



# Mac S-Design

MAKE YOUR SLOPE SAFER

available on [edesign.maccaferri.com](https://edesign.maccaferri.com)

**Speaker:**

**LUCA GOBBIN**

*Corporate Rockfall Technical Specialist*

## Webinar Agenda?



**20'** *The design of soil nailing applications with Mac S-Design*

**10'** *A real case developed with Mac S-Design*

*Live Q&A Session*

# WATCH THE VIDEO ANIMATION OF MAC S- DESING

<https://www.youtube.com/watch?v=syYFS6VVF38>

The logo features a stylized 'T' shape with a vertical line extending downwards, ending in a white arrowhead pointing downwards.

# Mac S-Design

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## **SOIL NAILING AT A GLANCE**

## **DESIGNING SOIL NAILING APPLICATIONS**

## **Q&A SESSION**

## SOIL NAILING AT A GLANCE

## SOIL NAILING AT A GLANCE

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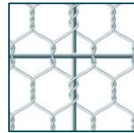
What it is

### Soil Nailing



**Nails**

increasing the  
stability of the slope



**Facing**

contains the soil movement  
between nails

Soil nailing is a technique used **to stabilize slopes with low cohesion or purely frictional behavior.**

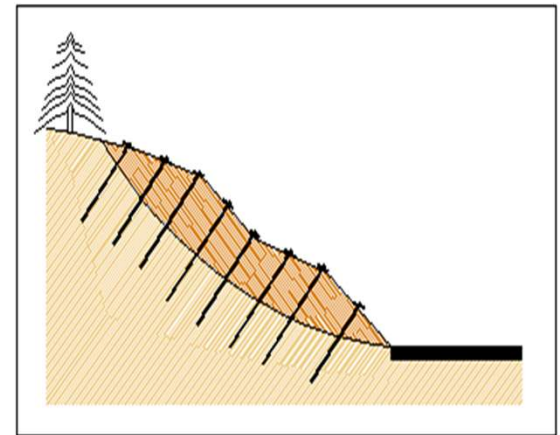
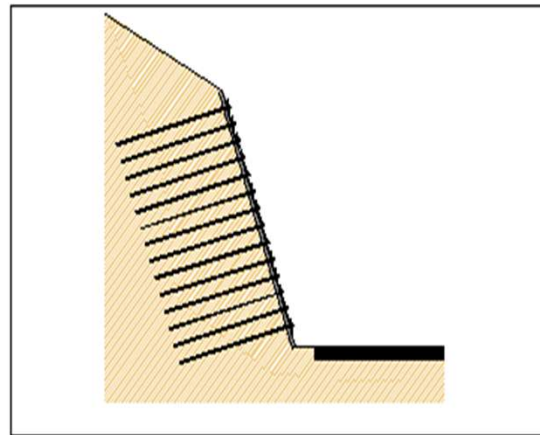
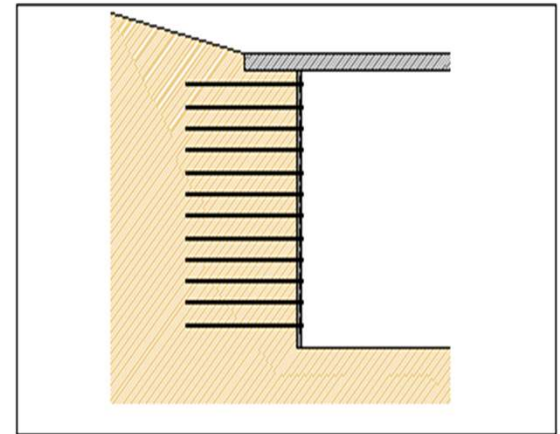
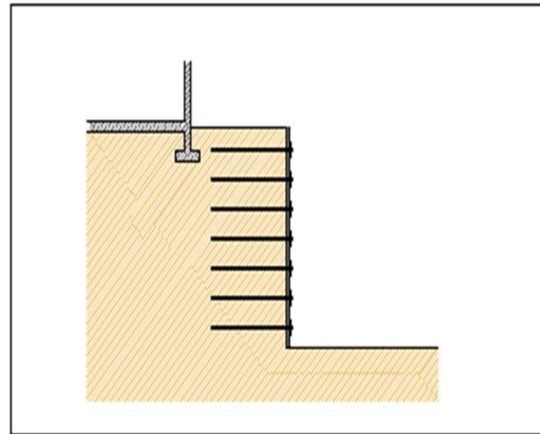
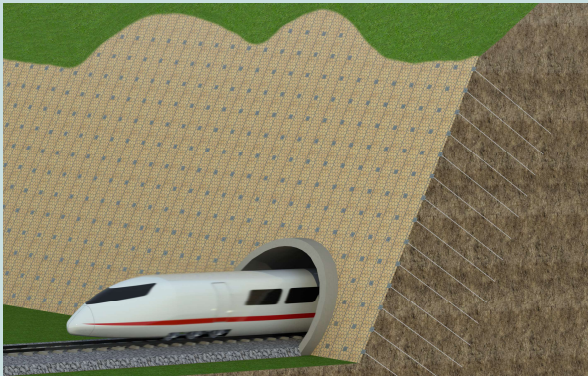
It is recommended for soil with no groundwater presence, partially saturated, with a miscellaneous granular matrix (from sandy gravel to clayey silt) and with a low to medium cementation grade, or for altered rocks (Cola et al., 2011)



## SOIL NAILING AT A GLANCE

Where it is used and why

- Easy and fast to install
- Requiring limited excavations
- Environmentally friendly
- Can be applied on new excavated slopes/walls or on existing slopes



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## SOIL NAILING IN INTERNATIONAL STANDARDS

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British Standard vs FHWA



BRITISH STANDARD  
8006-2:2011+A1:2017

- It deals with **soil nailing** applications realized **with soft, flexible and hard facing**



FHWA-NHI-14-007

- It only deals with **long-term support soil nailing solutions**
- It includes a **final shotcrete or cast-in-place-concrete** (CIP) facing is installed.

**FOR HARD  
FACING ONLY**

## SOIL NAILING AT A GLANCE

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The nails in the British Standard



### THE NAILS

**bsi.**

**BS EN 14490:2010**

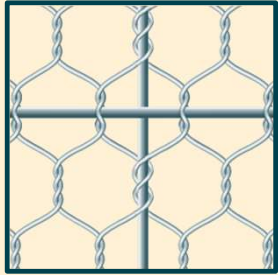
“Soil nail: reinforcing element installed into the ground, usually at a sub-horizontal angle, that mobilizes resistance with the soil along its entire length.”



## SOIL NAILING AT A GLANCE

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### The Facing in the British Standard



## THE FACING

**bsi.**

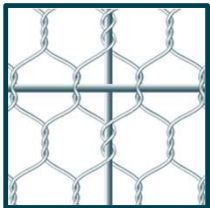
**BS EN 14490:2010**

“Facing: covering to the exposed face of the reinforced ground that may provide a stabilizing function to retain the ground between soil nails, provide erosion protection and have an aesthetic function.”



## THE SOIL NAILING AT A GLANCE

### The Facing in the British Standard



**bsi.**  
**BS 8006-2:2011**

The BS 8006-2:2011 identifies three different facing options: hard, flexible and soft facings

**HARD FACING**



**FLEXIBLE FACING**

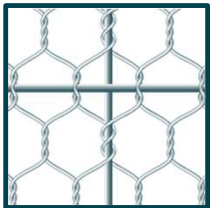


**SOFT FACING**



## THE SOIL NAILING AT A GLANCE

### The Facing in the British Standard



**bsi.**  
**BS 8006-2:2011**

The BS 8006-2:2011 identifies three different facing options: hard, flexible and soft facings

#### HARD FACING



#### FLEXIBLE FACING



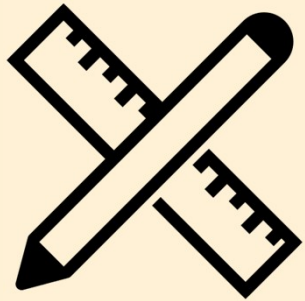
#### SOFT FACING



## SOIL NAILING AT A GLANCE

The Design in the British Standard

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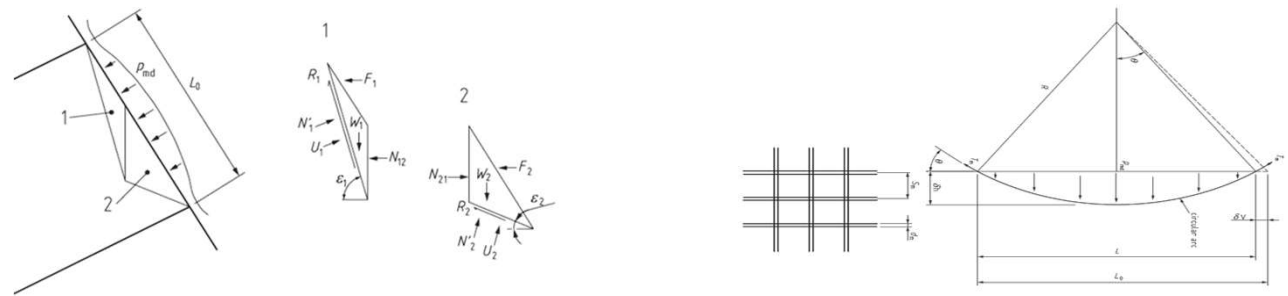
### DESIGN OF SIMPLE FLEXIBLE FACING

**bsi.**

**BS 8006-2:2011  
+ A1:2017**

“A simple flexible facing restrains the surface soil between the nail plate positions only. [...] But the surface soil between the nail plates is not self supporting and the facing must be designed to restrain it. A method for calculating the loading to be resisted by the facing based on a two-part wedge failure mechanism forming between two rows of nails is given in the top figure.

The flexible facing may be designed to meet this loading by assuming that it acts as a tensioned catenary as shown in the bottom figure.”



**LEM ON UNDEFINED SLOPE**

**SOIL NAILING AT A GLANCE**

**DESIGNING SOIL NAILING APPLICATIONS**

**Q&A SESSION**

## DEFINITION OF THE SOLUTION: MAC S-DESIGN

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Maccaferri has a centre of excellence entirely dedicated to **research and development**, concentrating in a single place the capital of **knowledge** and **know-how**: in Bolzano (Italy) the Maccaferri Innovation Center (M.I.C.) is constantly working to innovate our products and solutions



*developed in collaboration with **Politecnico di Milano***



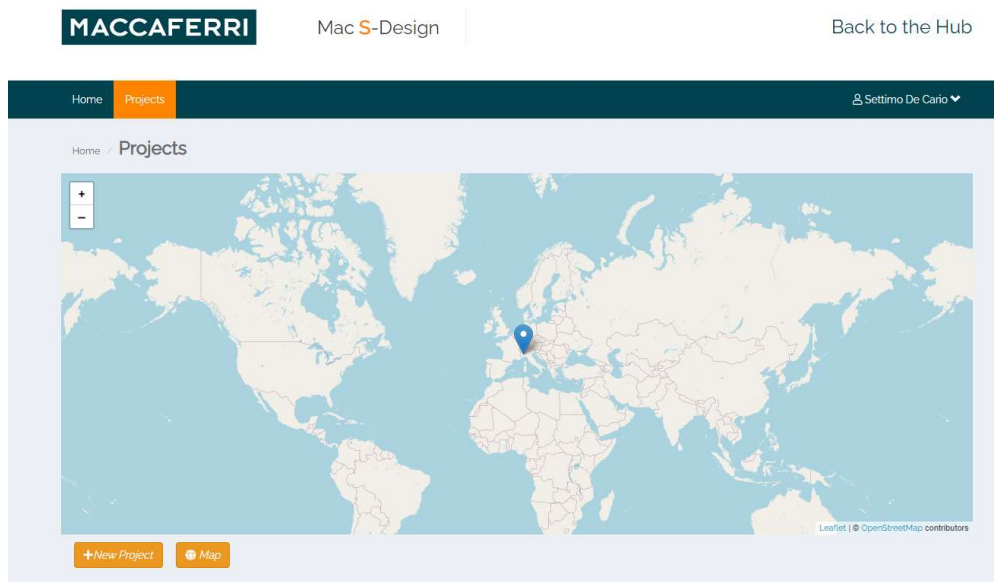
## DEFINITION OF THE SOLUTION: MAC S-DESIGN

MACCAFERRI

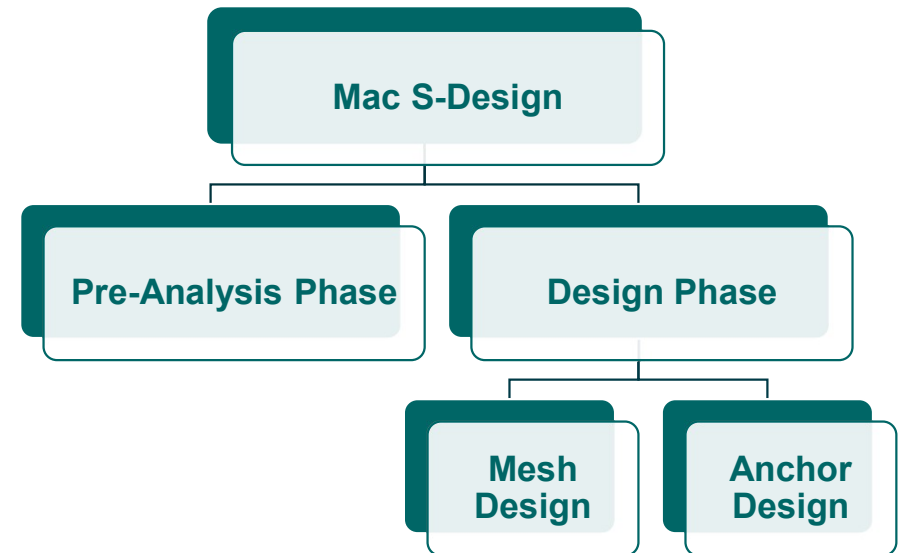
### Mac S-Design

is a web-based tool accessible via

[edesign.maccaferri.com](https://edesign.maccaferri.com)



Mac S-Design has been developed with a modular approach:





**Mac S-Design** is based on a **hybrid approach**:

- the **stabilizing action** provided by the passive structural intervention is expressed as a **function of the relative soil-structure displacement**;
- the **equilibrium** of the **soil mass** is still analyzed by means of usual **LEM**.

## BRIEF EXPLANATION OF THE «HYBRID APPROACH»

### Which are the main characteristics of the “Hybrid Approach”?

- M** It is based on a **LEM approach** (Limit Equilibrium Method)
- M** It can be assumed as a **combination of both ULS and SLS**:
  - i. ULS expresses the soil strength parameters (as described for instance in Eurocodes), while
  - ii. SLS expresses the displacements condition;
- M** It is consistent with the **concept of “Mitigation & Prevention of Structures”**
- M** The design of both mesh and anchors is based on the **soil-mesh interaction** system through the use of a **Characteristic curve**
- M** The above hypotheses can be summarized in the following general equation:

$$E_k^F = \frac{R_k^F}{F_S} + A_k^F(U) *$$

\* Where the term  $E$  represents the driving forces (e.g. the weight  $W$ ),  $R$  is the soil strength and  $A$  is the resulting stabilizing action provided by the mesh depending on the soil-mesh interaction

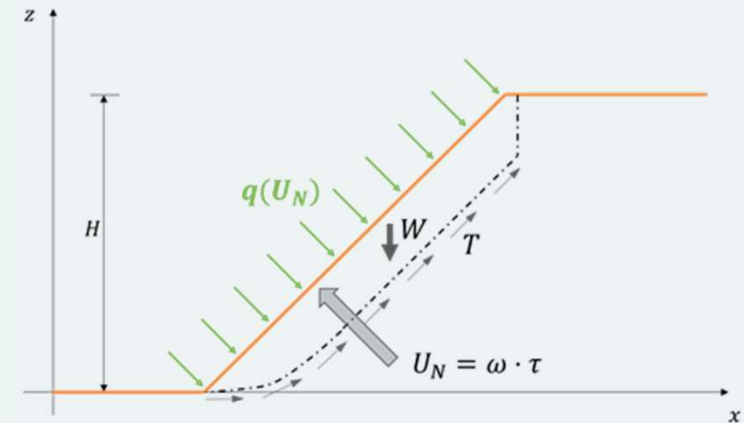
DO YOU WANT TO KNOW MORE ABOUT OUR SOIL NAILING DESIGN SOFTWARE? TEXT "**TRAINING**" IN THE CHAT BOX



The problem of the stability of the surficial layer of a slope can be tackled through 3 subsequent phases of analysis:

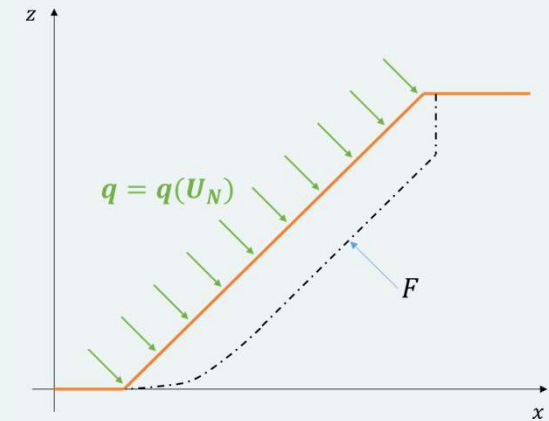
### Phase 1: Identification of the potential failure mechanism

- Identification of both the “failure surface” and of the related field of displacements  $\mathbf{U}(\mathbf{x}, \mathbf{z})$  of the soil
- Analysis in the frame of driving forces and resisting forces
- Instability due to: slope angle, unstable soil layer and soil strength parameters, tension crack, water table depth, etc.



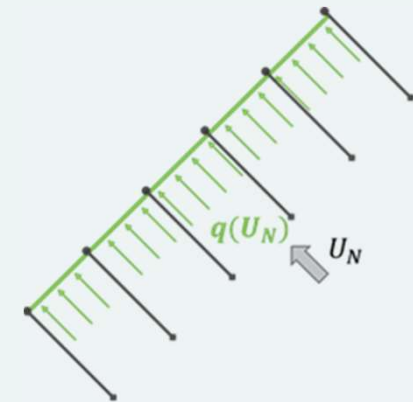
### Phase 2: Analysis of Stability

- Definition of the required 'q' stabilizing pressure
- The mesh shall be able to bear the needed 'q' pressure, in case of soil movements



### Phase 3: Definition of the Characteristic curve

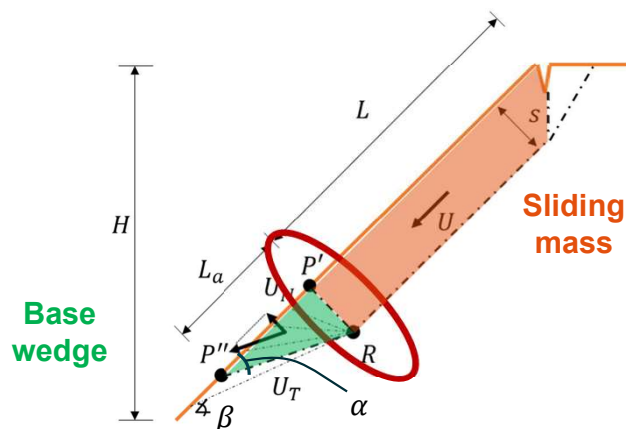
- The Characteristic curve can be defined
- The pressure 'q' that shall be withstood by the mesh is related to the Soil displacements  $\mathbf{U}(\mathbf{x}, \mathbf{z})$  and it also depends on the applied product
- The force acting on the anchor can be computed to guarantee the equilibrium of the system



## BASIC METHOD ASSUMPTIONS & SCHEMATIC APPROACH

Two approaches are included and they differ due to the geometry of the considered blocks

**Method 1**

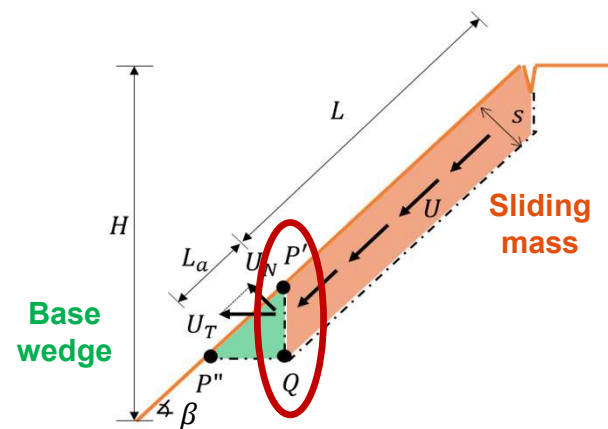


This method considers a stabilizing «soil wedge» where:

- the induced forces are transferred through an interface  $P'R$  orthogonal to the slope surface,
- Several wedge elements can be defined for each  $P'$  point and each one is defined by a different value of the  $\alpha$  angle.

*This method is rather compatible with steep slopes*

**Method 2**



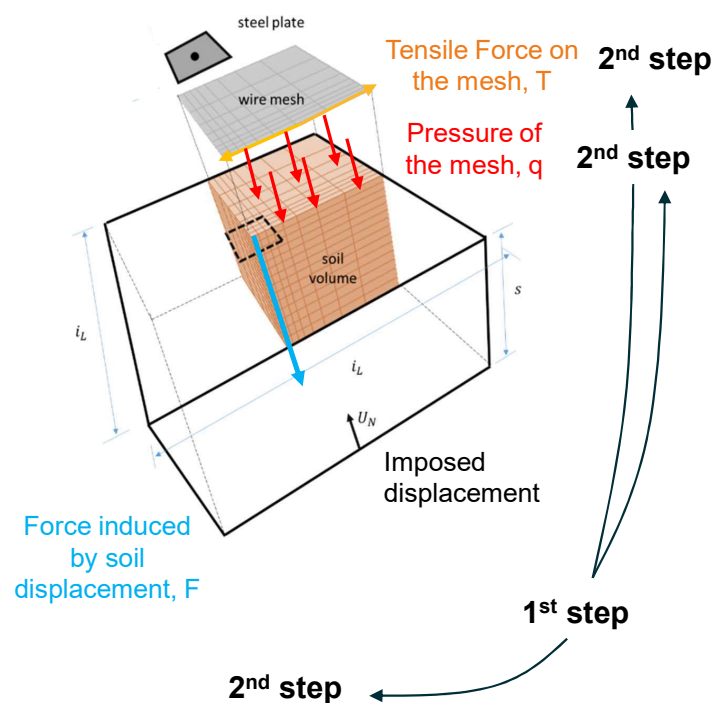
This method considers a stabilizing «soil wedge» where:

- the induced forces are transferred through a vertical interface  $P'Q$ ,
- A single wedge element exists for each  $P'$  point.

*This method is rather compatible with gentle slopes*

## THE DEFINITION OF THE CHARACTERISTIC CURVE

The characteristic curve describes the interaction behavior between mesh and soil through an equation. This equation is calibrated on FEM analyses and laboratory tests.



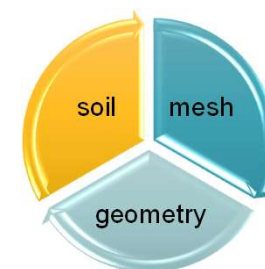
HP

INPUT

OUTPUT

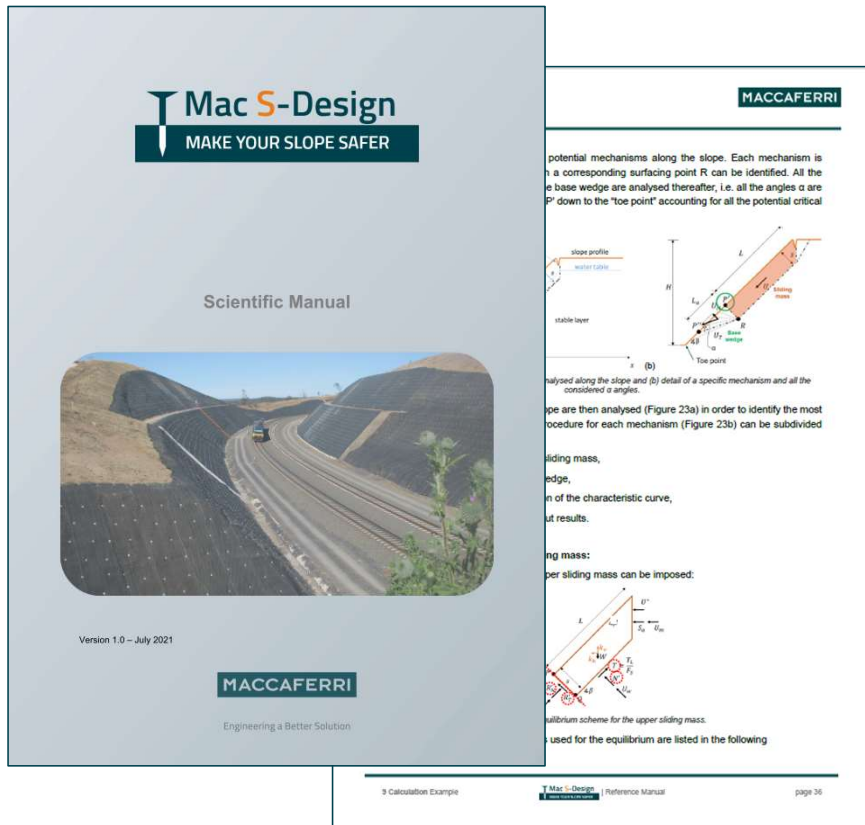
- Isotropic / quasi-isotropic wire mesh

- Mechanical properties of the soil (e. g. cohesion, Young modulus, Poisson ratio, etc.)
- Mechanical characteristics of the mesh (e. g. tensile strength, tensile stiffness)
- Anchor spacing

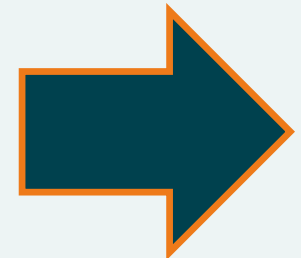


The results of the calculation process are expressed in terms of:

- Load - displacement curve « $F-U_N$ »**  
Tensile force " $F$ " on the anchor vs " $U_N$ " soil displacement
- Characteristic curve: Load - displacement curve « $T-U_N$ »**  
Tensile force " $T$ " on the mesh vs " $U_N$ " soil displacement
- Pressure " $q$ "** provided by the mesh against the soil to reach the equilibrium of the system



FOR A DETAILED  
EXPLANATION OF  
THE SOFTWARE  
APPROACH,  
DOWNLOAD THE  
**SCIENTIFIC MANUAL**  
AND USER GUIDE

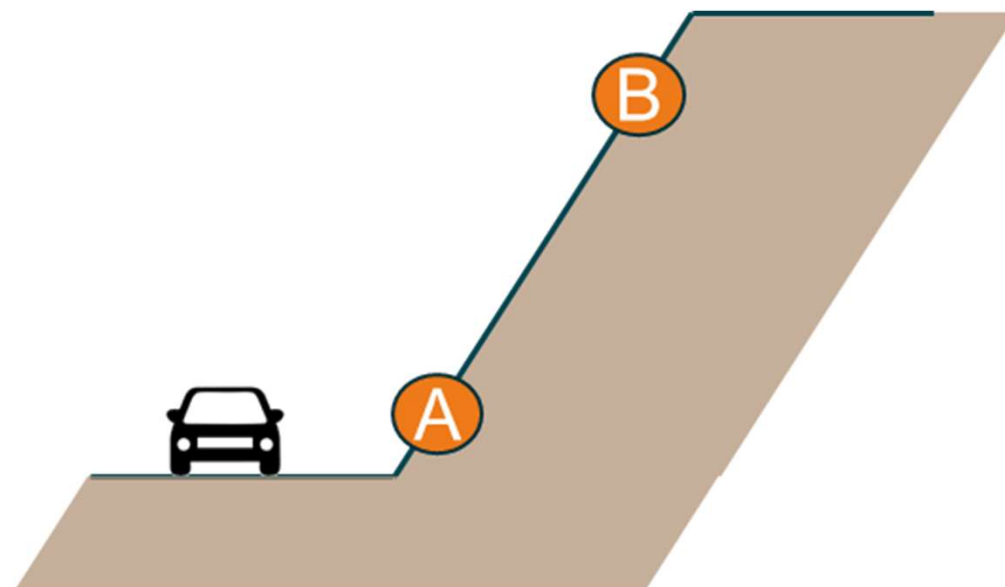
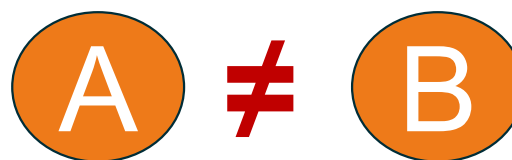


## REAL SLOPE HEIGHT

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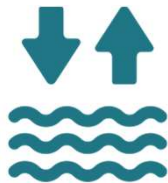
HEIGHT  
OF  
THE  
SLOPE



**Mac S-Design** considers the real height of the slope (defined slope approach). The load applied to the mesh varies along the slope.

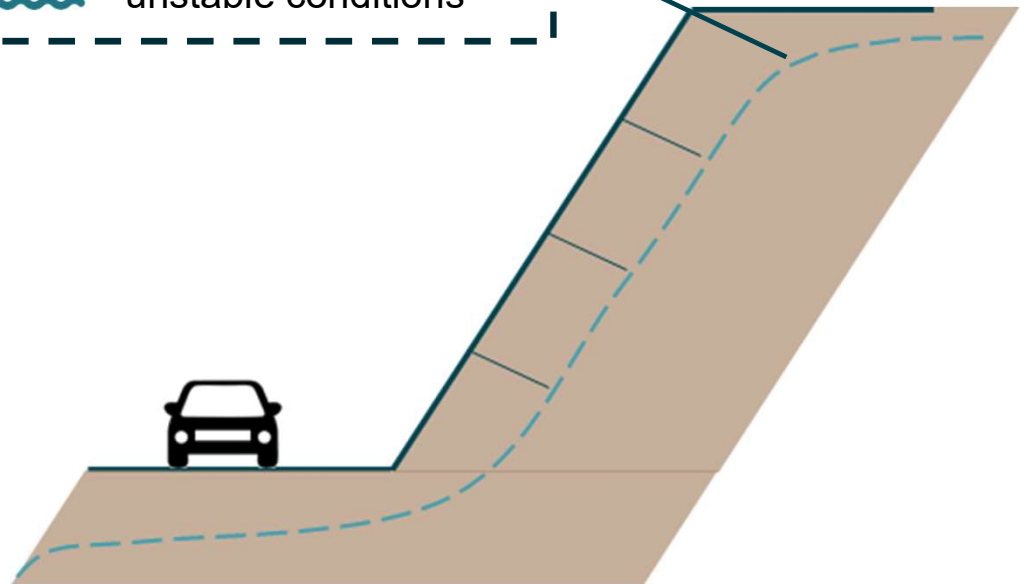
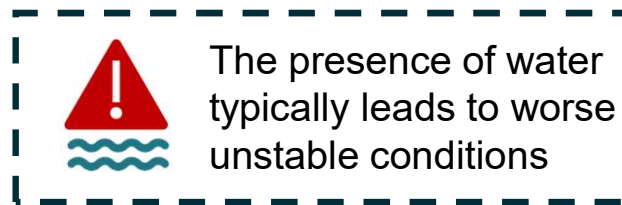
# WATER TABLE LEVEL

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WATER TABLE LEVEL CAN BE TAKEN INTO ACCOUNT

**Mac S-Design** enable designers to consider the water table level in their soil nailing calculation.



# ANALYSIS OF THE UNSTABLE LAYER

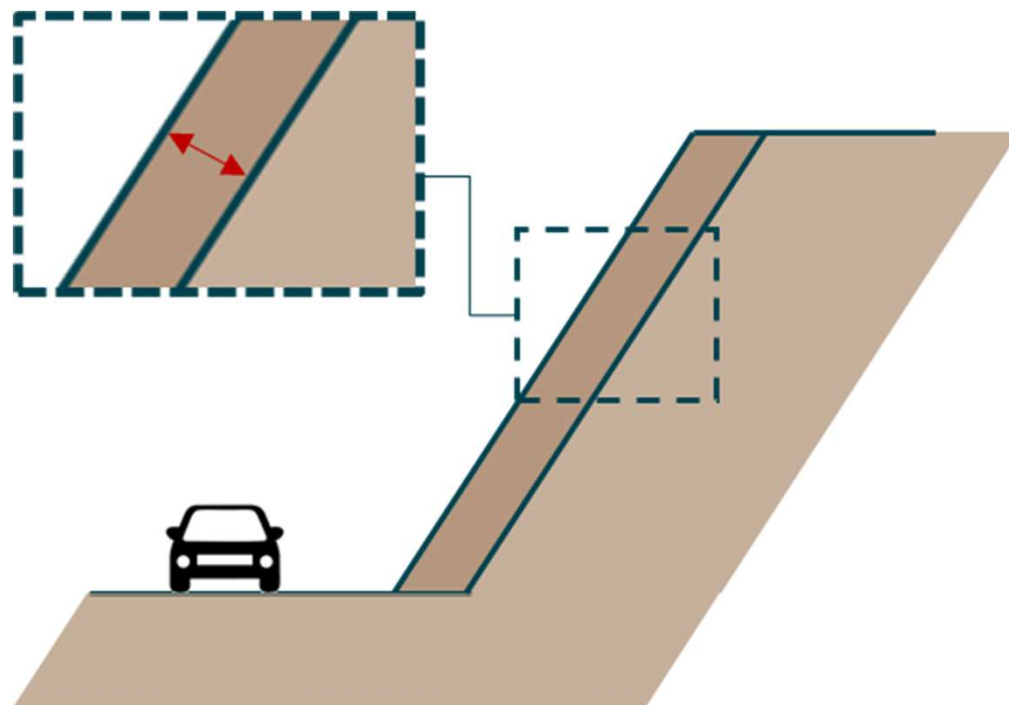
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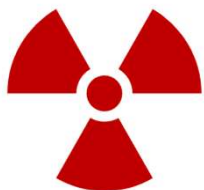
20% of SLOPE  
HEIGHT



THICKNESS OF THE  
UNSTABLE LAYER

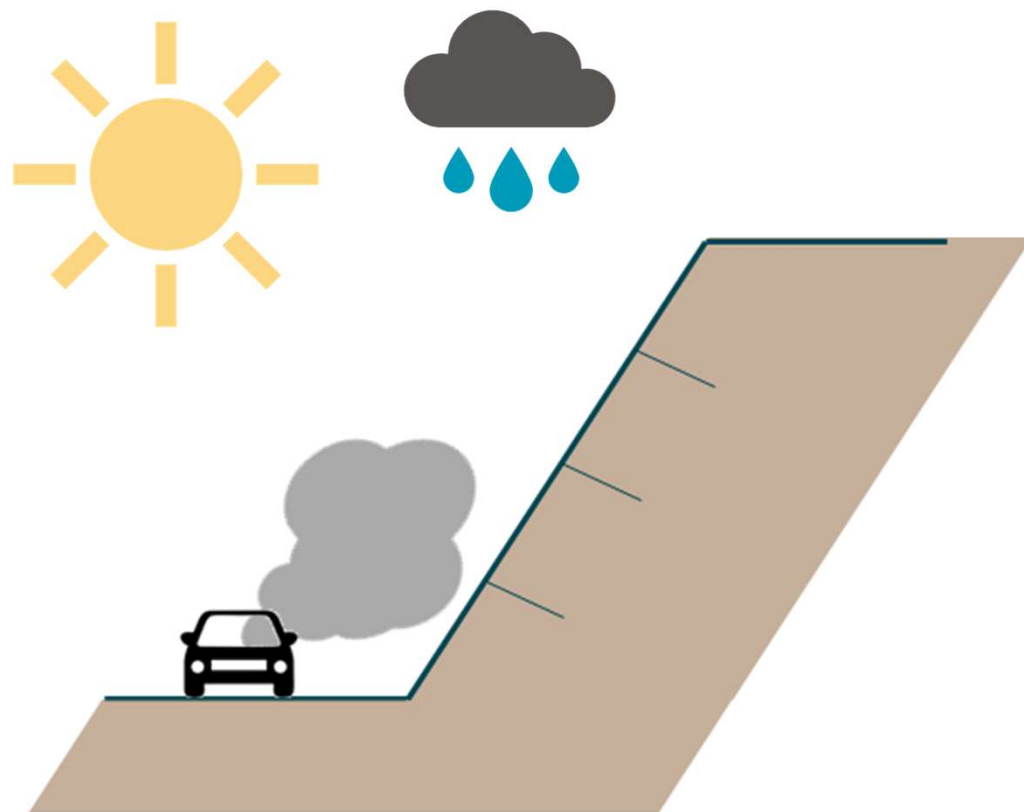
**Mac S-Design** allows to consider an unstable layer of soil up to a thickness of 20% of the slope height. This enables the analysis of a wide range of cases.





## ENVIRONMENTAL EXPOSURE ACCORDING TO EN10223-3 AND EN10244-2.

**Mac S-Design** enables designers to consider environmental exposure in their soil nailing calculation for both the mesh and the nails (corrosion crown).



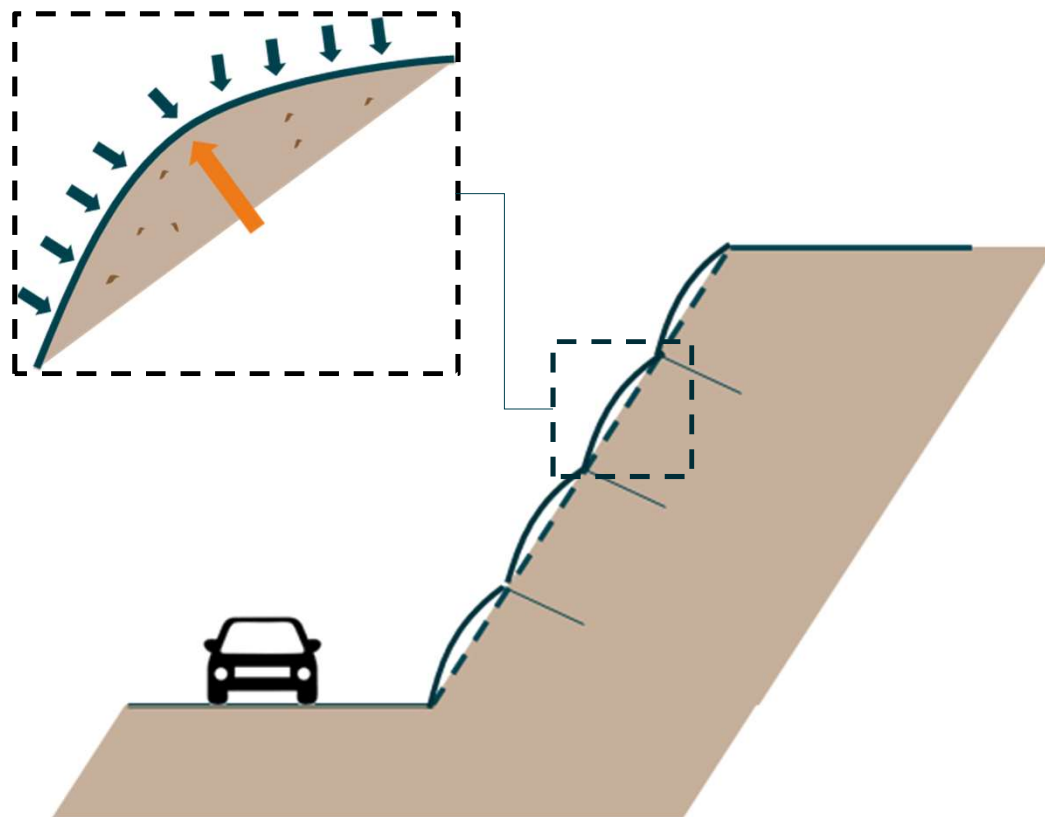
# STRESS-DISPLACEMENT

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THE MESH DOES NOT  
EXERT ANY PRESSURE ON  
SOIL IF NOT DEFORMED

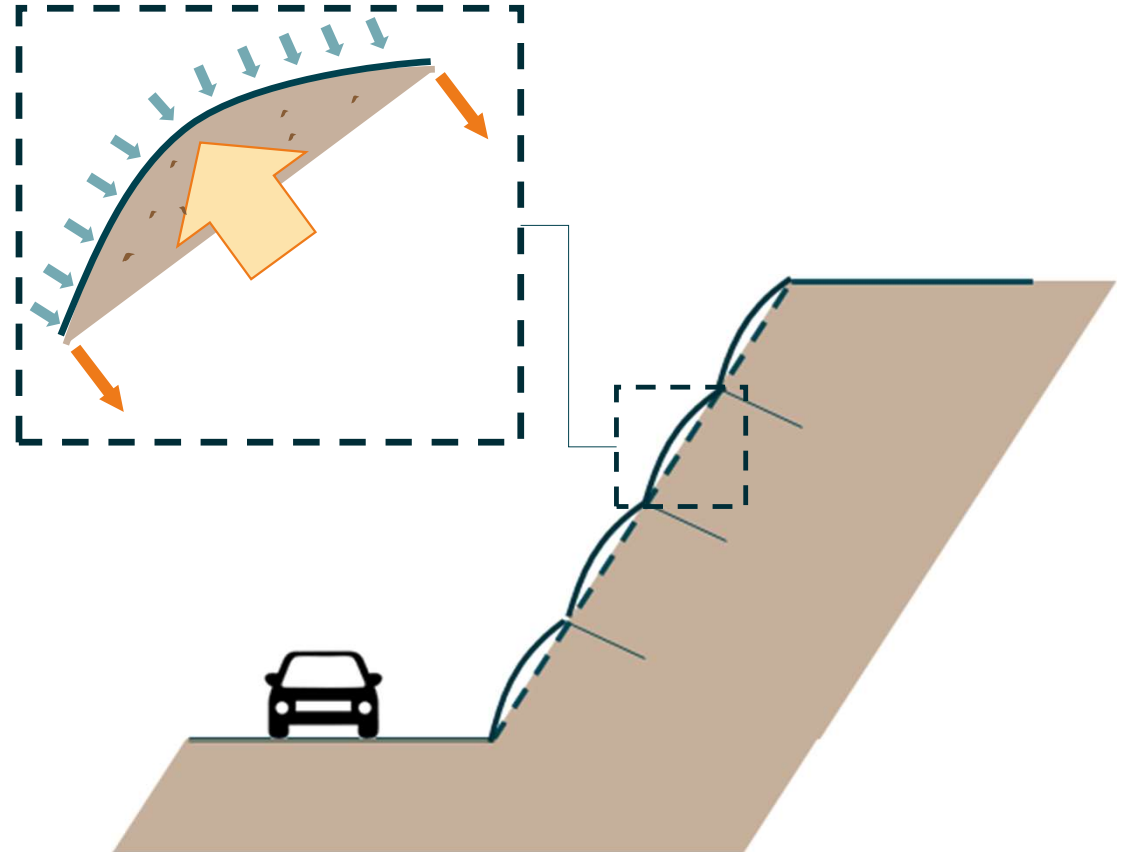
**Mac S-Design** is based on stress-displacement curves. There is no need of inputting arbitrary forces that might affect the reliability of the output





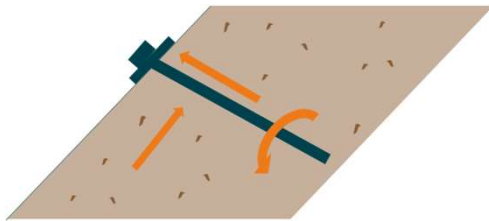
## MESH WORKING RATIO

**Mac S-Design** optimizes the mesh design returning its working ratio.



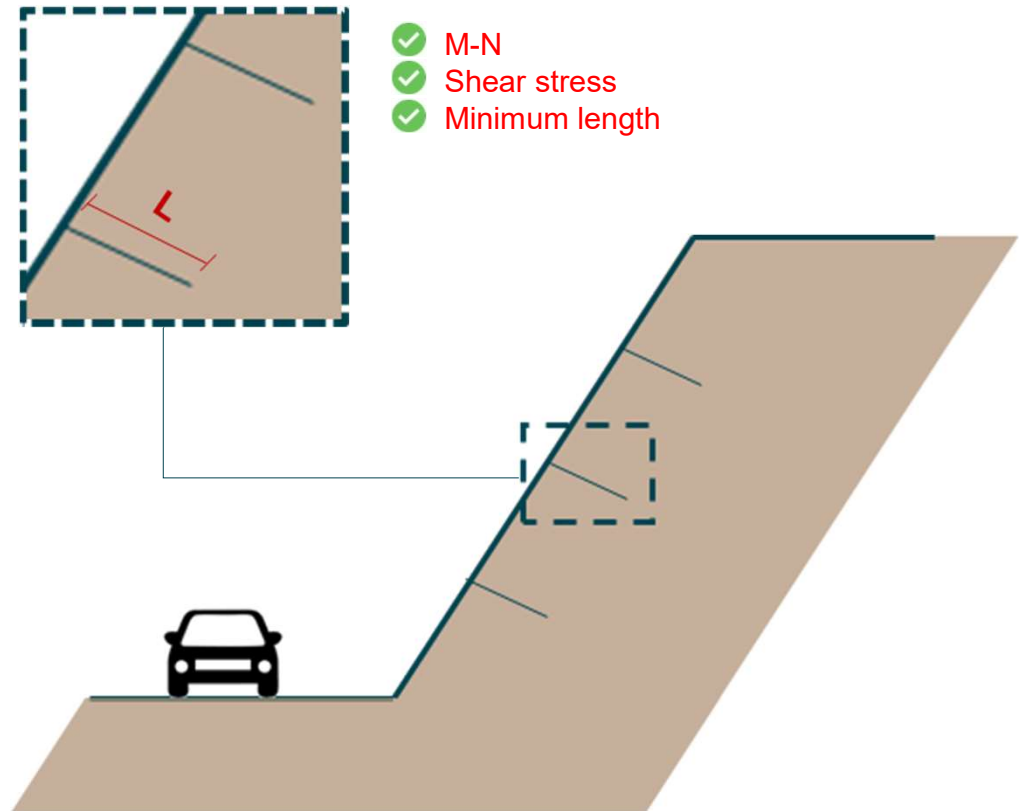
# ANALYSIS OF SOIL NAILS

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CHECK ON NAILS'  
STABILITY

**Mac S-Design** checks the nails for shear stress, bending moment and axial forces, and calculates their length.



## BASIC METHOD ASSUMPTIONS & SCHEMATIC APPROACH

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The conceptual framework of Mac S-Design can be summarized as follows:

### INPUT

- Geometry  
(height and angle of the slope, thickness of unstable layer, etc.)
- Geotechnical Parameters  
(friction angle, cohesion, specific weight, etc.)
- Water Table, Partial Coeff., Seismic Coeff., Safety Factor

### PRE-ANALYSIS

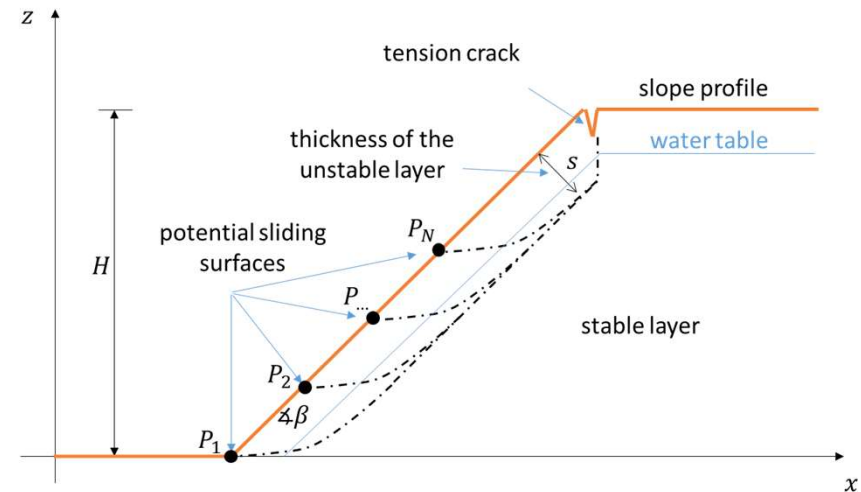
- Analysis of all the potential sliding surfaces
- Stability analysis through “**Method 1**” and “**Method 2**”
- Identification of the most unstable mechanism (i.e. lowest FS)

### DESIGN

- When  $FS < FS_{design}$ :
- Selection of the appropriate mesh to provide the needed ‘q’ stabilizing pressure
  - Definition of the anchors characteristics

### ANALYSIS

- Calculation of the **characteristic curve** of the selected mesh
- Stability analysis through “**Method 1**” and “**Method 2**”



### OUTPUT

- Verification of the  $FS_{design}$
- Mesh verification and Working Ratio
- Verification of nails

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# A REAL CASE WITH MAC S-DESIGN

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A REAL CASE EXAMPLE

## Main Input Data

### GEOMETRY:

Slope height: 25 m

Slope angle: 45°

Unstable soil thickness: 2.0 m

### GEOTHECNICAL PARAMETERS:

Soil friction angle: 40°

Cohesion: 10 kPa

Unit weight: 21 kN/m<sup>3</sup>

Saturated unit weight: 22 kN/m<sup>3</sup>

### WATER TABLE:

Water table depth: 1.5 m

### SEISMIC COEFFICIENTS:

Horizontal seismic coefficient: 0.0

Vertical seismic coefficient: 0.0

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