Successful hazard prevention using flexible multi-level barriers

Corinna WENDELER[1*], Axel VOLKWEIN[2], Andrea ROTH[1] and Nobuhito NISHIMURA[3]

1 Geobrugg AG, Switzerland, e-mail: info@geobrugg.com
2 Swiss Federal Institute for Forest, Snow and Landscape Research WSL, e-mail: axel.volkwein@wsl.ch
3 Geobrugg Japan K. K, e-mail: nobuhito.nishimura@geobrugg.com
*Corresponding author. E-mail: corinna.wendeler@geobrugg.com

The villages Hasliberg Reuti and Meiringen were affected by flood and debris flow events during unusually large rainfall in August 2005. Around 13,000 m^3 of the weathered schist material in the catchment were mobilized and transported in three surges down the channel. Additional 25,000 m^3 were entrained along the flow path, increasing the volume of the flow to around 40,000 m^3.
Due to the difficult natural basic conditions in the catchment area with permanent sliding alénien schist material with very low friction coefficient if water is infiltrated, conventional preventive stiff measures could not be used there because of foundation problems. A promising new solution was selected with 13 flexible ringnet barriers providing a total retention capacity of 12,000 m^3.
On 10th October 2011, again a big storm occurred at Hasliberg area with a 100 year flood declared from Federal Office for the Environment FOEN. Around 2,000 m^3 of material got mobilized in the catchment area of Hasliberg by a shallow landslide flowing into the torrent. One barrier got filled completely and two others half. The new protection measure installed in 2008 predict a bigger debris flow event by stopping already the material in the catchment area and avoid further erosion of the flow process river upstream which happened in August 2005.

Key words: Debris flow prevention, multilevel ringnet barriers, shallow landslides

1. INTRODUCTION

The Milibach rises in the Gummen Region at the watershed of the Oberhasli to the Canton Obwalden. On its way down it flows through the eastern to the western part of the Hasliberg settlement and flows after a deep canyon into the Aare River. The local situation can be seen in Fig 1.

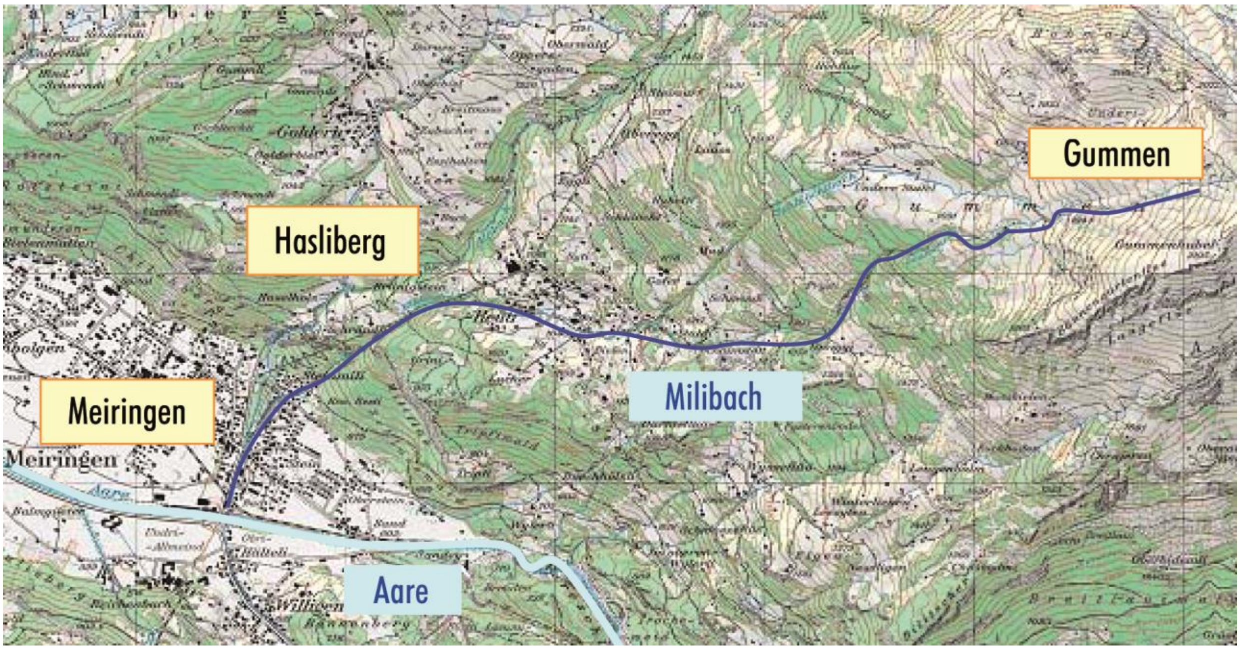

Fig. 1 Situation of the Milibach, taken out of LK 1:25'000, Number 1209 Innertkirchen.

The valley of Gummen is made of slope parallel black clay rich alénien schist (Alénienschiefer). Sometimes there are some parts of sandstone in between. The slope parallel schist is very sensitive to weather and acts as aquiclude (Wenger, 2006).

This formation is overlaid by a weathered, several meter thick debris layer. This layer forms the origin for the debris flow material and consists of weathered part of the upper Doggers. Parts of moraines are only infrequently within the debris.

The debris is a very clayey, silty and also sandy with a lot of bigger stones and bolders. If the material is dry its internal friction angle φ' lies between 25-28° with an apparently cohesion of c' = 0-3 kN/m^2. If the material is saturated with water, these values rapidly get lower, even the internal friction angle reach values of 15°. After wet periods with a lot of rainfall these packets of granular soil are mobilized as hillslope debris flows and transport the debris into the river. Very particular is the low plasticity of the material. The part of clay and silt is 15-20 %. This fact is a very big problem for the disposal construction because they have to be built very flat with retaining walls (Wendeler et al. 2008).

Fig. 2 Catchment area with the Milibach in the Gummen region

Fig. 3 Alénien schist material.

2. BACKGROUND: EVENT 2005

In August 2005 during heavy rainfalls the settlements of Hasliberg Reuti and Meiringen were flooded. The debris flows triggered at the Gummen catchment area caused the main disaster at infrastructure.

Around 13,000 m^3 of the weathered schist material in the catchment were mobilized during the intensive rainfall and were transported within 3 surges down the channel. Along its way down further 25,000 m^3 were picked up by erosion processes and expand the total volume of the flow up to 40,000 m^3.

The flow velocities of this event could be determined reliably to 7 up to 9 m/s out of the superelevation. The velocities, flow heights and flow discharges can be recalculated as a turbulent Newton flow regime after Cheyz or Strickler.

Fig. 4 Caused damages in Meiringen in 2005.

Fig. 5 Deposited debris in the village of Meiringen (violet)

The marginal shear stress could be approximated out of border deposition after the events to 600 / 1100 N/m^2 hence these debris flow were muddy flows. The water content of the flows was around 50 %. The density of the flow itself was in the range of 18 - 20 kN/m^3 (Wendeler et al. 2008).

3. PROPOSED PROTECTION MEASURE WITH FLEXIBLE NETS AT THE GUMMEN

To avoid damages like in 2005 one measure of the complete protection measure concept of the village Hasliberg and Meiringen was to place 13 multilevel flexible barriers in the catchment area Gummen. To stop the starting debris flows already there before developing the enormous erosion potential flowing down the channel seemed to be reasonable. Flexible structures with nets are the best solution because of the unstable alénien schist material which is creeping and moving. Fix and stiff protection measures like concrete check dams will result in a lot of maintenance work because of cracks and eroded foundations.

The design parameter for the flexible nets were reconstructed from the past event in 2005 and are shown in table 1 (Herzog Ingenieure, 2006).

The design and dimensioning of the barriers was done as described in Wendeler (2008). The flow regime of the design debris flow is given in terms of flow height, flow velocity. The expected debris density describes the texture of the debris flow, i.e. whether a granular or muddy event is expected. The load model is based on hydrostatic and dynamic pressures acting on the barriers. The pressures are distributed over the barrier height according to its filling state. The filling process is discretised over time: the barrier is filled stepwised with filling steps equal to the flowing height. This discretisation considers the impacted material as stopped and loading the barrier statically. The further material is modeled to arrive on top of the settled material transferring hydrostatic and dynamic pressure. If the oncoming debris volume exceed the barrier's retention capacity the load case overflow is considered as well.

Compared to rockfall, debris flows are characterized by distributed loads instead of a punctual load, longer braking time, smaller deflection and several surges arriving onto the net. The dimensioning of the flexible ring net barriers was carried out using the finite element software FARO (Volkwein 2005). The program has initially been developed to simulate the impact of a rigid body into a net structure and therefore for simulation of rockfall protection net structures. For the simulation of debris flows nodal forces are applied to the element nodes equivalent to the acting impact pressures and varying over time. The simulations have been validated with measurements of real scale field tests at the Illgraben torrent (Volkwein 2014).

For the dimensioning of the 13 nets at the Gummen project, the following load cases have been considered:

Granular debris flows
Muddy debris flows
Static load (active earth trust value)
Snow (gliding and impact of an avalanche)
Overload case

Tab 1: Debris flow design values.

Parameter	Design Value	Overloading case
Channel inclination	30 %	-
Type of debris flow	Mud flow, viscous flow	-
Total volume	10,000-15,000 m^3	-
Surge volume	5,000 m^3	-
Flow bulk density	18 - 20 kN/m^2	18 - 22 kN/m^2
Max. discharge	60 m^3/s	100 -150 m^3/s
Flow height	1.5 - 2 m	-
Flow velocity	6 - 12 m/s	up to 18 m/s

Barrier number 1 (first from the top) was calculated as a so called "debris flow breaker". The highest intensity level of debris flow was simulated for this first barrier. In the case of failure of this barrier because of overloading case in fact the retained volume of this barrier will be lost but already energy will be absorbed of the debris flow itself.

Barrier number 2 was additionally dimensioned to absorb the energy of an avalanche acting on the barrier with an impact angle of 10 degrees. Furthermore, results showed that for snow gliding, the forces in the cables do not reach the activation threshold of the brake elements and therefore do not have to be specially secured in winter time.

Calculations showed that for the given heavy requirements, only nets with very high resistance may be used for this project. Therefore, the net component like the ringnet, ropes and brake rings used are the strongest elements available at the moment.

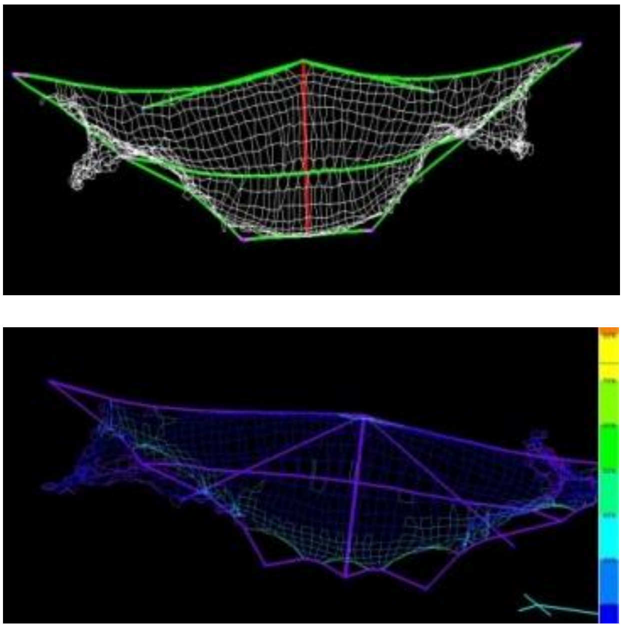

Fig. 6 Simulation of representative barrier for project Gummen using the software FARO.

The performed cost sensitive analysis done by the Canton of Bern only looking at the netting protection without the other measures done in that protection concept showed that the annual costs to avoid a 100 year flooding should not be higher than 1.3 Mio CHF. With the nets and the complete maintenance concept for a life time span of 20 years the complete costs for the nets are 177,000 CHF per year and are so 7 times cost effective. Additional remark, only with the protection nets the damages in the villages Hasliberg and Meiringen can be reduced for a 30-year debris flow event from 65 Mio CHF to 10 Mio CHF and for a 100-year event from 69 Mio to 65 Mio CHF (Wendeler 2008).

Fig. 7 Final project realization of the 13 flexible barriers in line.

The final installation of the 13 barriers in line was finished in 2009. Since that date regular inspection visits of the "Schwellenkooperation" (regional community for water engineering) are done to maintain the system in regular frequencies. Small blockage of the basal openings are cleaned out and height measurements of them are performed.

4. EVENT ON OCTOBER 10, 2011 AT GUMMEN HASLIBERG

On October 10, 2011, a big storm happened again. The main problem was that before in another rainfall storm more than 70 cm of snow fallen in the Berner Alps. Next day up to the lunch time on Monday the rainfall in the Berner Alps summarized in the last 12 hours up to 80 mm. The fresh water entry by rainfall plus the stored water by the snow fall of up to 70 cm resulted in flooding of mountain rivers, slope failures and landslides. In the Berner Alps the federal institution for environmental concerns BAFU declared this storm to a 100 year flood.

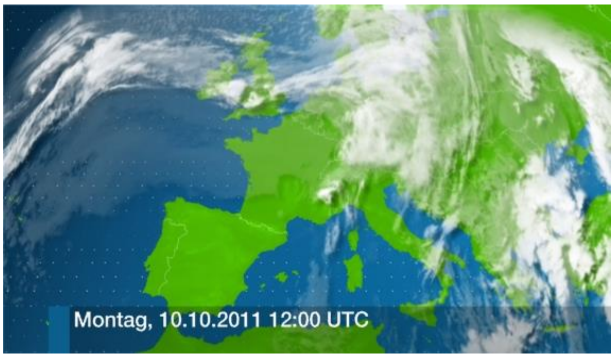

Fig. 8 Satelite picture of storm 10th October crossing the northern Swiss alps (source: SF meteo webpage).

Around 2,000 m^3 of material got mobilized 10th of October, most of the material by a shallow landslide close to flexible net No 2 from the top (see figure 9).

Fig. 9 Shallow landslide close to flexible barrier No 2 caused the filling of this net.

Flexible net No 2 got filled up to the max. level and flexible net No 5 filled up to half net height (see figure 10 and 11). The nets in between did not filled up because of their higher basal opening, the gap between the lower support rope and the river bed.

Fig. 10 Stopped material behind net No 2

Fig. 11 Stopped material behind net No 5

5. CONCLUSION

The customer, the two villages Hasliberg and Meiringen as well as the designer of this multi-level protection concept are satisfied with the function of the nets in the 2011 storm because without the barriers, the 2,000 m^3 of the 100-year flood would have eroded more material along the channel and could have caused much more damages again to Hasliberg village.

The customer as well as the geologist of this project decided to leave first net No 2 filled in the torrent to stabilize the foot of the shallow landslide at the slope to the right view river upstream. Net No 5 will be cleaned with normal water flow, some maintenance work will be required caused by eroded anchors. But this aspect is hard to avoid in an event case in such a loose soil condition of alénien schist material.

Also the complete developed design concept of the dimensioned barriers was proven by this event. No failure of the directly impacted barrier No 2 was happening even the shallow landslide brought a total volume of around 2,000 m^3 at once impacting the barrier. The material retained behind the barrier look dense with an estimated density of the slide of around 2,000 kg/m^3. To recalculate the impact forces of the slide to the barrier the velocity plays an important role. In that case for 30° inclined slope it can be estimated to max. 10 m/s. Flow height of the slide are much harder to estimate and cannot be declared thus impact pressure acted on the barrier No 2 unluckily cannot be back calculated precisely.

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