STABILIZING ROCK USING THE SPIDER® MESH SYSTEM

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STABILIZING ROCK USING THE SPIDER® MESH SYSTEM

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.

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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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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.

ROCK SLOPE STABILIZATION USING SPIDER® SYSTEM

SPIDER ® Rock Protection System

System consists of the following elements:

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

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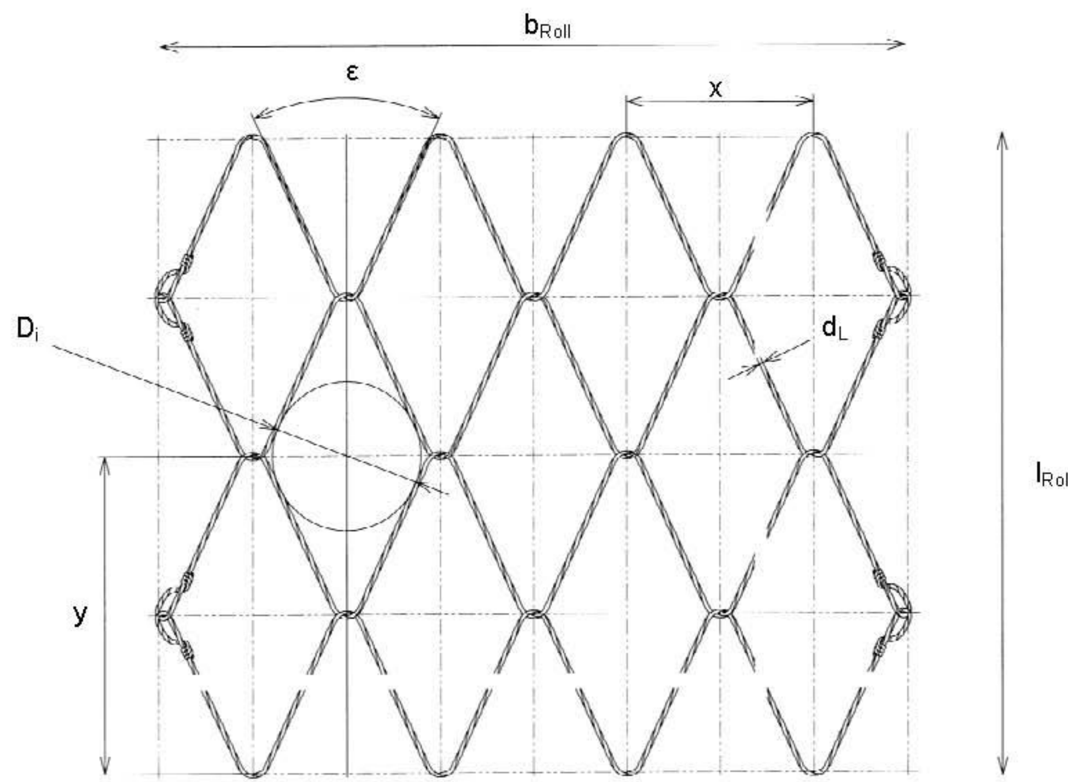
SPIDER ® S4/230 Net

SPIDER® S4



Mesh Width = 11.5 inches & Height = 19.7 inches

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Mesh to Mesh Connection - Single Twist

SPIDER NET S4

Knotted Ends

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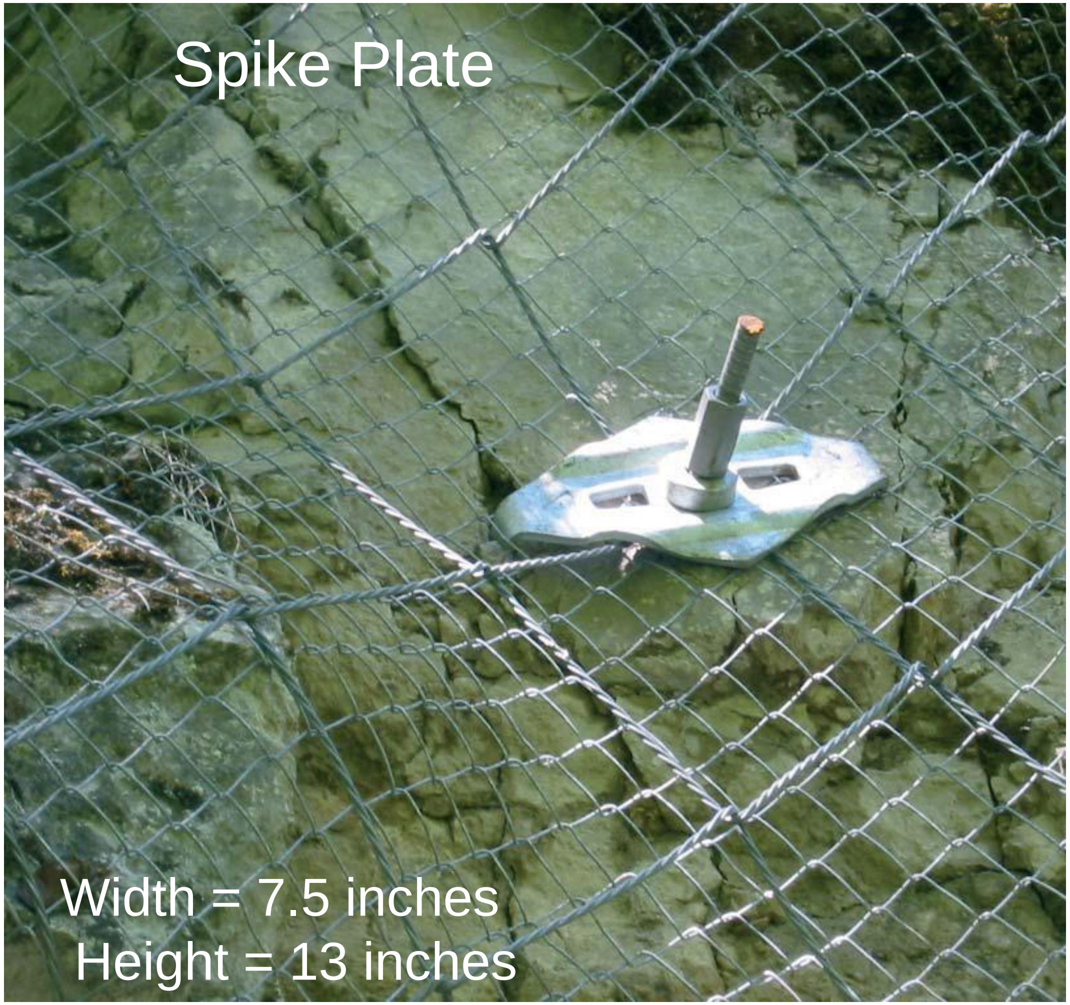

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Other Components Are Off the Shelf

- 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 – 1-inch, 1-1/8-inch or 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 (ϑ_o) and (ϑ_u) of the forces (Z_o) and (Z_u) in the net cover

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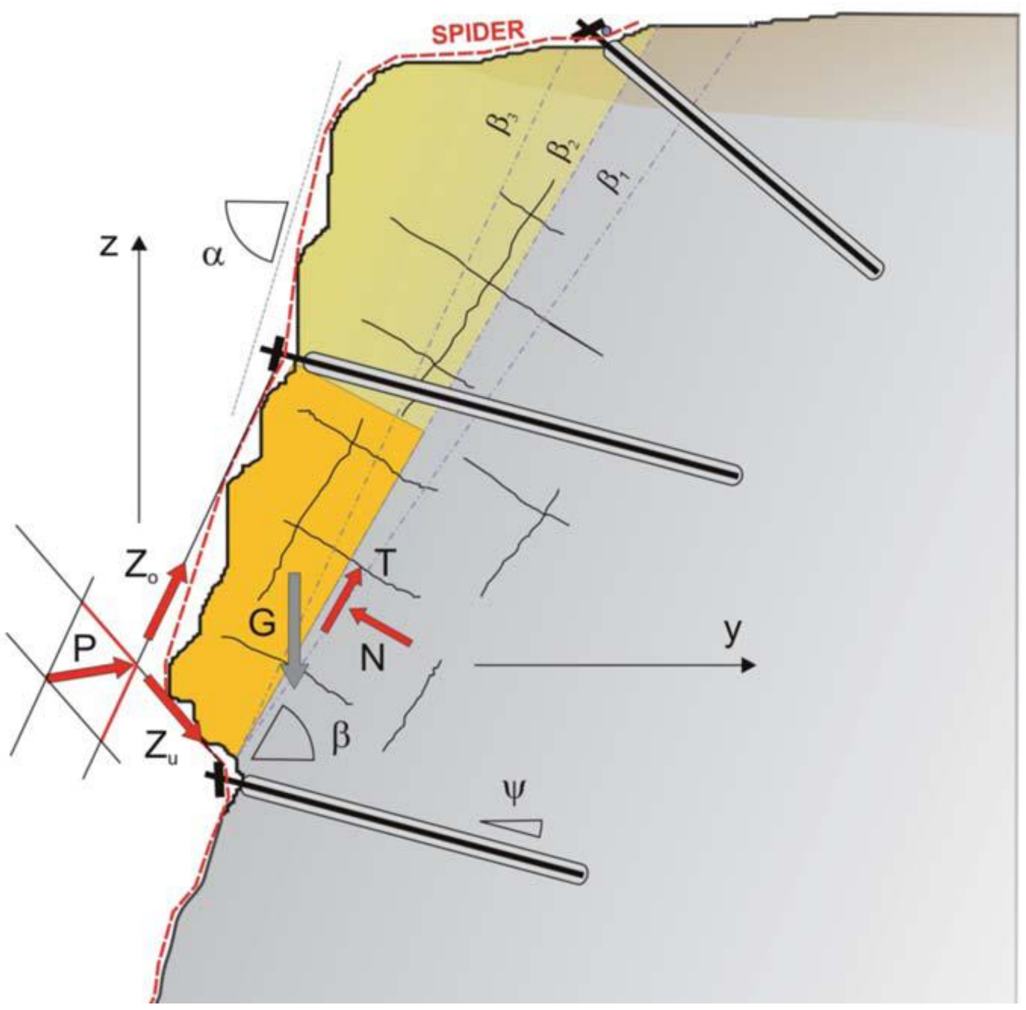

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The retaining force (P) can be calculated as follows based on taking into account the stabilization issues relevant to an individual block-shaped boulder as well as the model uncertainty correction value (γ_{mod}).

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

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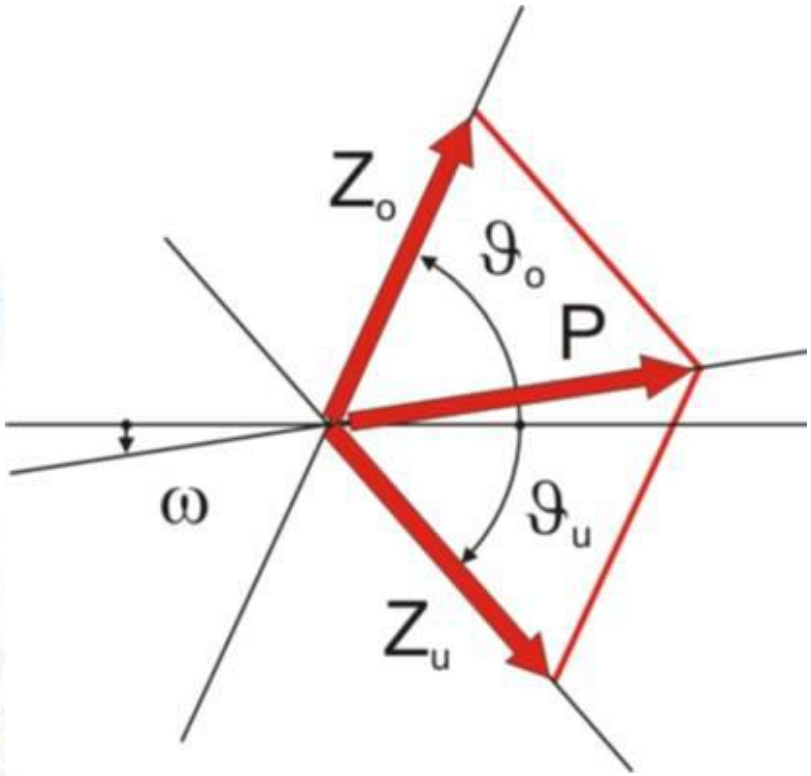

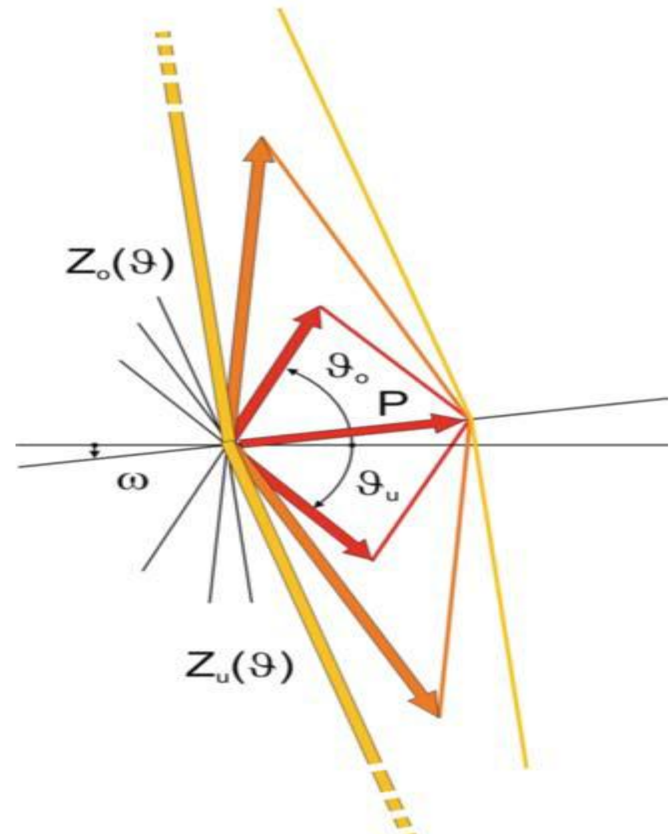

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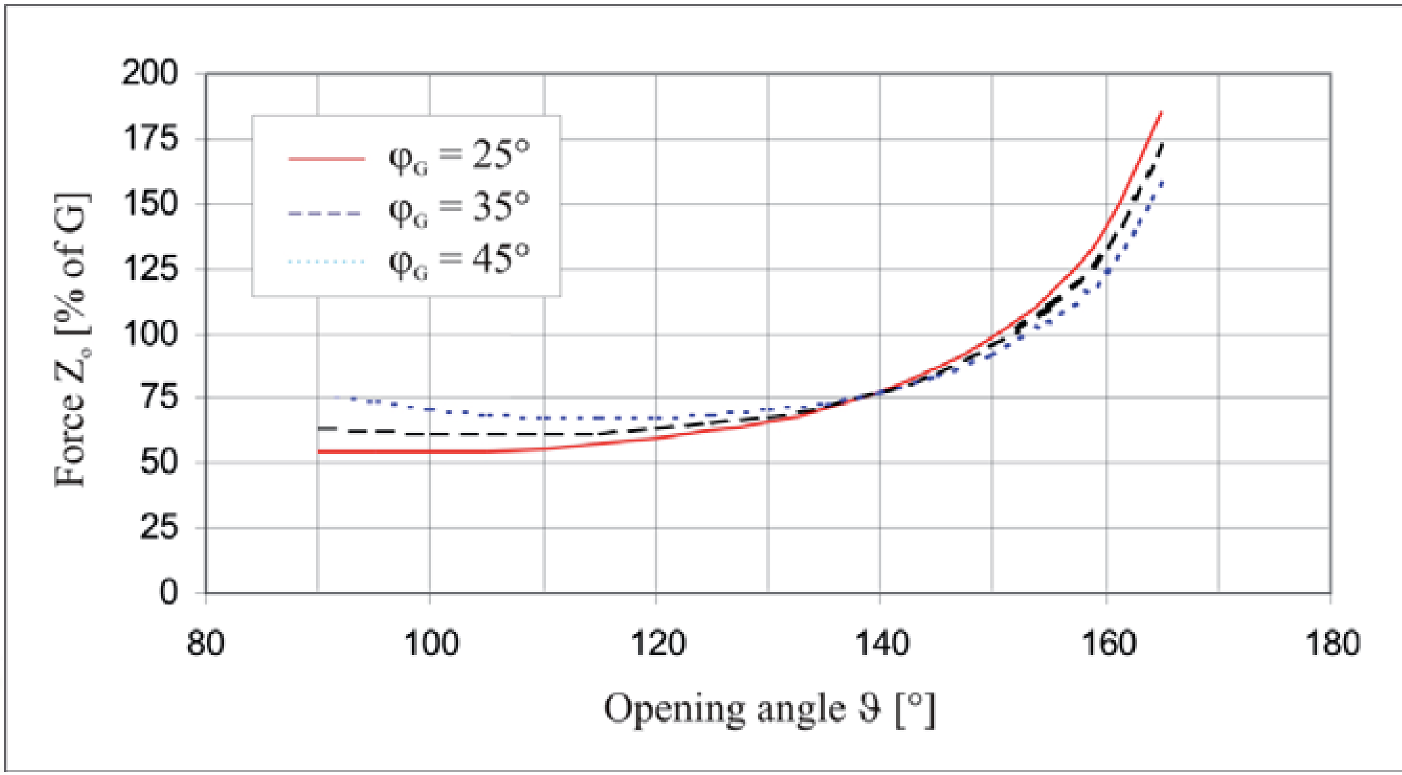

Friction angle (φ_G) between the boulder and the restraint is insignificant

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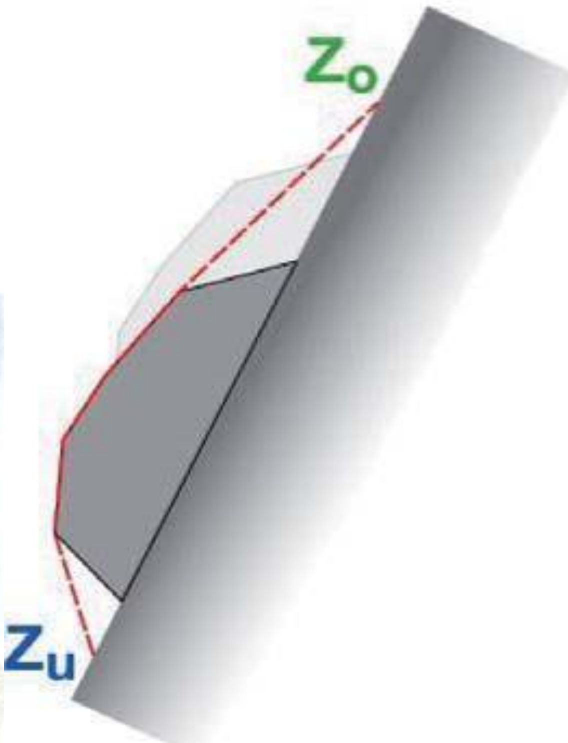

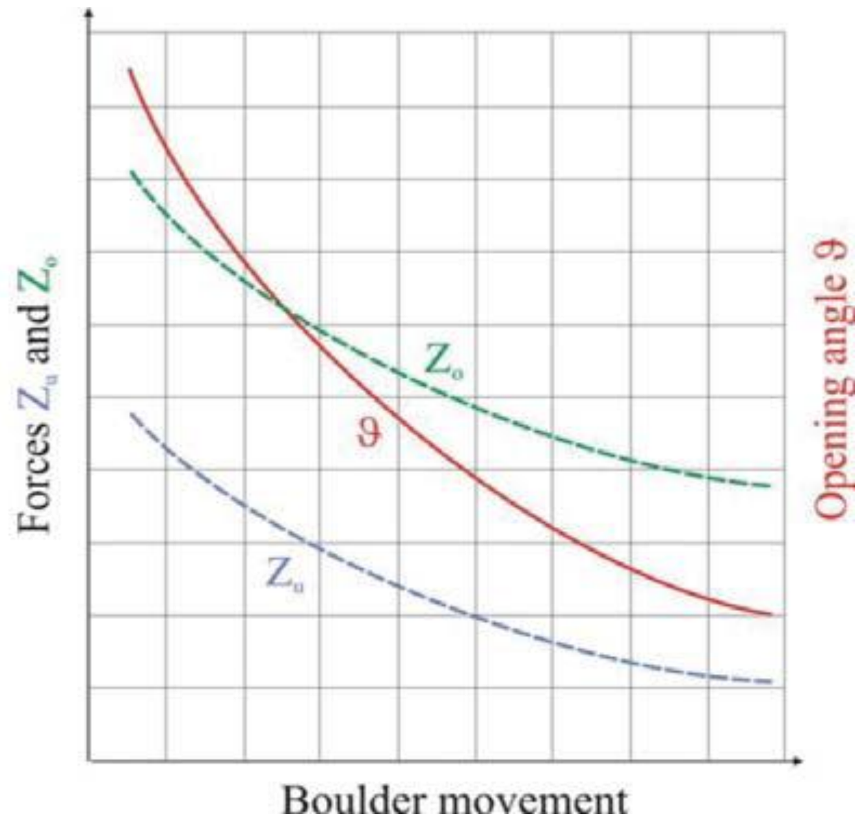

The opening angle ($\vartheta = \vartheta_o + \vartheta_u$) becomes smaller with increasing boulder movement and the upper and lower retention forces decrease.

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MODEL EXPERIMENTS

Scale of 1:3.5

Objectives included:

- implementation of the theoretical basic considerations
- comparison under real-life conditions
- determination of the distribution of forces in a three-dimensional system

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TEST SETUP

- Blue steel frame 4.9’ wide and 8.2’ long
- Rope and the Model Net was fastened to frame
- Slide face colored red
- Angle between the slide face and the frame was kept constant at 36°
- Strain gauges measured the forces acting on the rope, net and directly on the sliding body.
- Potentiometer measured the displacement of the block-shaped boulder.
- A wooden block weighing 128 pounds was the 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.
- 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.
- The influence of the lateral retention forces may reduce the longitudinal retention forces by approx. 15% - 30%.
- 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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RUVOLUM ROCK PROGRAM

Input parameters required:

- 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 (ϑ_o) on top of the boulder
- Angle of the net restraint to horizontal (ϑ_u) at the bottom of the boulder
- Angle of the lateral net restraint to horizontal (δ)

STABILIZING ROCK USING THE SPIDER® MESH SYSTEM

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	β =	60	[degrees]
Angle of the top restraint to horizontal	ϑ_o =	70	[degrees]
Angle of the bottom restraint to horizontal	ϑ_u =	50	[degrees]
Ratio Zu : Zo	η =	80	[%]

Lateral influence

Angle of the lateral restraint to horizontal related to vertical plane	δ =	5	[degrees]
Angle of the resultant, lateral restraint in line of slope	χ =	0	[degrees]
Ratio S : Zo	ζ =	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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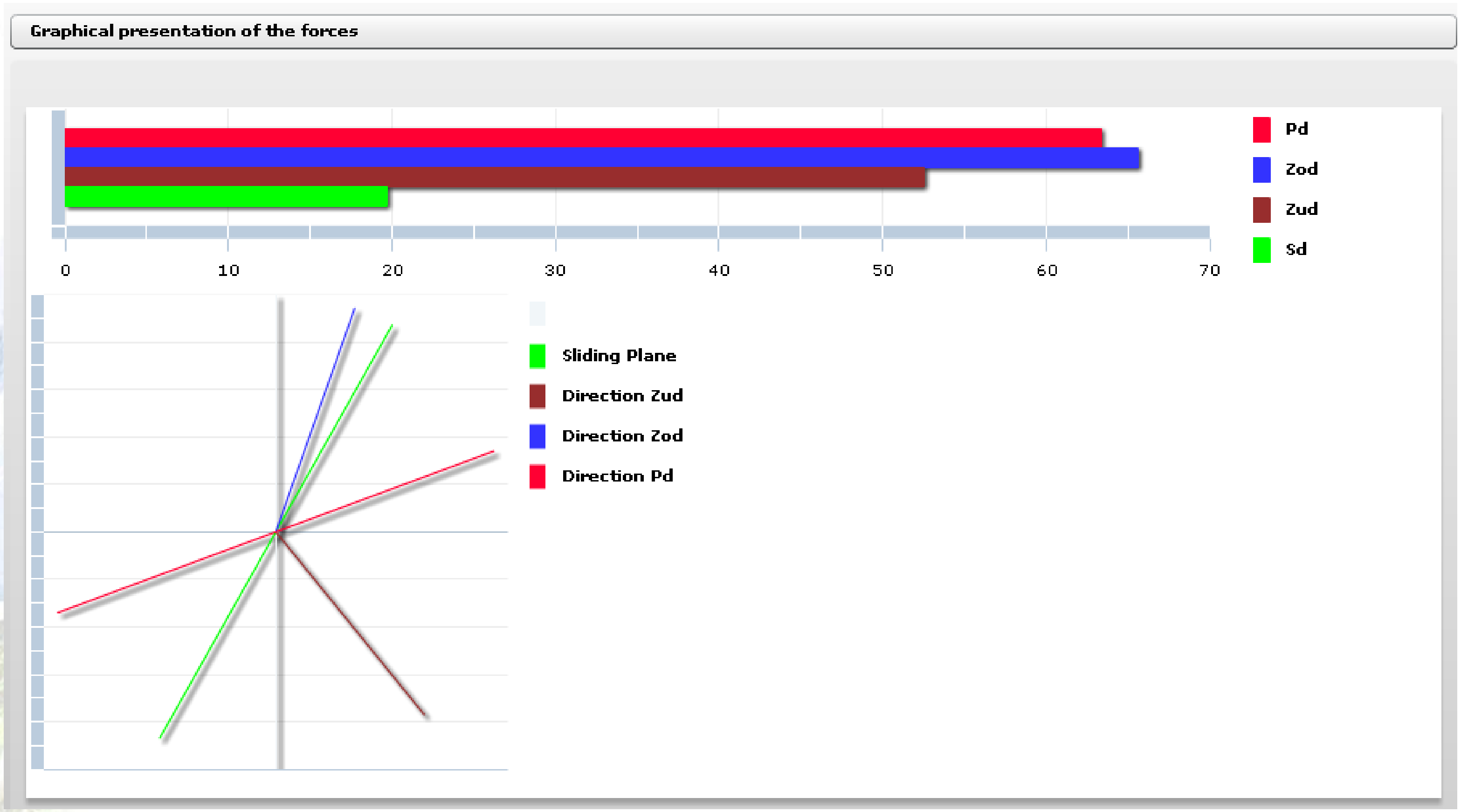
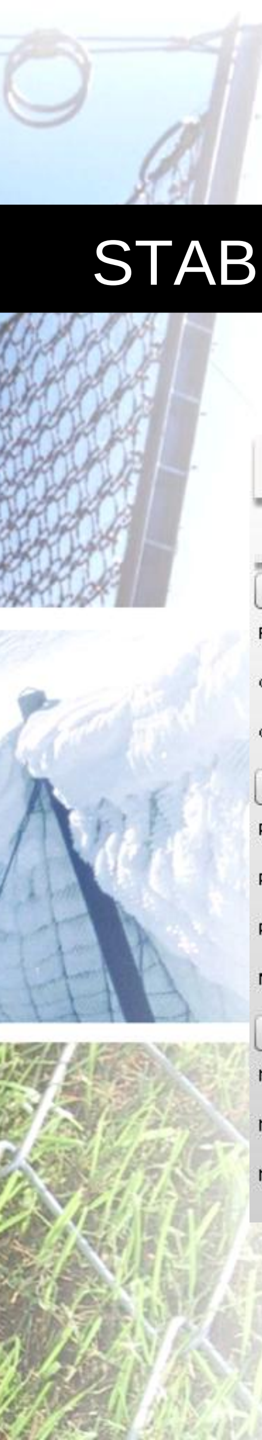


A graphical presentation of the forces (P_d, Z_{od}, Z_{ud} and S_d) is shown



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

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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_B =	1	–

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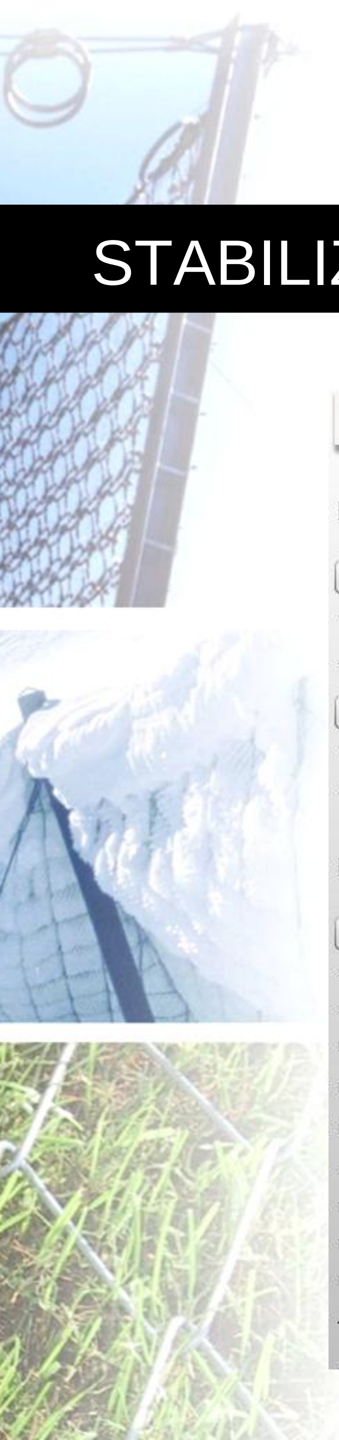

Dimensioning of the Rock Protection System SPIDER based on the RUVOLUM ROCK method

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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Program provides the following proofs to verify the design is acceptable:

- 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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SPIDER® Full-scale field tests in Felsburg, Switzerland

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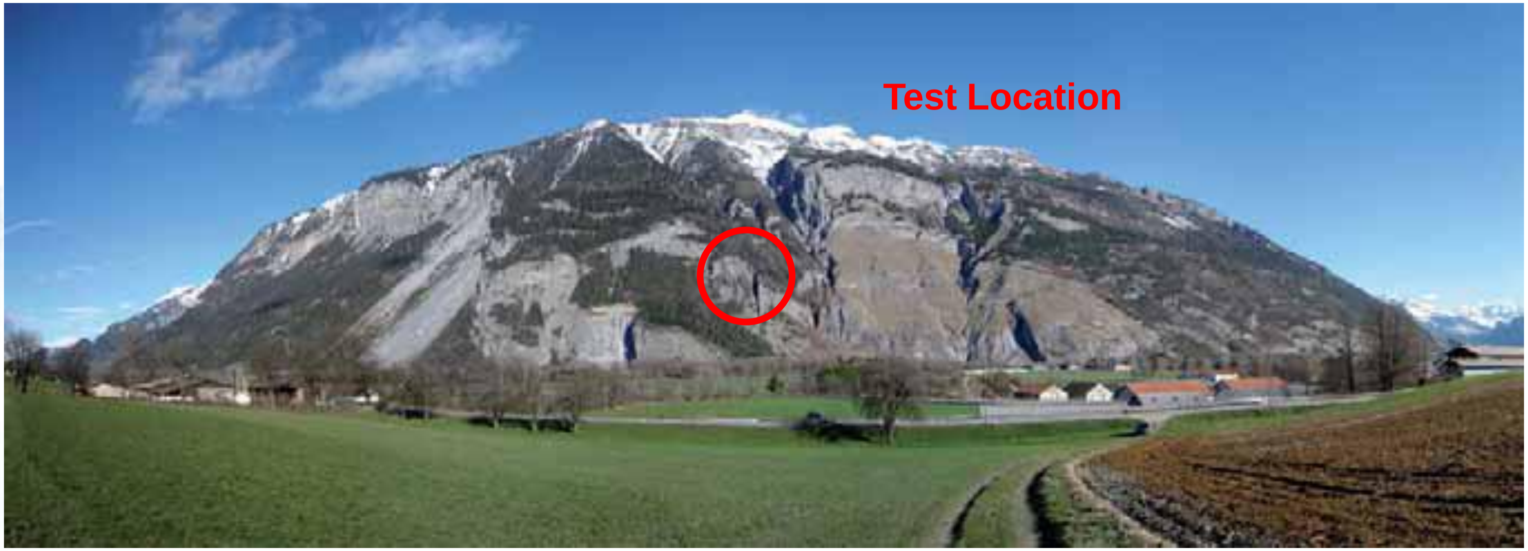

ROCK SLOPE STABILIZATION USING SPIDER® SYSTEM

- Inclination of the sliding surface b = 55 degrees
- Sliding body weight = 2,552 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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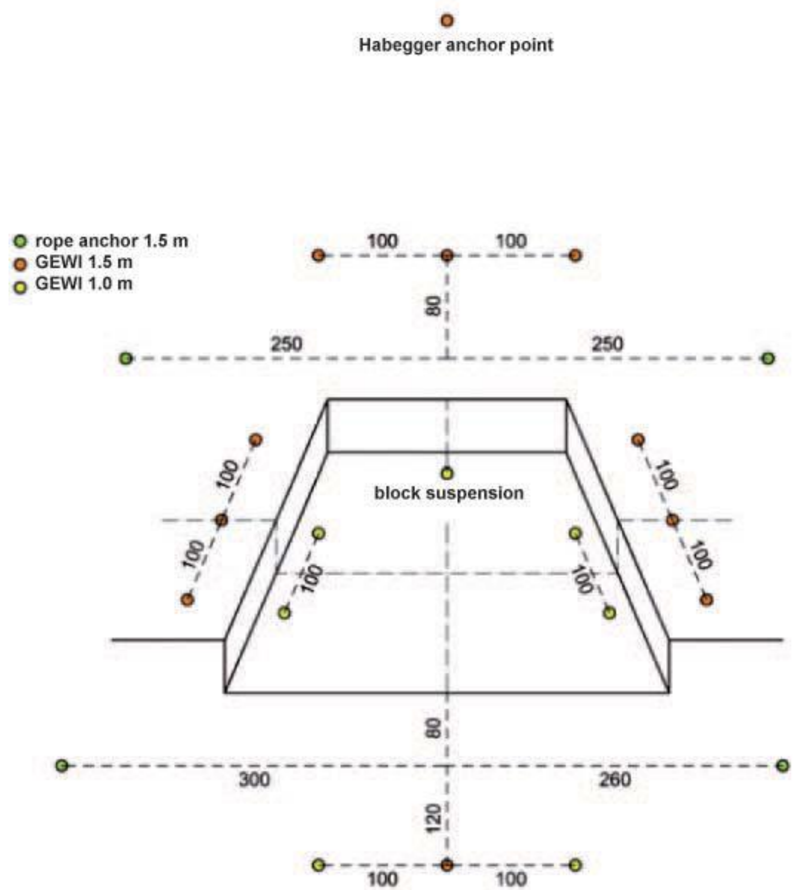

Anchorage Arrangement

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Positioning the Test Block

Test Installation Setup

Overview of Setup w/o boundary rope

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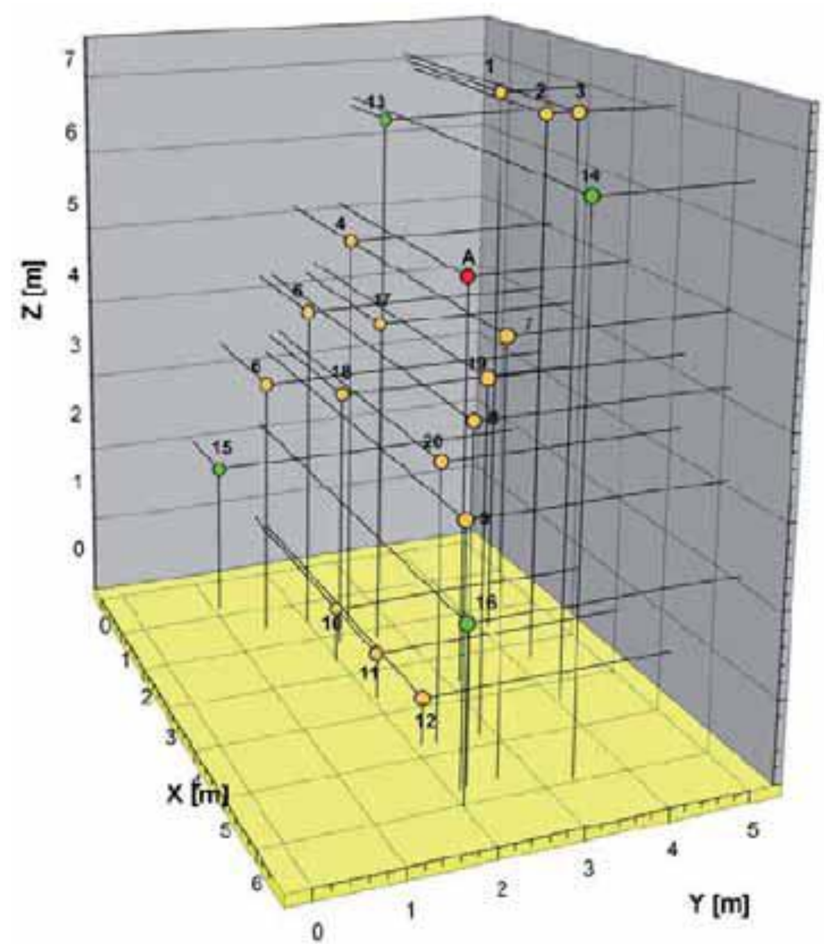
ROCK SLOPE STABILIZATION USING SPIDER® SYSTEM



Central perspective side view showing the spatial position of the anchors

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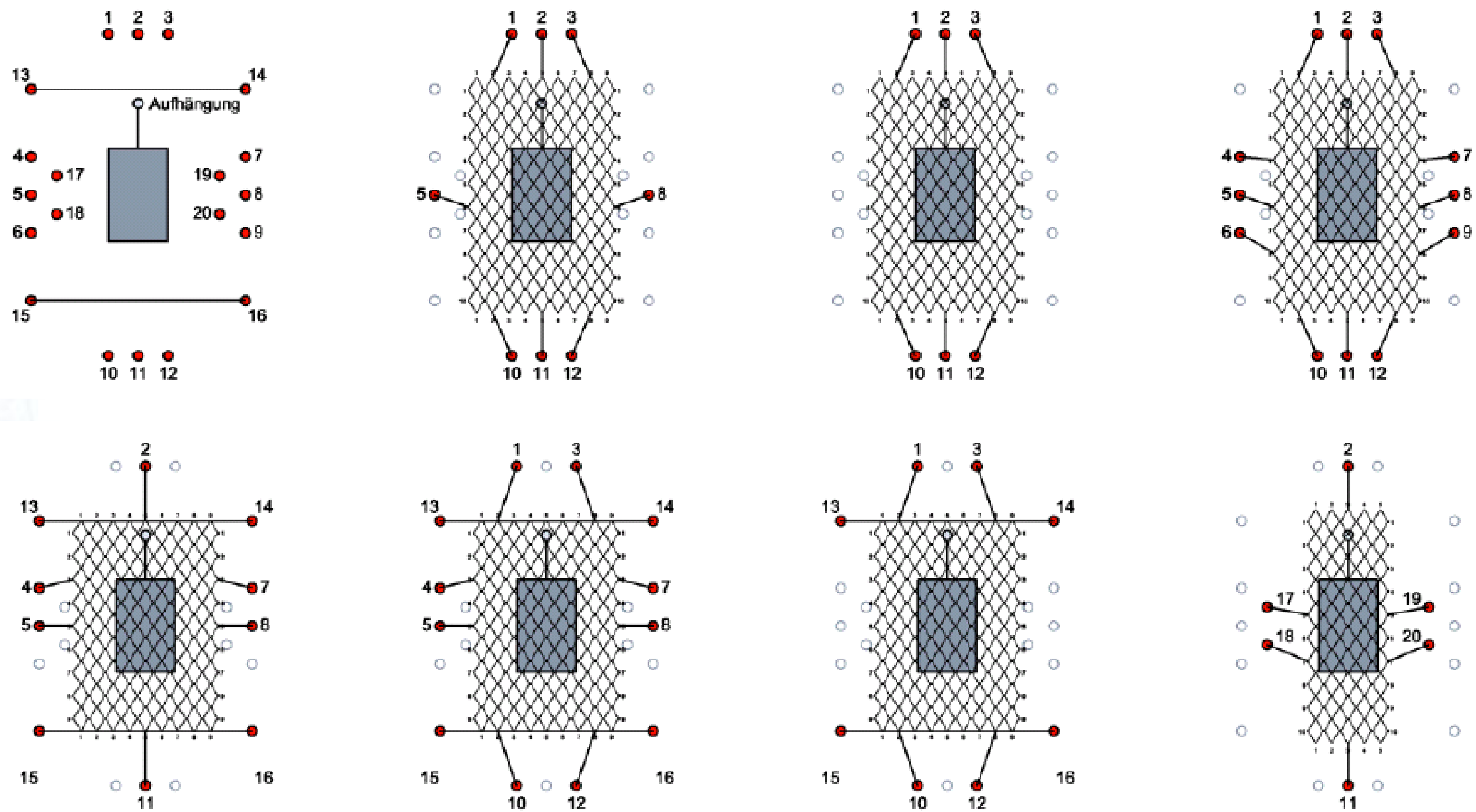

Test Procedure, different arrangements

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The tests yielded the following information and conclusions for practice:

- If a critical boulder is calculated purely statically on the basis of an equilibrium consideration the forces in the anchorages can sometimes be massively underestimated. As shown from the tests, the forces from the dynamic influence exceed the statically determined forces by a factor of 1.5 – 2.5 or more. Consequently a dynamic factor is to be taken into account when dimensioning flexible rock protection systems.
- In principle the forces are more likely to be transferred upwards. The size of the relationship of the upward forces to the downward forces depends on the nature of the meshing of the boulder with the rope net and whether boundary ropes are installed.

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The tests yielded the following information and conclusions for practice (cont'd):

- The large scale field tests have shown that when using a large mesh net for securing individual boulders, boundary ropes are to be fitted to the top and bottom and where possible also at the sides. This can essentially improve the supporting behavior of the system.
- The dimensioning of flexible rock protection systems can be carried out using a simple model based on the equilibrium consideration. It is obligatory for the individual relationship factors and above all the dynamic effects to be adapted to the local and project specific circumstances.

The RUVOLUM Rock program was upgraded accordingly

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Conclusions:

- 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 wide x 65.6 feet long rolls which facilitates an easier and faster installation.
- 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.

Thank you for your time!