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SPIDER ROCK PROTECTION SYSTEM FOR ROCK SLOPES

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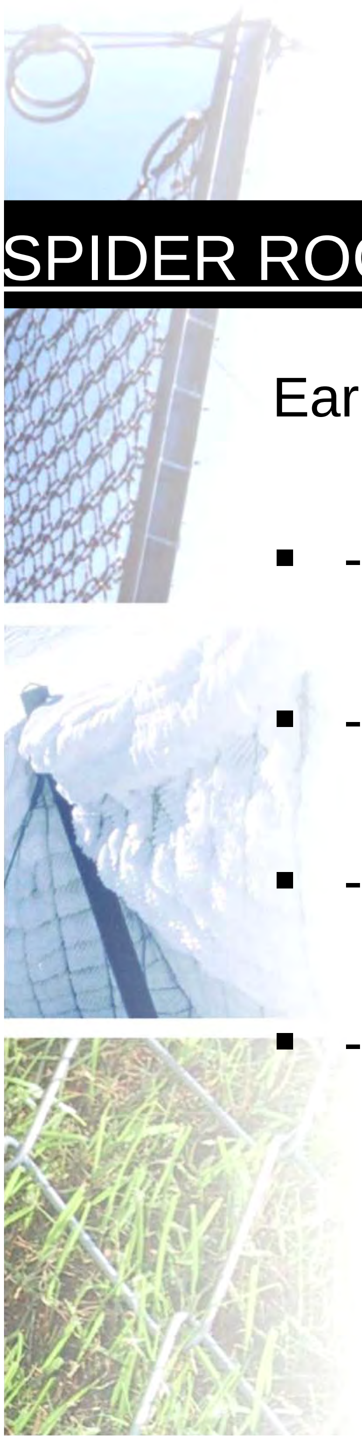

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Earlier Efforts To Stabilize Rock

- - Anchor beams
- - Shotcrete
- - Wire rope nets
- - Wire rope nets with rope restraints

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Anchor Beams

- Difficult and intensive construction to place directly on the rock slope
- Highly visibility and did not help the natural scenery

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Shotcrete

Costly installation with tight anchor spacing and thick layer of shotcrete
Not everyone likes its appearance - May eventually crack and spall

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Wire Rope Nets

- Shape of nets, square or rectangular , limited nail grid
- Net size limited which meant putting nets together.

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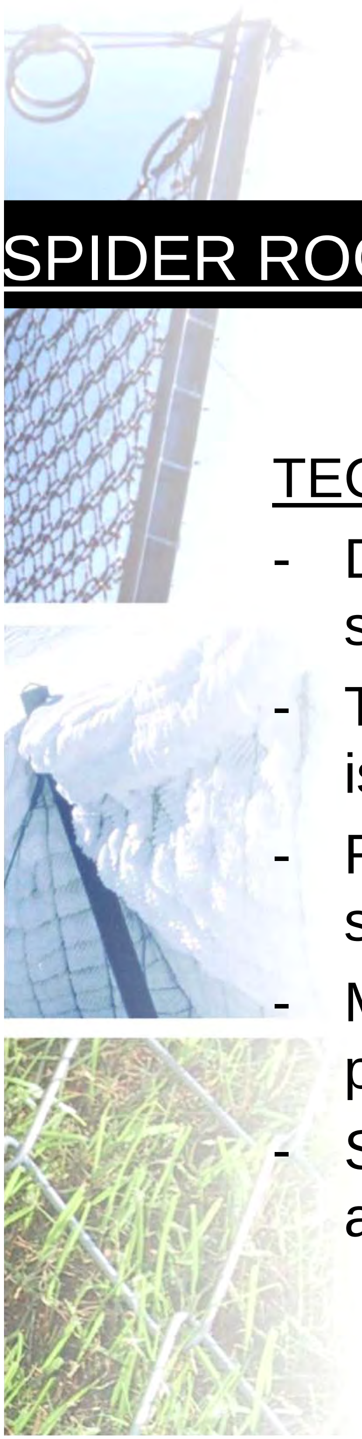
Cable Lashing With or Without Nets
- Improved system performance
- Nets and ropes did not work well together



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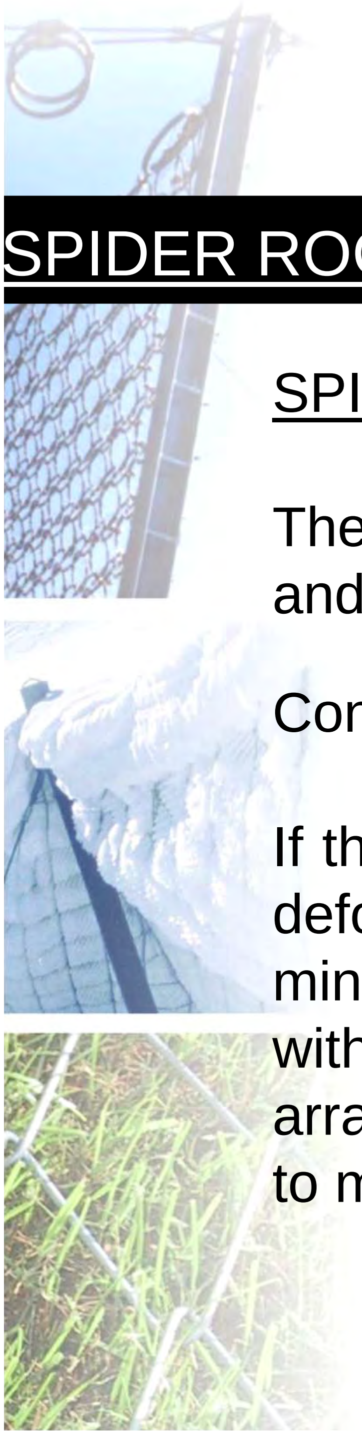
TECCO ® Slope Stabilization System

- Developed for soil slopes and highly weathered rock slopes
- TECCO mesh – an elongated diamond shaped mesh that is easy to handle and has strength of wire rope net
- Ruvolum Dimensioning program optimized nail/anchor spacing
- Mesh tensioned against ground to hold it in place and prevent movement
- Spike plates optimized in terms of size, geometrical layout and bending resistance.

SPIDER ROCK PROTECTION SYSTEM FOR ROCK SLOPES

SPIDER ® Rock Protection System

Designed to secure rock slopes where the rock is not prone to decomposition or weathering, where the surface is irregular and where rocks that come loose tend to be large.



SPIDER ROCK PROTECTION SYSTEM FOR ROCK SLOPES

SPIDER ® Rock Protection System

There are currently two concepts regarding the potential risks and maintenance requirements:

Concept (I):

If the critical area is to be secured in a proactive manner and deformation and maintenance work is to be kept to a minimum, the solution is to utilize nailing in the critical area with a net cover system including spike plates. The type and arrangement of nails as well as its lengths are to be adapted to meet the requirements for static loads.

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SPIDER® Rock Protection System

Concept (II):

Should it not be possible to drill through the critical areas or should the requirements regarding deformation and maintenance be less, the nails could be arranged around the critical area (e.g. around an unstable boulder). The protective measure in this instance is rather passive. Larger deformations must be anticipated should pieces of rocks or even a mass come loose under the protection of the net drapery. The concept is applied to limited areas only.

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SPIDER® Rock Protection System

System consists of the following elements:

1. SPIDER® Net
2. Nails/Anchors
3. Spike Plates
4. Shackles
5. Boundary ropes
6. Wire rope anchors
7. Optional secondary mesh

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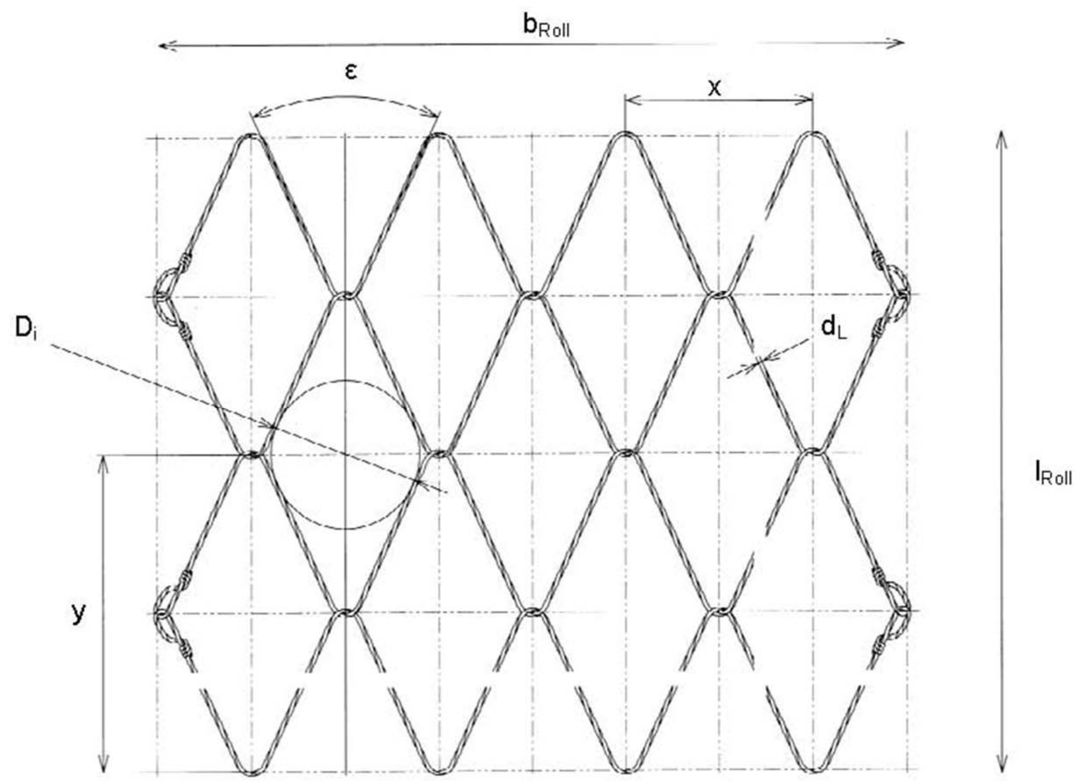
SPIDER® S4-230 Net

SPIDER® S4



Mesh Width = 292mm/11.5 inches & Height = 500mm/19.7 inches

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SPIDER® NET S4

Mesh to Mesh Connection - Single Twist

Knotted Ends

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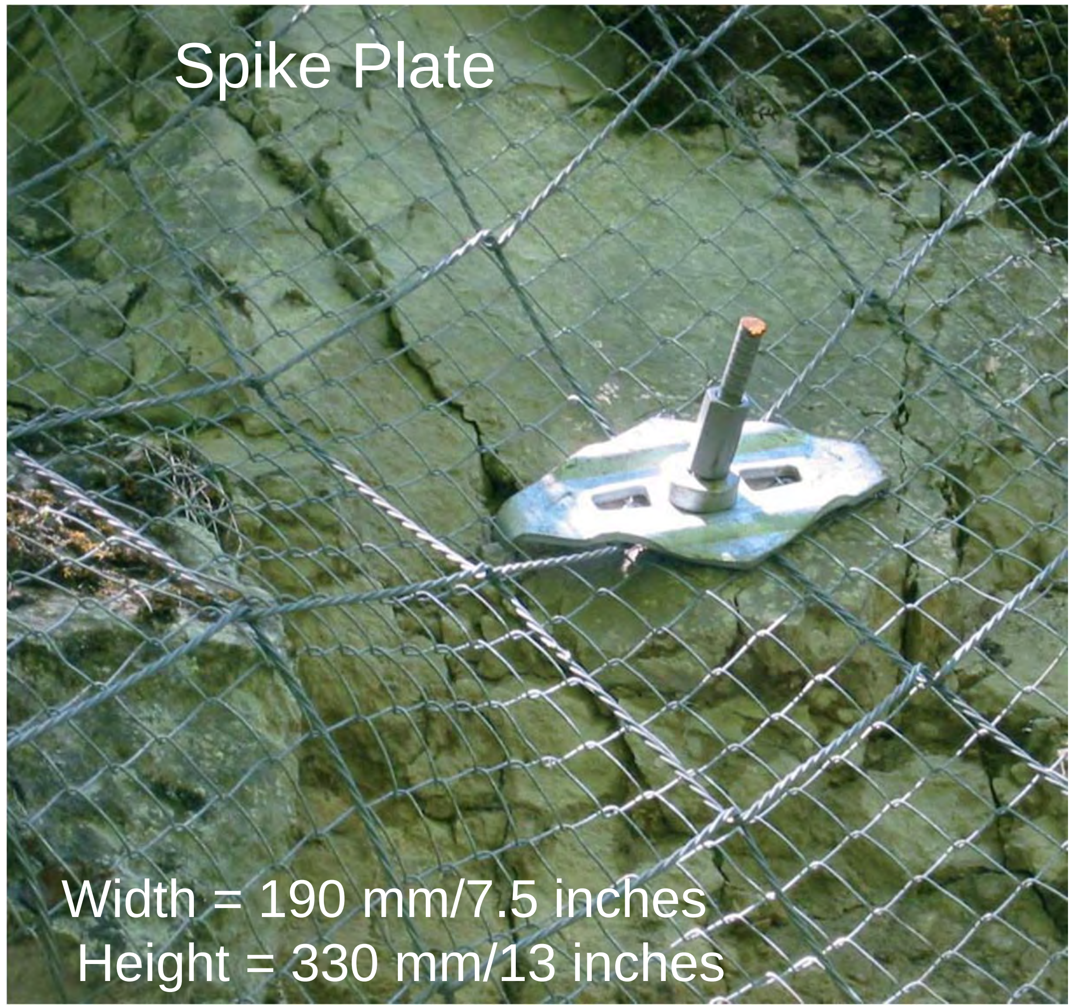

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Other Components Are Off the Shelf

- Boundary Rope – 1/2-inch diameter wire rope – pulled through mesh openings
- Wire Rope Anchors – 3/4-inch diameter wire rope
- Shackles – 3/8-inch galvanized screw pin anchor type
- Rock Bolts/Nails – 25 mm/1-inch, 28 mm/1-1/8-inch or 32 mm/1-1/4-inch diameter grade 75 bar
- Optional Secondary Mesh - chain link (2-inch x 2-inch, 9 gauge)

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Design Approach

In order to secure an individual boulder, an external stabilizing force (P) is required to hold the boulder against the stable ground. This force depends predominantly on the following:

- dead weight (G) of the block-shaped boulder
- inclination of the sliding surface to horizontal (β)
- friction angle (ϕ) between the stable ground and the block
- cohesion (c) or interlocking force along the slide plane and its size (A)
- direction (ϑo) and (ϑu) of the forces (Zo) and (Zu) in the net cover

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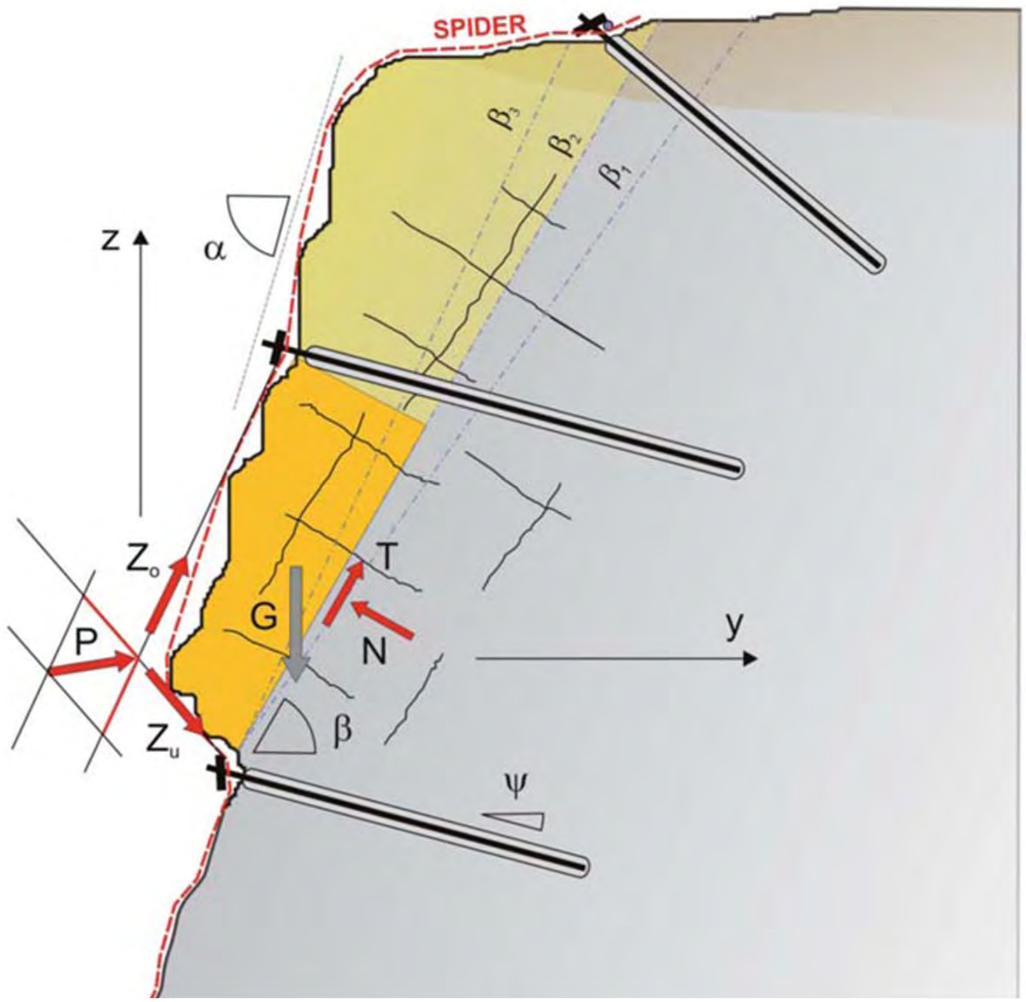

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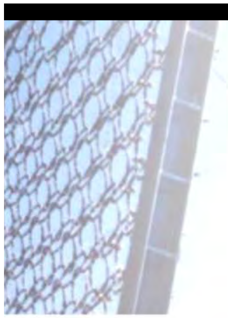

The retaining force (P) can be calculated as follows based on taking into account the stabilization issues relevant to an individual block-shaped boulder as well as the model uncertainty correction value (γmod).

$$P\,[kN] = \frac{\gamma mod \cdot \cos(\beta - \omega) + \sin(\beta - \omega) \cdot \tan\phi}{G \cdot (\gamma mod \cdot \sin\beta - \cos\beta \cdot \tan\phi) - c \cdot A}$$

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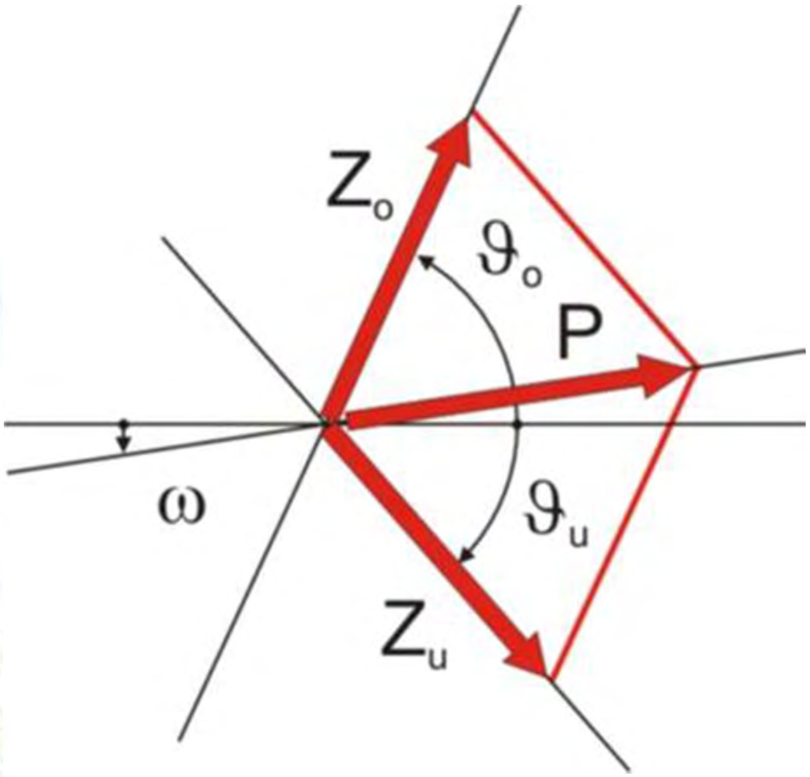

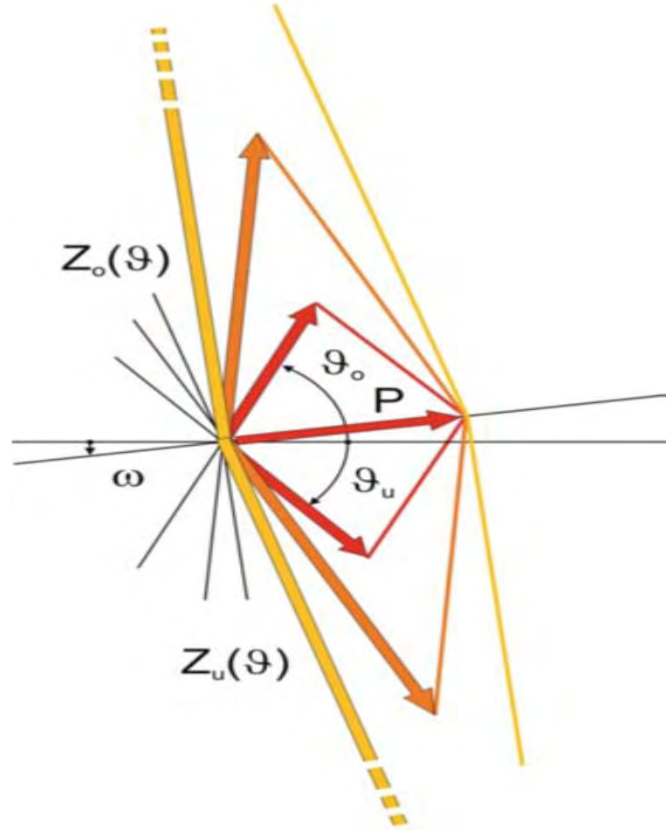

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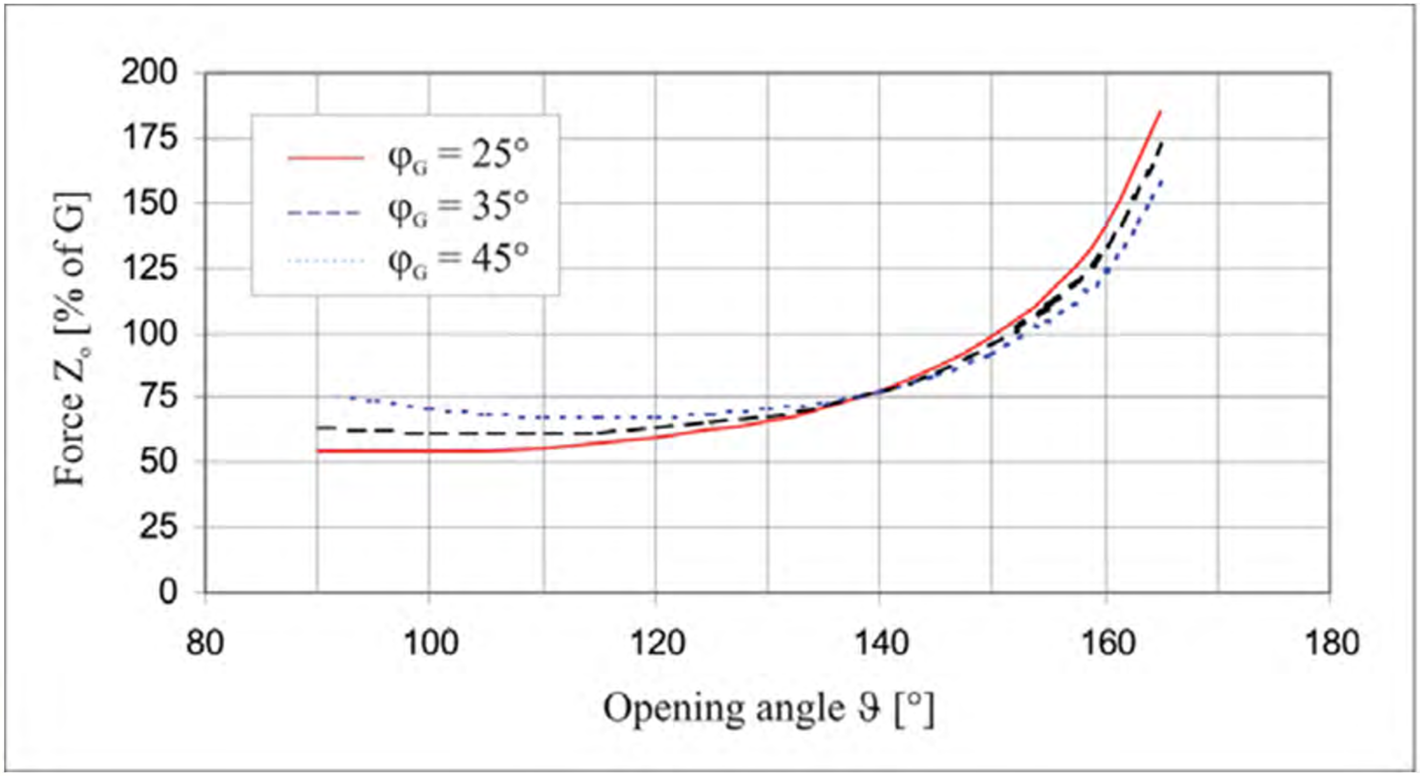

Friction angle (φG) between the boulder and the restraint is insignificant

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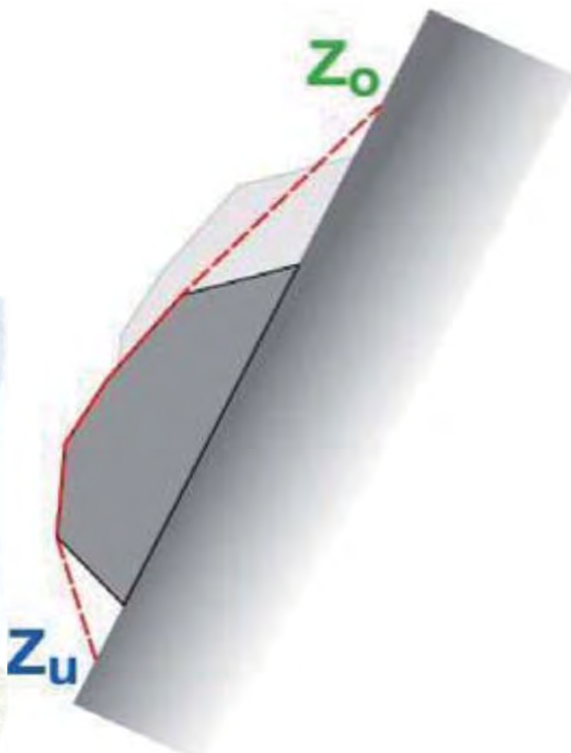

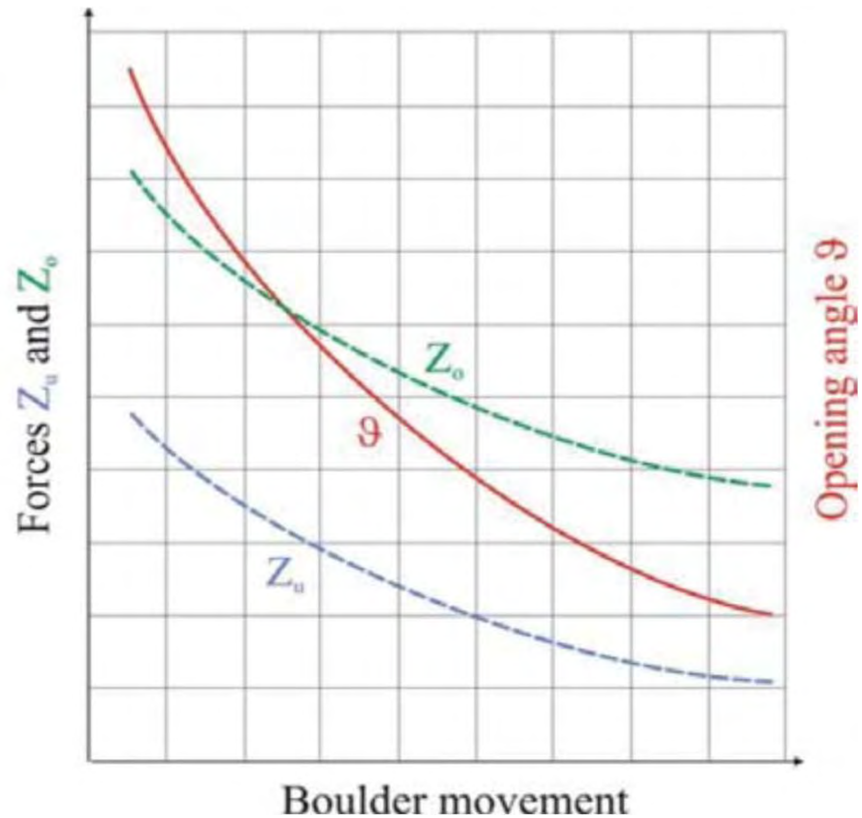

The opening angle ($\vartheta = \vartheta_o + \vartheta_u$) becomes smaller with increasing boulder movement and the upper and lower retention forces decrease.

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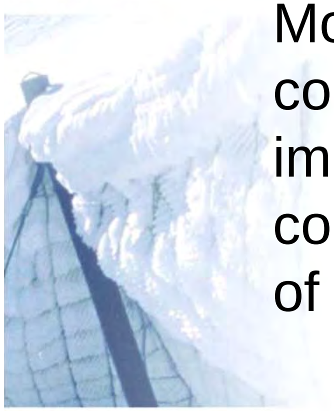
MODEL EXPERIMENTS

Objectives

Model experiments with the SPIDER® system were conducted on a scale of 1:3.5. Objectives included the implementation of the theoretical basic considerations, the comparison under real-life conditions, and the determination of the distribution of forces in a three-dimensional system.



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Test setup

The test setup basically consisted of a blue steel frame to which the rope and the model net was fastened and a slide face red colored in between. The frame was 1.5 m wide and 2.5 m long. The angle between the slide face and the frame was kept constant at 36°. Strain gauges were used to measure the forces acting on the rope, net and directly on the sliding body. A potentiometer was used to measure the displacement of the block-shaped boulder. A wooden block that weighed 58 kg/128 pounds was used as a sliding body.

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Left
Test setup

Middle
Cable restraint only

Right
Restraints arranged around the net without any cables

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Findings from model experiments

The forces calculated by means of the two-dimensional model were in general congruent with those measured as a result of the experiments.

1. The friction between the net and the block-shaped boulder can increase the calculated upper retention force by 10% - 20% and reduce the lower retention force accordingly.
2. The influence of the lateral retention forces may reduce the longitudinal retention forces by approx. 15% - 30%.
3. The lateral retention forces may exceed 50% of the upper retention force, depending on the arrangement and deflection of the net in the restrained section.

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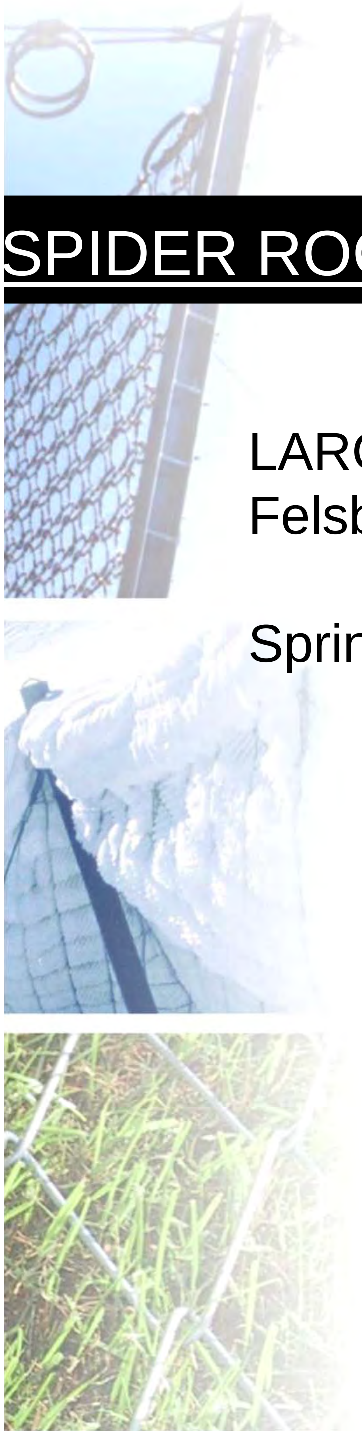
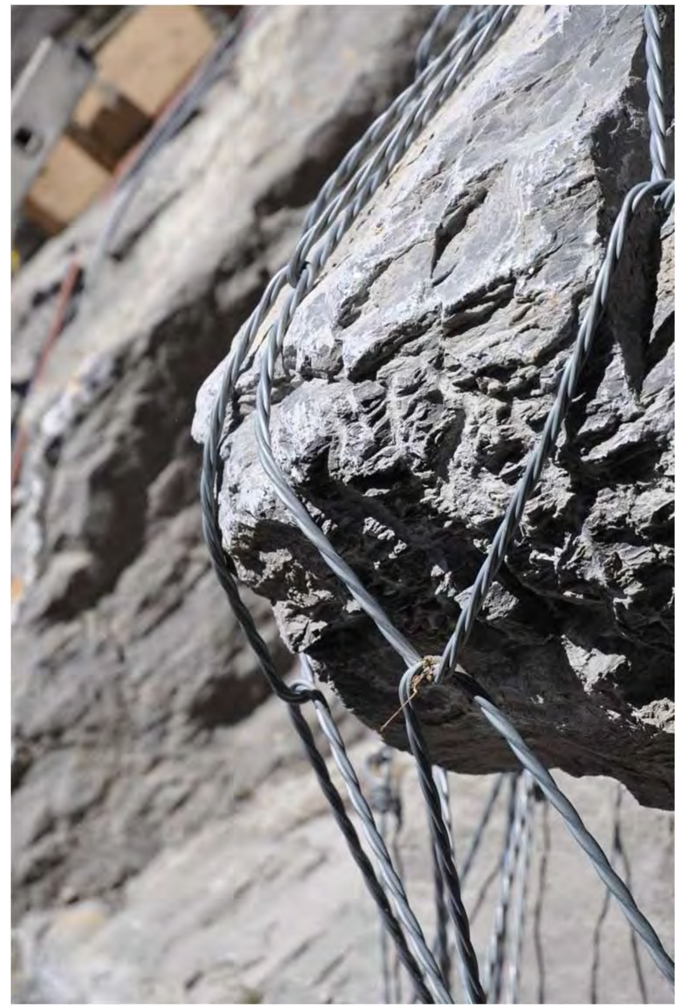


LARGE SCALE FIELD TESTS
Felsburg, Switzerland

Spring 2010



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-Inclination of the sliding surface
b = 55 degrees
- Sliding body weight = 1160 kg/2552 pounds
- SPIDER® Net S4-230

Several nails and rope anchors were installed to fix the net in place and allow test arrangements with different geometries.

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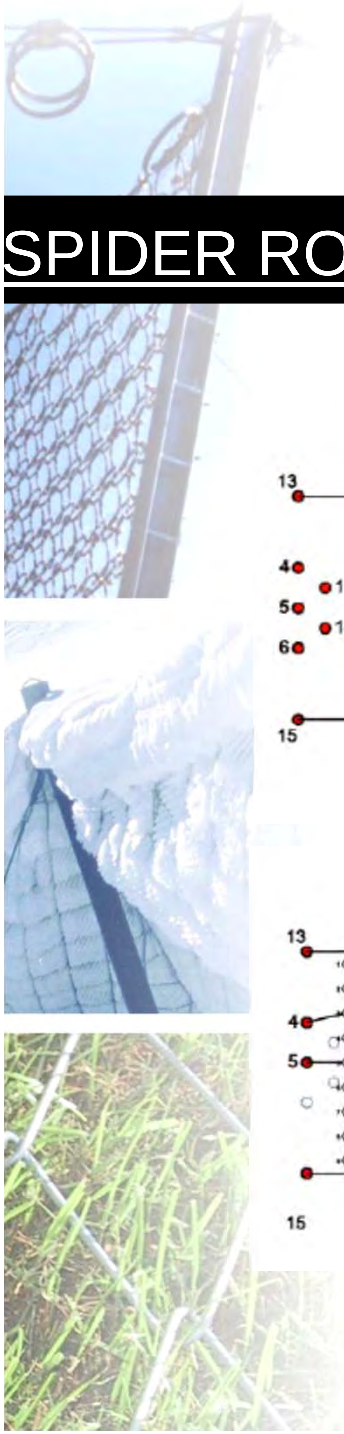

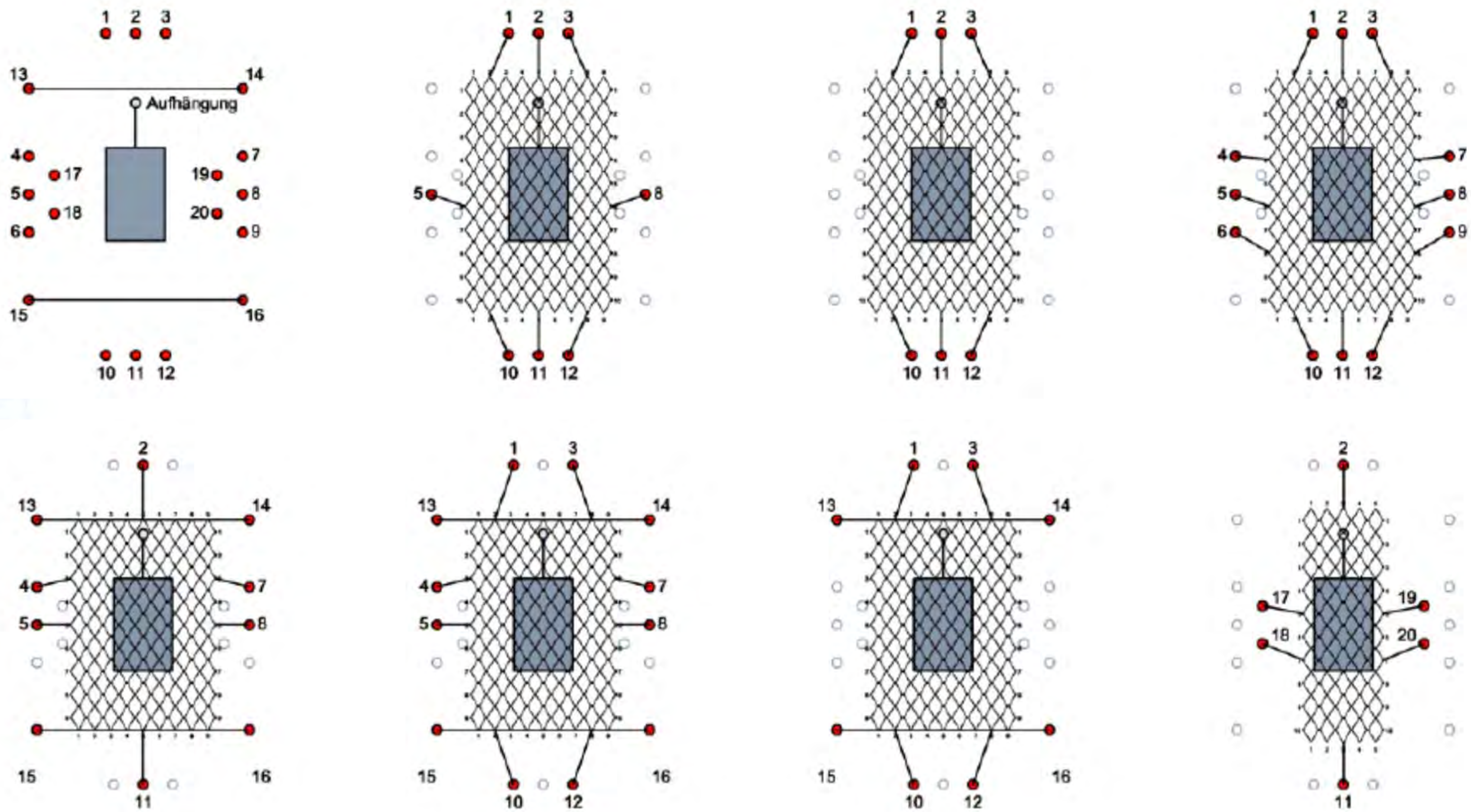

Test Procedure, different arrangements

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Installation Photos

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Results of the large scale field tests

- The measured static forces from the field tests correspond with those determined based on the theoretical model.
- It could be shown that the forces in the boundary ropes were lower than expected.
- If the block can be accelerated over 0.5 m/1.64 feet before touching the net, the forces can go up to more than 300% compared with the required static loads.
- The Ruvolum Rock Program needed to be revised.

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Ruvolum Rock Program

The first step is to determine through field investigation the relevant input parameters for the slope or block and they are:

- Weight, geometrical dimension of the block-shaped boulder
- Inclination of the sliding surface (β)
- Shear parameters along the sliding surface (friction angle and possibly cohesion)
- Angle of the net restraint to horizontal (ϑo) on top of the boulder
- Angle of the net restraint to horizontal (ϑu) at the bottom of the boulder
- Angle of the lateral net restraint to horizontal (δ)

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Dimensioning of the Rock Protection System SPIDER based on the RUVOLUM ROCK method

Print preview

Input Quantities

Weight, Geometry

Block weight (characteristic value)	$G =$	100	[kN]
Inclination of the sliding plane to horizontal	$\beta =$	60	[degrees]
Angle of the top restraint to horizontal	$\vartheta_o =$	70	[degrees]
Angle of the bottom restraint to horizontal	$\vartheta_u =$	50	[degrees]
Ratio Zu : Zo	$\eta =$	80	[%]

Lateral influence

Angle of the lateral restraint to horizontal related to vertical plane	$\delta =$	5	[degrees]
Angle of the resultant, lateral restraint in line of slope	$\chi =$	0	[degrees]
Ratio S : Zo	$\zeta =$	30	[%]

When the program is opened there are preset default values in place and the determined input quantities are entered in their place

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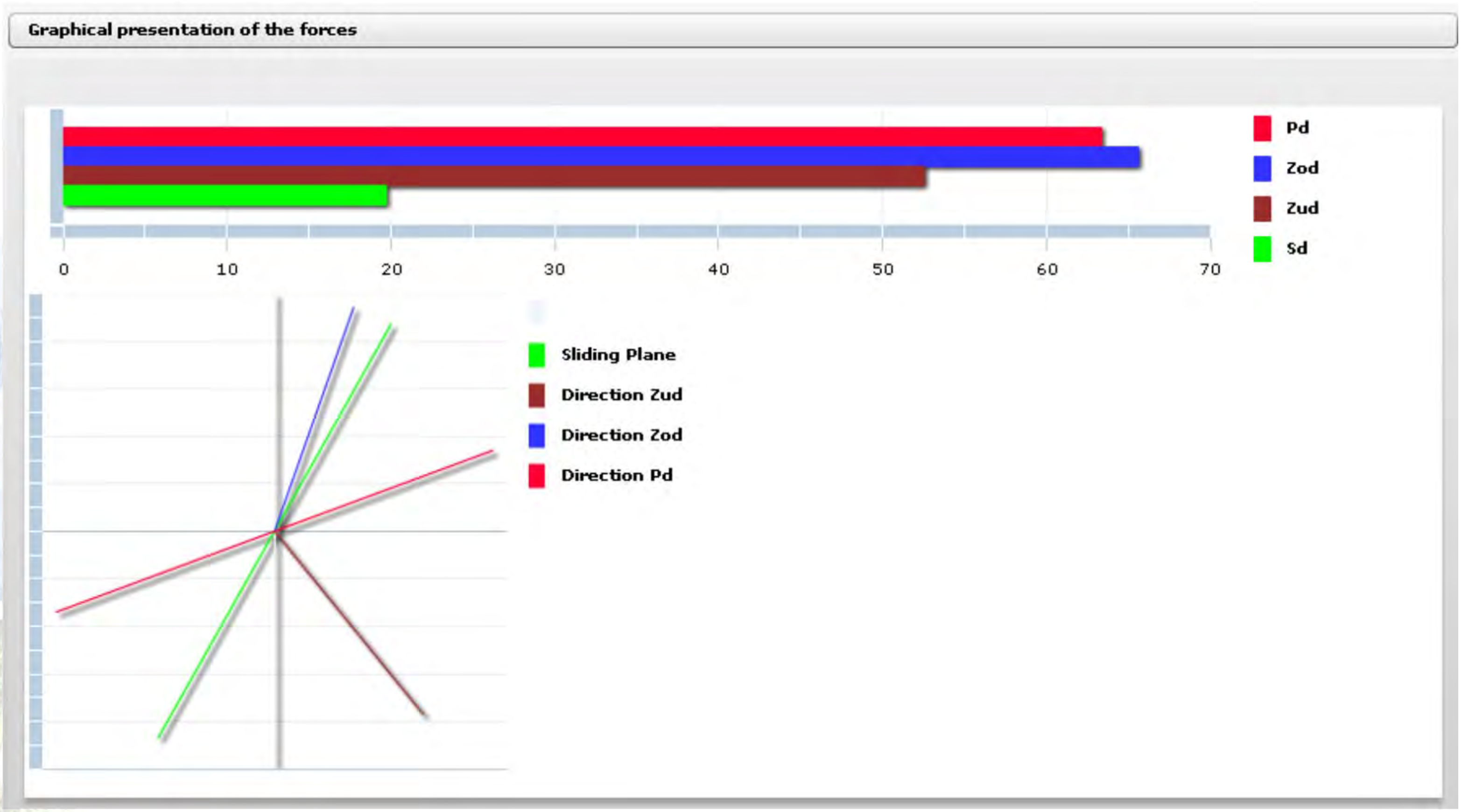

A graphical presentation of the forces (Pd, Zod, Zud and Sd) is shown

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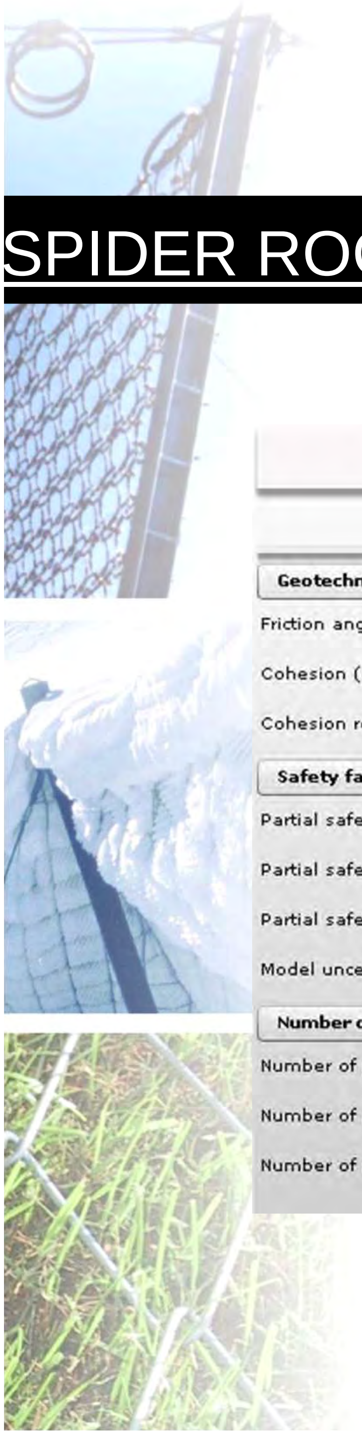
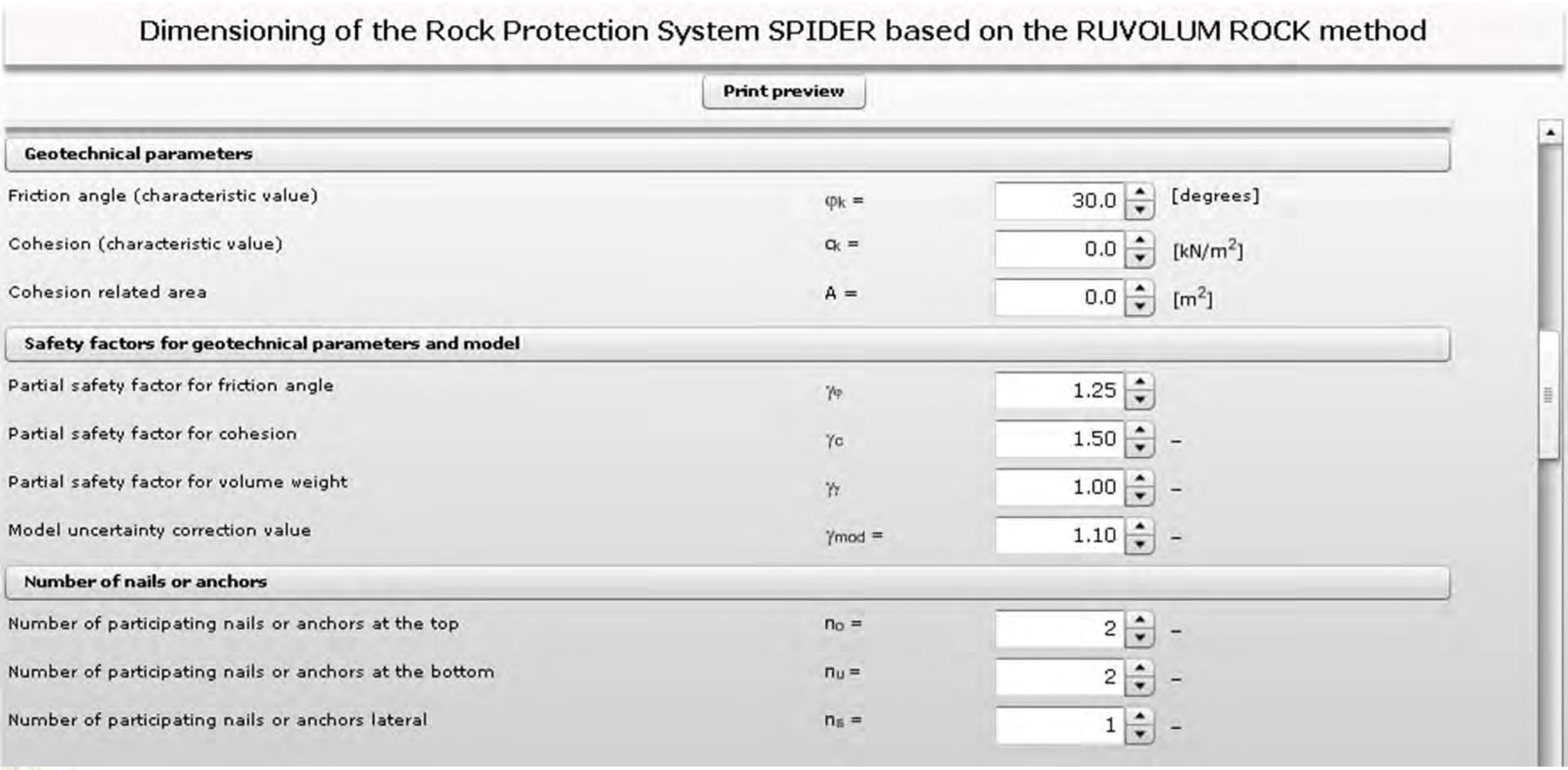
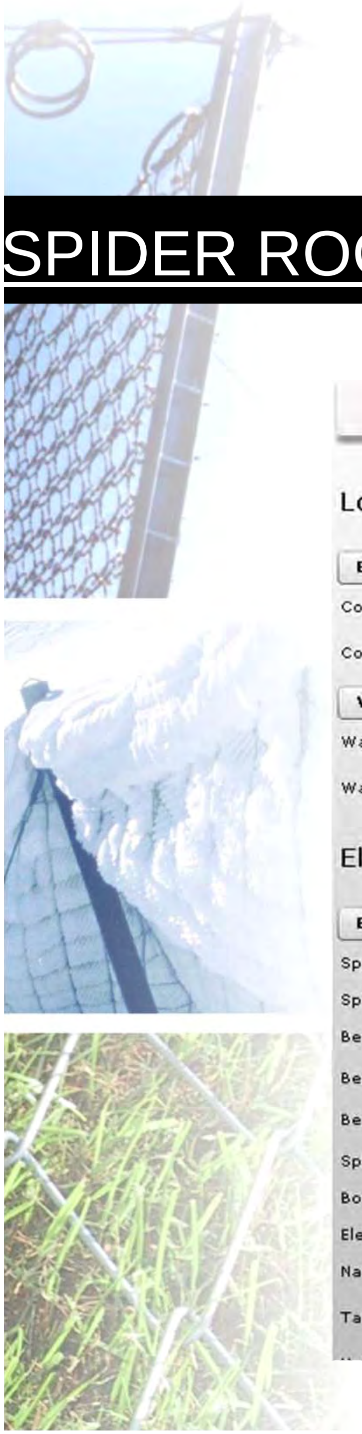




Dimensioning of the Rock Protection System SPIDER based on the RUVOLUM ROCK method

Print preview

Geotechnical parameters			
Friction angle (characteristic value)	φ_k =	30.0	[degrees]
Cohesion (characteristic value)	c_k =	0.0	[kN/m^2]
Cohesion related area	A =	0.0	[m^2]
Safety factors for geotechnical parameters and model			
Partial safety factor for friction angle	γ_φ	1.25	
Partial safety factor for cohesion	γ_c	1.50	–
Partial safety factor for volume weight	γ_γ	1.00	–
Model uncertainty correction value	γ_{mod} =	1.10	–
Number of nails or anchors			
Number of participating nails or anchors at the top	n_o =	2	–
Number of participating nails or anchors at the bottom	n_u =	2	–
Number of participating nails or anchors lateral	n_s =	1	–



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Dimensioning of the Rock Protection System SPIDER based on the RUVOLUM ROCK method

Print preview

Load cases

Earthquake

Coefficient of horizontal acceleration due to earthquake	ε_h =	0.000	–
Coefficient of vertical acceleration due to earthquake	ε_v =	0.000	–

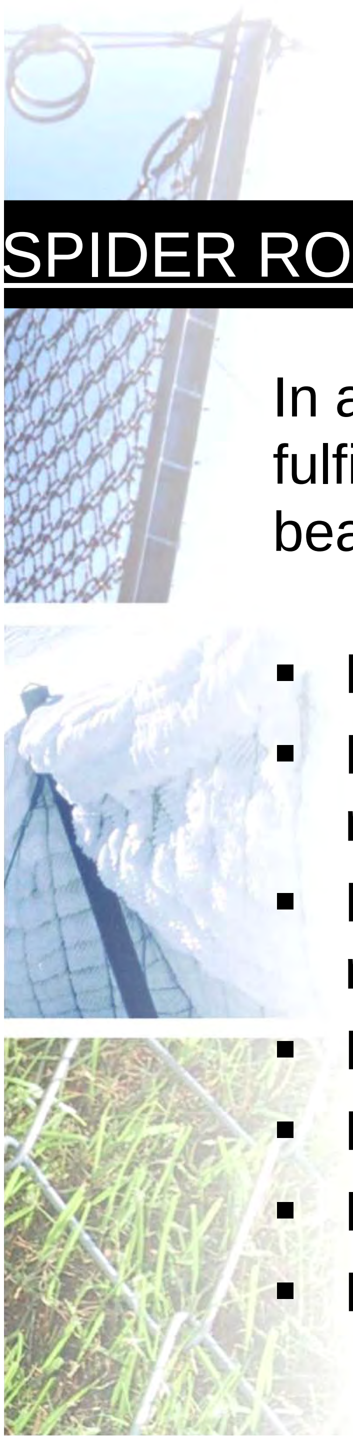
Water pressure acting onto the block

Water pressure from behind, perpendicular to the sliding plane	W_h =	0	[kN]
Water pressure from above, parallel to the sliding plane	W_o =	0	[kN]

Elements of System

Elements of System

Spiral rope net	SPIDER S4-230	
Spike plate	System spike plate P33/40S	
Bearing resistance of the spiral rope net to tensile stress	z_n [kN/m] =	220
Bearing resistance of the spiral rope net to local force transmission longitudinal	Z_{R1} [kN] =	60
Bearing resistance of the spiral rope net to local force transmission transversal	Z_{R2} [kN] =	45
Spiral rope anchor (standard)	Spiral rope anchor D= 14.5 mm	
Boundary rope (standard)	Steel wire rope , D=14 mm	
Elements to connect the net panels between each other	Shackles 3/8"	
Nail type	GEWI D = 32 mm	
Taking into account rusting away (nail diameter reduced by 4 mm)	yes	



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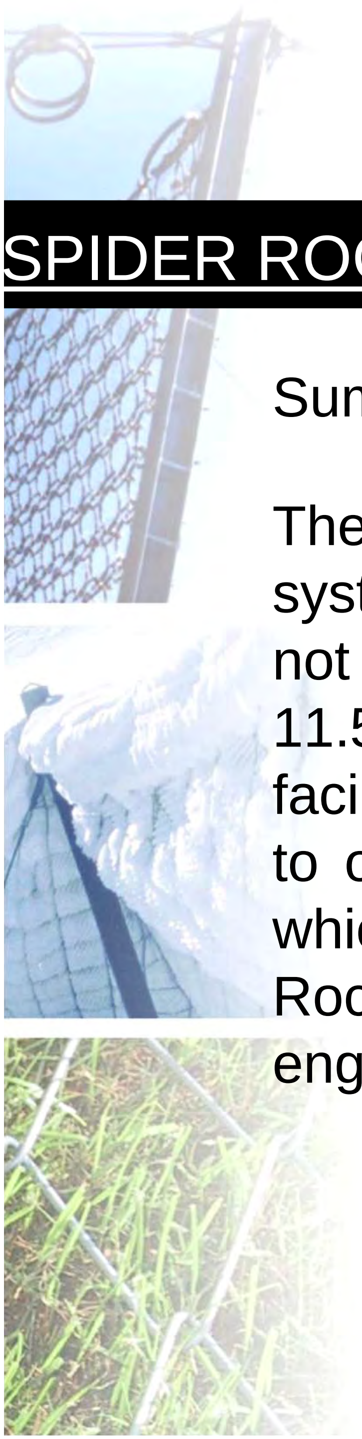
In additional to balancing the load, a key consideration is to fulfill 3 proofs of bearing resistance of the net and 4 proofs of bearing safety of the nails.

- Proof of local force transmission in the net to the top nails
- Proof of local force transmission in the net to the bottom nails
- Proof of local force transmission laterally in the net to the nails
- Proof of shear stress in nails at the top
- Proof of combined stress in the nails at the top
- Proof of shear stress in nails at the bottom
- Proof of combined stress in the nails at the bottom



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Summary

The SPIDER® net along with the SPIDER® rock protection system was developed specifically for rock slopes where it is not practical to remove loose rock. The net is supplied in 11.5 feet/3.5 meter wide x 65.6 feet/20 meter long rolls which facilitates an easier and faster installation. Plus, it is possible to optimize the net and anchors so the loads are balanced which was not possible using other techniques The Ruvloum Rock Dimensioning Program is a new tool designers and engineers can use to optimize their applications.