Software Manual

Dimensioning tool for the rock protection system SPIDER® for individual rock boulders

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BRUGG Geobrugg

Safety is our nature

PREFACE

Geobrugg AG, Geohazard Solutions, is grateful to you for using the SPIDER® ONLINE-TOOL software. Every effort is made to give you the best possible support in the dimensioning of the SPIDER® rock protection system.

The SPIDER® ONLINE-TOOL offers the possibility of considering water pressure and accelerations due to earthquake in horizontal as well as in vertical direction. The calculations can be done based on International Units in English and German.

This manual provides you with the most important references and function descriptions to enable you to use the program correctly. Please read the operating instructions prior using the program for the first time. Keep this reference book close at hand always.

The aim has been to develop a program which, despite its complexity of structure and application, is as clear and straightforward as possible as far as aspects of graphic presentation and user-friendliness are concerned.

Numerous parameters need to be entered for the dimensioning operations. It is the responsibility of the user of this program to select and enter these parameters correctly.

Armin Roduner
Geobrugg AG

July 2023

PRODUCT LIABILITY CLAUSE OF GEOBRUGG AG, GEOHAZARD SOLUTIONS

Rockfall, landslides, debris flows or avalanches are sporadic and unpredictable. Causes can be human (construction, etc.) or environmental (weather, earthquakes, etc.). Due to the multiplicity of factors affecting such events it is not and cannot be an exact science that guarantees the safety of individuals and property.

However, by the application of sound engineering principles to a predictable range of parameters and by the implementation of correctly designed protection measures in identified risk areas the risks of injury and loss of property can be substantially reduced.

Inspection and maintenance of such systems are an absolute requirement to ensure the desired protection level. The system safety can also be impaired by events such as natural disasters, inadequate dimensioning parameters or failure to use the prescribed standard components, systems and original parts; and/or corrosion (caused by pollution of the environment or other man-made factors as well as other external influences).

TABLE OF CONTENTS

1. Introduction 4
2. The SPIDER® Rock Protection System 5
3. Bearing resistances of the system 6
4. Access to the online-tool 7
5. The software 9

1. INTRODUCTION

The software SPIDER® ONLINE-TOOL serves to dimension the SPIDER® rock protection system consisting of the high-tensile spiral rope net SPIDER® S3-130 with a strand diameter of 6.5 mm and a mesh width of 130 mm, system spike plates and adequate nailing.

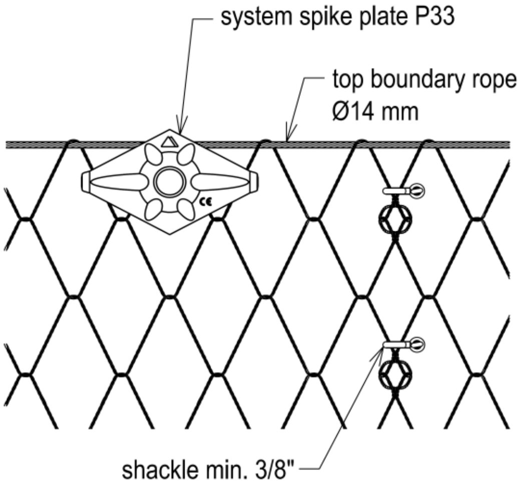
The software is based on the homonymous concept which is basically applicable to all rock protection systems which are commonly available on the market and which allow for a flexible application of the nails both horizontally and in the slope's fall-line.

The SPIDER® ONLINE-TOOL concept analyzes the stability of specific rock boulders liable to break down and determine the number and arrangement of nails and other fixations around the critical block.

If, depending on the prevailing geological circumstances, potential sliding surfaces exist at deeper levels, the overall stability of the slope must be analyzed in addition to the investigation of instabilities close to the surface, and the protection measures must be dimensioned accordingly.

2. THE SPIDER® ROCK PROTECTION SYSTEM

The SPIDER® rock protection system has been developed by Geobrugg AG and consists of the following elements: the SPIDER® spiral rope net, nailing, system spike plates, shackles, boundary ropes, spiral rope anchors, secondary mesh (optional) and intermediate fixations.



SPIDER® S3-130 rock protection system

The SPIDER® spiral rope net features a rhomboidal-shaped mesh with a mesh width of 130 mm and diagonals 164 x 270 mm in size. The spiral rope used for this application consists of three twisted together high-tensile steel wires, each 3 mm in diameter, with a tensile strength of at least 1’770 N/mm². Like the TECCO® high-tensile steel wire mesh, this spiral rope is first crisscrossed to form the spiral shape and then twisted together to form a net. The ends of the spiral cables are tied to one another to permit the full transmission of force to the adjoining panels. Basic protection from corrosion consists of a coating of 95% zinc and 5% aluminum. The spiral rope net can also be made of stainless steel if exacting requirements concerning the protection from corrosion must be met. The basic dimensions of the net rolls are 3.5 x 20 m. One roll weights 203 kg.

Commercially available nails such as e.g. GEWI bars or TITAN self-drilling anchors can be used for fixing the net cover, which must fulfill all static requirements. Raw nails are usually used and grouted with at least 20 mm of mortar. With permanent protection measures, an allowance for corrosion of 4.0 mm about the static nail diameter is often considered.

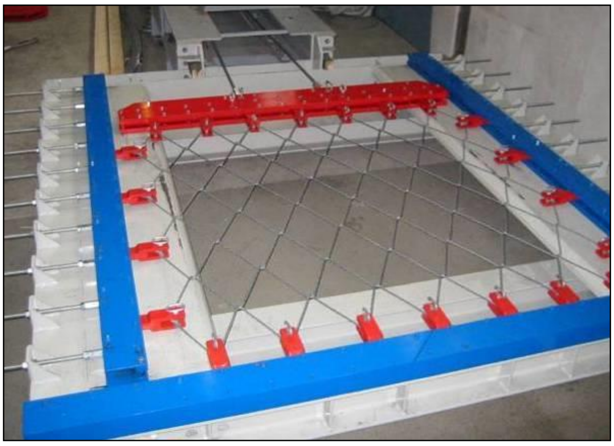
Contrary to earlier cable net covers where so-called ear heads were utilized for fastening the cable nets to the nails, a system of rhomboidal-shaped spike plates of type P33 resp. P66 are now used with which the spiral rope net can be simply tensioned against the ground. The geometrical layout, size and bending resistance have been optimized based on various puncturing and bending tests and adapted to the system requirements. For the force-locked connection of the net panels, 3/8“ shackles are used normally. The loss due to overlapping is kept to a minimum.

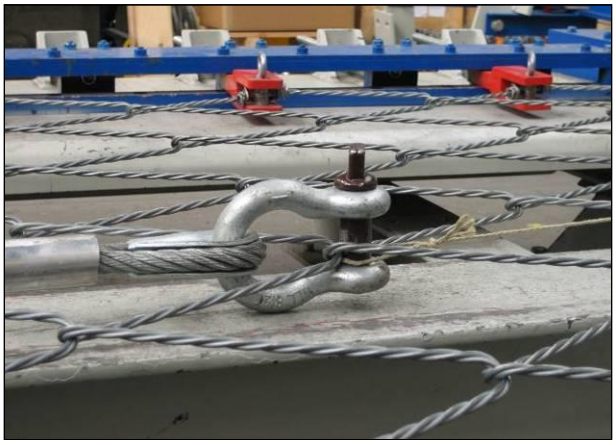
To achieve an ideal load transfer in adjoining areas and to reinforce the boundaries, boundary ropes, 14 mm in diameter, should be used all the way around, and they should be braced against the spiral rope anchors laterally. The boundary ropes can be pulled directly through the mesh openings from the top, bottom or sides. Seam ropes, boundary shackles or compression claws to attach the net to the boundary ropes are thus not needed. The shackles may be fixed with glue to prevent possible vandalism. In the event of overhangs, it may be wise to attach additional cables under the overhangs to optimize the bearing behavior of the system.

As an option it is possible to install a secondary steel wire mesh underneath the spiral rope net if there is a risk of rocks coming loose that might fall through the mesh openings. Intermediate fixations are often provided to ensure the protective measure will be adequately braced against the ground. A simple spike plate will do the job.

3. BEARING RESISTANCES OF THE SYSTEM

Extensive tensile tests have been conducted with the SPIDER® S3-130 spiral rope net under the supervision of the LGA Nuremberg, Germany. The bearing resistance to tensile stress in the main bearing direction of SPIDER® S3-130 is 220 kN/m.
The bearing resistance to a localized force in the area around the knot is Z_{R1} = 60 kN longitudinally and Z_{R2} = 45 kN transversally. These values are important for the design of the protective system to secure rocks from coming loose and sliding off.



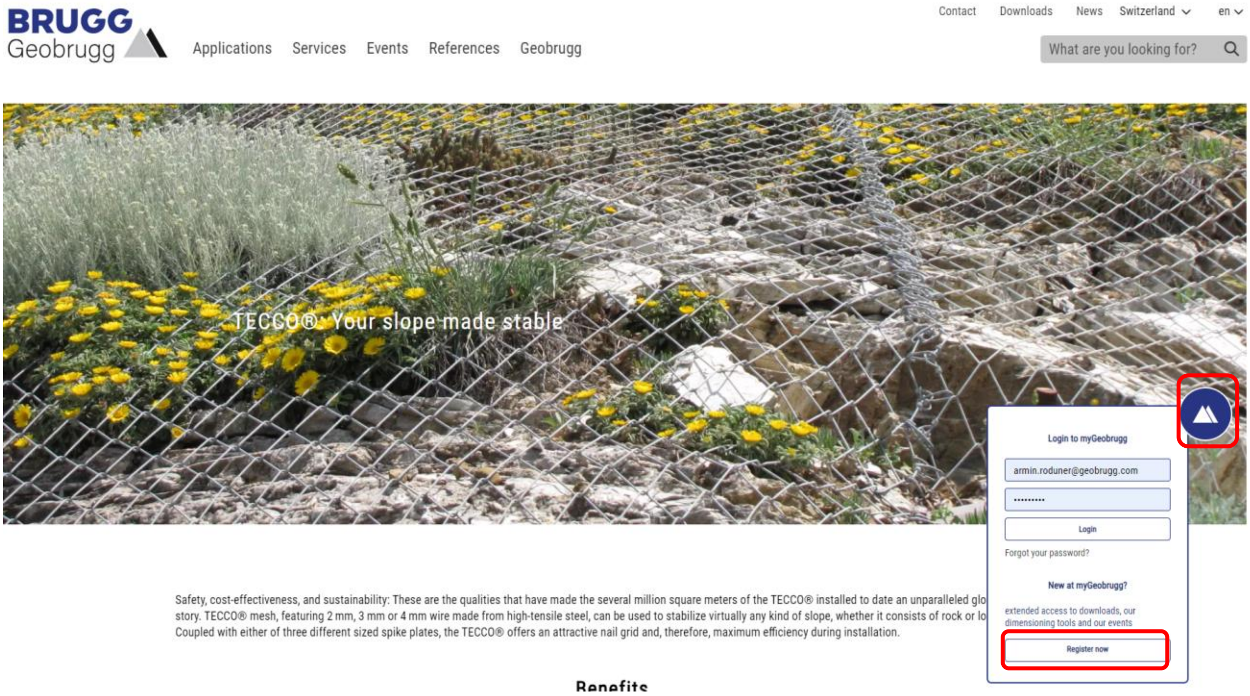


Left: Standard test for the determination of tensile strength per running meter
Right: Determination of the bearing resistance to local force transmission

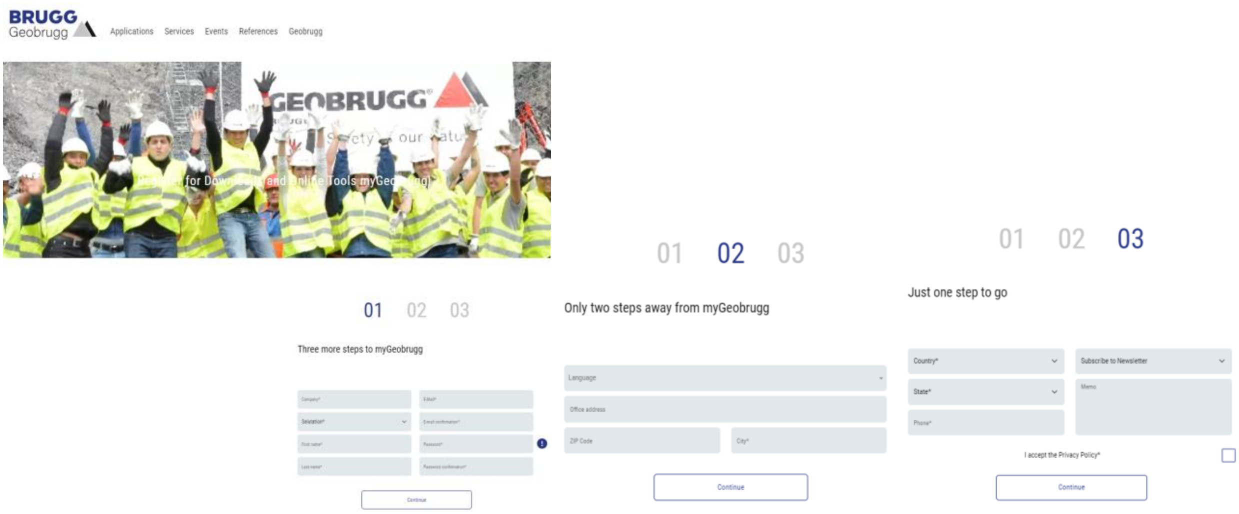
4. ACCESS TO THE ONLINE-TOOL

Our homepage www.geobrugg.com offers the access to the online software.

After clicking on the top right corner to “myGeobrugg” the below shown window appears, which offers the possibilities of the first-time personal registration, the Login and the function of the delivery of the forgotten password per e-mail.



If the program is used the first time one must click on “register here" and the registration form with the 3 steps should be filled out once. Afterwards one will get the personal username and password automatically sent per e-mail.



With the so gotten personal login it can be logged in to “myGeobrugg”.
One can choose between the following dimensioning software packages:

RUVOLUM® Online Tool

The dimensioning tool for the TECCO® and SPIDER® slope stabilization system, in German, English, Spanish, Polish, Portuguese, Romanic, Russian, Chinese, Turkish, French and Italian.

DEBFLOW

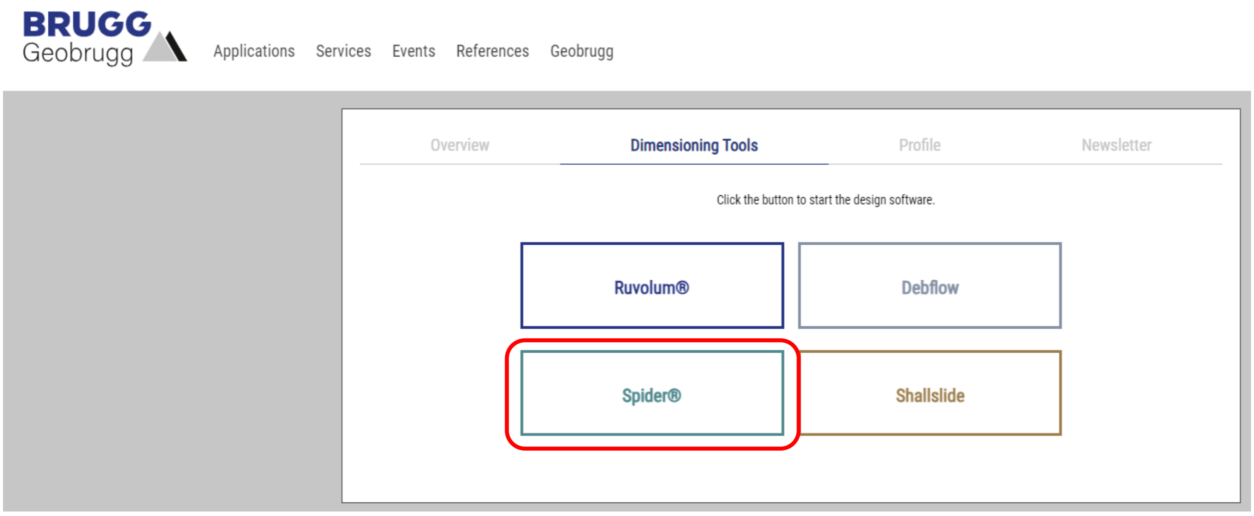
The dimensioning tool for flexible ring net barriers against debris flows, in German, English, Spanish, French, Russian, Chinese and Italian.

SPIDER®

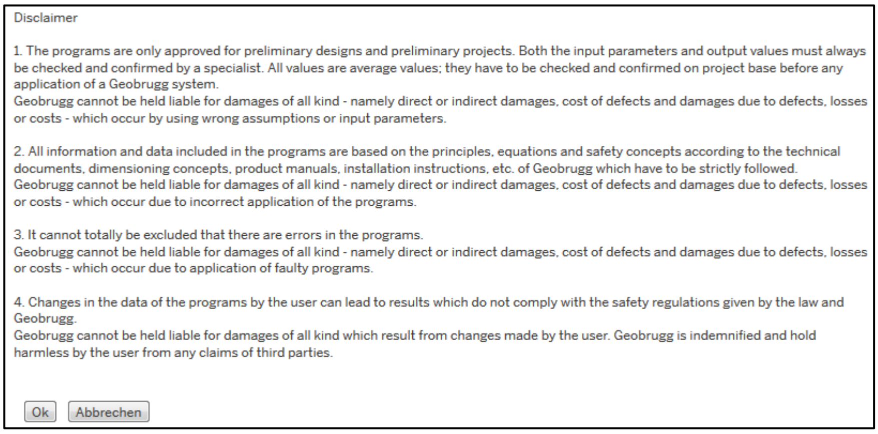
The dimensioning tool for the SPIDER® rock protection system in German and English.

SHALLSLIDE

The dimensioning tool for flexible barriers against shallow landslides in German and English.



When starting the online tool, there is first a disclaimer to be accepted:



Disclaimer

1. The programs are only approved for preliminary designs and preliminary projects. Both the input parameters and output values must always be checked and confirmed by a specialist. All values are average values; they have to be checked and confirmed on project base before any application of a Geobrugg system.
Geobrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur by using wrong assumptions or input parameters.

2. All information and data included in the programs are based on the principles, equations and safety concepts according to the technical documents, dimensioning concepts, product manuals, installation instructions, etc. of Geobrugg which have to be strictly followed.
Geobrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur due to incorrect application of the programs.

3. It cannot totally be excluded that there are errors in the programs.
Geobrugg cannot be held liable for damages of all kind - namely direct or indirect damages, cost of defects and damages due to defects, losses or costs - which occur due to application of faulty programs.

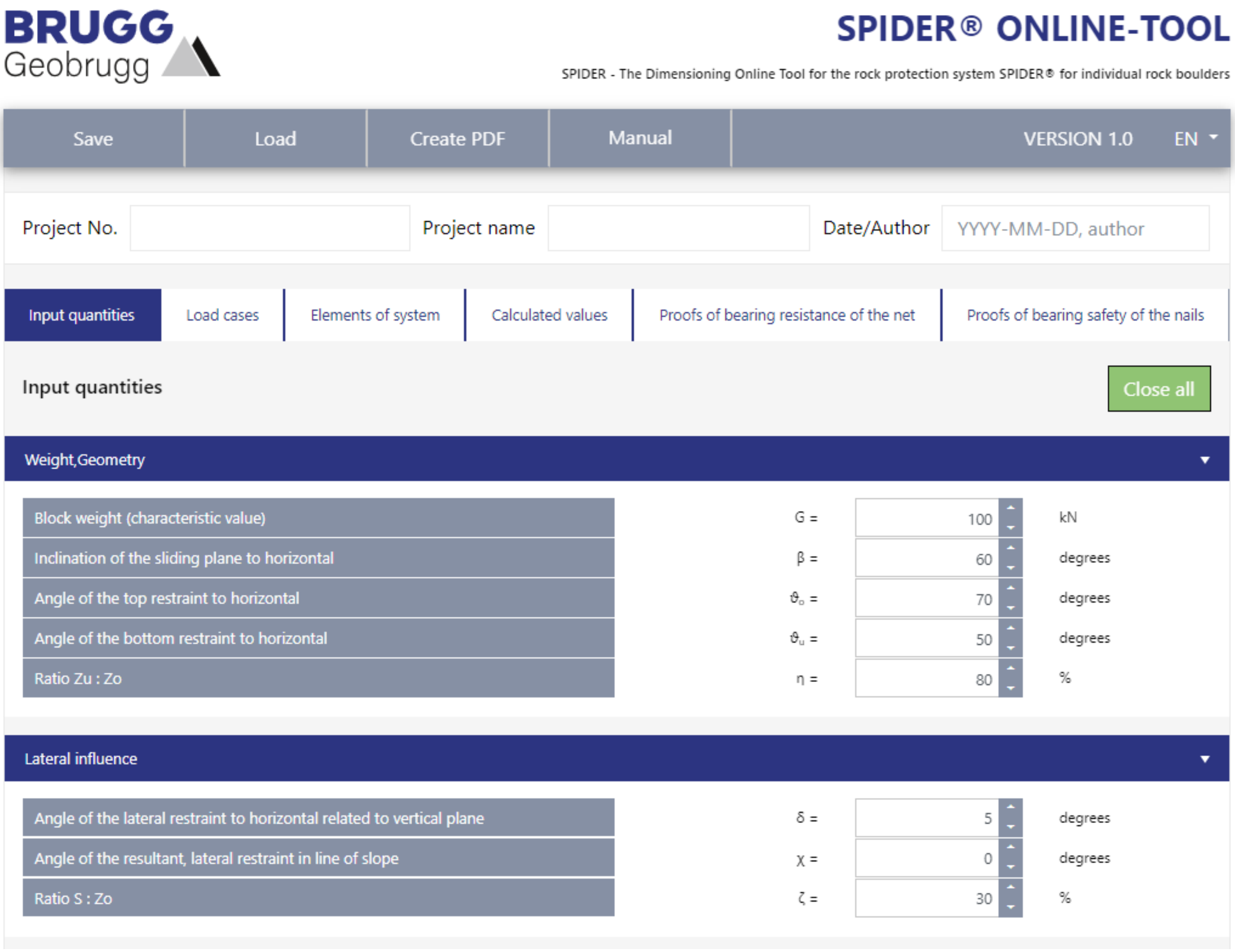
4. Changes in the data of the programs by the user can lead to results which do not comply with the safety regulations given by the law and Geobrugg.
Geobrugg cannot be held liable for damages of all kind which result from changes made by the user. Geobrugg is indemnified and hold harmless by the user from any claims of third parties.

Ok Abbrechen

There is no installation of the software on the user’s computer neither necessary nor possible. The software has to be used online only.
Every calculation can be stored as a json or pdf file with all information included.

5. THE SOFTWARE

The software is structured in six pages format with “Input parameters”, “Load cases”, “Element of system”, “Calculated values”, “Proofs of bearing resistance of the net” and “Proof of bearing safety of the nails”. After accessing the program, the below window will appear:

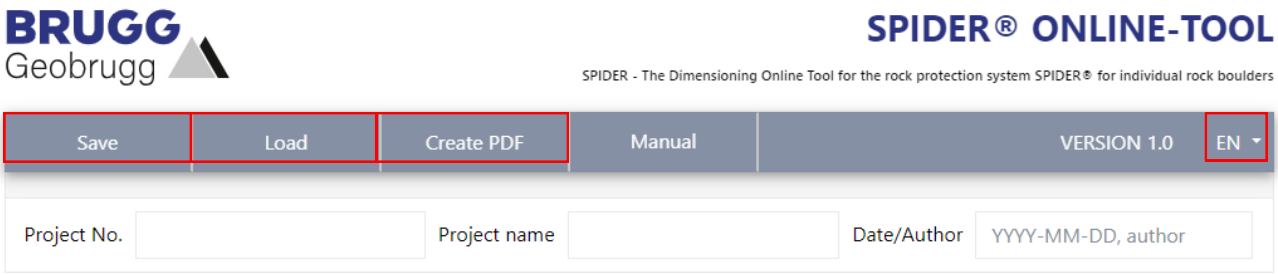


All the white colored boxes in the software indicates that they can be and has to be filled in manually according to the project specific conditions while the values without boxes indicate automatically calculated figures.

The software is structured as follows:

The upper part of the window

In this section four tabs are selectable:



Save: It allows the performed calculation to be saved locally on the computer.

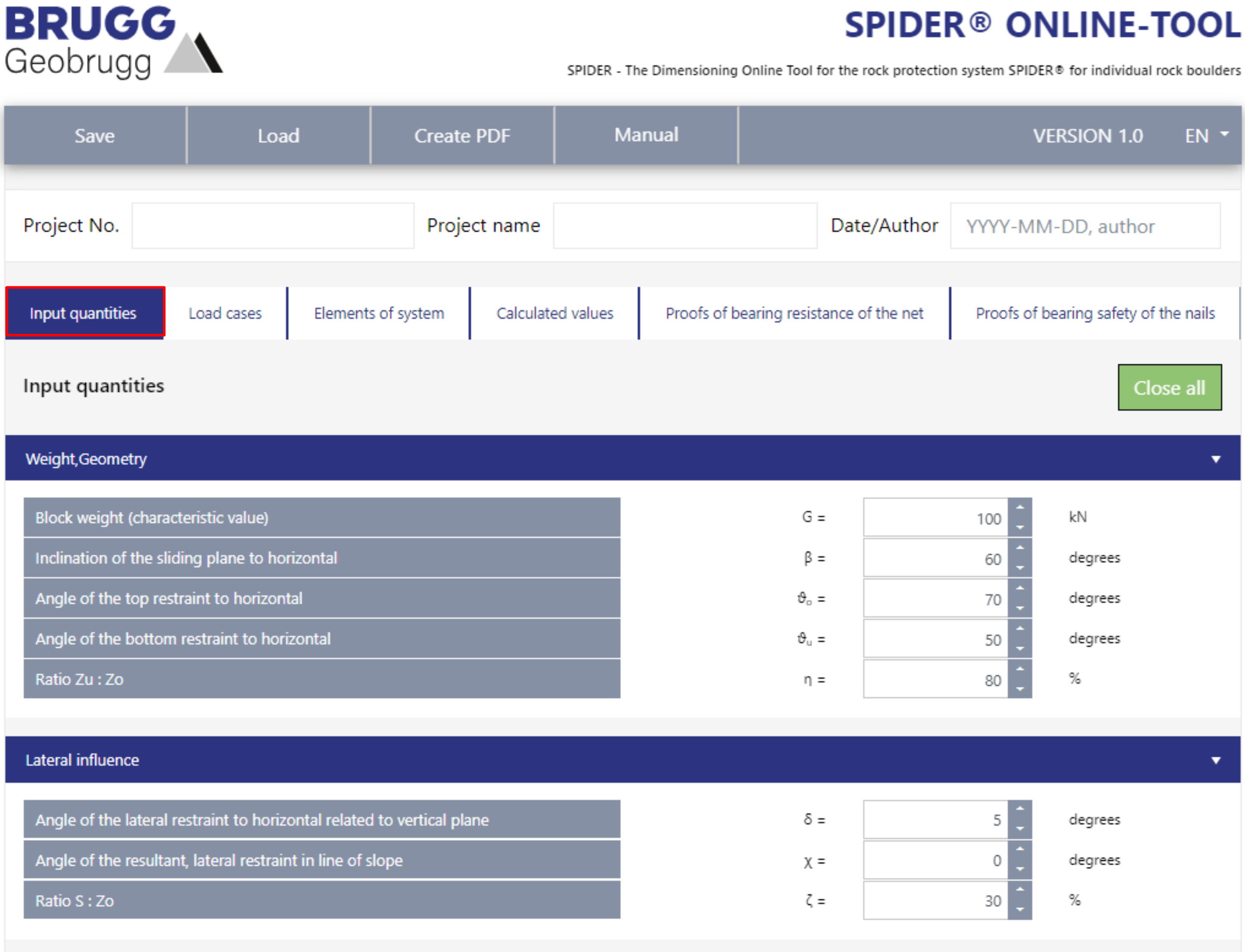
Load: It allows to load a previous saved calculation.

Create PDF: It allows to generate a PDF and print it out.

Language: Choose between English and German

Information about the project and the date can be typed in which will appear then on the print out in the head area.

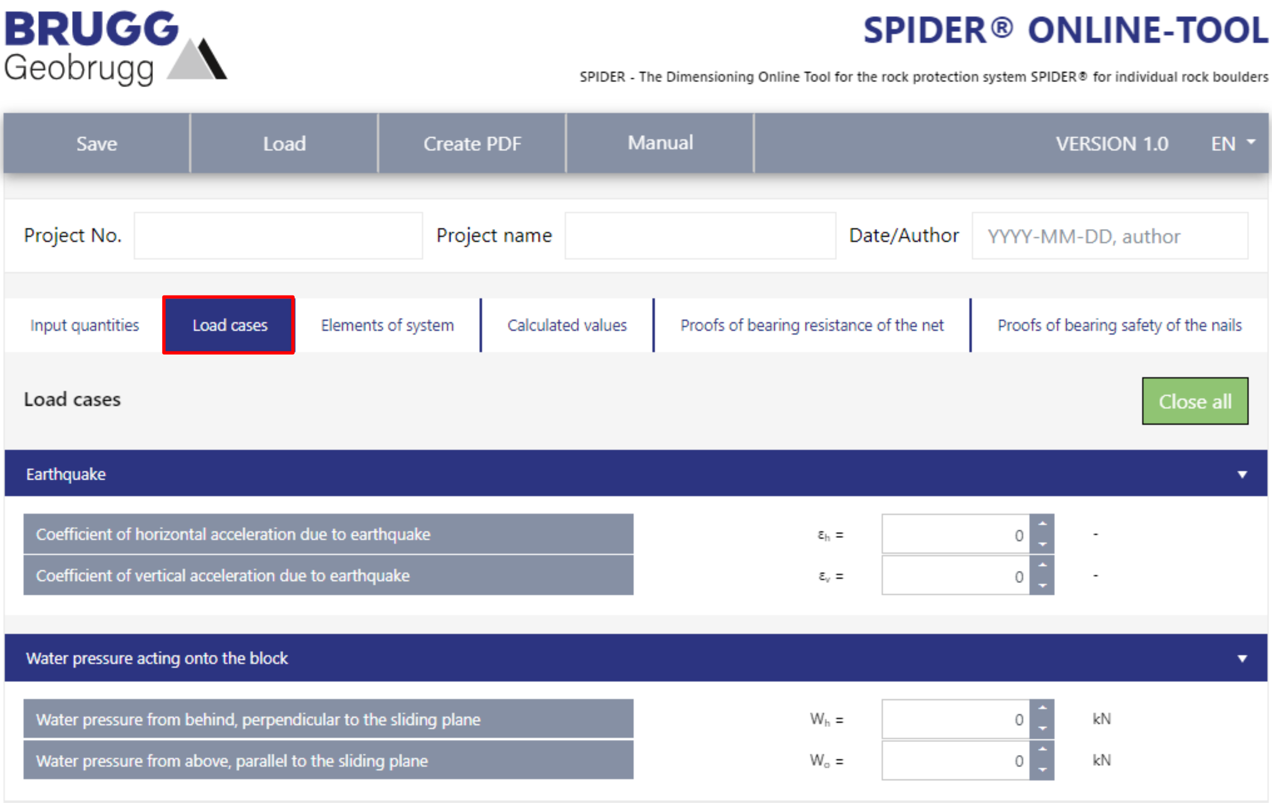
“Input parameters” window:



The main input parameters to be considered in the calculation are directly visual in the starting window and can be adapted there. They can be overwritten in the field or adjusted by clicking with the mouse. When the window is active, the “Input parameters” button has a steel color while when is not active is grey colored.

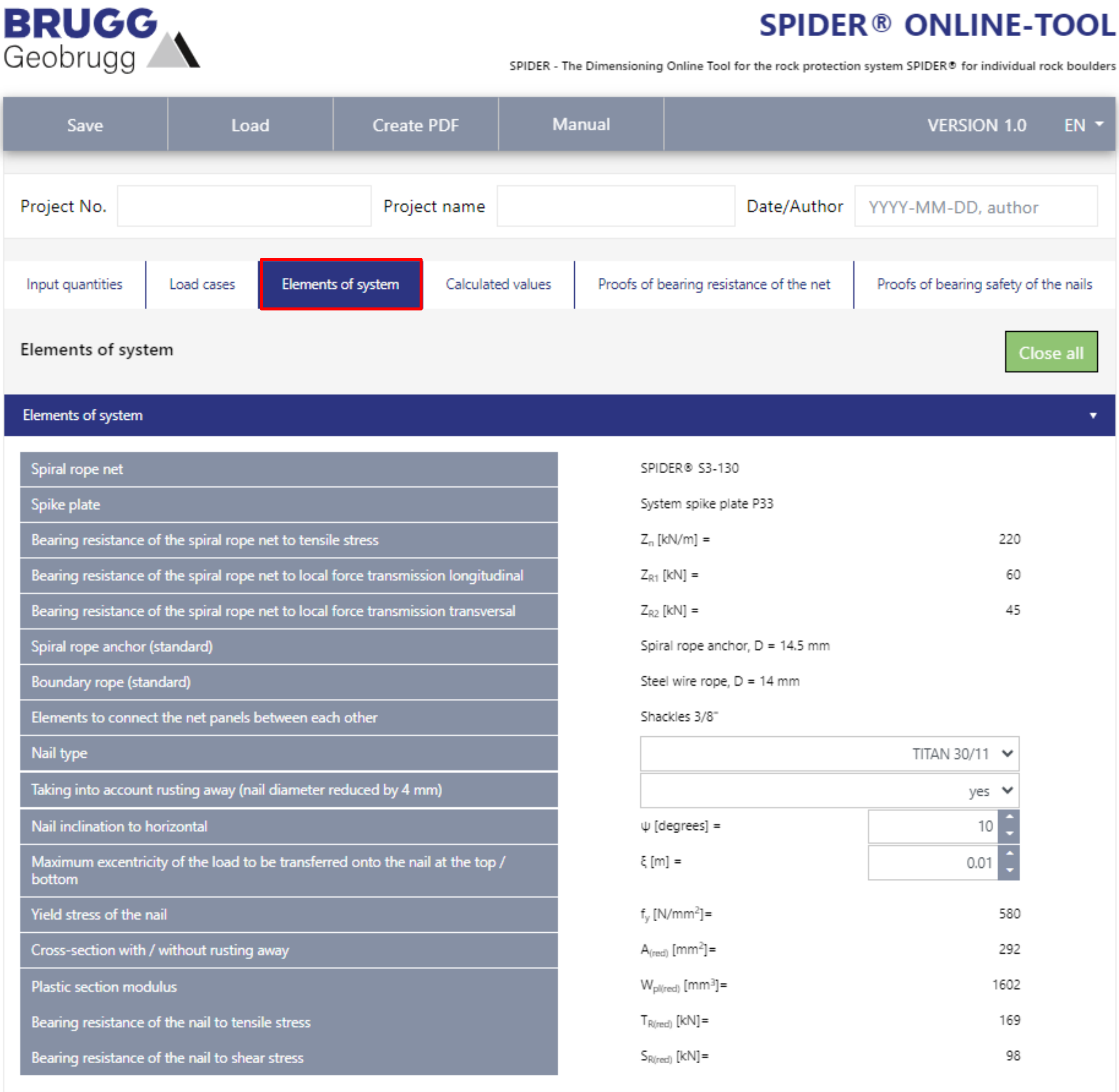
“Load cases” window:

In this window, the load cases earthquake and water pressure can be activated. The window becomes active by clicking the grey colored “Load cases” button which turns into a steel colored afterwards.



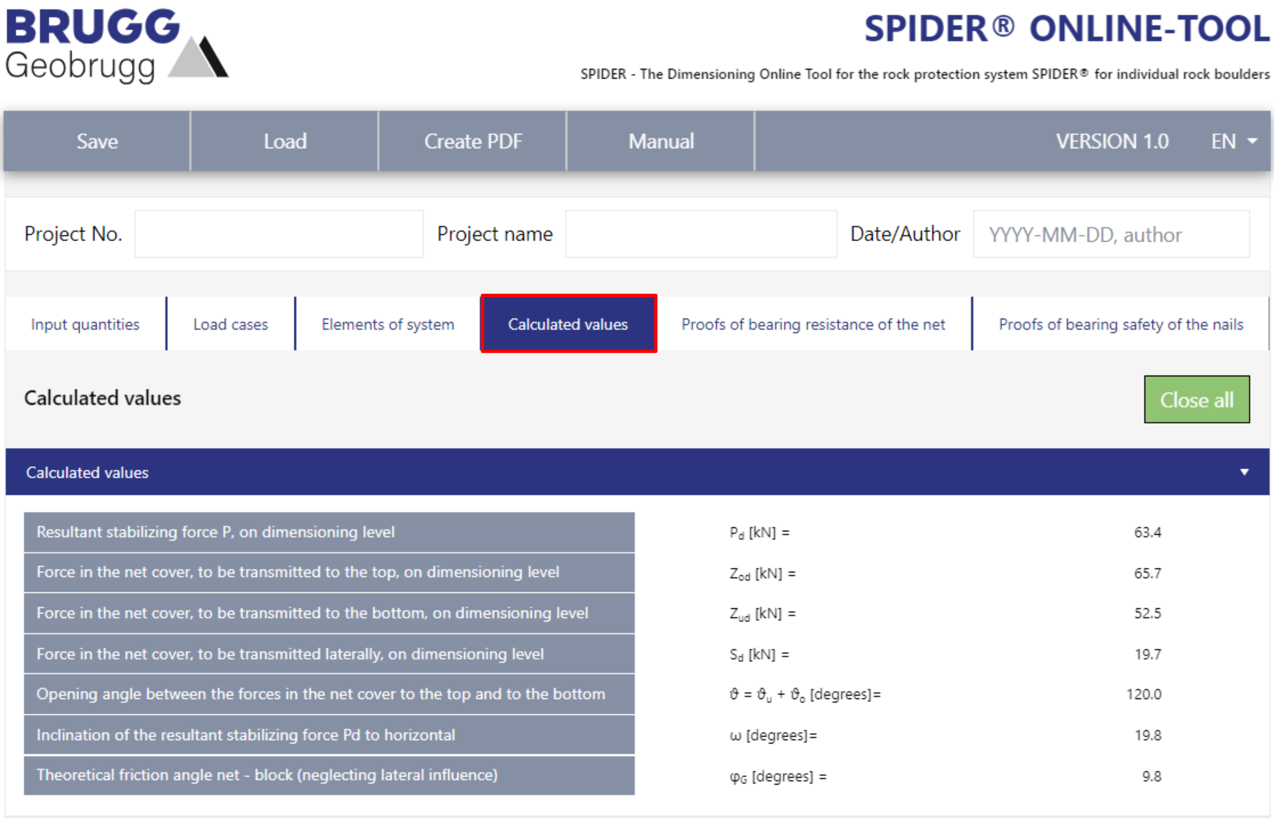
“Element of system” window:

Here the system elements are listed and the nail type and nail inclination can be chosen. The window becomes active by clicking the grey colored “Elements of system” button which turns into a steel colored afterwards.



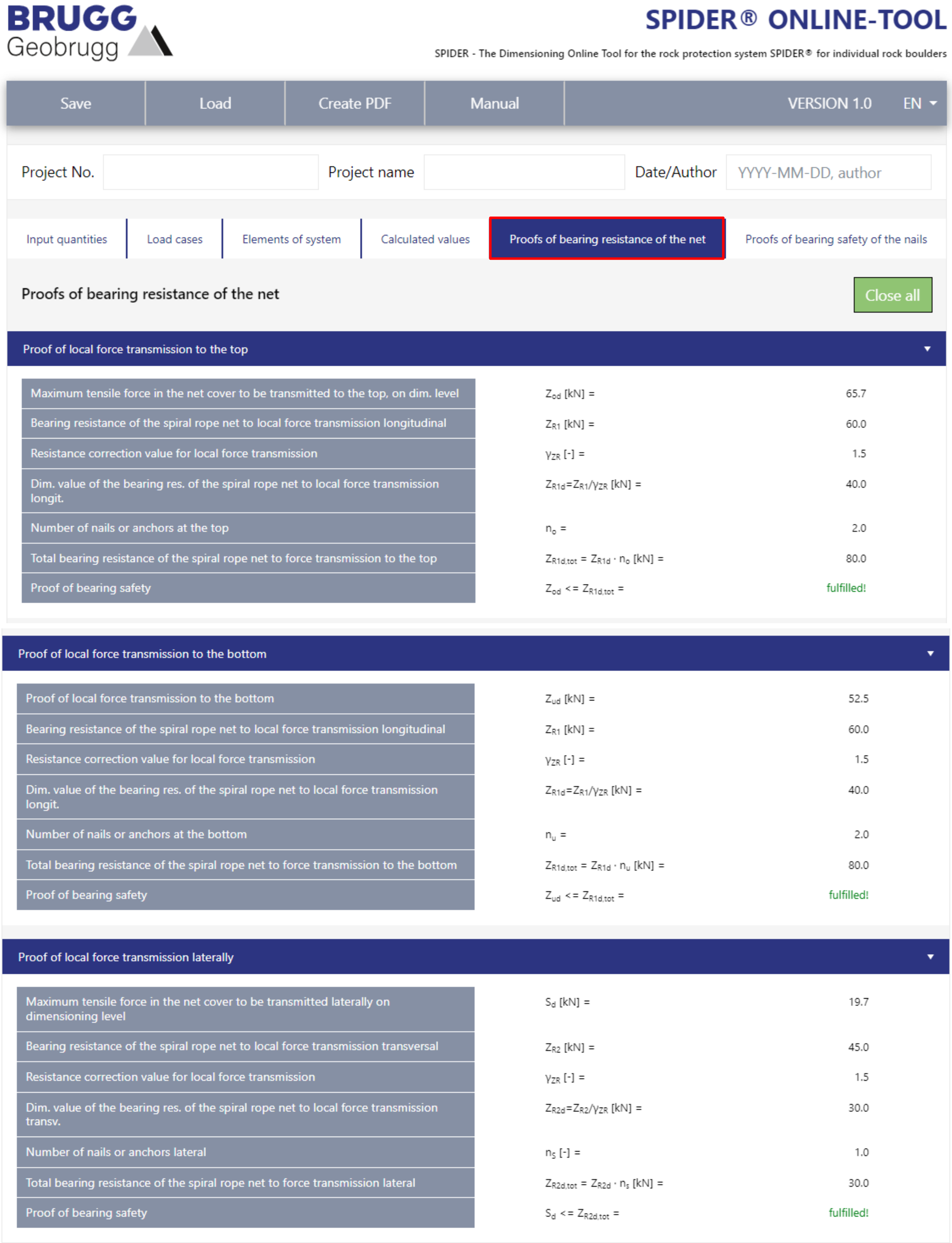
"Calculated values" window:

In this window, all the calculated forces and angles are displayed. The window becomes active by clicking the grey colored "Summary of results" button which turns into a steel colored afterwards.



“Proofs of bearing resistance of the net” window:

Here the proofs are shown for the force transmission from the net to the nail at the top, bottom and sideward. The window becomes active by clicking the grey colored “Proofs of bearing resistance of the net” button which turns into a steel colored afterwards.



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SPIDER® ONLINE-TOOL

SPIDER - The Dimensioning Online Tool for the rock protection system SPIDER® for individual rock boulders

Save | Load | Create PDF | Manual | VERSION 1.0 | EN

Project No. | Project name | Date/Author: YYYY-MM-DD, author

Input quantities | Load cases | Elements of system | Calculated values | Proofs of bearing resistance of the net | Proofs of bearing safety of the nails

Proofs of bearing resistance of the net

Close all

Proof of local force transmission to the top

Maximum tensile force in the net cover to be transmitted to the top, on dim. level	Z_{od} [kN] =	65.7
Bearing resistance of the spiral rope net to local force transmission longitudinal	Z_{R1} [kN] =	60.0
Resistance correction value for local force transmission	γ_{ZR} [-] =	1.5
Dim. value of the bearing res. of the spiral rope net to local force transmission longit.	$Z_{R1d}=Z_{R1}/\gamma_{ZR}$ [kN] =	40.0
Number of nails or anchors at the top	n_o =	2.0
Total bearing resistance of the spiral rope net to force transmission to the top	$Z_{R1d,tot} = Z_{R1d} \cdot n_o$ [kN] =	80.0
Proof of bearing safety	$Z_{od} <= Z_{R1d,tot}$ =	fulfilled!

Proof of local force transmission to the bottom

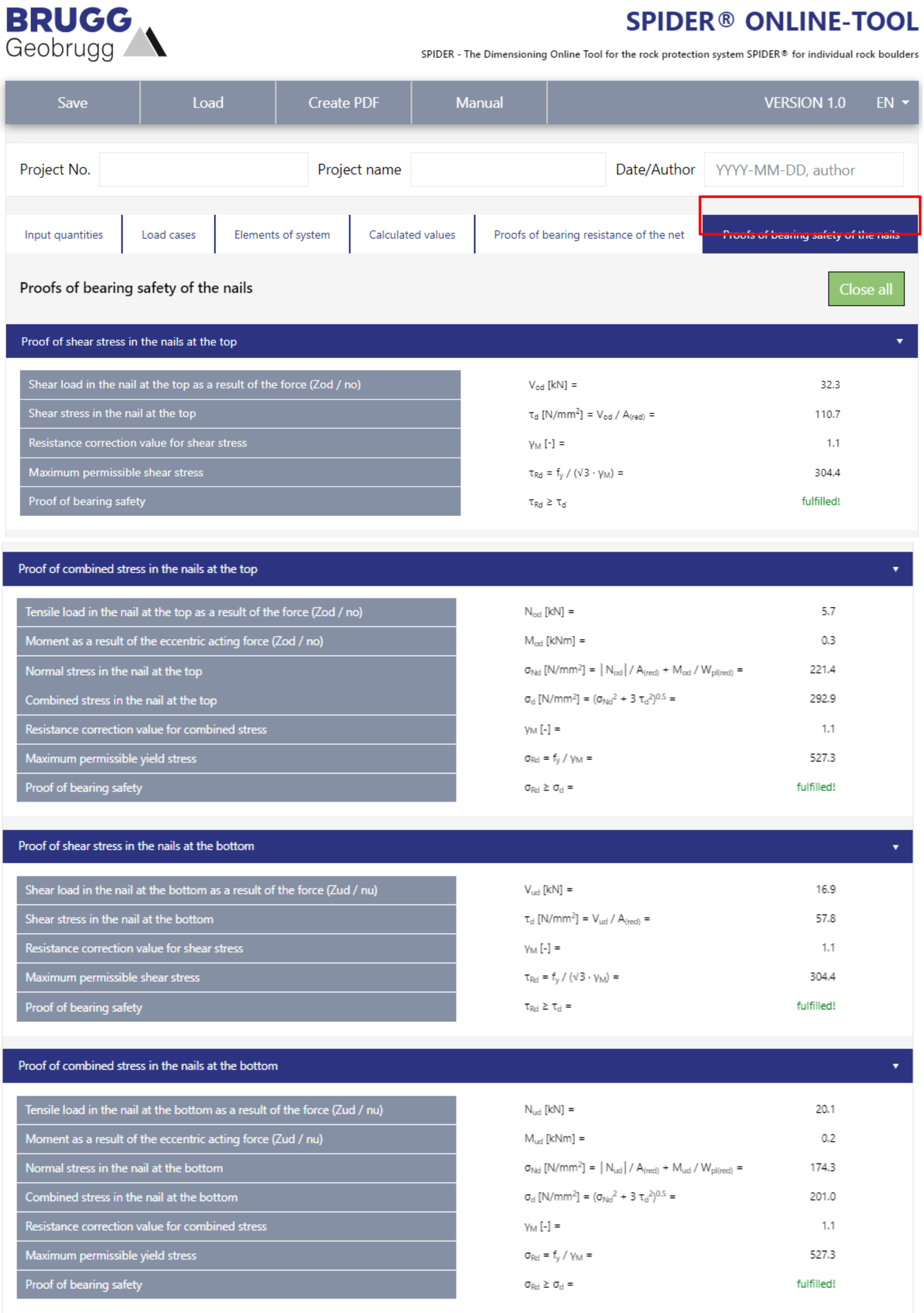
Proof of local force transmission to the bottom	Z_{ud} [kN] =	52.5
Bearing resistance of the spiral rope net to local force transmission longitudinal	Z_{R1} [kN] =	60.0
Resistance correction value for local force transmission	γ_{ZR} [-] =	1.5
Dim. value of the bearing res. of the spiral rope net to local force transmission longit.	$Z_{R1d}=Z_{R1}/\gamma_{ZR}$ [kN] =	40.0
Number of nails or anchors at the bottom	n_u =	2.0
Total bearing resistance of the spiral rope net to force transmission to the bottom	$Z_{R1d,tot} = Z_{R1d} \cdot n_u$ [kN] =	80.0
Proof of bearing safety	$Z_{ud} <= Z_{R1d,tot}$ =	fulfilled!

Proof of local force transmission laterally

Maximum tensile force in the net cover to be transmitted laterally on dimensioning level	S_d [kN] =	19.7
Bearing resistance of the spiral rope net to local force transmission transversal	Z_{R2} [kN] =	45.0
Resistance correction value for local force transmission	γ_{ZR} [-] =	1.5
Dim. value of the bearing res. of the spiral rope net to local force transmission transv.	$Z_{R2d}=Z_{R2}/\gamma_{ZR}$ [kN] =	30.0
Number of nails or anchors lateral	n_s [-] =	1.0
Total bearing resistance of the spiral rope net to force transmission lateral	$Z_{R2d,tot} = Z_{R2d} \cdot n_s$ [kN] =	30.0
Proof of bearing safety	$S_d <= Z_{R2d,tot}$ =	fulfilled!

“Proofs of bearing safety of the nails” window:

Here the proofs are shown for the force transmission from the net to the nail at the top, bottom and sideward. The window becomes active by clicking the grey colored “Proofs of bearing resistance of the net” button which turns into a steel colored afterwards.



Proof of shear stress in the nails at the top

Shear load in the nail at the top as a result of the force (Zod / no)	V_{od} [kN] =	32.3
Shear stress in the nail at the top	τ_d [N/mm²] = $V_{od} / A_{(red)}$ =	110.7
Resistance correction value for shear stress	γ_M [-] =	1.1
Maximum permissible shear stress	$\tau_{Rd} = f_y / (\sqrt{3} \cdot \gamma_M)$ =	304.4
Proof of bearing safety	$\tau_{Rd} \geq \tau_d$	fulfilled!

Proof of combined stress in the nails at the top

Tensile load in the nail at the top as a result of the force (Zod / no)	N_{od} [kN] =	5.7
Moment as a result of the eccentric acting force (Zod / no)	M_{od} [kNm] =	0.3
Normal stress in the nail at the top	σ_{Nd} [N/mm²] = $\lvert N_{od} \rvert / A_{(red)} + M_{od} / W_{pl(red)}$ =	221.4
Combined stress in the nail at the top	σ_d [N/mm²] = $(\sigma_{Nd}^2 + 3\,\tau_d^2)^{0.5}$ =	292.9
Resistance correction value for combined stress	γ_M [-] =	1.1
Maximum permissible yield stress	$\sigma_{Rd} = f_y / \gamma_M$ =	527.3
Proof of bearing safety	$\sigma_{Rd} \geq \sigma_d$ =	fulfilled!

Proof of shear stress in the nails at the bottom

Shear load in the nail at the bottom as a result of the force (Zud / nu)	V_{ud} [kN] =	16.9
Shear stress in the nail at the bottom	τ_d [N/mm²] = $V_{ud} / A_{(red)}$ =	57.8
Resistance correction value for shear stress	γ_M [-] =	1.1
Maximum permissible shear stress	$\tau_{Rd} = f_y / (\sqrt{3} \cdot \gamma_M)$ =	304.4
Proof of bearing safety	$\tau_{Rd} \geq \tau_d$ =	fulfilled!

Proof of combined stress in the nails at the bottom

Tensile load in the nail at the bottom as a result of the force (Zud / nu)	N_{ud} [kN] =	20.1
Moment as a result of the eccentric acting force (Zud / nu)	M_{ud} [kNm] =	0.2
Normal stress in the nail at the bottom	σ_{Nd} [N/mm²] = $\lvert N_{ud} \rvert / A_{(red)} + M_{ud} / W_{pl(red)}$ =	174.3
Combined stress in the nail at the bottom	σ_d [N/mm²] = $(\sigma_{Nd}^2 + 3\,\tau_d^2)^{0.5}$ =	201.0
Resistance correction value for combined stress	γ_M [-] =	1.1
Maximum permissible yield stress	$\sigma_{Rd} = f_y / \gamma_M$ =	527.3
Proof of bearing safety	$\sigma_{Rd} \geq \sigma_d$ =	fulfilled!

5.1 Input Quantities

5.1.1 *Weight, Geometry*

The following table shows the minimum, maximum and the default values with its increments. The given values can be changed by overwriting or using the arrow buttons nearby.

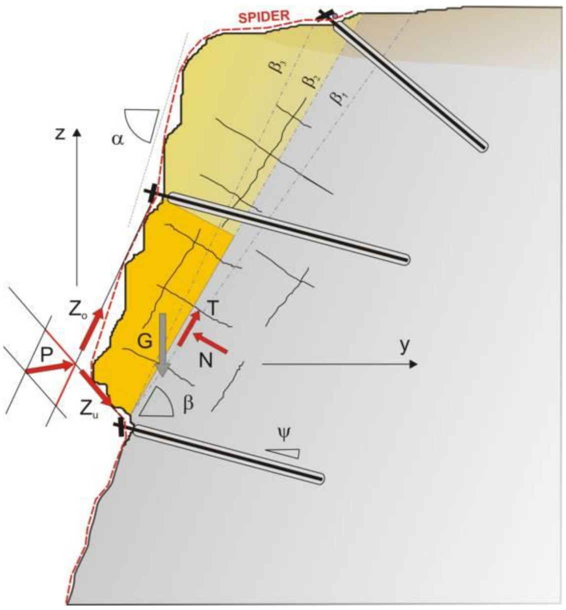
There is following constraint to consider when entering the value for the angle of the bottom restraint to horizontal: $\vartheta_u \leq 180° - \vartheta_o$.

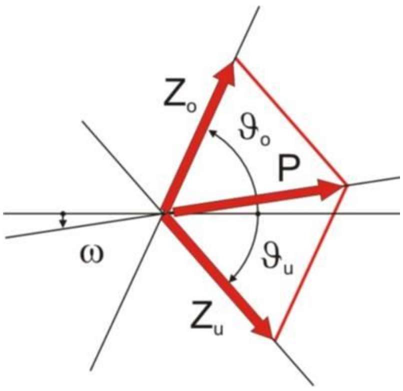
Z_o signifies the force in the net cover transferred to the top as a reaction if an unstable rock boulder slips into the protection measure.

Z_u signifies the force in the net cover transferred to the bottom as a reaction if an unstable rock boulder slips into the protection measure.

Parameters		Default value	Minimum value	Maximum value	Increment
Block weight	G [kN]	100	0	10'000	2
Inclination of the sliding plane to horizontal	β [°]	60	0	90	1
Angle of the top restraint to horizontal	ϑ_o [°]	70	0	180	5
Angle of the bottom restraint to horizontal	ϑ_u [°]	50	0	180	5
Ratio $Z_u : Z_o$	η [%]	80	0	100	5

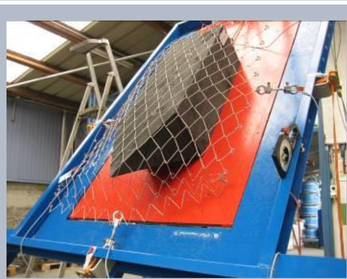
ϑ = theta, η = eta

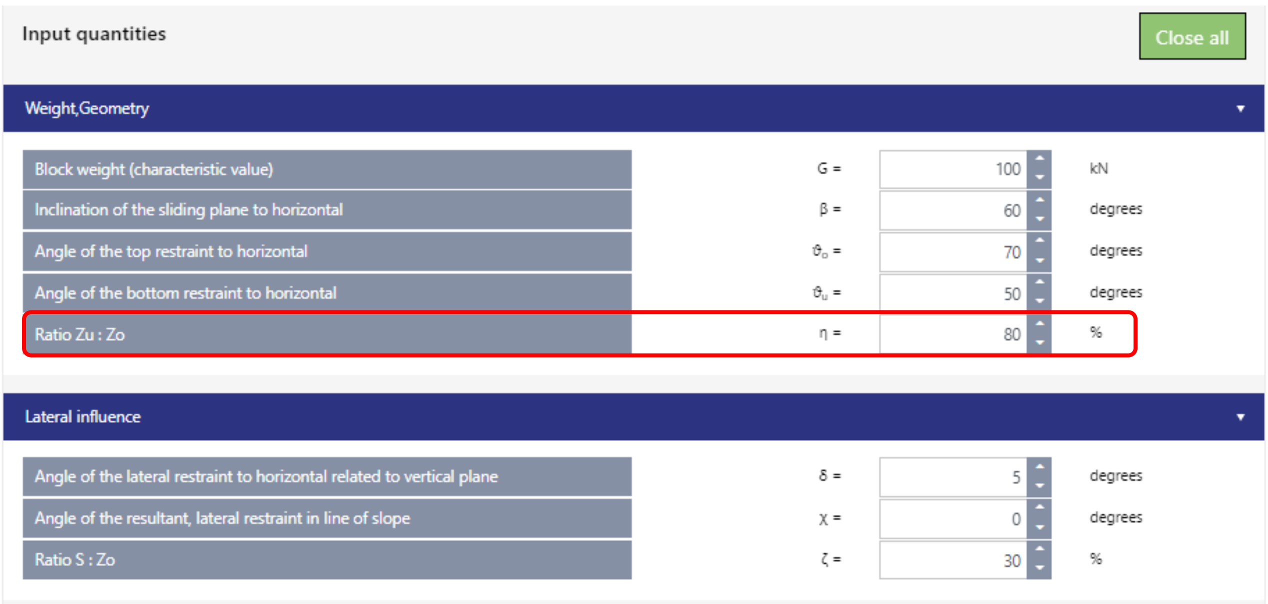




The block weight G, the inclination of the sliding plane to horizontal β, the angle of the top and bottom restraint to horizontal ϑ_o and ϑ_u must be chosen in accordance with the real geometrical conditions.

The ratio $\eta = Z_u / Z_o$ results from model tests and can be chosen as follows:

Case	Requirements, area of application	η [%]	Example from model tests
A	If the contact zone between block and net is not restricted to a linear zone only. This might be the case in rock prone to weather (sedimentary rock, conglomerates, schist, shale) or in strongly fractured rock slopes.	100	
B	If the contact zone between block and net is restricted to a linear zone. This is the standard case. Applications in limestone or dolomite are thereby typical. Often blocky material must be protected from sliding down.	80	
C	If the contact zone between block and net is limited to individual meshes only. This might be relevant if the block is pointed or very slim. The rock must be very resistant against weathering (granite, gneiss). The joints must be closed enough and unfavorable orientated to each other to create such slim mechanism with sharp edges.	50	

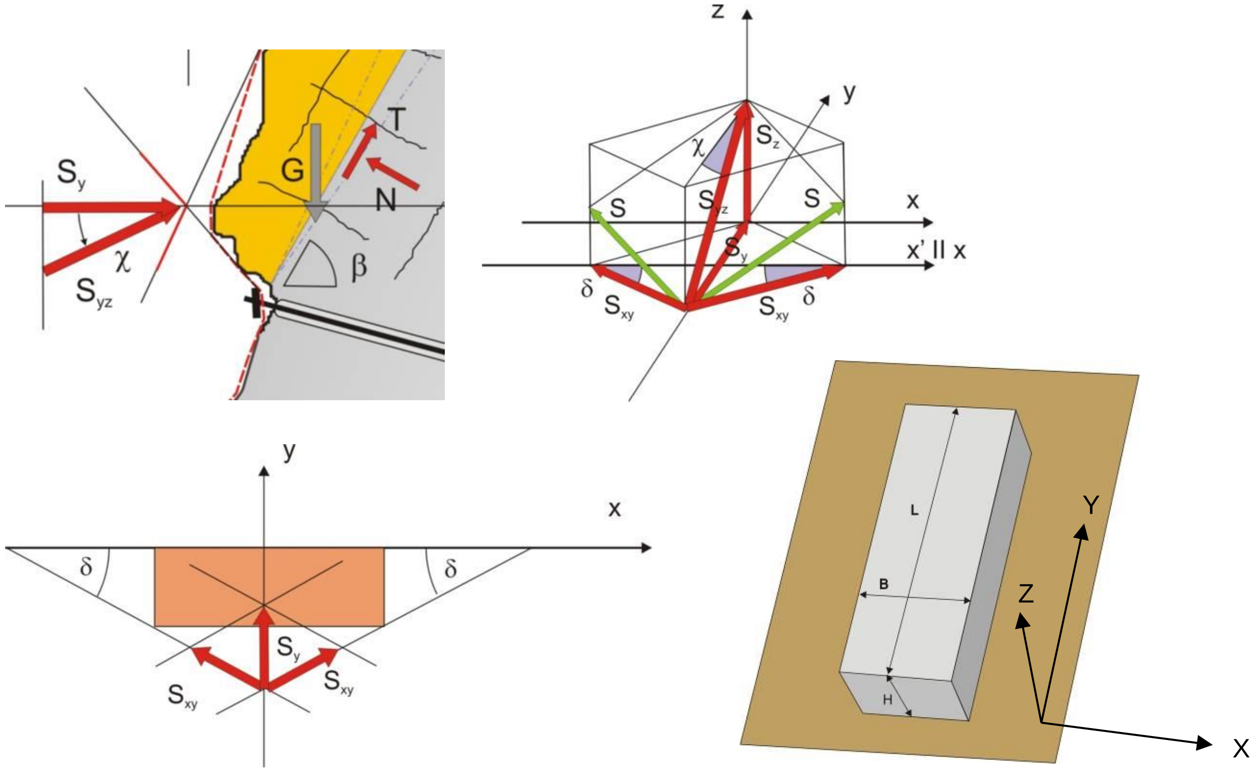


5.1.2 Lateral influence

Depending on the geometrical conditions, lateral stabilizing influences can be considered by angles δ, χ and the ratio ζ. S stands for the resultant force transferred laterally to anchors, nails and boundary ropes on both sides of the block. In general, the angle of the resultant lateral restraint in line of slope is set to χ = 0°.

Parameters		Default value	Minimum value	Maximum value	Increment
Angle of the lateral restraint to horizontal related to the vertical plane	δ [°]	5	0	90	5
Angle of the resultant, lateral restraint in line of slope	χ [°]	0	0	90	5
Ratio S : Z_o	ζ [-]	30	0	50	5

χ = chi, ζ = zeta

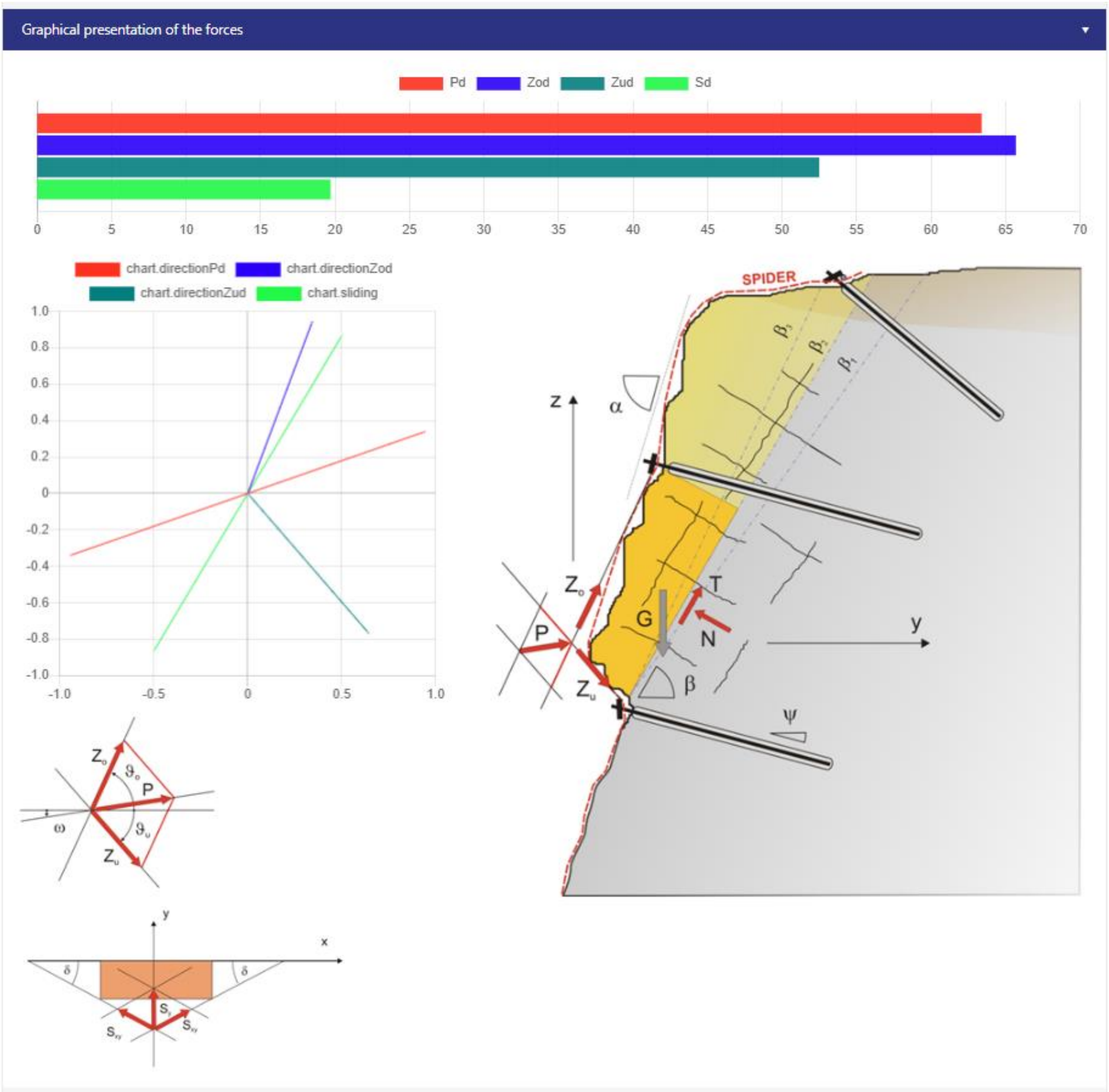


ζ (χ = 0)	L/B ≤ 1.0	1.0 < L/B ≤ 1.7	1.7 < L/B ≤ 3.4	3.4 < L/B
0° ≤ δ < 10°	0%	10%	20%	30%
10° ≤ δ < 20°	5%	20%	30%	40%
20° ≤ δ < 30°	10%	25%	35%	45%
30° ≤ δ < 45°	15%	30%	40%	50%
45° ≤ δ	20%	35%	45%	50%

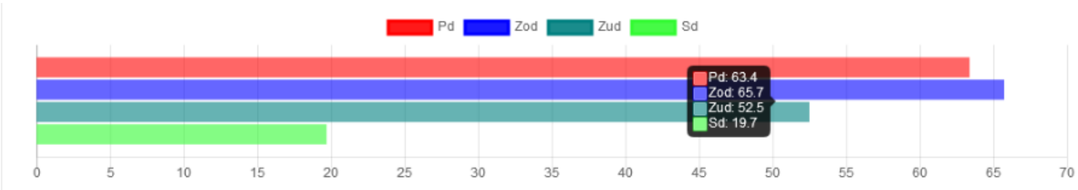
Ratio ζ = S / Z_o in function of δ and the relation L/B for χ = 0°

The following figure visualizes the occurring forces according to amount and shows the relation to each other. Thereby, the red beam stands for P_d, the blue for the force Z_{od} in the net cover transferred to the top, the blue-green for Z_{ud} and the green beam stands for the forces S_d transferred laterally on dimensioning level.

Next to that, the directions of the restraints to the top and to the bottom are visualized by the blue and the blue-green line. The inclinations of these two lines correspond to the angles of the top and bottom restraints to horizontal ϑ_o and ϑ_u. The red line is the direction of action the resultant P_d considered lateral stabilizing influences. Finally, the green line clarifies the orientation of the sliding surface.



If the mouse is moved on one of the beams, the corresponding value is shown at the beam's end.

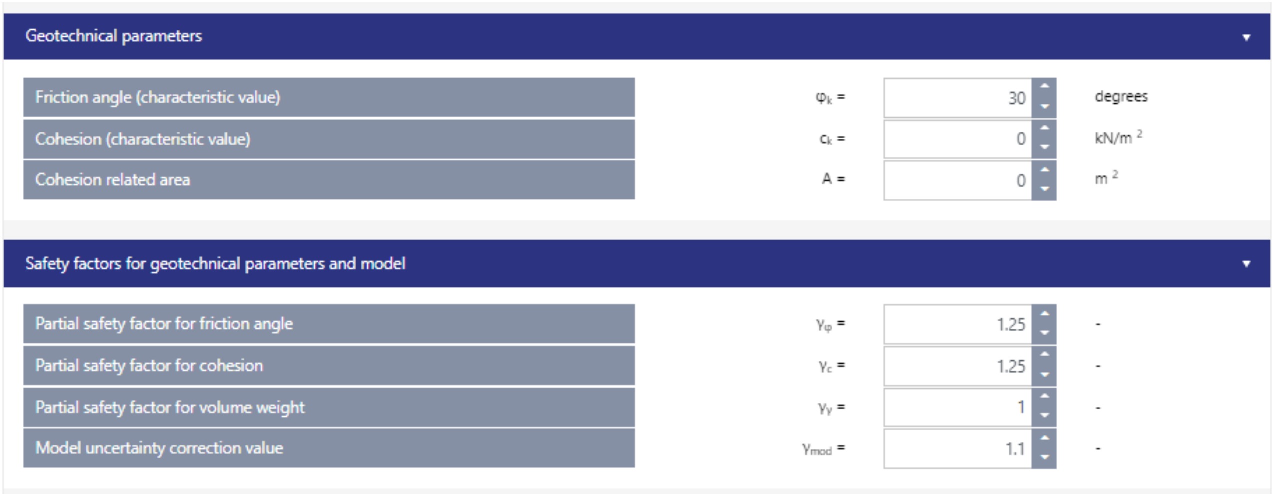


5.1.3 Geotechnical parameters and safety factors

As a base for the calculation, the characteristic value of the friction angle and the cohesion acting along the sliding surface must be defined. To describe any interlocking effects, a technical cohesion or an angle of total shear strength can be introduced depending on the local situation.

If a cohesion $c_k \neq 0$ kN/m² is introduced, the cohesion related area A must be introduced as well.

Parameters		Default value	Minimum value	Maximum value	Increment
Friction angle (characteristic value)	φ_k [°]	30.0	5.0	60.0	0.5
Cohesion (characteristic value)	c_k [kN/m²]	0.0	0.0	200.0	1.0
Cohesion related area	A [m²]	0.0	0.0	1000.0	0.5
Partial safety factor for friction angle	γ_φ [-]	1.25	1.00	2.00	0.05
Partial safety factor for cohesion	γ_c [-]	1.25	1.00	2.00	0.05
Partial safety factor for volume weight	γ_γ [-]	1.00	1.00	2.00	0.05
Model uncertainty correction value	γ_{mod} [-]	1.10	1.00	2.00	0.05



The calculations can be done based on the partial safety concept or on the global safety concept, respectively. The following table presents standard values.

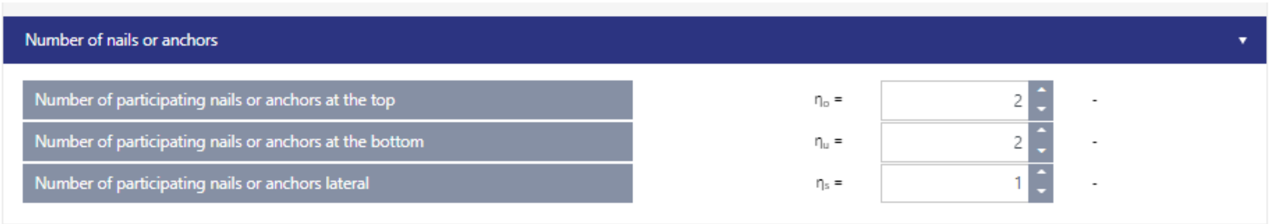
Safety factors		Geobrugg (partial)	Geobrugg (global)	SIA 267 (partial)	EC 7 (partial)
Partial safety factor for friction angle	γ_φ [-]	1.25	1.00	1.20	1.25
Partial safety factor for cohesion	γ_c [-]	1.25	1.00	1.50	1.25
Partial safety factor for volume weight	γ_γ [-]	1.00	1.00	1.00	1.00
Model uncertainty correction value	γ_{mod} [-]	1.10	1.40		

The dimensioning values of the geotechnical parameters are determined as follow:

$$\varphi_d = \arctan(\tan \varphi_k / \gamma_\varphi)$$
$$c_d = c_k / \gamma_c$$
$$\gamma_d = \gamma_k \cdot \gamma_\gamma$$

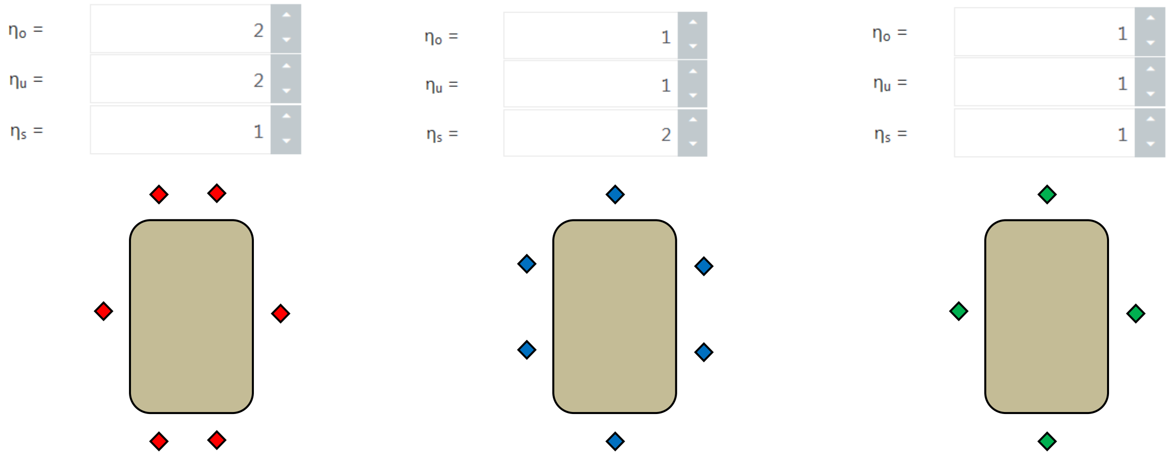
5.1.4 Number of nails

After entering all input parameters, the rock protection can be dimensioned and optimized by choosing the number of participating nails or anchors at the top, at the bottom and laterally on both sides each.

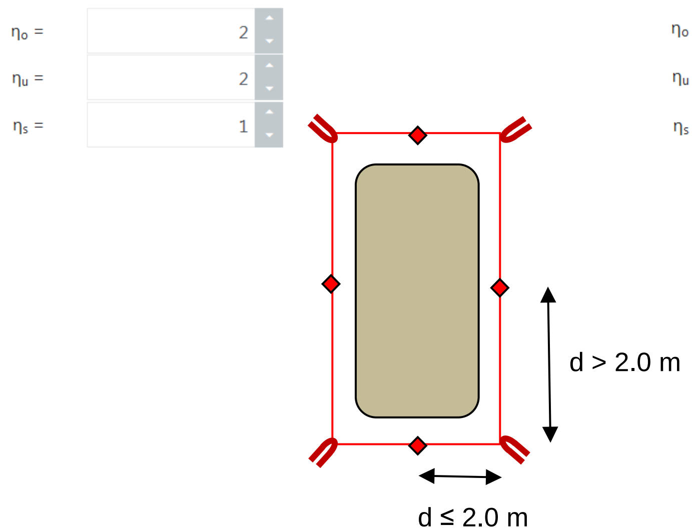


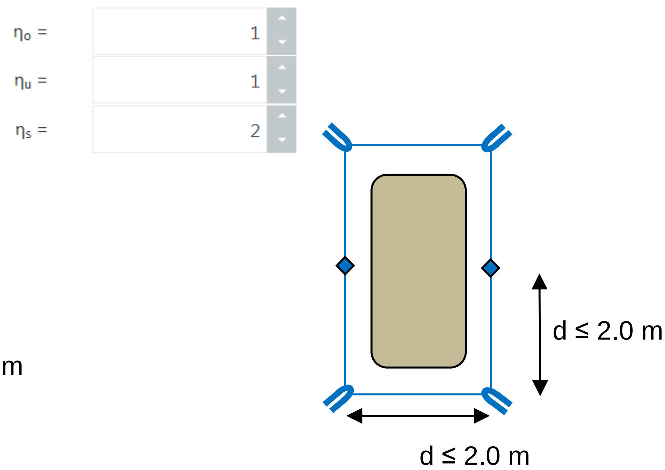
Parameters		Default Value	Minimum Value	Maximum Value	Increment
Number of participating nails or anchors at the top	n_o [-]	2	0	20	1
Number of participating nails or anchors at the bottom	n_u [-]	2	0	20	1
Number of participating nails or anchors lateral	n_s [-]	1	0	20	1

The following figures show possible arrangements of nails or anchors around an individual boulder to be protected.



If the distance “d” between nails or anchors at the top, at the bottom or laterally does not exceed 2.0 m, then, one nail can be calculatory compensated by a boundary wire rope of a minimum diameter of 14 mm which is laterally tensioned against spiral rope anchors. The following figures show two cases.





General rules:

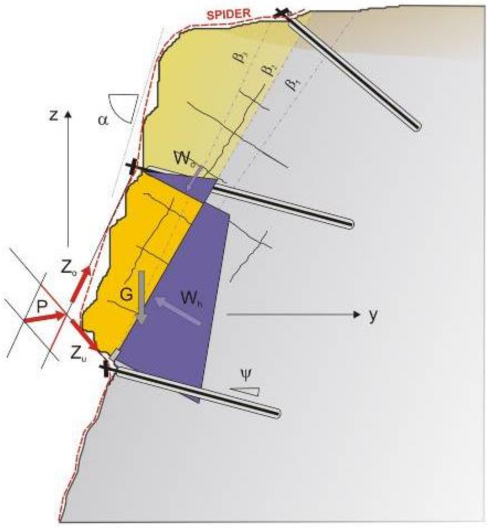
1. Along the edge of the SPIDER® spiral rope net, a boundary rope must be installed in any case.
2. If an individual boulder must be protected, a boundary rope must be installed all around.

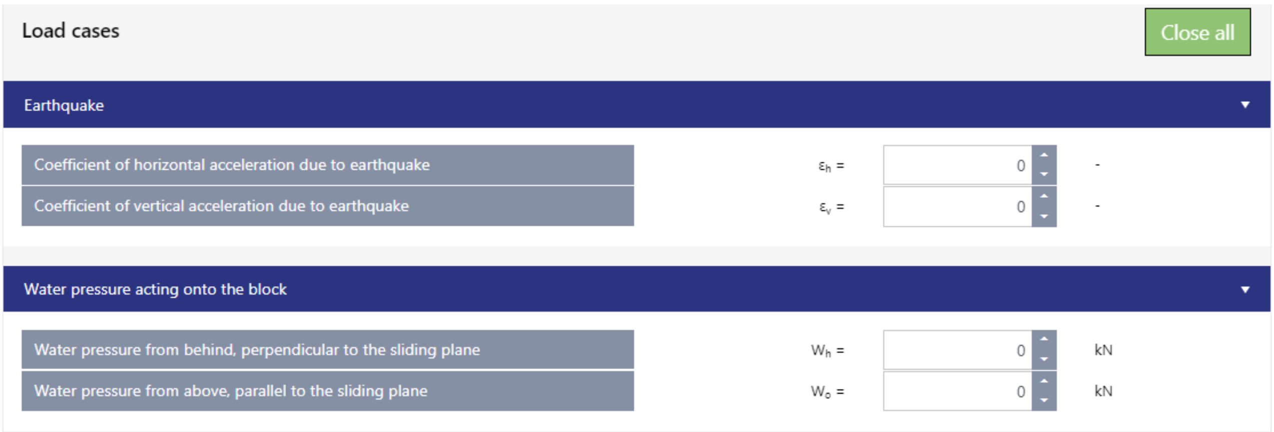
5.1.5 Load cases

The software offers the consideration of the load cases “Earthquake” and “Water pressure”.

In the load case “Earthquake”, the coefficient of horizontal as well vertical acceleration due to earthquake ε_h and ε_v can be introduced. Often, the vertical acceleration ε_v is considered as 50% of ε_h.

In the load case “Water pressure”, one resultant force acts from behind, perpendicular to the sliding plane. Another resultant act downwards parallel to the sliding plane. Instead of water pressure, ice pressure and any further loadings can be simulated by W_h and W_o instead.





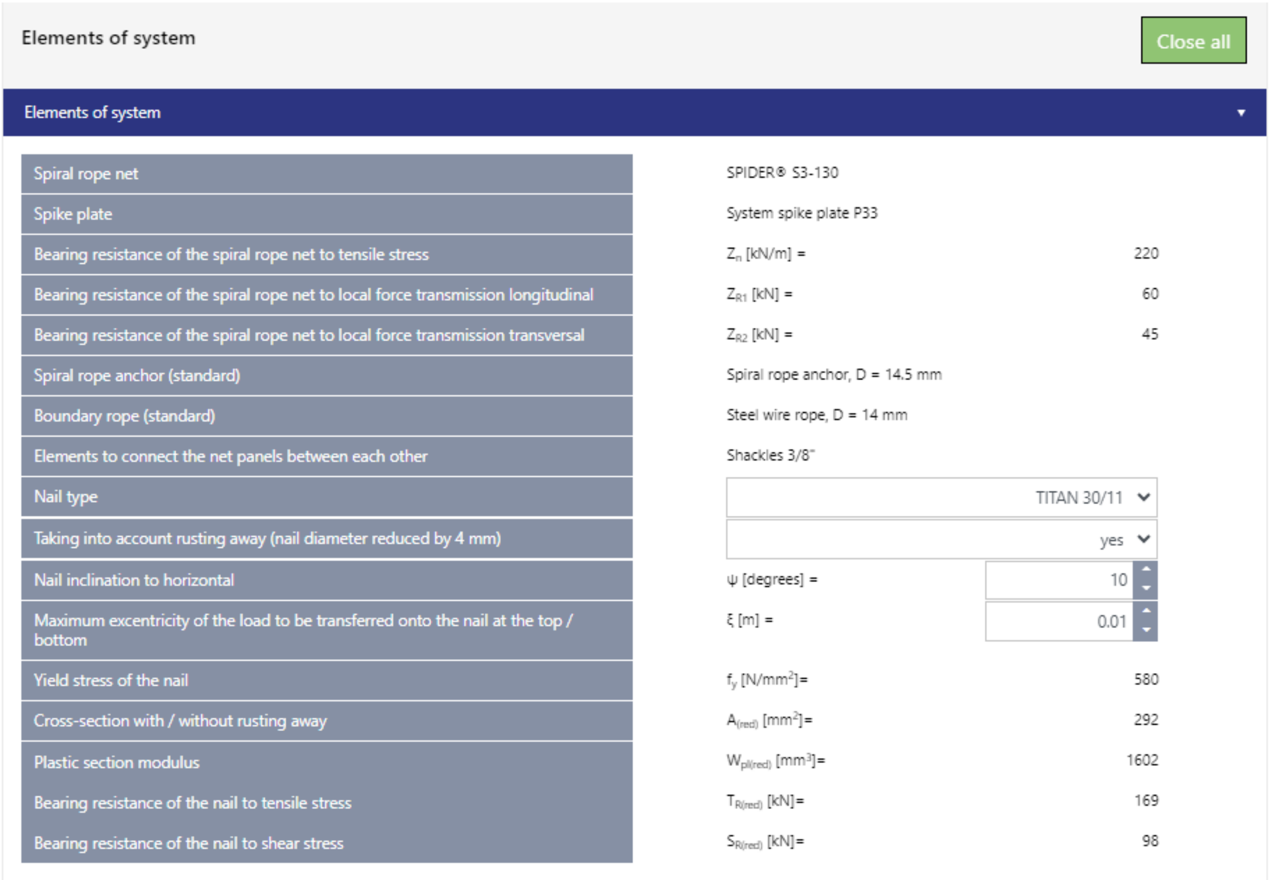
Parameters		Default value	Min. value	Max. value	Increment
Coefficient of horizontal acceleration due to earthquake	ε_h [-]	0.000	0.000	1.000	0.005
Coefficient of vertical acceleration due to earthquake	ε_v [-]	0.000	0.000	1.000	0.005
Water pressure from behind, perpendicular to the sliding plane	W_h [kN]	0	0	1000	1
Water pressure from above, parallel to the sliding plane	W_o [kN]	0	0	1000	1

5.1.6 *Elements of the system*

The following elements of the system are given and cannot be changed in the software:

- Spiral rope net SPIDER® S3-130
- System spike plate P33
- Spiral rope anchor D = 14 mm
- Boundary rope D = 14 mm
- Shackles 3/8" for connecting net panels between each other

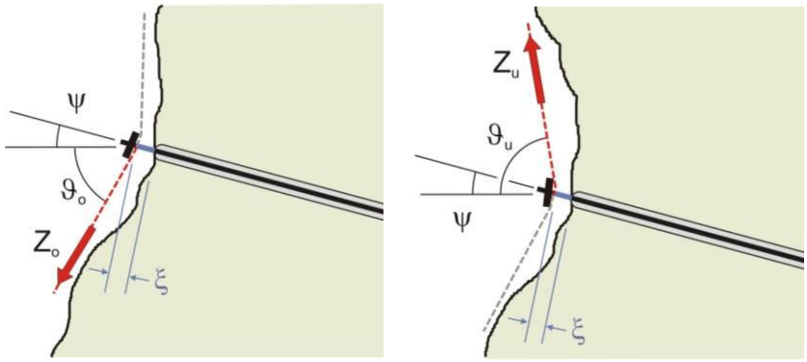
The nail type, its orientation to horizontal as well as the eccentricity of the load to be transferred from the net onto the nail can be individually chosen. In regard of the nail's long-term behavior, the nail's cross-section can be reduced by 4 mm because of rusting away.



The following table shows the provided nail types and their resistance.

Nail type	D_E [mm]	D_I [mm]	Δ [mm]	f_y [N/mm²]	A [mm²]	A_{red} [mm²]	T_R [kN]	T_{Rred} [kN]	τ_y [N/mm²]	S_R [kN]	S_{Rred} [kN]
GEWI D = 25 mm	25.0		4.0	500	491	346	246	173	289	142	100
GEWI D = 28 mm	28.0		4.0	500	616	452	308	226	289	178	130
GEWI D = 32 mm	32.0		4.0	500	804	616	402	308	289	232	178
DYWIDAG 25 mm, Grad 75	25.0		4.0	517	491	346	254	179	298	147	103
DYWIDAG 28 mm, Grad 75	28.0		4.0	517	616	452	318	234	298	184	135
DYWIDAG 32 mm, Grad 75	32.0		4.0	517	804	616	416	318	298	240	184
TITAN 30/11	26.2	11.0	4.0	580	444	292	258	169	335	149	98
TITAN 40/20	36.4	20.0	4.0	590	726	510	428	301	341	247	174
TITAN 40/16	37.1	16.0	4.0	590	880	659	519	389	341	300	224
IBO R32N	29.1	18.5	4.0	560	396	226	222	127	323	128	73
IBO R32S	29.1	15.0	4.0	570	488	318	278	181	329	161	105

If the net cannot be installed in such a way a full contact of the net with the rock surface can be guaranteed, an eccentricity ξ must be considered causing a combined stress in the nail head area.



5.1.7 Calculated values

The following figure shows the relevant calculated values. The opening angle ϑ between the forces in the net cover to the top and to the bottom, the in inclination ω of the resultant stabilizing force P_d to horizontal and the theoretical friction angle between the net cover and the block are for additional information.

Calculated values | Close all

Calculated values

Resultant stabilizing force P, on dimensioning level	P_d [kN] =	63.4
Force in the net cover, to be transmitted to the top, on dimensioning level	Z_{od} [kN] =	65.7
Force in the net cover, to be transmitted to the bottom, on dimensioning level	Z_{ud} [kN] =	52.5
Force in the net cover, to be transmitted laterally, on dimensioning level	S_d [kN] =	19.7
Opening angle between the forces in the net cover to the top and to the bottom	$\vartheta = \vartheta_u + \vartheta_o$ [degrees]=	120.0
Inclination of the resultant stabilizing force Pd to horizontal	ω [degrees]=	19.8
Theoretical friction angle net - block (neglecting lateral influence)	φ_G [degrees] =	9.8

5.1.8 Proofs of bearing safety

In the following, the individual proofs of bearing safety of the net to local force transmission to the top, to the bottom and laterally are presented in a detailed way.

Proofs of bearing resistance of the net

Close all

Proof of local force transmission to the top

Maximum tensile force in the net cover to be transmitted to the top, on dim. level	Z_{od} [kN] =	65.7
Bearing resistance of the spiral rope net to local force transmission longitudinal	Z_{R1} [kN] =	60.0
Resistance correction value for local force transmission	γ_{ZR} [-] =	1.5
Dim. value of the bearing res. of the spiral rope net to local force transmission longit.	$Z_{R1d}=Z_{R1}/\gamma_{ZR}$ [kN] =	40.0
Number of nails or anchors at the top	n_o =	2.0
Total bearing resistance of the spiral rope net to force transmission to the top	$Z_{R1d,tot} = Z_{R1d} \cdot n_o$ [kN] =	80.0
Proof of bearing safety	$Z_{od} <= Z_{R1d,tot}$ =	fulfilled!

Proof of local force transmission to the bottom

Proof of local force transmission to the bottom	Z_{ud} [kN] =	52.5
Bearing resistance of the spiral rope net to local force transmission longitudinal	Z_{R1} [kN] =	60.0
Resistance correction value for local force transmission	γ_{ZR} [-] =	1.5
Dim. value of the bearing res. of the spiral rope net to local force transmission longit.	$Z_{R1d}=Z_{R1}/\gamma_{ZR}$ [kN] =	40.0
Number of nails or anchors at the bottom	n_u =	2.0
Total bearing resistance of the spiral rope net to force transmission to the bottom	$Z_{R1d,tot} = Z_{R1d} \cdot n_u$ [kN] =	80.0
Proof of bearing safety	$Z_{ud} <= Z_{R1d,tot}$ =	fulfilled!

Proof of local force transmission laterally

Maximum tensile force in the net cover to be transmitted laterally on dimensioning level	S_d [kN] =	19.7
Bearing resistance of the spiral rope net to local force transmission transversal	Z_{R2} [kN] =	45.0
Resistance correction value for local force transmission	γ_{ZR} [-] =	1.5
Dim. value of the bearing res. of the spiral rope net to local force transmission transv.	$Z_{R2d}=Z_{R2}/\gamma_{ZR}$ [kN] =	30.0
Number of nails or anchors lateral	n_S [-] =	1.0
Total bearing resistance of the spiral rope net to force transmission lateral	$Z_{R2d,tot} = Z_{R2d} \cdot n_s$ [kN] =	30.0
Proof of bearing safety	$S_d <= Z_{R2d,tot}$ =	fulfilled!

Regarding the proofs of bearing safety of the nails to shear and combined stress, there are four proofs of bearing safety to fulfil.

Proofs of bearing safety of the nails

Close all

Proof of shear stress in the nails at the top

Shear load in the nail at the top as a result of the force (Zod / no)	V_{od} [kN] =	32.3
Shear stress in the nail at the top	τ_d [N/mm²] = $V_{od} / A_{(red)}$ =	110.7
Resistance correction value for shear stress	γ_M [-] =	1.1
Maximum permissible shear stress	$\tau_{Rd} = f_y / (\sqrt{3} \cdot \gamma_M)$ =	304.4
Proof of bearing safety	$\tau_{Rd} \geq \tau_d$	fulfilled!

Proof of combined stress in the nails at the top

Tensile load in the nail at the top as a result of the force (Zod / no)	N_{od} [kN] =	5.7
Moment as a result of the eccentric acting force (Zod / no)	M_{od} [kNm] =	0.3
Normal stress in the nail at the top	σ_{Nd} [N/mm²] = $\lvert N_{od} \rvert / A_{(red)} + M_{od} / W_{pl(red)}$ =	221.4
Combined stress in the nail at the top	σ_d [N/mm²] = $(\sigma_{Nd}^2 + 3\,\tau_d^2)^{0.5}$ =	292.9
Resistance correction value for combined stress	γ_M [-] =	1.1
Maximum permissible yield stress	$\sigma_{Rd} = f_y / \gamma_M$ =	527.3
Proof of bearing safety	$\sigma_{Rd} \geq \sigma_d$ =	fulfilled!

Proof of shear stress in the nails at the bottom

Shear load in the nail at the bottom as a result of the force (Zud / nu)	V_{ud} [kN] =	16.9
Shear stress in the nail at the bottom	τ_d [N/mm²] = $V_{ud} / A_{(red)}$ =	57.8
Resistance correction value for shear stress	γ_M [-] =	1.1
Maximum permissible shear stress	$\tau_{Rd} = f_y / (\sqrt{3} \cdot \gamma_M)$ =	304.4
Proof of bearing safety	$\tau_{Rd} \geq \tau_d$ =	fulfilled!

Proof of combined stress in the nails at the bottom

Tensile load in the nail at the bottom as a result of the force (Zud / nu)	N_{ud} [kN] =	20.1
Moment as a result of the eccentric acting force (Zud / nu)	M_{ud} [kNm] =	0.2
Normal stress in the nail at the bottom	σ_{Nd} [N/mm²] = $\lvert N_{ud} \rvert / A_{(red)} + M_{ud} / W_{pl(red)}$ =	174.3
Combined stress in the nail at the bottom	σ_d [N/mm²] = $(\sigma_{Nd}^2 + 3\,\tau_d^2)^{0.5}$ =	201.0
Resistance correction value for combined stress	γ_M [-] =	1.1
Maximum permissible yield stress	$\sigma_{Rd} = f_y / \gamma_M$ =	527.3
Proof of bearing safety	$\sigma_{Rd} \geq \sigma_d$ =	fulfilled!