UNIVERSITY OF PADOVA (ITALY)
DEPT. OF CIVIL, ENVIRONMENTAL AND ARCHITECTURAL ENGINEERING, DICEA

DALLA GASSA SRL
Geotechnical Engineering, Cornedo Vicentino (Vicenza, Italy)

ZABEZPIECZENIE OSUWISK PRZY POMOCY KOTEW SIRIVE®

LANDSLIDE PROTECTION USING SIRIVE® ANCHORS

MSc Ryszard Murzyn (Geo-Inz-Bud, Poland)
Dr Eng Alberto Bisson (Dept. ICEA, University of Padova, Italy)

DALLA GASSA SRL

COMPANY PROFILE

Main activities:

- Excavation support systems: Soil Nailing, Micropiles

- Landslide stabilization, rockfall protection

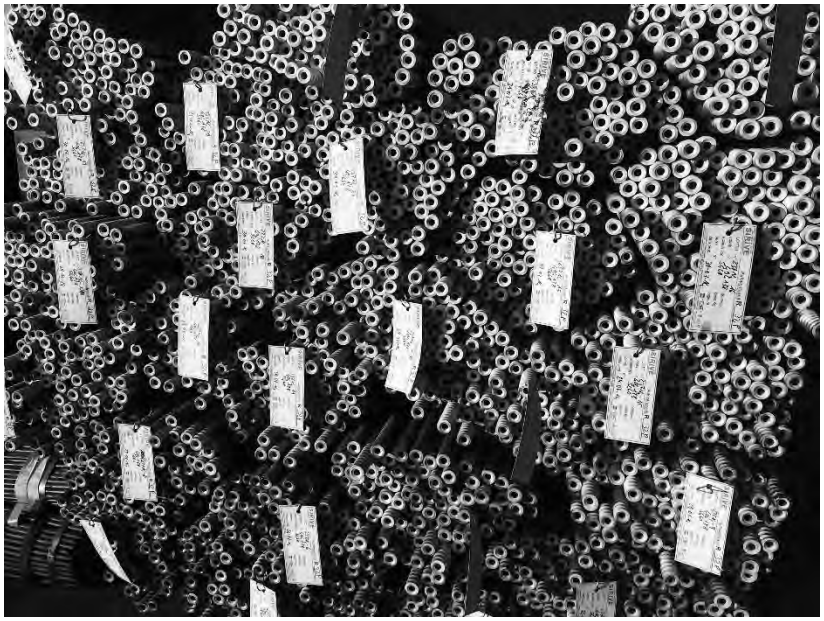
- Foundations engineering

DALLA GASSA SRL

SIRIVE® PRODUCTION

PRODUCTION

Dalla Gassa is the first Italian producer of self-drilling bars (since 2001)



CERTIFICATIONS

RINA Certificate
in accordance with
UNI EN ISO 9001:2008

Internal certificate
of the complete
Bar-Nut-Coupling system

Member of CISQ Federation
RINA
ISO 9001:2008
Sistema Qualità Certificato

DALLA GASSA SRL

SIRIVE® QUALIFICATION

- Qualification as **Official Producer** of Sirive® Self Drilling Bars in accordance with the Italian Ministerial Decree 14/01/2008
- **Certificate of qualification** nr. 002/14-AM for the production of "Self-drilling hollow bars S460J0 with continuous threading, nominal diameter 28 to 38 mm, for passive anchors for geotechnical use"
- Date: **September 9, 2014**
- **Internal laboratory**


autoperforanti SIRIVE®

ATTESTATO DI QUALIFICAZIONE
002/14-AM

In conformità al D.M. 14.01.2008 "Norme tecniche per le costruzioni", si attesta che il prodotto da costruzione:

ACCIAIO PER STRUTTURE METALLICHE

Barre cave autoperforanti S460J0 a filettatura continua di diametro nominale da 28 a 38 mm per tiranti di ancoraggio ad uso geotecnico di tipo passivo.

Etichetta di identificazione

prodotto da:
DALLA GASSA s.r.l.
Via Fogazzaro, 71
36073 - CORNEDO VICENTINO (VI)

nello stabilimento di:
via Fogazzaro,71 – 36073 CORNEDO VICENTINO (VI)

è stato sottoposto da parte del Produttore alle prove di qualificazione del prodotto effettuate a cura del Laboratorio Ufficiale Politecnico di Torino - Dipartimento di Ingegneria Strutturale e Geotecnica e il **Servizio Tecnico Centrale del Consiglio Superiore dei Lavori Pubblici** ha effettuato l'ispezione iniziale dello stabilimento e del controllo di produzione in fabbrica.

Il presente certificato attesta che tutte le disposizioni riguardanti la procedura di qualificazione definita nella norma

D.M. 14.01.2008: "Norme tecniche per le costruzioni"

sono state applicate.

Il presente attestato ha validità 5 anni dal **18.07.2014** a sino a che le condizioni di produzione in fabbrica e il controllo di produzione in fabbrica non subiscano modifiche significative.

Roma, 9.09.2014

IL DIRIGENTE DELLA DIV. III DEL SERVIZIO TECNICO CENTRALE
Dott. Ing. Marco Pancaldo

PANCALDO MARCO

Consiglio Superiore dei Lavori Pubblici - Servizio Tecnico Centrale

DALLA GASSA SRL

RESEARCH & DEVELOPMENT DIVISION

- Advanced **landslide monitoring**
- **Sirive®-1 technical validation:** a «green» Soil Nailing
- PhD on **Sirive® Floating Anchor** for landslide stabilization
- Research & Development of **Sirive® Special Composite Anchor**
- Partnership with **University of Padua** (Italy), **Polytechnic University of Turin** (Italy) and **University of Agricolture in Krakow** (Poland)

ICEA

Production Control Tutor
for Sirive® Self-Drilling Bars

UNIVERSITY OF AGRICULTURE
IN KRAKOW

DALLA GASSA SRL

AWARDS AND PRIZES

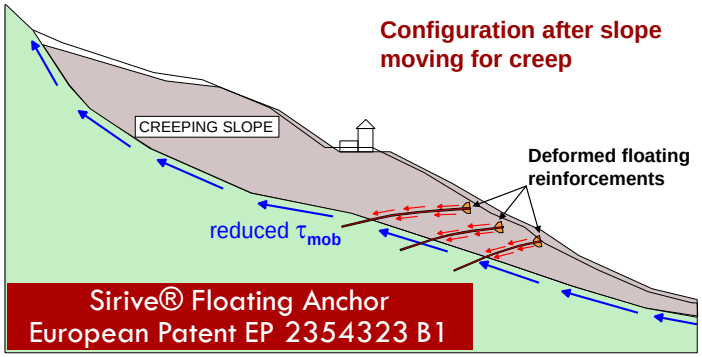
- **Bisson A.**, Dalla Gassa G. (2013)
  SIRIVE® FLOATING ANCHOR: PATENT AND RESEARCH PROJECT
  Galileo Innovactors' Festival 2013 - European exhibition on innovation and technology transfer
  Special mention at the Micro-Innovation Marathon (2013)

- **Bisson A.**, Cola S. (2014)
  FLOATING ANCHORS FOR THE STABILIZATION OF SLOW-MOVING LANDSLIDES
  CNG 2014: The geotechnical engineering in the defense of land and infrastructure from natural disasters, XXV National Geotechnical Congress, Baveno (Italy), Vol. 2, pp. 327-334
  ISBN: 9788897517054
  Italian Geotechnical Association Award: best paper for technical-scientific content (2014)

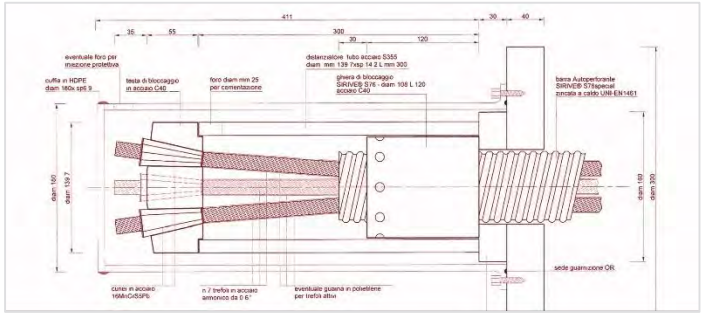
DALLA GASSA SRL

EUROPEAN PATENTS

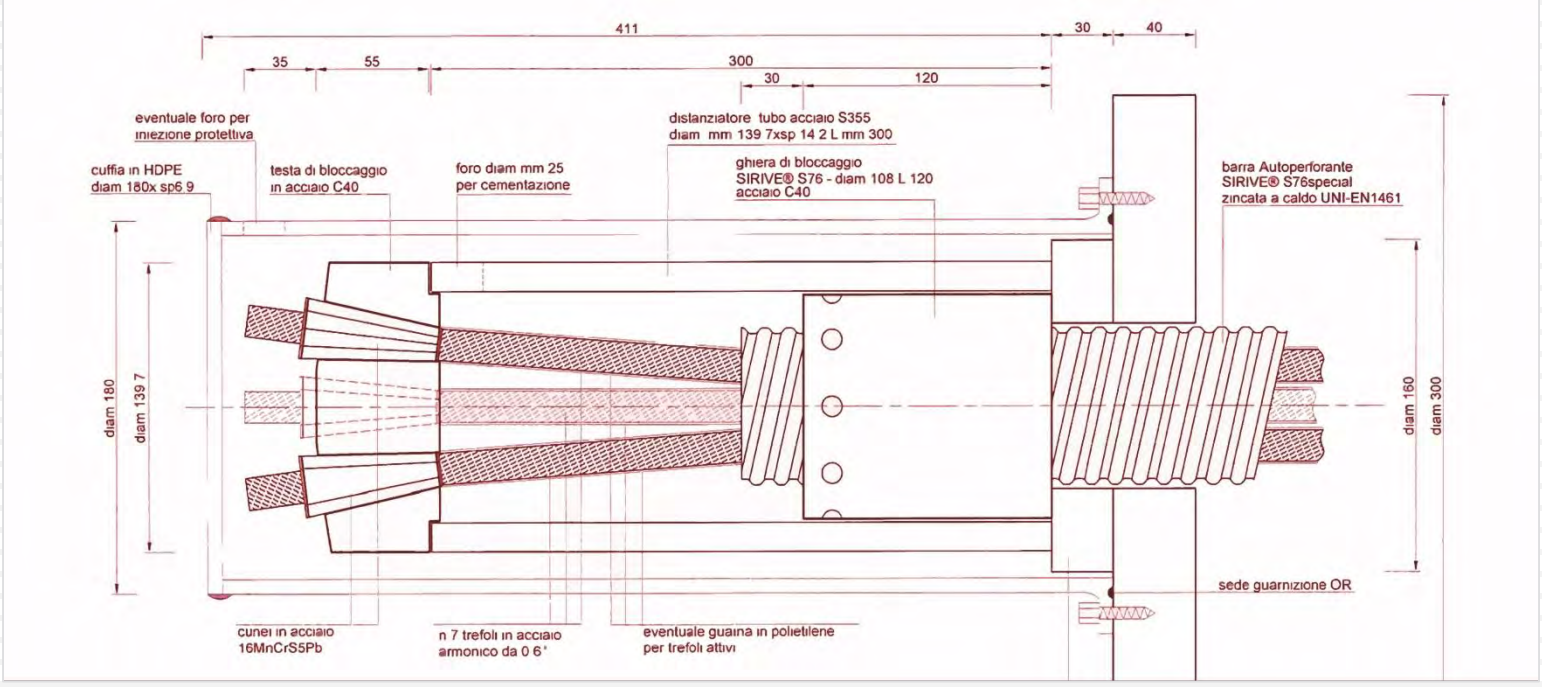
- **SIRIVE® FLOATING ANCHOR**
  European Patent
  EP 2354323 B1
  Date of publication and mention of the grant of the patent: April 1, 2015



- **SIRIVE® COMPOSITE ANCHOR**
  European Patent application
  EP 20130157515.1
  Date of application: March 1,2013
  The opposition process is still ongoing (2015)

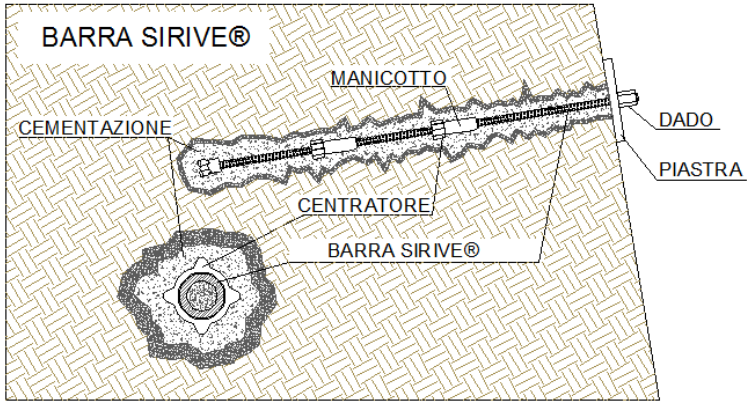


SIRIVE® SPECIAL COMPOSITE ANCHOR



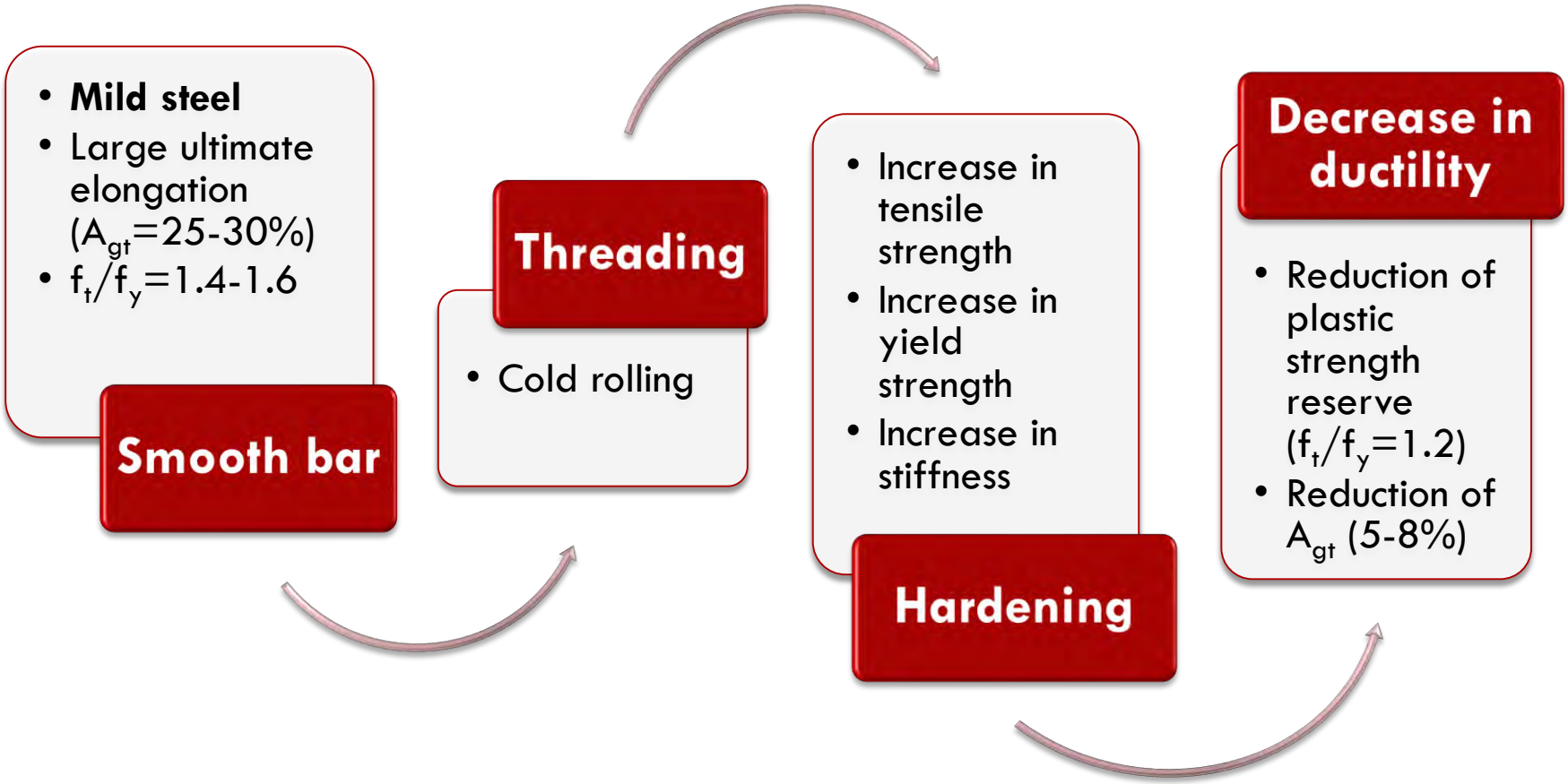
SIRIVE® SELF-DRILLING BARS

- Self-drilling hollow bars cemented along the entire profile (nails)
- **Passive** reinforcements (not pretensioned)
- **Advantages:**
  - Simple and **fast execution**
  - Increasing of the diameter of the cemented bulb
  - Low cost



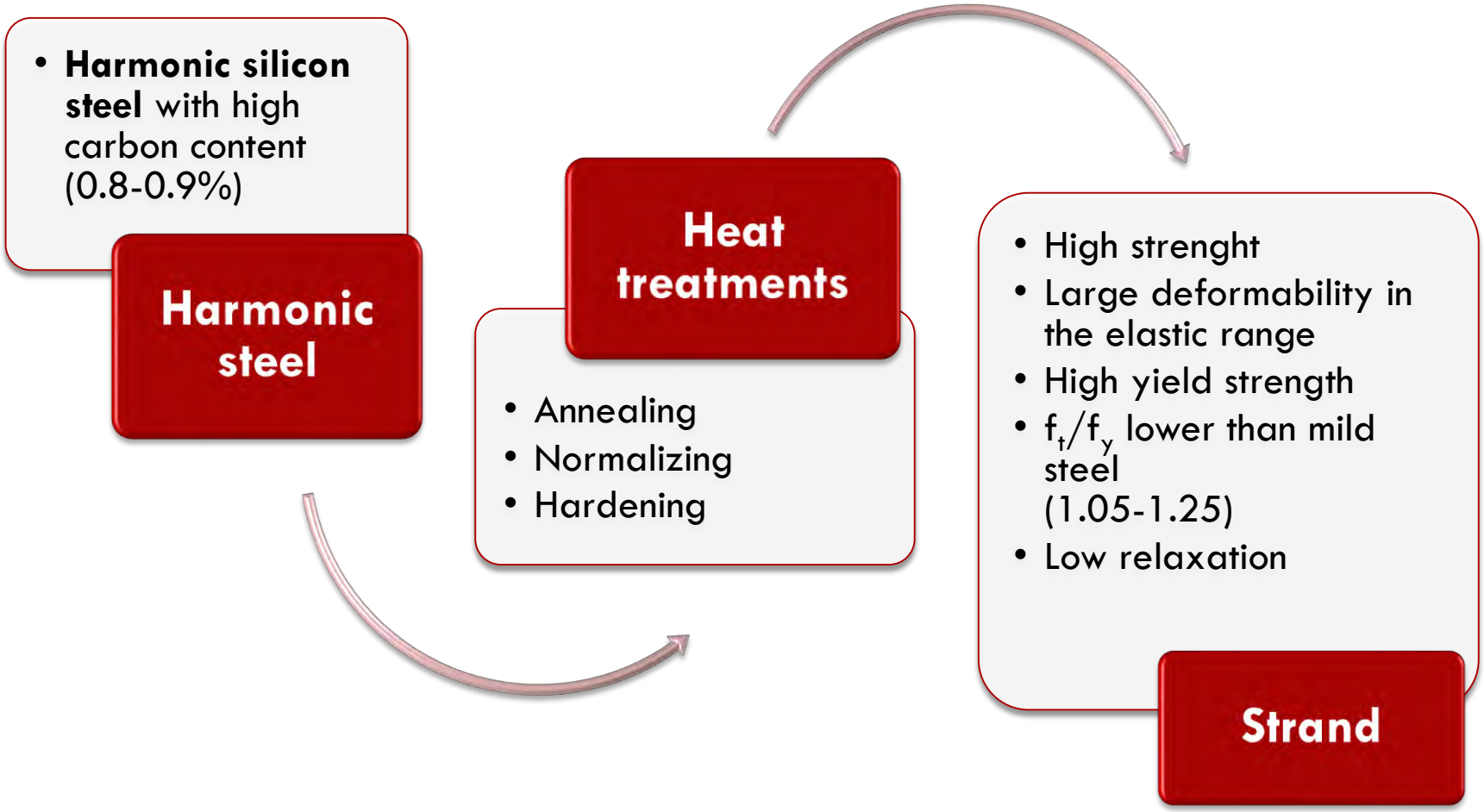
SELF-DRILLING BARS

PRODUCTION PROCESS



STRANDS

PRODUCTION PROCESS

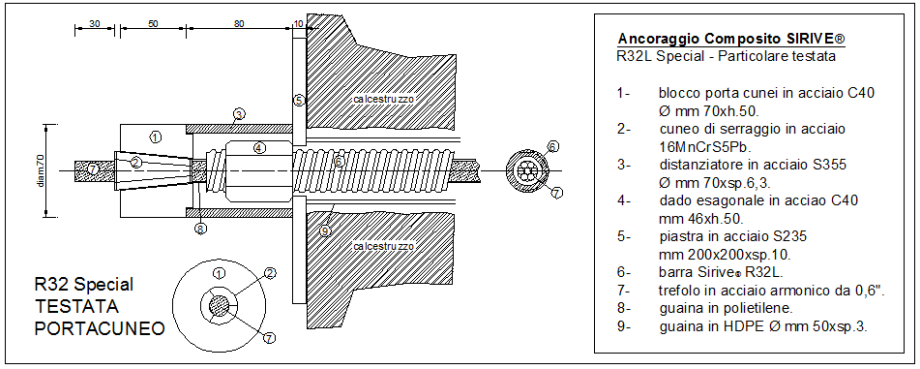


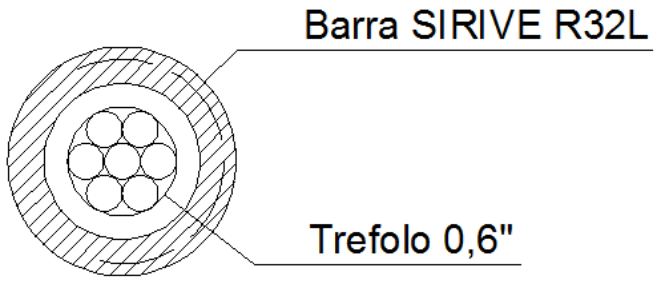
SIRIVE® SPECIAL COMPOSITE ANCHOR

BASIC IDEA

- Goals:
  - **Serviceability limit state:** increase of the admissible load at constant elongation in the elastic domain;
  - **Ultimate limit state:** decrease of the plastic deformations at constant elongation.
- Basic idea:

SELF-DRILLING BAR + STRANDS = SIRIVE® COMPOSITE ANCHOR





SIRIVE® SPECIAL COMPOSITE ANCHOR

ANALYTICAL MODEL

- Main hypotheses:
  - **Congruence** of the coupled system

$$\frac{F_b(\sigma)}{E_b(\sigma)\cdot A_b} = \frac{F_t(\sigma)}{E_t(\sigma)\cdot A_t} = \frac{F(\sigma)}{(EA)_{eq}(\sigma)} \qquad dove:\ A = A_b + A_t$$

  - **Equilibrium** of the coupled system

$$F_b(\sigma) + F_t(\sigma) = F(\sigma) = (EA)_{eq}(\sigma)\cdot\frac{\Delta l(\sigma)}{l_0}$$

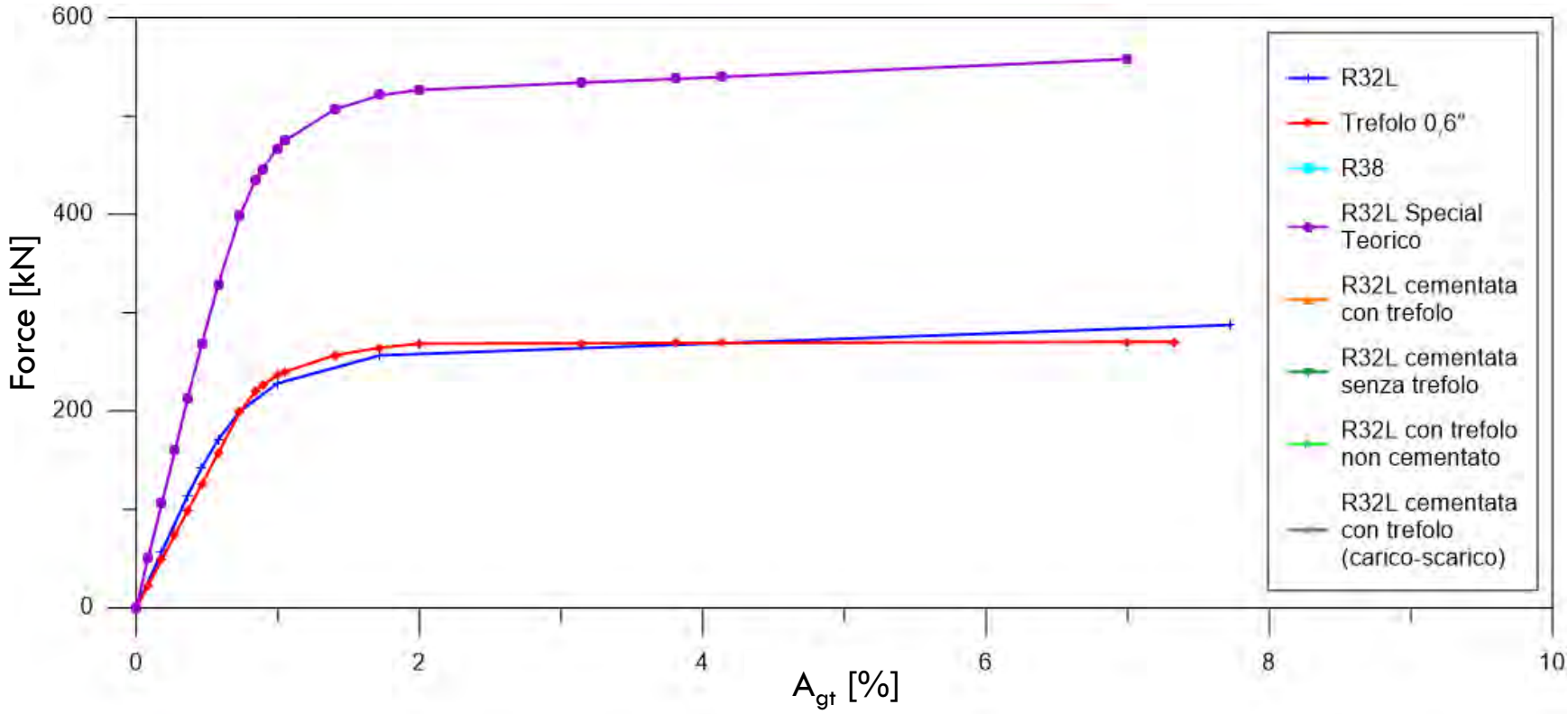
  - Negligible thermal variations

- Axial stiffness and elastic modulus **equivalence:**

$$(EA)_{eq}(\sigma) = [E_b(\sigma)\cdot A_b + E_t(\sigma)\cdot A_t] \qquad E_{eq}(\sigma) = \frac{[E_b(\sigma)\cdot A_b + E_t(\sigma)\cdot A_t]}{A_b + A_t}$$

SIRIVE® SPECIAL COMPOSITE ANCHOR

EXPERIMENTAL TESTS

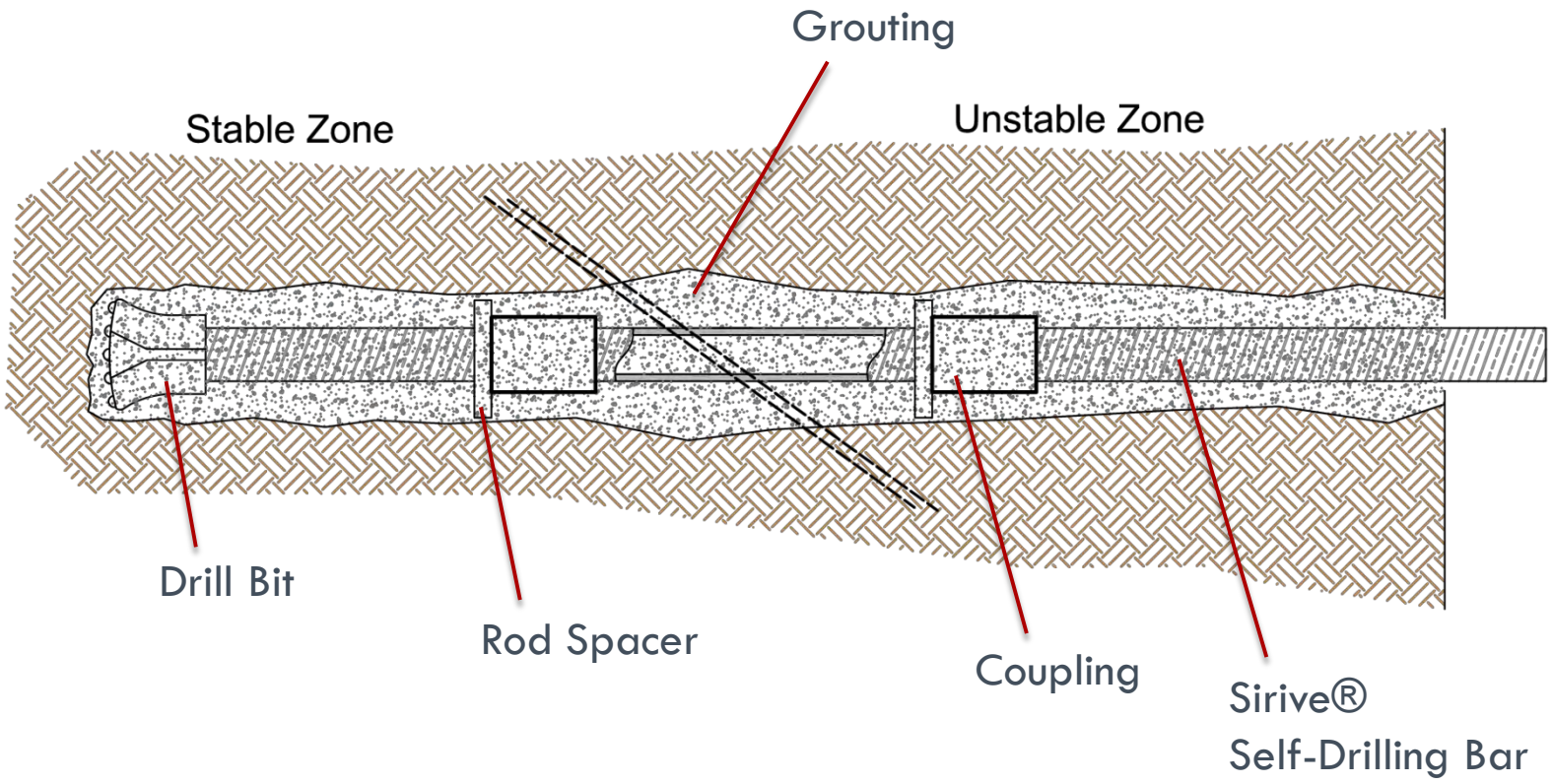


*Mechanical behaviour of **R32L Sirive® Self-drilling** traditional bar **(blue)**, a **0,6" strand** (red) and **Sirive® Special R32S Composite Anchor (violet)**.*

SIRIVE® SPECIAL COMPOSITE ANCHOR

INSTALLATION STEPS FOR ROCK SLOPE STABILIZATION

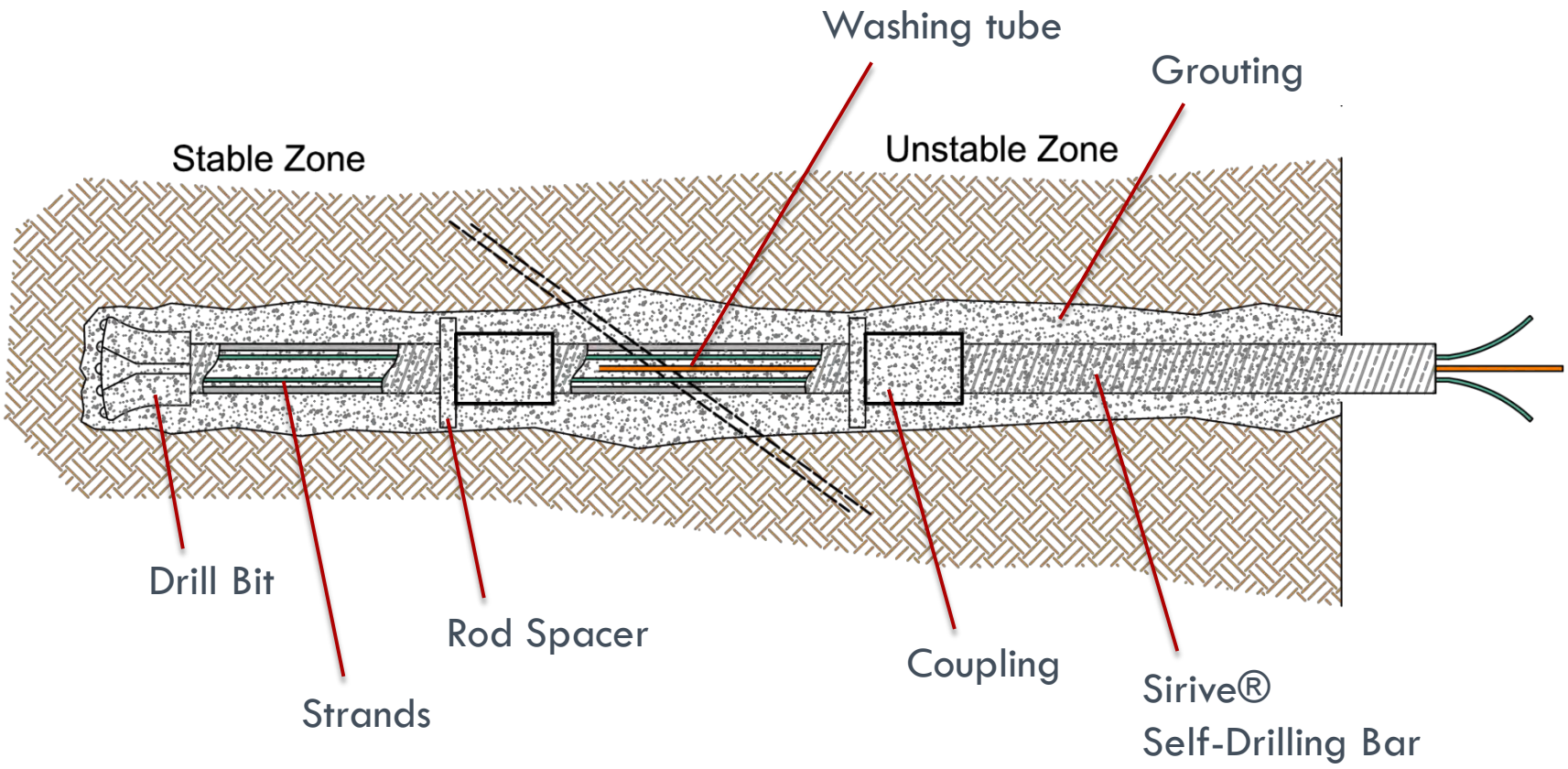
- **STEP 1:** Installation of the self-drilling bar



SIRIVE® SPECIAL COMPOSITE ANCHOR

INSTALLATION STEPS FOR ROCK SLOPE STABILIZATION

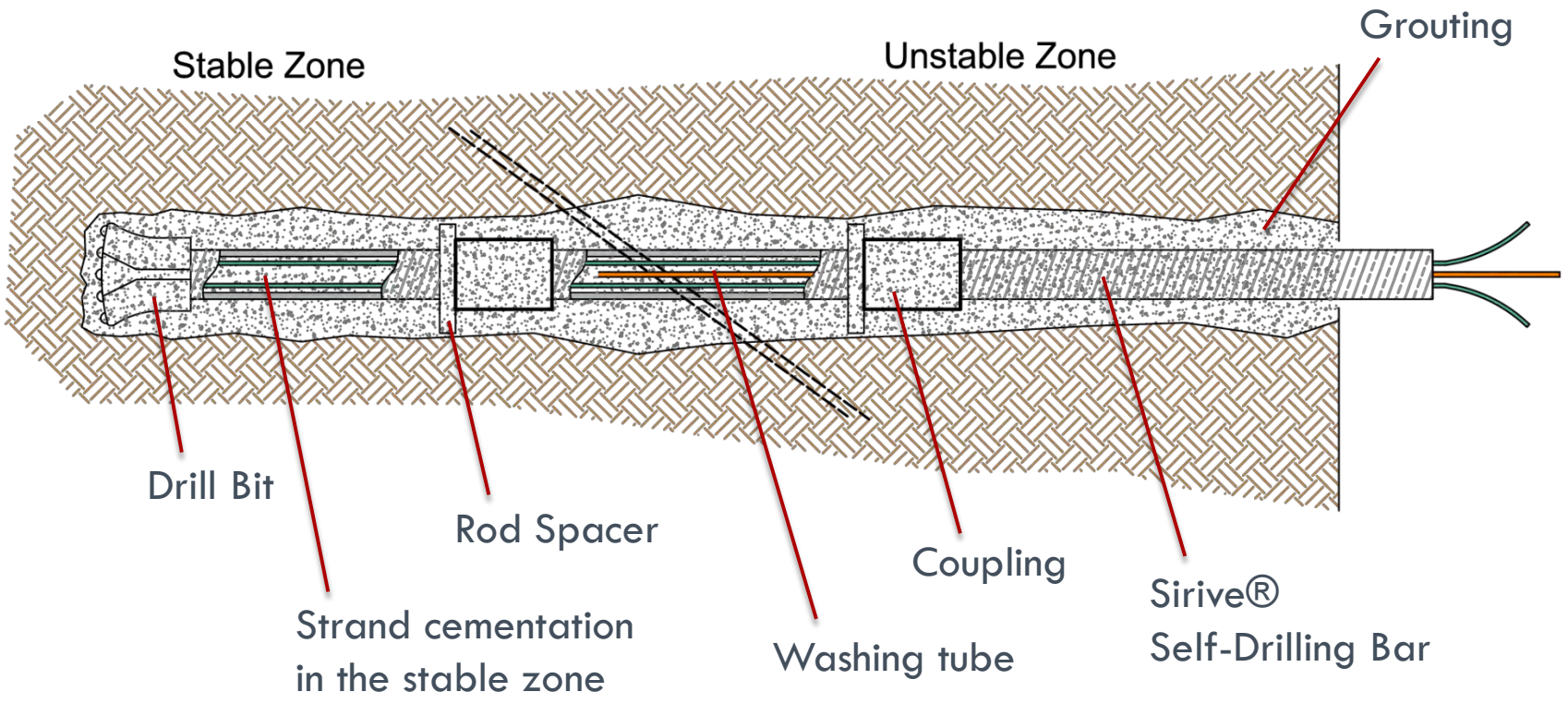
- **STEP 2:** Installation of strands and washing tube



SIRIVE® SPECIAL COMPOSITE ANCHOR

INSTALLATION STEPS FOR ROCK SLOPE STABILIZATION

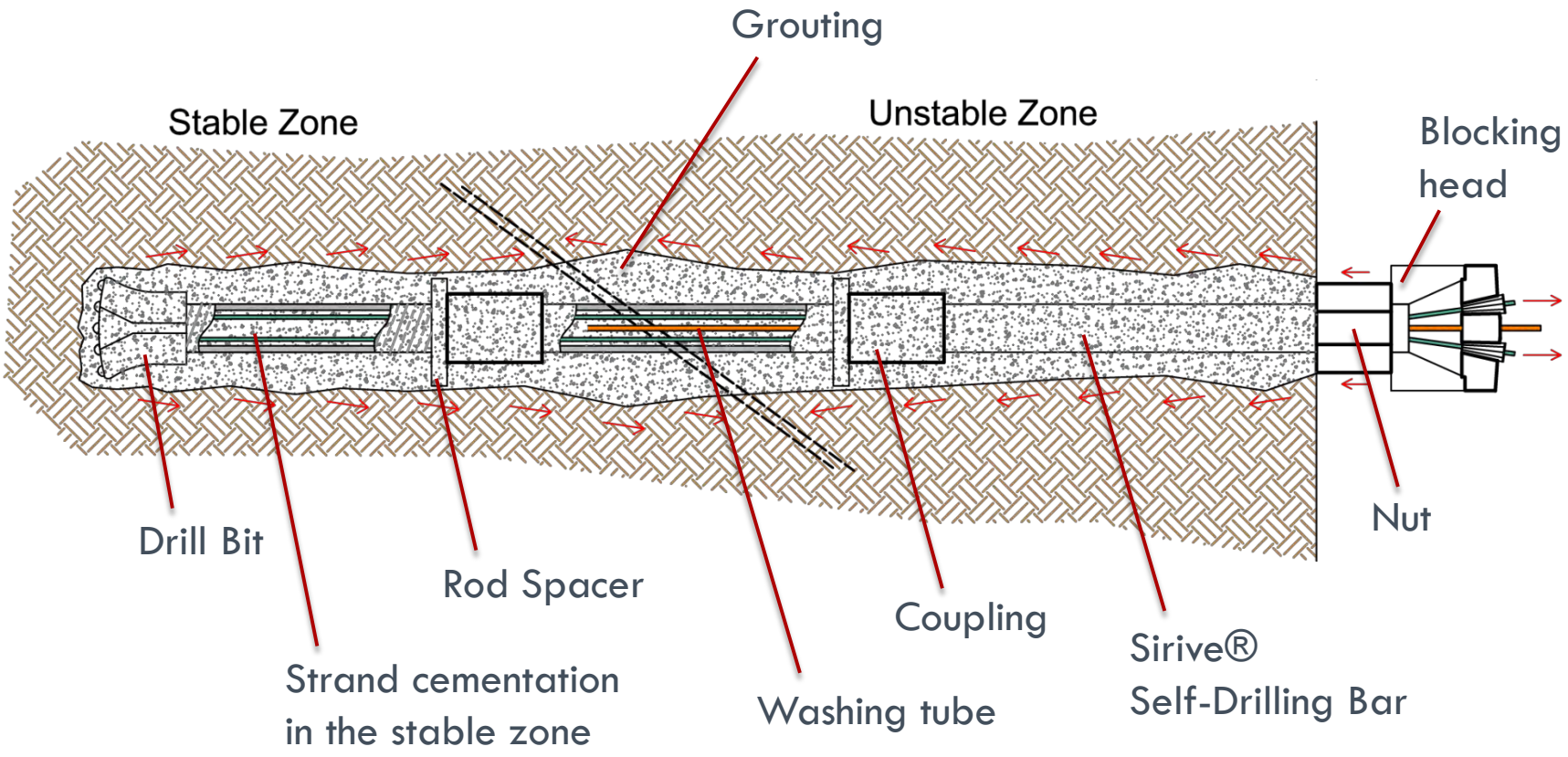
- **STEP 3:** The anchor active zone is washed (with water) and the inner cementation removed (only in the active/unstable part of the anchor)



SIRIVE® SPECIAL COMPOSITE ANCHOR

INSTALLATION STEPS FOR ROCK SLOPE STABILIZATION

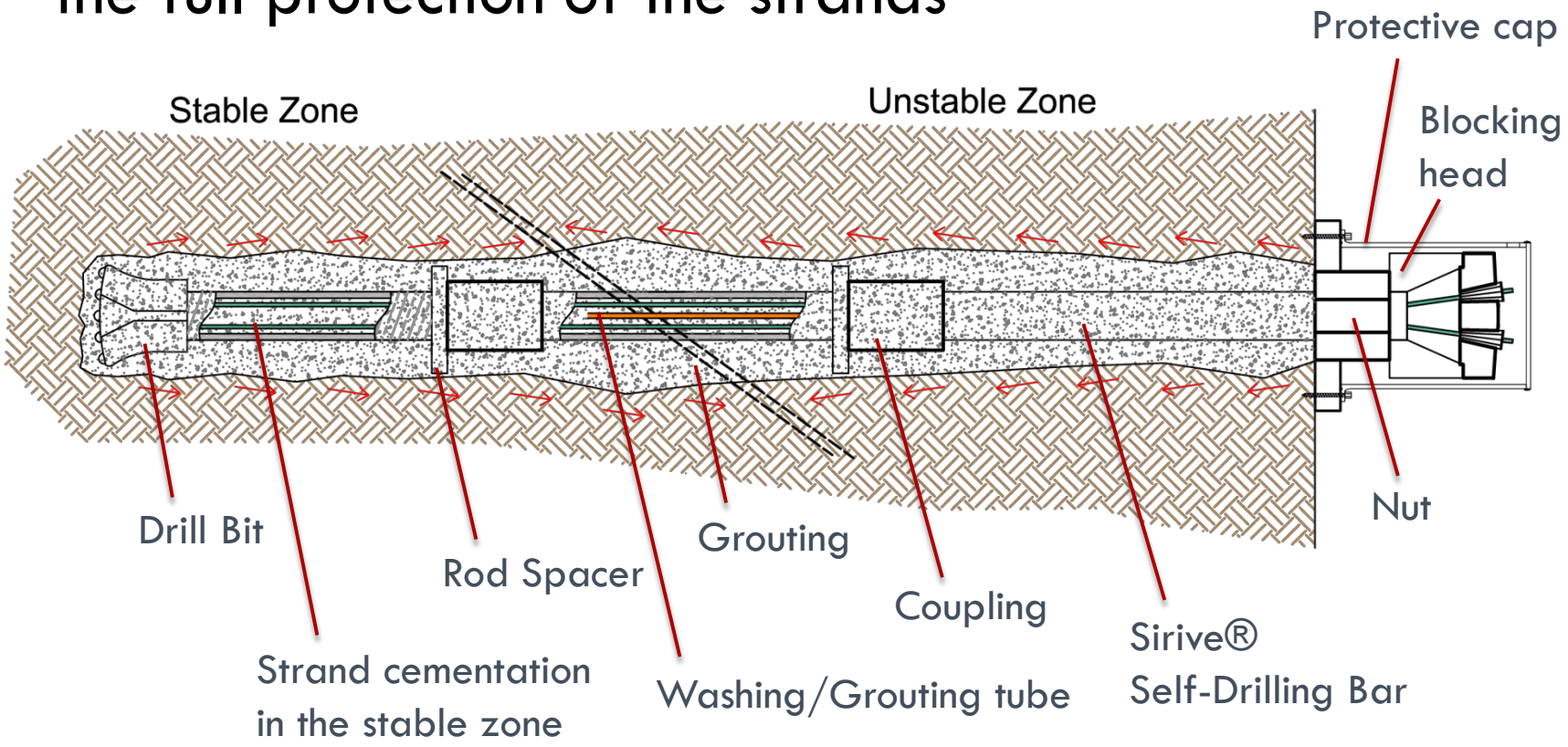
- **STEP 4:** After the grout full maturity, the strands are tensioned at the design load



SIRIVE® SPECIAL COMPOSITE ANCHOR

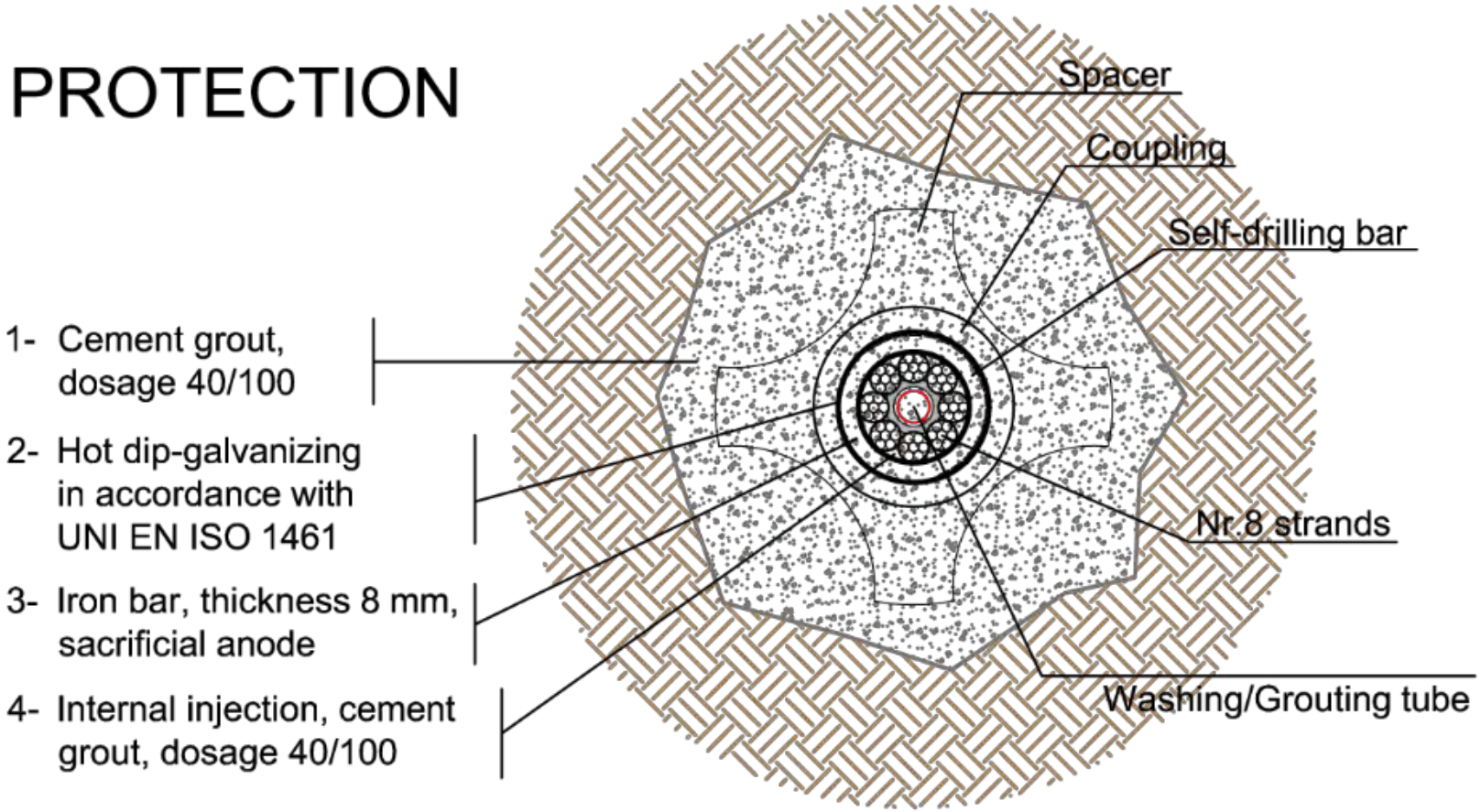
INSTALLATION STEPS FOR ROCK SLOPE STABILIZATION

- **STEP 5:** Injection of cement mixture and complete cementation of the strands within the bar to restore the full protection of the strands



SIRIVE® SPECIAL COMPOSITE ANCHOR

PROTECTION

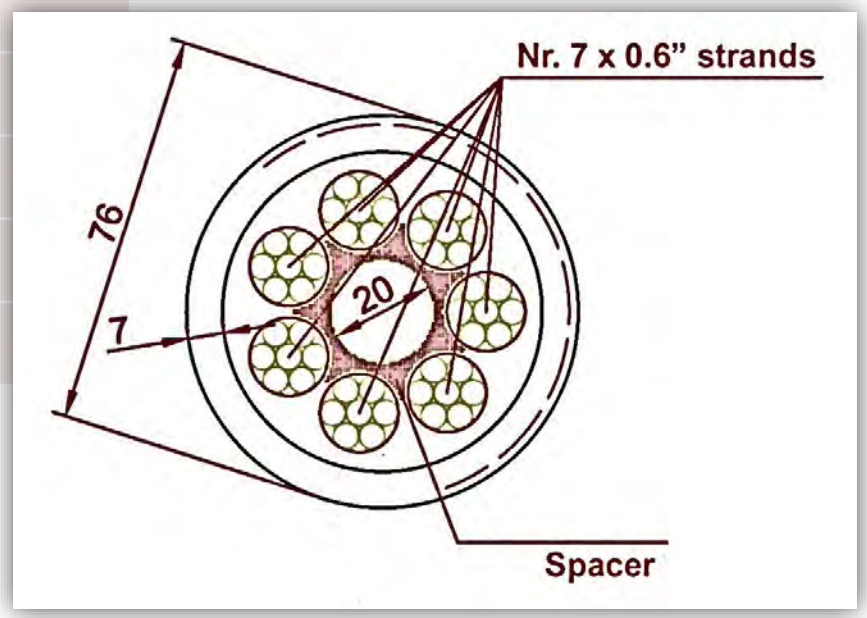


SIRIVE® SPECIAL COMPOSITE ANCHOR

ULTIMATE TENSILE LOADS

Anchor bar type	Ultimate tensile load (*) [kN]
R32 Special	550
R38 Special	700
R51 Special	1100
S60 Special	2000
S76 Special	3000
S90/A Special	4000
S90/B Special	5000

(*) Minimum warranted load

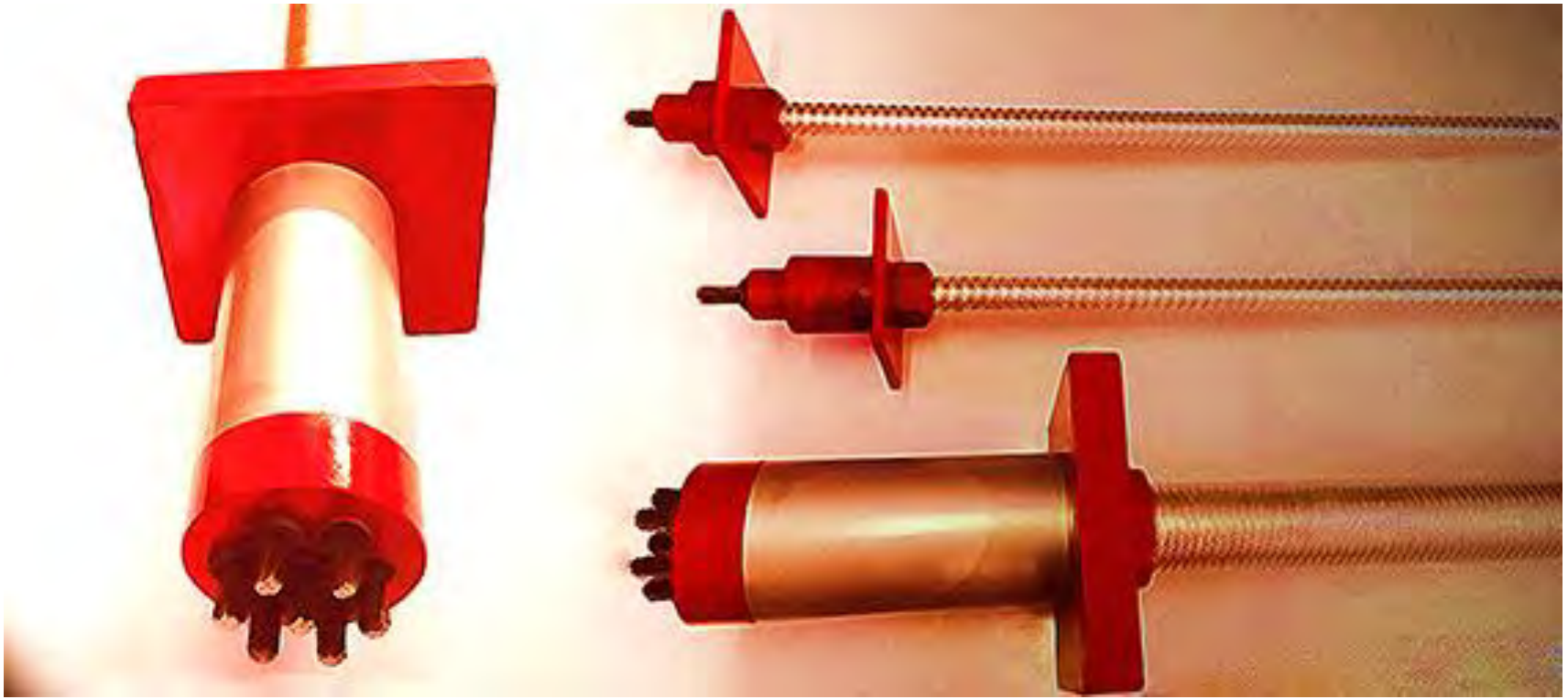


Sirive® Special Composite Anchor S76
CROSS SECTION

SIRIVE® SPECIAL COMPOSITE ANCHOR

ACCESSORIES

- **Sirive® Special Head Blocks**
  (custom-made for both active and passive anchor configuration)



Sirive® Special Composite Anchor S76

SIRIVE® SPECIAL COMPOSITE ANCHOR

COST ANALYSIS

DESCRIPTION	COST [€/meter]		
	Self-drilling bar	Anchor with 12 ∅0,6"strands	Composite bar ∅76 8mm thick +8 ∅0,6"strands
Bar, Fe55, steel section 1800 mm^2			21.06
Nr. 8 strands, diameter 0.6"			8.00
Bar, Fe55, steel section 5455 mm^2	63.83		
Nr. 12 strands, diameter 0.6"		12.00	
Accessories and installation	67.00	69.00	42.85
Subtotal production costs	130.83	81.00	71.91
General costs: 8%	10.47	6.48	5.75
Subtotal	141.30	87.48	77.66
Profit for the enterprise: 30%	42.39	26.24	23.30
TOTAL COST	183.69	113.72	100.96
Saving with composite anchor %	45.0	11.2	-

Comparison of the cost of 3 alternative anchoring systems for a ultimate tensile strength of 3000 kN

SIRIVE® SPECIAL COMPOSITE ANCHOR

ADVANTAGES

- **Minor cost** at constant mechanical properties;
- High ultimate tensile streght and low elongation (serviceability);
- **Durability** (minor cracking, better protection from corrosion);
- Easy transport and quick **installation;**

- **Anchorage length is adaptable** to different geological and geotechnical conditions found *in situ*;
- **Increased flexural inertia and continuity** given by strand to the full reinforcement (improved if compared to simple coupling sleeve).

SIRIVE® FLOATING ANCHOR

SIRIVE® FLOATING ANCHOR

SEARCH FOR NEW SOLUTIONS

- **Lack of economic resources available** to meet the emergency.
- Search for new types of intervention:
  - Low cost;
  - Quick installation;
  - Environmental care.
- **«Floating Anchor» project**: partnership between University of Padova, Province of Vicenza and Dalla Gassa s.r.l.
- Stabilization of slopes subject to landslides with low to medium depth (up to 25 m deep).

- **SUMMARY**:
  - Technical/economical comparison between most commonly used strengthening intervention works;
  - The «floating anchor» tecnique;
  - Advantages.

SIRIVE® FLOATING ANCHOR

THE BASIC IDEA

- What type of landslides? **Slow/Very slow**

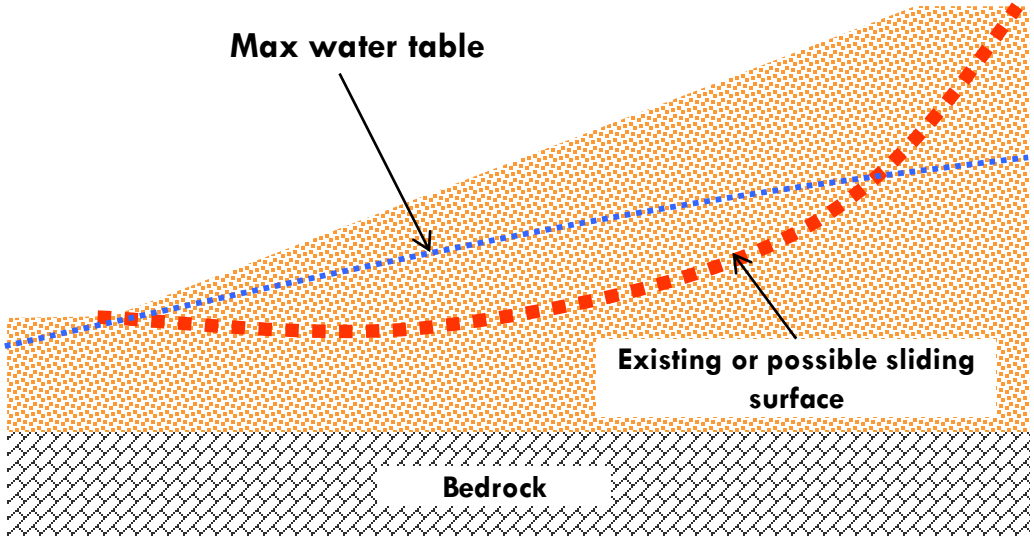
Velocity Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid	5×10^{3}	5 m/sec	Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
6	Very Rapid	5×10^{1}	3 m/min	Some lives lost; velocity too great to permit all persons to escape
5	Rapid	5×10^{-1}	1.8 m/hr	Escape evacuation possible; structures; possessions, and equipment destroyed
4	Moderate	5×10^{-3}	13 m/month	Some temporary and insensitive structures can be temporarily maintained
3	Slow	5×10^{-5}	1.6 m/year	Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
2	Very Slow	5×10^{-7}	15 mm/year	Some permanent structures undamaged by movement
	Extremely **SLOW**			Imperceptible without instruments; construction **POSSIBLE WITH PRECAUTIONS**

Cruden & Varnes (1996)

SIRIVE® FLOATING ANCHOR

THE BASIC IDEA

- Slope stabilization with reinforcement provides for **increasing shear strength** or **reducing the sliding actions** along the slip surface with various types of structures:
  - Retaining walls
  - Dowels
  - Micropiles
  - Anchors
  - Soil nailing

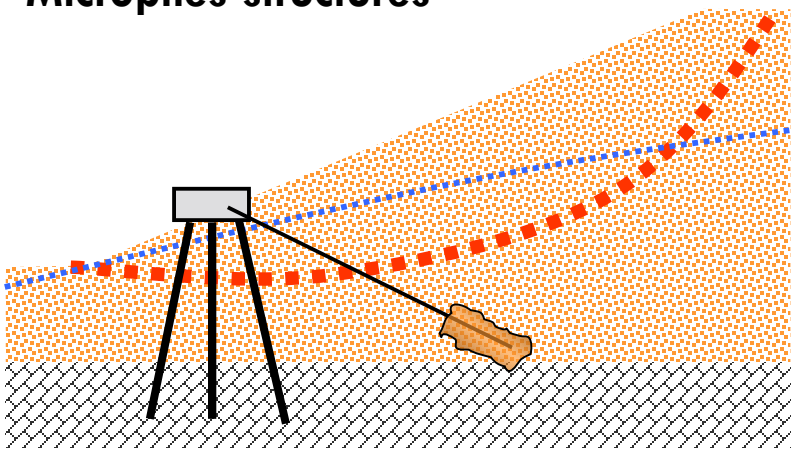


SIRIVE® FLOATING ANCHOR

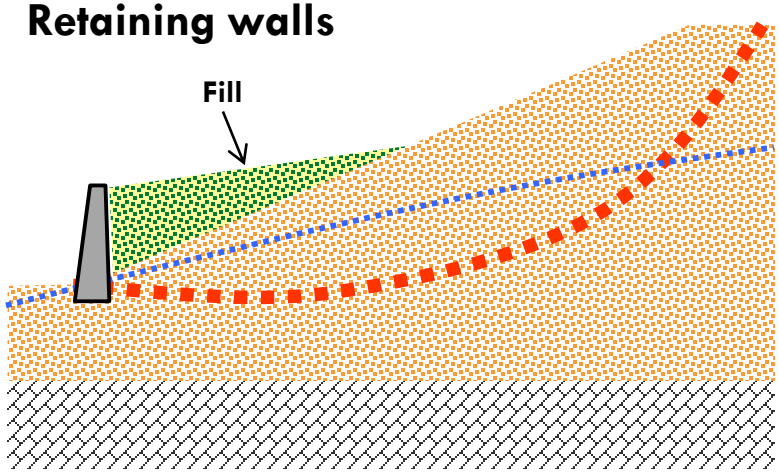
THE BASIC IDEA

- **Alternative to rigid techniques** normally used, which have some disadvantages:
  - Need for an accurate assessment of the acting forces (collapse);
  - High stiffness, poor adaptability to any movement of the slope;
  - High internal stresses;
  - Lack of modularity;
  - High costs ...

Micropiles structures



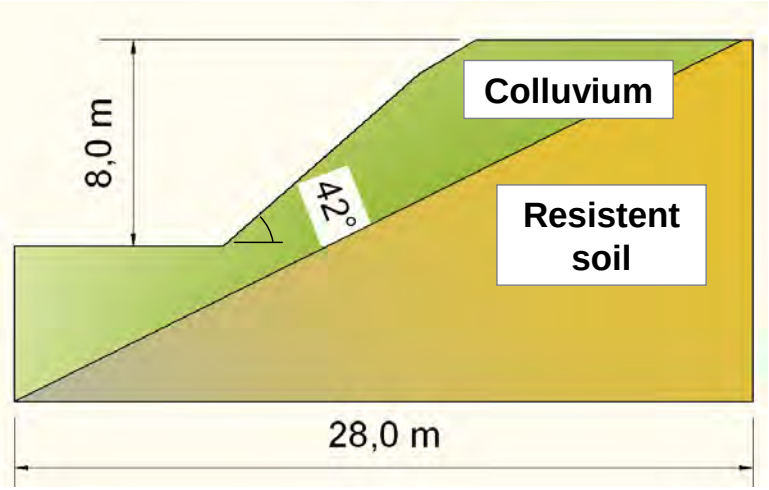
Retaining walls



TRADITIONAL REMEDIATION WORKS

A COST-EFFECTIVENESS COMPARISON

- Stabilization of a generic slope with a limited height.
- **Design** of the intervention according to Italian NTC 2008.
- **Limit equilibrium (LE) analysis.**
- Assessment of the **global safety factor** for the rotational instability.
- Assessment of the **intervention cost** per linear meter.



Formation	Type of soil	γ [kN/m³]	c' [kPa]	ϕ [°]
Colluvium	Silty clayey sand	18	0	28
Bedrock	Gravel	19	0	38

TRADITIONAL REMEDIATION WORKS

A COST-EFFECTIVENESS COMPARISON

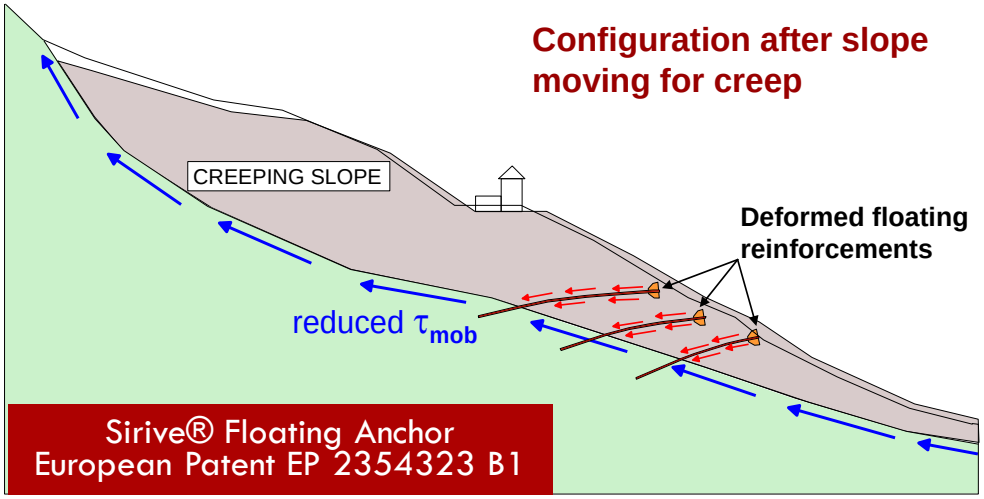
N.	Type of intervention	Characteristics of intervention	FS	Price[(1)] (Euro/m)	Price/ΔFS[(1)] (Euro/m)
a	Cantilever wall	Height = 5,0 m; Width = 3,5 m; Depth of tooth = 0,7 m	1.29	1694	**5841**
b	Gabion wall	Height = 5,0 m; Width = 4,5 m; base dip = 6°	1.30	2614	**8713**
c	Reinforced earth wall	Height = 5,0 m; Width = 3,5 m	1.39	1360	**3487**
d	Dowels	Height = 2,0 m; Depth = 7,0 m; 1 lines of piles with 0,4 pile/m; D=60 cm; reinforcement rods 16Ø26	1.58	1781	**3071**
e	Wall founded on micropiles	Height = 2,8 m; Depth = 4,0 m; 2 micropile lines with spacing i=0,2; 0,66 micropile/m; D_{ex}=114,3 mm; s=6,3 mm; passive anchor R38 spacing 1,5 m; L = 10 m; a = 25°	1.60	1420	**2367**
f	Anchored micropile sheet-wall	Height = 2,5 m; Depth = 4,2 m; 2 micropile lines with spacing i=0,5; 2 micropile/m; D_{ex}=127 mm; s=8 mm; passive anchor R38 spacing 2,5 m; L = 12 m; a = 30°	1.46	1584	**3443**
g	**Passive nails**	L = 6, 6, 6, 9 m; i_x= i_z =1,6 m; a = 15°; facing with steel net	1.39	883	**2264**

"Reinforcement works for the slope stabilization: standard and new approaches for the use of micropiles and anchors"
S. Cola, A. Bisson, C. Pilati, S. Frasson, G. Stevan, G. Tessari, ISM 2012: International Workshop on Micropiles, Milan, 2012

SIRIVE® FLOATING ANCHOR

A BRIEF INTRODUCTION

- Nails are designed to absorb significant horizontal stresses, thus **reducing the stresses that induce the viscous motion**, in order to slow down the evolution process of the landslides
- As opposed to active anchors, the floating anchor absorbs a part of the shear stresses induced by the landslide movement by mean of the **friction forces** activated along its profile
- In this way, it transfers to the external plate a small tension: it does not require a continuous facing, but only a small **head plate**



SIRIVE® FLOATING ANCHOR

A BRIEF INTRODUCTION

- External concrete plate (**floating element**) + nail (passive)
- The set is an "**energy dissipator**" that activates **by friction** within the moving slope (viscous medium)
- If the slope deforms and the ground moves, the plate may be englobed into the soil

SIRIVE® FLOATING ANCHOR

A BRIEF INTRODUCTION

- Single reinforcing elements, each of them designed to absorb a fraction of the shear stress
- **Total ultimate pullout resistance** for one element:

$$Q_a = Q_p + \int_L \pi D \tau_u dx$$

Head force (external plate)

Lateral friction (passive bar)

SIRIVE® FLOATING ANCHOR

A BRIEF INTRODUCTION

- The system activation occurs with **relative displacements at the soil-concrete interface.** It may produce:
  - **Complete stabilization** of the slope: the axial force remains less than the maximum available axial strength;
  - **Only deceleration** of the slope: activation of the maximum available axial strength;
  - **In any case:** no structural failure of reinforcements.

SIRIVE® FLOATING ANCHOR

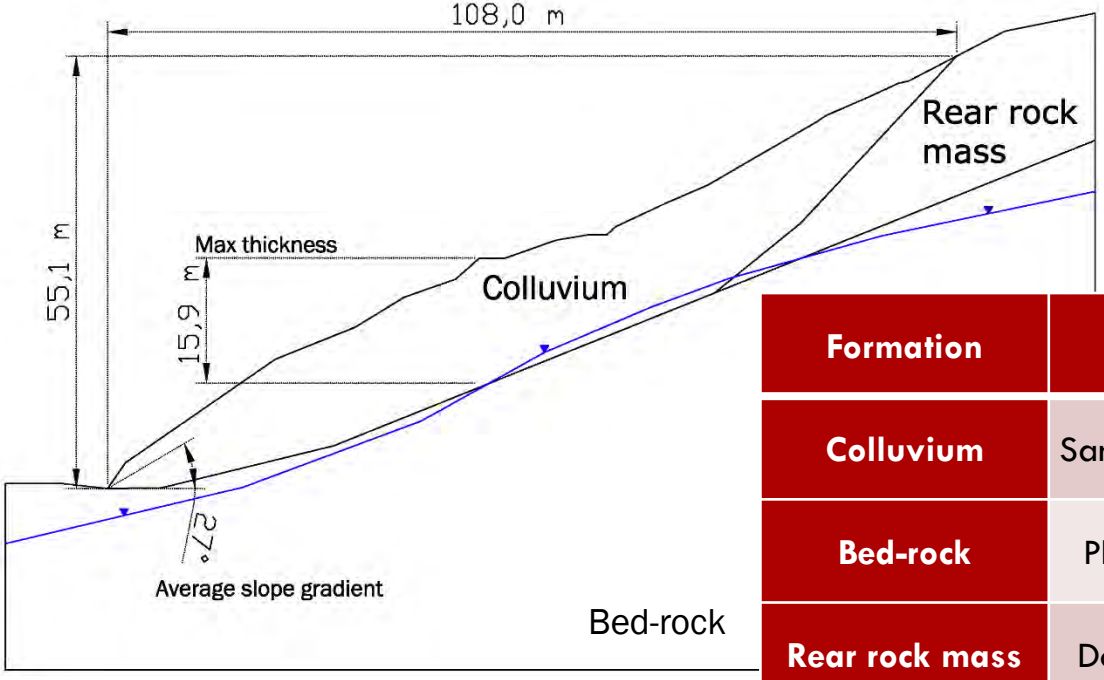
ADVANTAGES

- Flexible, not rigid
- Modularity, **calibration** of the intervention work in progress
- Easy and quick to **install**
- Good protection against **corrosion** of the bars
- **Low environmental impact** (facing ratio about 5-6%)
- **Low cost**

GISBENTI LANDSLIDE

SIRIVE® SPECIAL COMPOSITE ANCHORS/SIRIVE® FLOATING ANCHORS

- Location Gisbenti, district of **Valli del Pasubio** (Vicenza, Italy).
- Stabilization work placed at the foot of a landslide (autumn 2010), **replacing a retaining wall** collapsed by slippage due to the landslide.
- 3 rows of floating anchors (Sirive® Special Composite Anchor S60, ultimate strength 2000 kN), 3 m horizontal spacing, 20 to 40 m long.



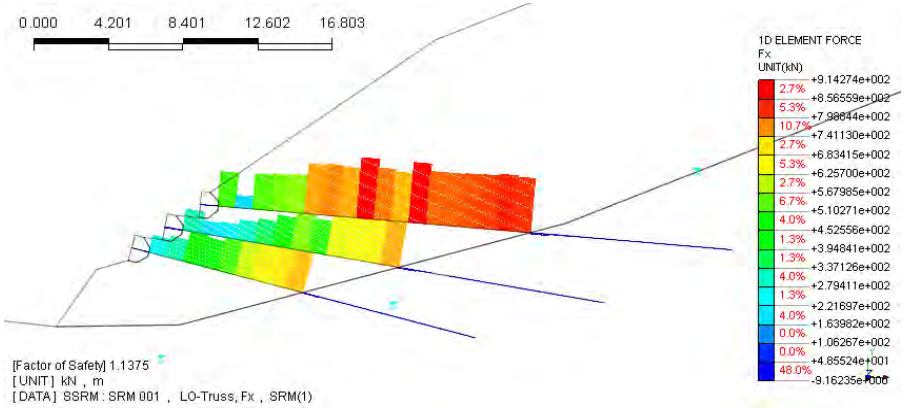
(Bisson A. & Cola S., 2014)

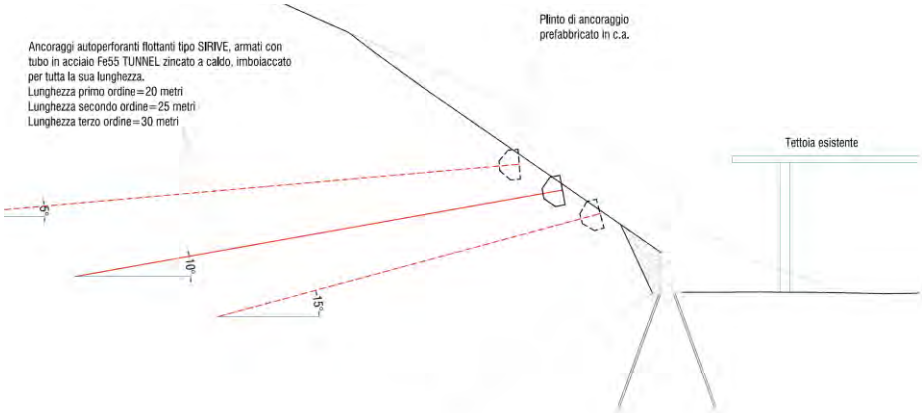
Formation	Soil	γ [kN/m³]	c' [kPa]	ϕ [°]
Colluvium	Sandy clay	18	13	20
Bed-rock	Phyllites	24	150	35
Rear rock mass	Dolomite	22	300	36

GISBENTI LANDSLIDE

SIRIVE® SPECIAL COMPOSITE ANCHORS/SIRIVE® FLOATING ANCHORS

- **Maximum traction force** mobilized at the sliding surface to resist to destabilizing actions.
- **Low axial force behind the plates,** due to the balance of tangential shear stresses developed along the soil-grout interface along the bar.





VAL MASO LANDSLIDE

SIRIVE® SPECIAL COMPOSITE ANCHORS/SIRIVE® FLOATING ANCHORS

- Location Val Maso, district of Valli del Pasubio (Vicenza, Italy).
- Landslide reactivated in 2010 due to an **extreme rainfall**
- **Roto-translational collapse of about 200,000 m^3** that threatened the stability of a road and produced a **small earth-flow** that damaged some houses
- Eluvial/colluvial deposits and past landslide debris
- Slope **mean inclination angle of about 40°**
- Landslide retrogression by multiple rotational slides, with a **sliding surface 20 m deep**

VAL MASO LANDSLIDE

SIRIVE® SPECIAL COMPOSITE ANCHORS/SIRIVE® FLOATING ANCHORS

- Adopting **Sirive® Special S60 Composite** anchor bars (60 mm diameter bars with 3x0.6" diameter strands and a minimum tensile strength of 2000 kN) anchored to the bedrock, **3 rows of floating anchors spaced 6.0 m and 6.0 m respectively in horizontal and vertical direction** were built.

VAL MASO LANDSLIDE

SIRIVE® SPECIAL COMPOSITE ANCHORS/SIRIVE® FLOATING ANCHORS

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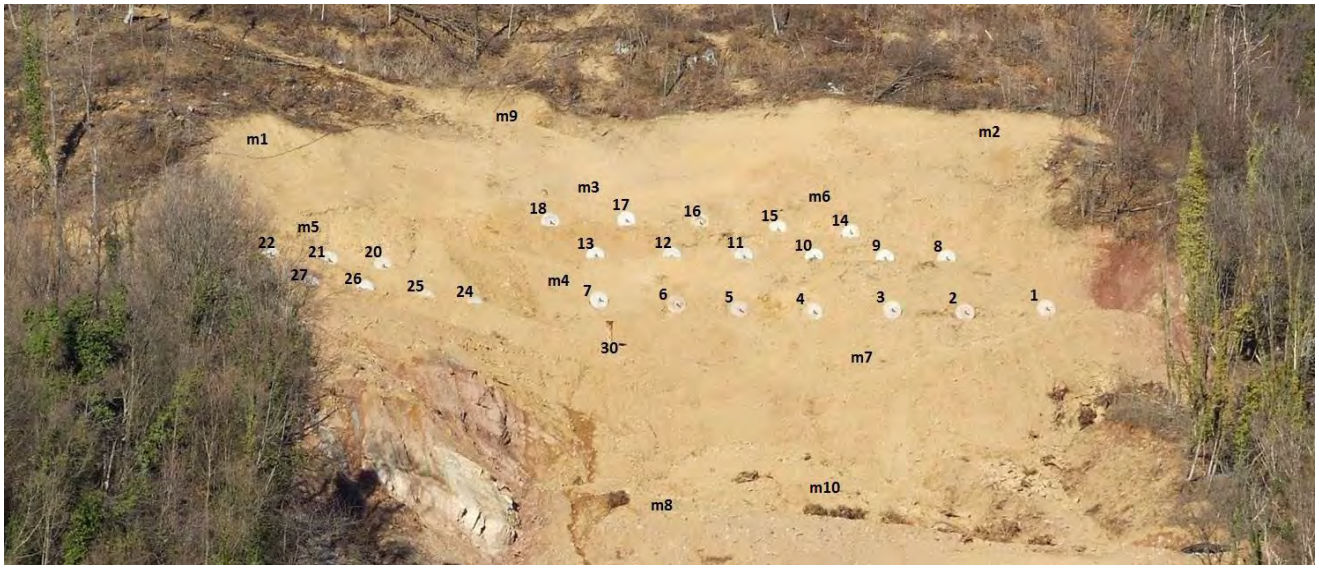
VAL MASO LANDSLIDE

MONITORING SYSTEM: DISPLACEMENTS



Leica TCRA1101 Total Station

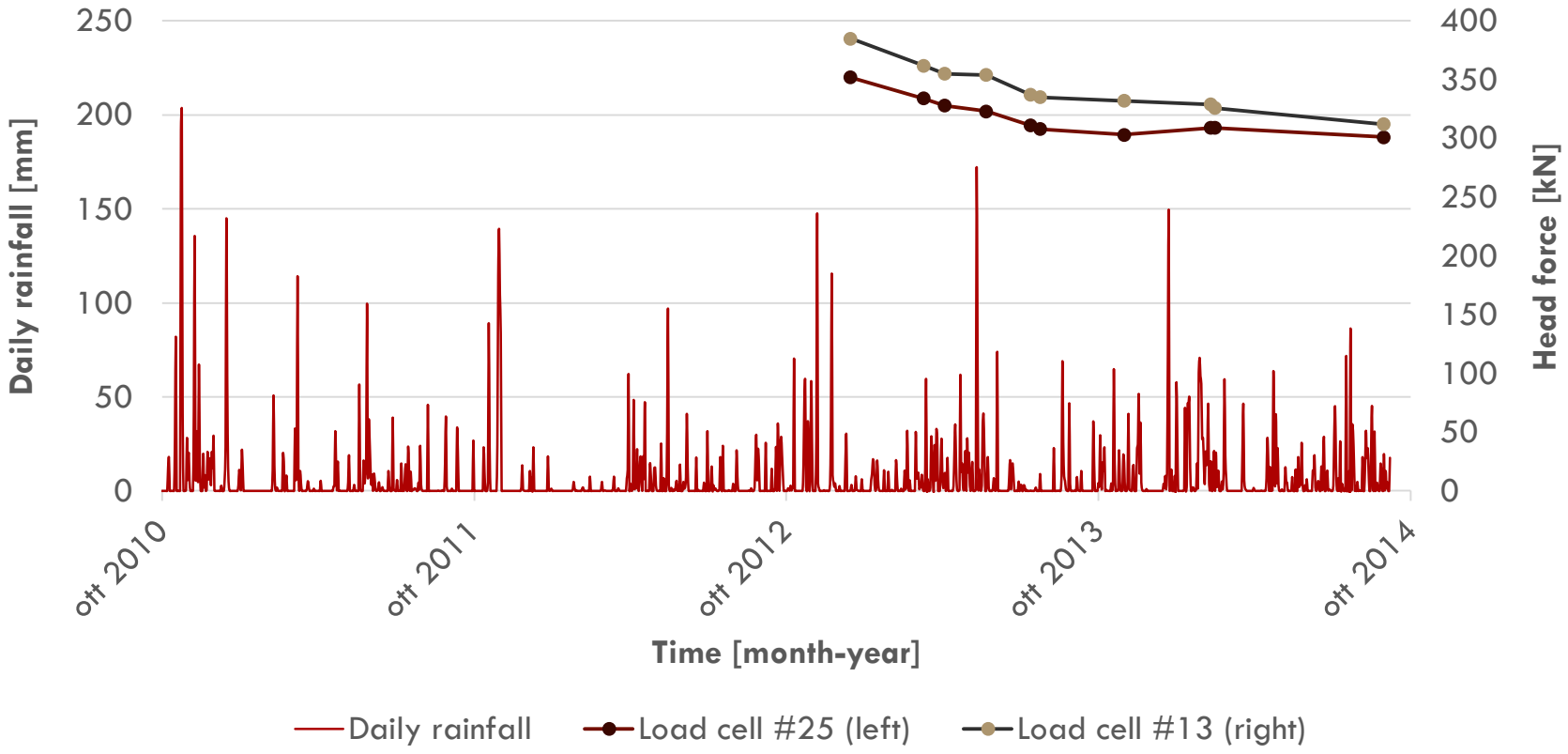
Precision** in distance measurements = **±2 mm

Topographical survey:

- Determine displacements of 10 points selected on the slope and 30 on the plate of each anchor
- Landslide medium displ. rate = **2.6 cm/year (post) vs 160 cm/year (pre)**
  Anchor medium displ. rate = 1.6 cm/year

VAL MASO LANDSLIDE

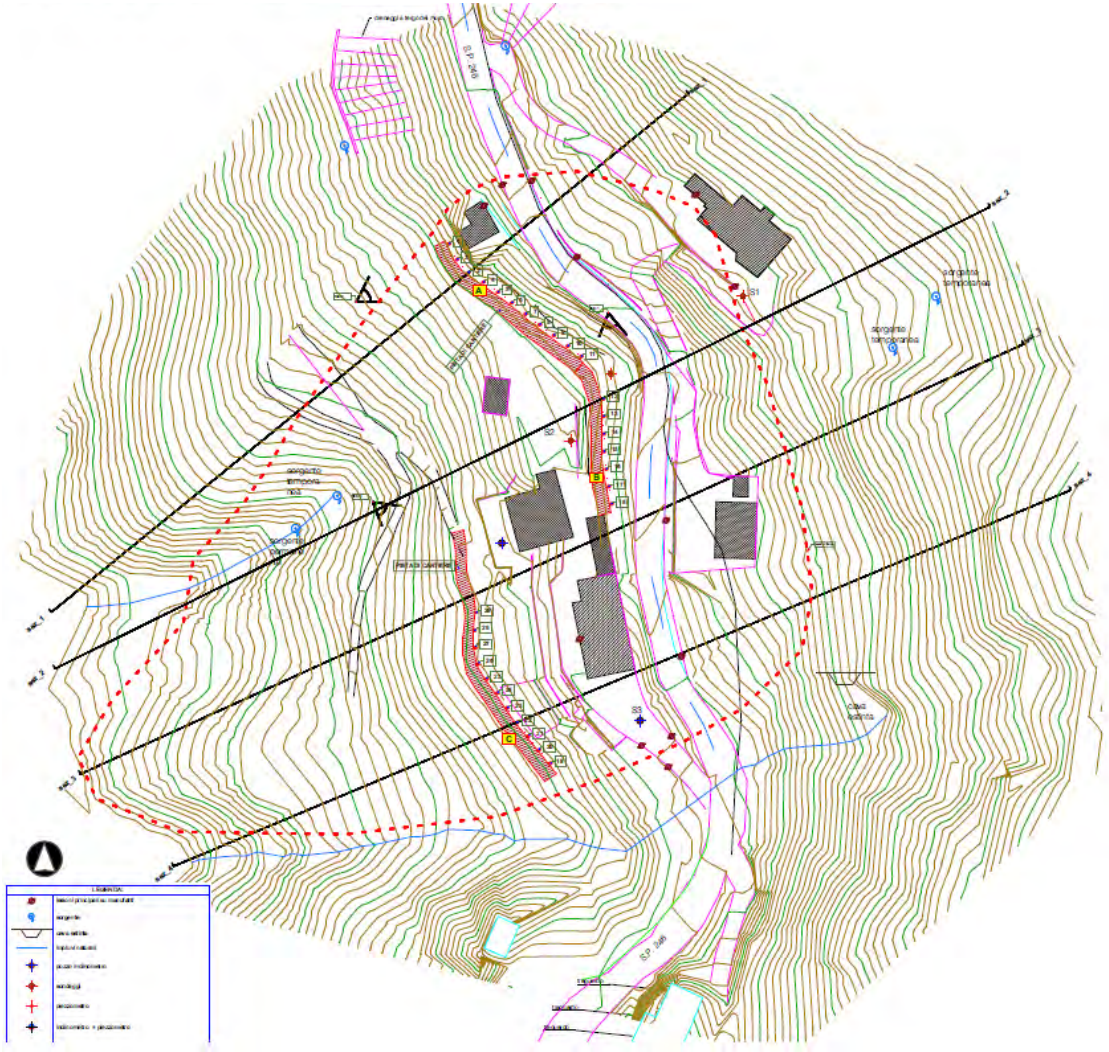
MONITORING SYSTEM: HEAD FORCE



The load cells indicate a small decrease of the head-forces in time (14.5-18.9%), which may denote a sort of **asymptotic adjustment** of the soil close to the concrete plates.

CISCHELE LANDSLIDE

SIRIVE® SPECIAL COMPOSITE ANCHORS/SIRIVE® FLOATING ANCHORS

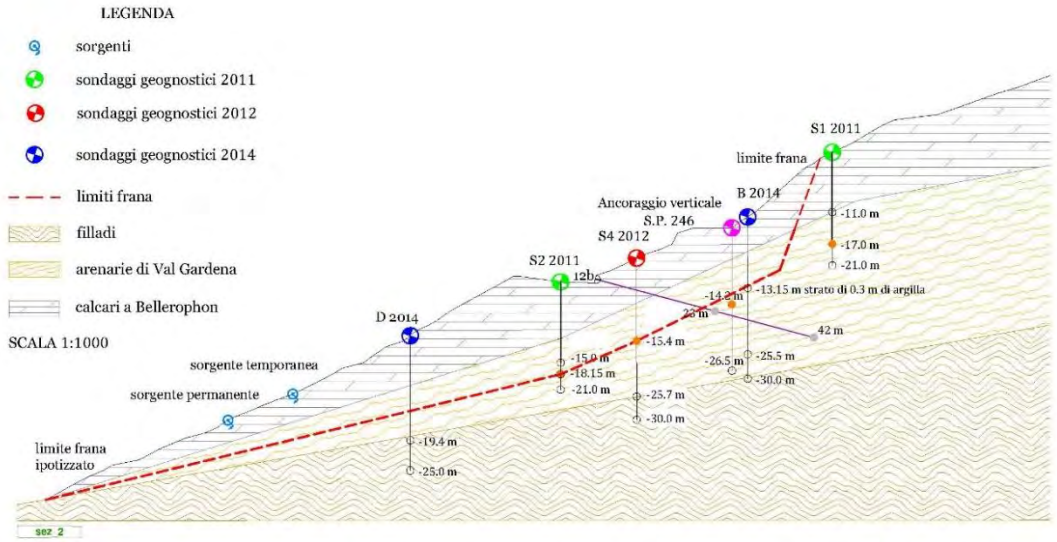


- Cross and longitudinal extent: 120 and 180 m
- Medium slope gradient: 24°
- Houses cracked and damaged

CISCHELE LANDSLIDE

SIRIVE® SPECIAL COMPOSITE ANCHORS/SIRIVE® FLOATING ANCHORS

- Slow-moving translational landslide
- Displacements are strongly correlated with the change in pore pressure
- 2 inclinometers: slip surface 18-20 m deep
- 33 floating anchors (Sirive® Special S76 Composite Anchors), 40 to 50 m long, 3000 kN ultimate tensile strength, 5 m horizontal spacing, frusto-conical concrete plates (1.5 m diameter)



CISCHELE LANDSLIDE

SIRIVE® SPECIAL COMPOSITE ANCHORS/SIRIVE® FLOATING ANCHORS

THANK YOU

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