variation is investigated



ξ computation for U-brake

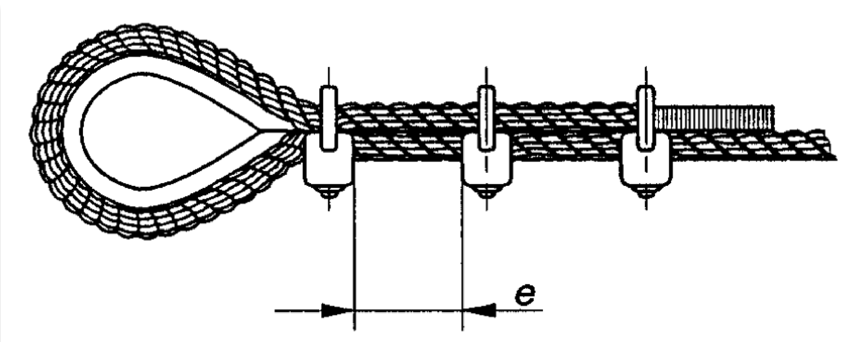


ξ computation for squared thin-walled tube

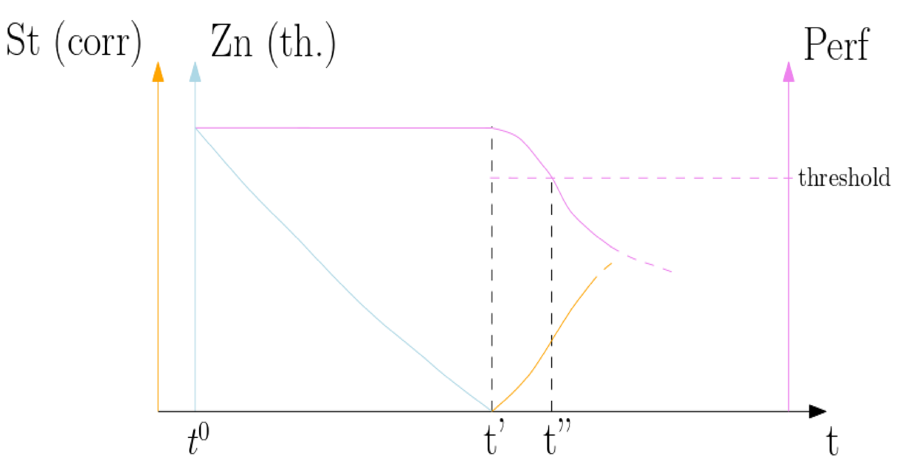


ξ computation for double tube crushing dissipator

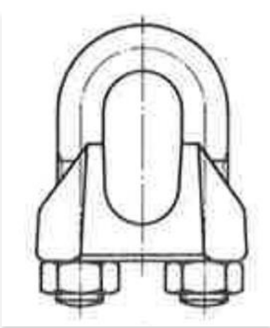
Corrosion test campaign on rope end connections (critical element)



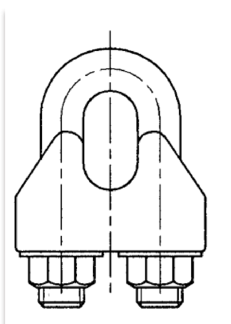
Rope dead end connection



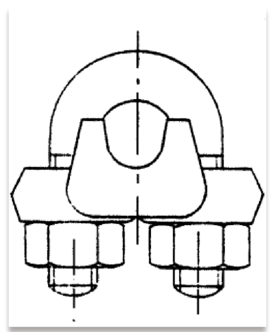
Different regulations standirdised connections have different geometry and coating



DIN 741



EN 13411-5: Type A



EN 13411-5: Type B

Oldest → Most recent

Key

- t^0 → Installation time
- t' → Zinc coating loss time
- t'' → Performance threshold time
- Zn(th) → Zinc coating thickness
- St(corr) → Corroded steel thickness

Artificial corrosion test choice

Preliminar tests on a small number of specimens in order to correlate lab results with exposition enviroments

- On-site measurements
- Use of corrosion measuring devices

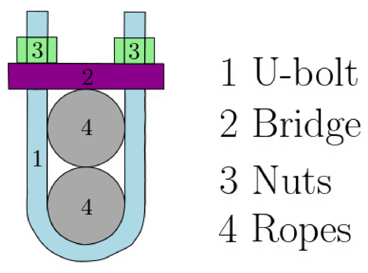
Testing time choice and extended artificial corrosion test campaign realization, considering tests on

- multiple scales
- different rope diameters (from ϕ12 to ϕ22)
- different rope end connection technologies

EN 16701
RH cycles: 12 hours duration
Temperature is constant
→ Best option to simulate on-site corrosion

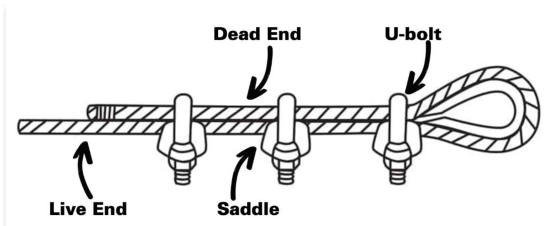
DIN 55635
RH cycles: one week duration
Temperature is variable
→ Useful for preliminary tests

Preliminary tests (DIN 55635): climatic chamber



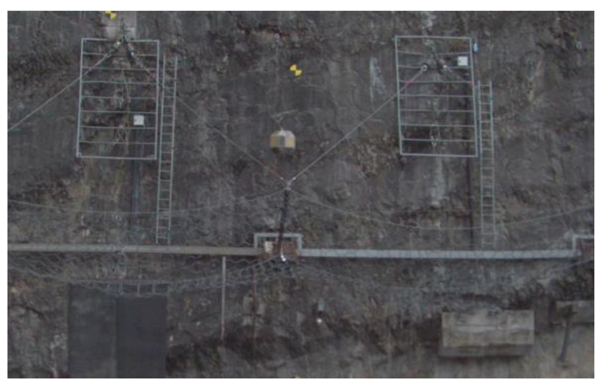
a. scale: single components

b. scale: single grip



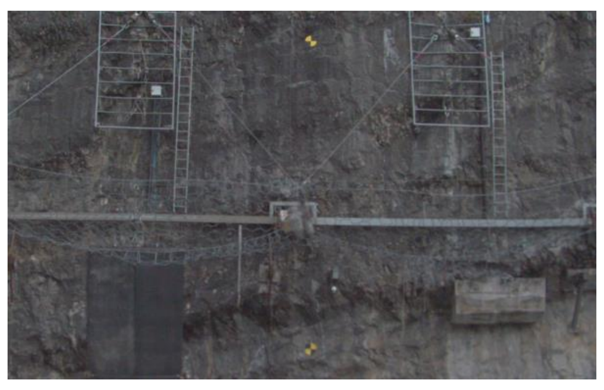
c. scale: entire connection

Impacted post: numerical modeling



Impact on steel post test: undeformed stage

Impacted steel post: on-site scan (side 1)



Impact on steel post test: deformed stage

Impacted steel post: on-site scan (side 2)

Rockfall barriers performance is evaluated in terms of energy dissipation. The certification is demanded to a standard test procedure in which the impact is produced only on the intercepting structure, and in detail at the centre of its central functional module. There is limited data concerning impacts on sustaining structural elements, which can happen on site

Experimental test

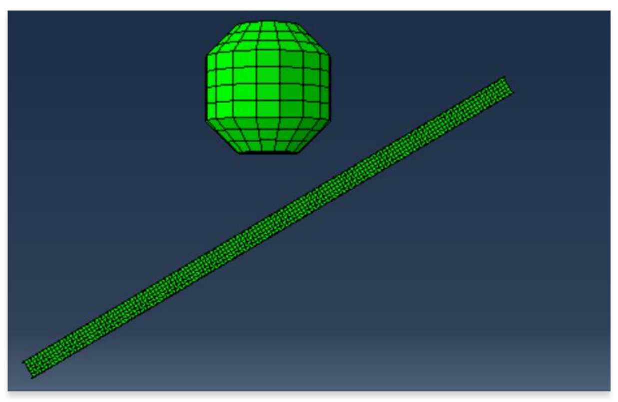
The test has been performed in Geobrugg test site in Walenstadt (Switzerland), with the following features:

- Service Energy level (SEL) test with ≈180 kJ incoming energy
- Impactor mass: 580 kg
- Impactor shape: compliant to EAD 340059-00-0106
- Post profile: HEA 120
- Impact produced at midspan
- Known geometry and rope diameters

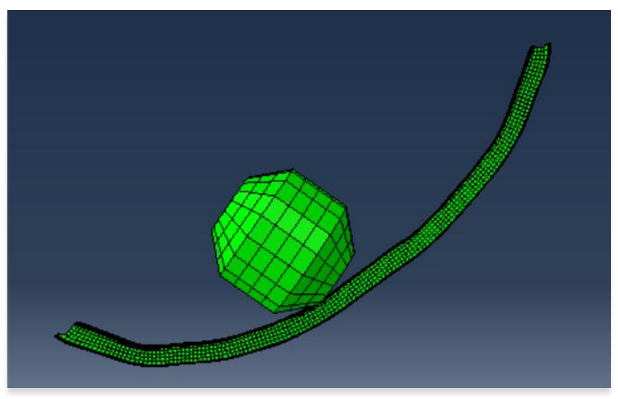
Numerical modeling

Calibration by means of a back-analysis on the deformed shape

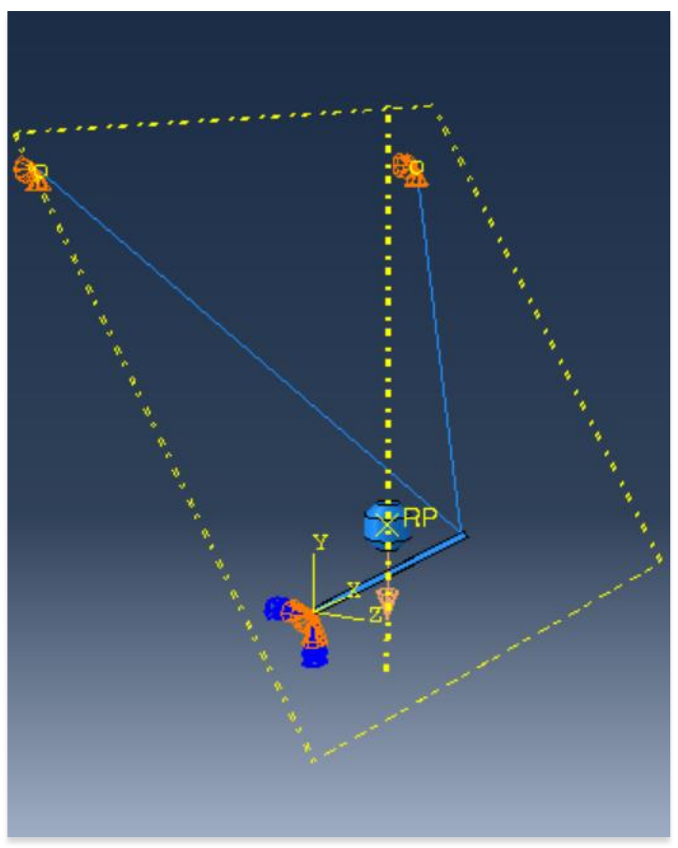
Execution of multiple simulations considering different flexible barrier typologies and various impacting energies



Hinged boundary conditions: undeformed configuration



Hinged boundary conditions: deformed configuration



Boundary conditions refinement

Additional activities

Hard skills courses: 115 h (Score → 178.33)

Soft skills courses: 40 h (Score → 53.33)

The PhD scholarship is co-financed by the Ministerial Decree no. 352 of 9th April 2022, based on the NRRP - funded by the European Union - NextGenerationEU - Mission 4 "Education and Research", Component 2 "From Research to Business", Investment 3.3, and by Geobrugg AG.