Flexible ring net barriers for debris flow protection: The economic solution.

Debris flow barriers from Geobrugg:
- enormous reduction in construction time
- cost-savings of 30 to 50% compared to concrete structures
- environment-friendly solutions adapt visually into the landscape
- tested in field trials with the Swiss Federal Research Institute for Forest, Snow and Landscape (WSL)
- single-level barriers for events of up to 1’000 m³, multilevel barriers for events of several 1’000 m³
Debris flows: Their causes – and how to limit their effects.

A debris flow is a fast flowing mixture of water and a high proportion of solids (stones, blocks, boulders, timber) which moves downhill in channels in the form of a wave. A debris flow has a destructive potential comparable with rockfall, avalanche and high water.

The most clearly defined front can reach a velocity of 2 to 10 m/s. With larger debris flows, sediment discharges from several 1'000 m³ to some 10'000 m³ can be transported downhill. But even the much more frequent minor debris flows of up to 1'000 m³ have a destructive force.

The climate as a risk factor.

Global warming is causing high-alpine permafrost soil and rock glaciers to melt, liberating more potentially mobilizable material which is expected to result in a rise in debris flow events. Debris flows can also be initiated by ever more frequently observed, extremely heavy regional rainfalls. Also in certain regions of the world, bush fires are breaking out more and more frequently after lengthy periods of drought (e.g. California). These burn off the entire vegetation cover. Heavy rainfalls on the erosion surface then render slopes unstable: The material slides into the river channel and debris flows can develop.
Debris flow protection systems: Comparison of two different methods

Flexible ring net barriers...
...withstand high static and dynamic loads. They can be installed with a low outlay of material and man hours, greatly reducing costs and construction time.

Traditional systems...
...are well suited for separating water from rubble but are not flexible and can be damaged by larger rock fragments. Fitting the anchors in the flanks is time consuming and costly. The very heavy components require massive foundations which in terrain without roads can only be constructed at a high cost.
Our flexible ring net barriers: Two types of systems to meet all cases.

Depending on the nature of the drainage channel and the project, we execute debris flow barriers according to two different system types. With both, the basal opening permits an unhindered flow of water in the normal case. If the barriers are overtopped after an event, the wing shaped arrangement of the top support ropes guarantees a clearly defined outflow section.

**VX barrier: For narrower V-cuttings.**

With smaller mountain torrents we anchor the debris flow barriers in the channel flanks without posts with spiral rope anchors or self-drilling anchors with flexible anchor heads. The ring net is hung from the upper and lower support ropes fitted with braking rings, using shackles. This type of structure is suitable for a span width of up to approx. 15 m and an installation height of up to 6 m.

**UX barrier: For wider, U-shaped channels.**

The debris flow barrier for larger mountain torrents is preferably supported by two posts in the river bed — and with spiral rope anchors or via flexible anchor heads. This type of structure is suitable for span widths of up to approx. 25 m and an installation height of up to 6 m.
Carefully matched components function as an overall system.

As we know, any chain is only as strong as its weakest link. That is why we developed our flexible ring net barriers as a system of components, each complementing the other to form a perfectly functioning whole. To verify the functional capability, our debris flow barriers were tested in 1:1 debris flow tests.

The ROCCO® ring net
The protective effect of ROCCO® high-tensile steel wire ring nets is based upon more than 60 years’ continuous research: knowledge we have acquired from field tests and in collaboration with international institutions has been incorporated into their development. The result is impressive: Thanks to the elastoplastic behavior, ROCCO® ring nets themselves absorb energy, thereby reducing stress on the anchors.

The brake ring
Brake rings are incorporated in the support and border ropes. With major events the brake rings are activated, dissipating energies from the ring net without damaging the ropes. The rope breaking load is not reduced by the activation of the brakes, enabling the force-path characteristic to be fully utilized.

The abrasion protection
In order to protect the top support ropes from the abrasive effect of rubble and boulders we clad them with thick-section angle steel. These protective elements are simple to change when worn.

The spiral rope anchors
‘If it can bend it won’t break’: The heads of our anchors are flexible and thus insusceptible to impact. The spiral rope is made from steel wires with a strength of 1'770 N/mm². Our spiral rope anchors are superior to traditional anchors – not least because they are also suitable for diverting forces in the direction of tension that can deviate by up to 30 degrees from the drill axis without loss of supporting capacity.

Self-drilling anchor with Geobrugg FLEX head
The FLEX head absorbs tension and bending forces according to the same principle as the head of the Geobrugg spiral rope anchor. It is insusceptible 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.

The posts
For UX barriers we use posts type HEB that are mounted on a baseplate via a link. Their function is to guide the ropes to which the ring net is suspended. The associated guides are rounded to protect these support ropes.
1) Individual barrier for retaining minor debris flows

**Problem** (Engler, Meiringen Switzerland):
In the upper catchment area, an ancient rockfall area with schistic substrate, movement activities are leading to minor earthslips and debris flows that are endangering the settlement boundary and the Meiringen hospital. The aim is to brake the high energy debris flow in the very steep terrain and create retention basins for the mobilized material.

**Geobrugg solution:**
Downstream, with good accessibility and a flatter incline, a UX single barrier with a capacity of 700 m³ was installed that can fully withstand a possible event. A second ring net barrier in the steep terrain, in front of the single barrier, brakes the energy of the debris flow front.
2) Multilevel debris flow barrier for retaining larger debris flows

Problem (Milibach, Meiringen Switzerland):
In 2005 approx. 13'000 m³ of schistic material was mobilized in the catchment area of the Milibach, which through the erosion power of the flow, increased to around 40'000 m³ down into the valley. Rubble coverage in the villages of Reuti and Meiringen resulted in enormous damage. The requirement was for a protection measure, simple and quick to install and that would blend discreetly into the landscape in this region popular with tourists.

Geobrugg solution:
Installation of 13 debris flow barriers arranged in series in the catchment area with a total retention volume of approx. 12'000 m³. The uppermost debris flow barrier was equipped with an over-dimensioned ring net as a debris flow breaker for braking the debris flow front. Access roads and landfill sites permit simple, efficient emptying and disposal following an event.

3) Debris flow breakers for braking the debris flow front

Problem (Engler, Hasliberg Switzerland):
Installed in front of a barrier, for breaking the debris flow front in very steep terrain without retaining large volumes of material.

Geobrugg solution:
Installation of a specially designed debris flow barrier with a stronger ring net, additional support ropes and brake rings for the targeted energy absorption of the debris flow front.

4) Protection against the blocking of passages

Problem (Gaviota Pass, California USA):
The pass road was flooded and jammed due to the blockage of culverts. The aim was to retain the debris flow material before the culverts.

Geobrugg solution:
Installation of a ring net barrier directly in front of the culverts that retains solid material and allows watery, fine material to flow through. The material was retained in the course of three debris flow events without impairing the through traffic. Following excavation the barriers were again fully functional.
5) Drain-off element of a rubble collector

Problem (Schlucher Rüfe, Malbun Liechtenstein):
An existing check dam is to be fortified with a ring net barrier for debris flow and rubble retention. Here the selected basal opening permits the normal high water flow and only is activated in the case of a debris flow.

Geobrugg solution:
Enhancement of a two-sided dam with concrete flanks for anchoring the ring net barriers. Material retention and outflow capacity can be mutually adapted by means of the adjustable basal opening.
6) Diversion structure for correcting the channel course

Problem (check dam 25, Illgraben Switzerland):
Debris flows and high water are flowing around the existing concrete structure and constantly eroding material at the slope flanks. There is a risk of further erosion and displacement of the channel outflow.

Geobrugg solution:
Construction of a first ring net barrier in the flow area between the concrete structure and the eroded slope. After natural filling with debris flow material, a second ring net barrier was installed with inclined upper rope guide which again diverts high water and debris flow over the concrete structure.

7) Protection against scouring and erosion

Problem (Merdenson Switzerland):
Continuous water and debris flow discharge had scour away the footing of the concrete structure. The aim is to protect this footing and maintain the stability of the wall by means of a construction that piles debris flow material so that water and material discharge onto this retention cone.

Geobrugg solution:
Construction of a ring net barrier 5 to 10 m downstream of the concrete structure. After retention of the debris flow material, the ring net remains permanently backfilled in the channel, thus protecting the wall footing.

8) Protecting the channel flanks against erosion

Problem (Merdenson Switzerland):
Erosion through high water and debris flows is present in the channel and its flanks. The aim is to fill the streambed, thus stabilizing the flanks.

Geobrugg solution:
Individual dimensioning of two ring net barriers that remain filled and perform the function of a check dam. An abrasion guard protects the top support rope in the case of overtopping. The barriers flatten the channel slope and raise the energy grade line. The barriers are regularly monitored.
Extensive laboratory and field tests were carried out with renowned institutions such as the Swiss Federal Research Institute for Forest, Snow and Landscape (WSL). They proved that Geobrugg single-level ring net barriers can retain up to 1’000 m³.

**The test site in the Illgraben (Canton Valais / Switzerland)**

With an average of four to six debris flows per year, the Illgraben is one of the most active debris flow rivers in the Swiss Alps. It has been monitored by the WSL since 2000. Geophones measure the rate of progression of a debris flow. Lasers are also installed for determining the flow height. A debris flow weighing system supplies information on the weight and density of debris flows. Video cameras plot interactions of the debris flow with the barrier and force measuring cells measure the load on the support ropes during the debris flow event.

**Overtopping of flexible ring net barriers...**

The test barrier was constructed in the Illgraben river bed, together with the necessary earthworks in just one week at the end of April 2006. By 18. May 2006 this barrier had already retained a debris flow of approx. 1'000 m³. After being filled it was overtopped without damage. By October, five further debris flows totaling several 10’000 m³ had occurred (see image sequence at the bottom of the page).

**...as verification for multilevel ring net barriers**

These overtopping events proved that ring net barriers in a multilevel configuration can also successfully handle far greater volumes with rates of flow of up to 6 m/s. This was also confirmed by the evaluation of a debris flow event in the Merdenson channel (Canton Valais / Switzerland) where a cascade of three debris flow barriers is installed.

The Geobrugg flexible ring net barriers shortly after installation (top) and after the second debris flow (bottom): They satisfied the load test successfully in all respects.
Debris flow barriers are strong systems that can withstand the enormous forces of debris flows. Properly dimensioned flexible ring net barriers represent an effective, multifunctional retention system. Together with the WSL we have developed two programs to enable this to be adapted to anticipated events and the topographic circumstances:

The dimensioning software DEBFLOW, meticulously calibrated specifically for the reaction and interaction characteristics of the Geobrugg flexible debris flow barriers with all its components, is based on results from dozens of full scale field tests and laboratory experiments. Consequently both product performance and the dimensioning concept have been validated. DEBFLOW is available to our clients online on request.

With the FARO software we have at our disposal a sophisticated simulation program: With this we can not only simulate the effect of debris flows but also determine the loads through rockfall, avalanche or snow slide.

**Situation 1:** The first wave impact strikes the ring net with basal passage. The debris flow front reaches the installed ring net. Hydrostatic pressure ($P_{hyd}$) and a dynamic component impinge on the lower support rope, distributed over the height of flow ($h_f$). It is dependent on velocity, density and type of the debris flow.

**Situation 2:** The second wave impact surges over the stopped first wave with flow height $h_f$.
Now the hydrostatic pressure ($P_{hyd}$) acts over the filling height $2\times h_f$. With the second impact the dynamic component wanders up in its influence zone. The extra load of the second impact drains the material of the first.

**Situation 3:** Another wave impact fills the net. The total number of wave impacts until the net is filled depends on the flow height and the height of the ring net barrier. The sequence is identical to situation 1 and 2. The next wave surges over the material already stopped. The hydrostatic pressure ($P_{hyd}$) acts over the filling height and the dynamic shock over the flow height ($h_f$) of the third wave. The hydrostatic pressure is reduced slowly depending on the nature of the material, drainage behavior and filling time and approximates to the active earth thrust.

**Overtopping:** The next surge overtops the filled net. It acts on the ring net with the extra load of the debris flow $\sigma$ and its shear force $\tau$.

No further pressure surge acts on the net after overtopping. The weight of the overtopping debris flow and the shear force act on the retained material: The hydrostatic pressure acts with an additional component from the shear force and the extra load of the debris flow ($\sigma + P_{net}$). The hydrostatic pressure can fall according to the drainage behavior of the material and the duration of the filling process (see the blue dotted line).
In its simplest form — without brake rings — the Geobrugg system is ideally suitable as a barrier for driftwood and rubble. Why? Because in this application only a static load is present. This has been confirmed with other tests carried out by the Munich Technical University in Füssen/Germany.

Tests
The dimensioning of flexible ring nets for rubble and driftwood is based on a comprehensive model and 1:1 field tests at the TU Munich (Rimböck, 2002). The 18 field tests took place in the Lehenbachtal in Halblech/Füssen, building upon the detailed laboratory experiments. Similar to tests with debris flow barriers, the rope forces were measured on impact and on further filling by released driftwood. Flows of between 5 and 30 m³/s were able to be covered in the tests.

Results
The filling process was observed in detail in the course of the performed laboratory experiments. Initially the wood was caught up on the bottom support ropes before filling the net from bottom to top. A carpet-like backup of driftwood was formed.
wood formed horizontally at the same time (after overtopping). The retained wood acts against the flow, causing a swell with height $h_B$ to form at the net.

In the tests the static loads were measured after the entry of all the wood and the termination of all redepositions. A possible calculation statement of the net force is represented in the adjacent figure by means of the difference between the hydrostatic pressures in the subsurface water ($W_O$) and the tail water ($W_U$). Compared with the measured values from the 1:1 field tests, the dimensioning statement is above the effectively measured load due to the permeability of the ring net. Moreover, the field tests confirmed that the dynamic loads on the impact of wood are low compared to the high static loads of the wood blockage and the through-flowing water: In the tests they were some five times lower than the static loads.
Long service life and ease of maintenance: two decisive aspects.

Durability...
In their unfilled state, flexible ring net barriers stand in the streambed and provide retention space that can stop large amounts of debris flow material. 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 GEBRUG SUPERCOATING® zinc/aluminum coating. Compared to traditional galvanized ropes and wires this increases the service life by at least three times.

...and abrasion.
To ensure that in an event the barriers can withstand the weights and are not damaged by being overtopped, the top support ropes are provided with so-called abrasion protection profiles. They prevent abrasion (sand paper effect) taking place at the support ropes and nets. Our profiles are made from thick walled steel with a wear capability. They are also simple to replace on a modular basis.

Where barriers remain filled over long periods, it must be ensured that water, rubble or further debris flows only over protected parts, such as the abrasion profiles. Such barriers are to be periodically checked in each case.

After an event...
Barriers that have retained a debris flow must be inspected, emptied and maintained in order to restore the retention volume. 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 re-construction work on the barrier is of much less significance.
Decisive points for the ordering party, planner and contractor.

Light 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.
- Normally the river channel does not have to be dammed up or diverted.
- No access road is necessary.

Environment-friendliness
- The construction blends into the landscape and compared to massive constructions is hardly visible from a distance.
- The CO2 footprint is clearly better than with concrete structures.
- Protection of water resources is guaranteed during the construction phase.

Profitability
- In the case of an event, the investment will substantially reduce claims for damages.
- Delivery and installation are 30 to 50 % less costly than for concrete structures.

Performance verification / engineering dimensioning
- The WSL has determined the input parameters in a research project with actual debris flow events and in a series of laboratory experiments.
- DEBFLOW, our online dimensioning software permits risk and project related planning and the FARO program provides a realistic emergency simulation.

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

Simple maintenance after events
- Impounded boulders/rubble can be simply dredged / excavated or removed manually after taking down the ring net.
- A backfilled barrier can be left standing as a fixed barrier or check dam.
System variants at a glance

Debris flow barriers without posts

<table>
<thead>
<tr>
<th>Type</th>
<th>VX060L-H4</th>
<th>VX080-H4</th>
<th>VX140-H4</th>
<th>VX100-H6</th>
<th>VX160-H6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation height</td>
<td>2 - 4 m</td>
<td>2 - 4 m</td>
<td>2 - 4 m</td>
<td>5 - 6 m</td>
<td>5 - 6 m</td>
</tr>
<tr>
<td>Span width</td>
<td>up to 10 m</td>
<td>up to 15 m</td>
<td>up to 15 m</td>
<td>up to 15 m</td>
<td>up to 15 m</td>
</tr>
</tbody>
</table>

Debris flow barriers with posts

<table>
<thead>
<tr>
<th>Type</th>
<th>UX100-H4</th>
<th>UX160-H4</th>
<th>UX120-H6</th>
<th>UX180-H6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation height</td>
<td>2 - 4 m</td>
<td>2 - 4 m</td>
<td>5 - 6 m</td>
<td>5 - 6 m</td>
</tr>
<tr>
<td>Span width</td>
<td>up to 25 m</td>
<td>up to 25 m</td>
<td>up to 25 m</td>
<td>up to 25 m</td>
</tr>
</tbody>
</table>

VX/UX 060-180 ... = resistance to debris pressure and impulse during stopping, filling and overtopping process

VX/UX ... H4/H6 = maximum installation height in meters

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 four continents, we can offer not only short delivery paths and times, but also optimal local customer service. With a view towards a 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).

Debris fl ow barriers without posts

Debris fl ow barriers with posts

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