On unstable slopes, flexible shallow landslide barriers provide protection against landslips:
- lightweight construction cuts costs
- easy installation
- can also withstand multiple impacts
- effectiveness proven in large-scale field tests
- dimensionable using FARO simulation software
Shallow landslide: their causes – and how to limit their effects.

On steep slopes, saturated layers of soil can form shallow landslides, which can trigger spontaneously and flow at relatively high speeds of up to 10 m/s (35 km/h). If a shallow landslide flows into a river channel, this can spark a debris flow.

Depending on the flow speed and volume of the displaced material, shallow landslides can have a destructive impact, disrupting traffic routes and causing major damage to buildings.

The climate as a risk factor

With an expected increase in heavy rainfall in lower case alpine regions and more frequent winter storms, coupled with the fact that the snow line is moving ever higher, in the future the environment will contain more water to potentially trigger shallow landslides.

Meteorologists are predicting that the likelihood of extreme rainfall events will also rise across the world (global climate change).

Suitable protective measures are designed to secure roads and rail lines against shallow landslides. Exposed buildings must also be protected against these near-surface landslips.
Protection against shallow landslides: a comparison of different methods

1. Conventional protective measures
Erecting structures to divert the landslide — dams or reinforced mountainside walls — requires a huge amount of constructing work. Particularly in steep terrain alongside roads and rail lines, measures like this can only be taken in certain circumstances.

2. Flexible shallow landslide barriers
have been proven to retain mixtures of water and solids, such as mudslides and shallow landslides, even in the event of multiple impacts. The barriers can be installed with a low outlay of material and man hours, greatly reducing costs and construction time.
Flexible shallow landslide barriers.

1. Shallow landslide barrier SL-150
A SPIDER® spiral rope net together with a secondary mesh with a mesh width of 50 mm is installed in the danger zone, with posts installed up to eight meters apart. The retaining ropes and the upper and lower support ropes affixed to the ends of the protective structure are fitted with brake rings. This type of protective structure is suitable for use with a span width of up to 30 m without support rope separation.

2. Shallow landslide barrier SL-100
If the expected pressure is lower, an alternative type of protective structure may be used: the installation of a TECCO® mesh G65/4 with posts spaced as far as five meters apart and a barrier height of two meters. This type of protective structure has no secondary mesh.
The SPIDER® spiral rope net — manufactured from a spiral rope made of high-strength 4 mm steel wires has a tensile strength of more than 1770 N/mm². The spiral rope net made with a rhomboid mesh shows a load capacity of 220 kN/m lengthwise.

The FLEX head absorbs tension and bending forces according to the same principle as the head of the Geobrugg spiral rope anchor. It is unsusceptible to impact and can be mounted to self-drilling anchors available on the market. A concrete foundation is required for the transition from the anchor bar to the FLEX head.

A protective apron is installed across the entire width of the barrier to form an erosion seal between it and the ground below and to prevent erosion and material seepage.
Application possibilities cover a wide range of areas.

Rest and be Thankful, Scotland

Problem
Following heavy rainfall, on September 8, 2009, a shallow landslide - the second in quick succession - struck the A83, a key through road in northwest Scotland, near the “Rest and be thankful” viewpoint. The area is susceptible to shallow landslides that are impossible to prevent. A suitable protective measure was needed to protect road users and ensure that the road could remain open in the event of another landslide.

Geobrugg solution
A shallow landslide barrier 80 m long and 4 m high was installed, complete with a SPIDER® spiral rope net and a secondary mesh with a mesh width of 50 mm. As a combined measure, an additional VX debris flow barrier, 15 m long and 4 m high and fitted with ROCCO ring nets, was installed in an adjacent gully to prevent material seepage from flooding beneath the road.
Giampilieri, Sicily, Italy

Problem
On October 1, 2009 in Giampilieri, Messina, heavy rainfall — 223 mm of rain in the space of seven hours — led to multiple shallow landslides. These sparked a debris flow event and dumped large amounts of material on the SP 33 highway, forcing its closure.

Geobrugg solution
To protect the highway, debris flow barriers were installed on the steepest part of the slope. Where the slope was less steep — approx. 60 degrees — two 3.5 meter high flexible shallow landslide barriers were installed, one 25 and one 60 meters long and both fitted with a SPIDER S4/130 spiral rope net and secondary mesh, covering a total length of 85 meters. Heavy rain in January 2010 triggered a further shallow landslide. Around 90 m$^3$ of material was successfully retained by the shorter of the two shallow landslide barriers, preventing the highway from having to be closed once again.

Federal Highway Trieben, Austria

Problem
The March 20, 2012 caused several shallow landslides in Steiermark area. One slide flipped out the rockfall protection fence along federal highway B 114 and blocked the road for a certain time causing logistic problems to the community of Trieben.

Geobrugg Solution
After that occurrence special developed shallow landslide barriers type SL-150 from Geobrugg were installed to replace the damaged rockfall barriers. A short time later in following events on June 21 and August 20 in 2012 the barriers were impacted and retained successfully the material (Picture source: Marc-André Rapp, Amt der Steiermärkischen Landesregierung).
It's all a matter of correct dimensioning

Our special retention aprons have to withstand a great deal. Shallow landslides generate huge forces, which we model using complex measurement and simulation methods. Data on the flow behavior and the dynamic impact of the earth masses enable flexible barriers to be constructed according to the load situation. The retention volume here is key: maintaining an optimum distance between the posts increases the amount of usable height available and provides sufficient retention space. Even multiple rockfall loading was tested separately on shallow landslide barriers.

Simulating what the net has to hold back

In the numerical simulation, we calculate the forces acting on the barrier. The result is combined with the pressure on the force measurement plates in the direction of flow, which is calculated from tests. In addition, there is the hydrostatic pressure caused by the flow depth. The dimensions that are relevant for dimensioning the dynamic impact are the initial density $\rho$ of the shallow landslide and the speed $v$ at the planned protection net. Using our FARO simulation software, we can use the pressure calculated on the test barrier in a variety of system configurations and carry out a realistic simulation in each case.

Under static and multiple load

After the first landslide, the net is filled evenly with mud, earth and rubble. Behind the barrier, a hydrostatic pressure distribution ($P_{\text{phyd}}$) initially builds up across the fill depth ($h_{\text{fill}}$). As the water drains away, this pressure is reduced to an active earth pressure ($P_{\text{stat}}$). If another landslide strikes, its dynamic pressure will overlap with the pressure exerted by the material still partially filling the barrier (picture-session below).
Calculating the incalculable...

The retention volume of the protection net must be at least equal to or greater than the expected volume of landslide material, called the “breakout volume.” As with snowslides, the breakout volume is calculated from the area and force of the breakout. This latter can be determined using the hazard map or be identified on site by an engineer.

... and limiting the damage

If the protection net is too small in terms of volume, or if the structure is shorter than the impact width, this restricts the potential for protection against shallow landslides. In this case, the difference between the breakout and retention volume is calculated. This difference, together with the speed at which the landslide flows around and over the net, is used to recalculate the damage and optimize the construction of the net accordingly.

Retrieval volume holds the key

Following the barrier filling process \( h' = \frac{3}{4} h \), the calculated height is compared to the installation height. Assuming that the reduced net height following an impact \( h'_b \) is measured vertically to the slope, and ignoring the volume in the deformed bulge of the net, the retention volume \( V \) of a shallow landslide net is

\[
V = \frac{1}{2} h'_b \cdot l_{fill} \cdot l_b = \frac{3}{4} h \cdot \frac{3}{4} h'_{fill} \cdot l_b
\]

\[
= \frac{9}{32 \cdot \sin \phi} \cdot h'_b^2 \cdot l_b \, [\text{m}^3]
\]

Simulation and field test

The simulation shows how the subsequent landslide pushes into the material already deposited. The load level at the barrier increases \( (h'_{fill} + h_b) \).

At the field tests, the deviation between simulation and actual measurement is only approx. 10%, thus providing useful information on the dynamic wave impact that the test shallow landslide produces.

Geometric proportions of a filled shallow landslide net

\( l_b \) = impact width
\( h'_b \) = reduced net height following impact
\( h_{fill} \) = fill depth of the shallow landslide net
\( l_{fill} \) = fill length of the shallow landslide net
\( V \) = retention volume
\( \phi \) = slope inclination

Technical drawing: calculating the approximate maximum retention volume \( V \) of a shallow landslide net.

Multiple Load Rockfall

Shallow landslide nets are often installed on exposed slopes where also rockfall can occur. That’s the reason why we did additional rockfall testing up to 500 kJ on our origionally for area load developed system.
Long service life and ease of maintenance: two decisive aspects.

Durability...
Flexible shallow landslide barriers are built on steep slopes where shallow landslides can form, to hold back large amounts of soil, wet clods of earth and water. Because neither water nor rubble flows over or through the barrier in this “standby phase”, they are basically just as durable as rockfall and avalanche protection measures.

...thanks to outstanding protection against corrosion.
With a view to a long life and resistance to local corrosivity, all our steel components are hot-dip galvanized. The ropes and nets are treated with the GEOBRUGG SUPERCOATING® zinc/aluminum coating.

After an event...
Barriers that have retained shallow landslides must be inspected, emptied and maintained (image 1) in order to restore the retention volume (image 2). Here the emphasis must be placed on the evacuation and dumping of the material as this represents the principal outlay in time and cost. Experience shows that any dismantling and reconstruction work on the barrier is of much less significance.

...emptying and maintaining.
The easiest way is emptying the barrier from behind if accessible. More frequently the emptying happens from the front, as the deposit cone, compressed during the impact, is very stable. Nevertheless, the material can be excavated also from the front without dismantling the barrier (image above).

The main replacement parts are the brake rings: After events they must be inspected and changed where necessary. We also recommend that nets and ropes are inspected for serviceability.
Decisive points for the ordering party, planner and contractor.

Easy and simple installation
- The material is prefabricated and can be flown in by helicopter to even the most inaccessible sites.
- Installation requires no heavy construction machinery.
- Anchoring requires just a lightweight drilling carriage and weight-saving tie rods.
- No large-scale earthwork or access roads are required.

Environment-friendliness
- The installation blends into the landscape and compared to massive structures is hardly visible from a distance.
- The CO₂ footprint is clearly better than with concrete structures.

Profitability
- In the case of an event, the investment will substantially reduce claims for damages.
- Delivery and installation are less costly than for concrete structures.

Long service life
- The GEOBRUGG SUPERCOATING® corrosion concept for ropes and nets, the hot-dip galvanizing of posts, baseplates and brake rings profiles guarantee longevity.

Simple maintenance after events
- Retained sediment can easily be excavated or removed manually after taking down / lifting up the net.
Geobrugg, a reliable partner

It is the task of our engineers (and partners) to analyze the problem together with you in detail and then, together with local consultants, to present solutions. Painstaking planning is not the only thing you can expect from us, however; since we have our own production plants on three continents, we can offer not only short delivery paths and times, but also optimal local customer service. With a view to trouble-free execution, we deliver preassembled and clearly identified system components right to the construction site. There we provide support, if desired, including technical support — from installation right on up until acceptance of the structure.

Product liability

Rockfall, slides, mudflows and avalanches are natural events and therefore cannot be calculated. This is why it is impossible to determine or guarantee absolute safety for persons and property with scientific methods. This means that to provide the protection we strive for, it is imperative to maintain and service protective systems regularly and appropriately. Moreover, the degree of protection can be diminished by events that exceed the absorption capacity of the system as calculated to good engineering practice, failure to use original parts or corrosion (i.e., from environmental pollution or other outside influences).