ROCKFALL-X™ damping system makes rockfall protection galleries even stronger

The ideal solution for existing and new rockfall protection galleries:

- Better load distribution and enhanced damping properties without reinforcement of the structure
- Lightweight construction for new galleries
- Improved safety for workers through swift installation
- Permanent or temporary protection against rockfall for concrete galleries, roofs, or other objects that need to be protected
ROCKFALL-X™ G damping system: New solutions in the area of protection

Rockfall protection galleries at Mattstock and Churfirsten, Weesen, Switzerland

Initial situation
The state highway between Weesen and Amden is at risk of falling rocks and boulders. Since 1978, it has been protected by the two rockfall protection galleries Mattstock and Churfirsten, which are 110 and 155 meters long respectively. In accordance with the applicable standard, the two galleries can withstand impact energies of 300 to 500 kJ.

Special requirements
The latest geological expert opinion states that, with a return period of 30 years, one must expect significantly higher impact energies of up to 1'900 kJ. On the basis of the current risk analysis, the decision was made to reinforce the two galleries accordingly.

The chosen solution
With its extremely lightweight construction, the ROCKFALL-X™ G damping system improves the protection on the roof of the rockfall protection galleries, and at the same time reduces the static loading considerably. The conventional gravel damping material is replaced by the specially constructed damping modules, which are filled with cellular glass, and an additional TECCO® mesh covering.

The significantly lower unit weight of the overall system allows the volume of damping material to be increased by a factor of between six and eight without placing any additional load on the gallery structure.

ROCKFALL-X™ G damping system with cellular glass ballast
The intelligent damping system provides support quickly, simply, and effectively. When an impact occurs, the damping system dissipates the impact energy over a wider area, thereby activating more material than in the case of conventional damping materials. This considerably reduces the penetration force to which the protection gallery is subjected.
TECCO® mesh
The centerpiece of the ROCKFALL-X™ G damping system is the TECCO® G65/3 high-strength steel wire mesh. It is laid horizontally over the damping material, and has a tensile strength of 150 kN/m. In the case of maximum load events, the TECCO® mesh, together with the damping material, dissipates the impact energy in an elastoplastic manner. The area over which the residual impact energy is imposed on the gallery structure is enlarged, thereby significantly increasing the capacity of the overall protection system.

Longer service life
The TECCO® mesh is protected with GEOBRUGG ULTRACOATING®. This third-generation zinc/aluminum coating provides a service life that is six to ten times that of conventional galvanized wires. This has been demonstrated in salt-spray comparison tests.

Cellular glass ballast as damping material
Cellular glass is produced from recycling glass in grain sizes of between 10 and 50 mm, and has a cube compressive strength of 6 N/mm². With its density of 250 kg/m³, it is six to eight times lighter than conventional gravel. The damping material is supplied in cellular glass modules of 2 m³ (2 m high, diameter 0.95 m), each of which are encased in TECCO® mesh. In the event of an impact, the TECCO® mesh restricts lateral deformation of the damping material in order to provide optimal energy absorption.

The cellular glass does not contain any capillary pores, and is thus frost-proof. To ensure that the damping modules are permeable and allow water to flow away, the coverings are fitted with drainage openings at the factory.

Enclosing rope (optional)
An enclosing rope combines multiple cellular glass modules into larger units. During an impact, the horizontal forces are transmitted into the enclosing ropes, preventing the damping material from expanding laterally.

A vertical concrete end wall can provide an alternative means of lateral containment depending on the project-specific details.

Damping potential:
Depending on the concrete construction of the structure and the arrangement of the damping units, impact energy of up to 5'000 kJ can be absorbed.
Structure protection with ROCKFALL-X™ A: used tires as an economical component of the damping system

Rockface protection, R 11 Reigeldossen section, Lopper, Switzerland

Initial situation
Beginning in December 2008, traffic was diverted away from the rockfall-prone north face of the Lopper and through the Kirchwald tunnel. However, both slow-moving and local traffic continued to use the existing freeway. To protect road users, the Swiss Federal Roads Office arranged for rocks to be cleared from the slope.

Special requirements
At the R 11 Reigeldossen section, the 200-meter-high cliff face directly meets the freeway viaduct and the major cantonal road below it over a length of 150 meters, at an angle of 70°. In order to protect the viaduct and the road against damage while rocks are being cleared from the slope, special measures were urgently required.

The chosen solution
The freeway viaduct was protected using 1'500 m² of the ROCKFALL-X™ A damping system, which consisted of seven layers of used tires and high tensile TECCO® mesh.

The work was completed in the summer of 2011. The temporary protective measure provided the ideal protection during these rock clearance works.
Used tires as a damping material
When car tires are no longer safe for driving, they can still act as damping material, providing lasting protection. The used tires are stacked in layers with wire cables combining them into panels in sizes of approximately 1.8 x 7.2 meters.

TECCO® mesh
The TECCO® steel wire mesh is laid horizontally between the layers of used tires (see illustration). In the event of a rockfall, the high-strength construction distributes the point loading that arises through the boulder impact.

Damping potential:
It is possible to use up to fifteen layers of used tires for impact energies of up to 5'000 kJ.

ROCKFALL-X™ A damping system with used tires: a convincing system with two components

The ROCKFALL-X™ A damping system with used tires is suitable for use as protection of at-risk man-made structures, protection against flying rocks in the case of safety explosions, or for rock clearing work.

The ROCKFALL-X™ A damping system with used tires is up to fourteen times lighter than gravel-based damping material.
In cooperation with ETH (the Swiss Federal Institute of Technology Zurich) and WSL (the Swiss Federal Institute for Forest, Snow, and Landscape Research), extensive laboratory and field tests have been carried out on a large scale. The central focus here was on the impact loading of rockfall protection galleries. In each case, they were fitted with the ROCKFALL-X™G damping system with cellular glass ballast, or the ROCKFALL-X™A, comprising used tires in combination with the TECCO® high-strength steel wire mesh.

The results speak for themselves: the highly effective damping behavior of ROCKFALL-X™ was successfully demonstrated with both cellular glass ballast and used tires.

The research work, which was actively supported by Geobrugg AG, has made a decisive contribution towards the development of guidelines for future rockfall protection galleries, and for the evaluation methods for existing structures by the Swiss Federal Roads Office.
Quick installation
Installation is simple, and can be carried out quickly, resulting in greater safety for workers.

Step by step:
- The gallery roof is exposed (picture 1)
- Drilling / fixing of the rope anchors for optional horizontal bracing
- Damping units with the filler material are placed by crane or helicopter (pictures 2 and 3)
- Installation of the optional horizontal enclosing rope (picture 4)
- Installation of the horizontal TECCO® mesh (picture 5)
- Finally, the optional addition of approximately 15 cm of gravel as a top layer (picture 6).

Easy to maintain
After each rockfall event, the boulders are removed and all system components are checked for damage. In the event of a major incident, it is recommended that the top 10 to 20 centimeters of damping material be replaced. Although the gallery roof can be greened over without impairing its protective function, the planting of trees should be avoided for safety reasons.
**ROCKFALL-X™**

**Benefits at a glance**
- Economical solution for the repair of existing protection galleries
- Increases the dynamic load-bearing capacity
- Reduces the static loading
- Improved dimensioning of future protection galleries, through optimum design and innovative construction materials
- Quick and easy installation
- Problem-free maintenance

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**ROCKFALL-X™ G damping system with cellular glass ballast**

<table>
<thead>
<tr>
<th>Cellular glass ballast</th>
<th>Cube compressive strength</th>
<th>&gt; 6 N/mm²</th>
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<tbody>
<tr>
<td></td>
<td>Frost-proof</td>
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<tr>
<td></td>
<td>Weight &lt; 250 kg/m³</td>
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<tr>
<td></td>
<td>Cellular glass module, standard size 2 meters high, diameter 0.95 meters</td>
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<td></td>
<td>Special heights available, from 1.3 meters to 2 meters, in increments of 10 cm</td>
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<thead>
<tr>
<th>TECCO® G65/3 mesh</th>
<th>Strength 1'770 N/mm²</th>
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<tbody>
<tr>
<td></td>
<td>Delivery size for cellular glass modules in rolls of 2 x 30 meters</td>
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<tr>
<td></td>
<td>Delivery size for horizontal covering in rolls of 3.5 x 30 meters</td>
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<tr>
<td></td>
<td>Weight 1.65 kg/m²</td>
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<td></td>
<td>Corrosion protection GEOBRUGG ULTRACOATING® Zn/Al coating</td>
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**ROCKFALL-X™ A damping system with used tires**

<table>
<thead>
<tr>
<th>Used tires</th>
<th>Diameter 60 cm and height 20 cm</th>
<th>Connected into panels with 10 mm diameter wire cable</th>
<th>Weight &lt; 125 kg/m³</th>
<th>Delivery size in panels of approximately 1.8 x 7.2 x 0.2 meters</th>
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**Product liability**

Rockfalls, landslips, debris flows and avalanches are natural events and are therefore unpredictable. It is therefore impossible to determine or to guarantee absolute safety for people and property using scientific methods. This means that, in order to ensure the desired level of safety, protective systems must be checked and maintained appropriately at regular intervals. Moreover, events that exceed the rated capacity of the system, failure to use original parts, or corrosion (e.g. through environmental pollution or other external influences) can all reduce the level of protection.

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Technical details subject to change.