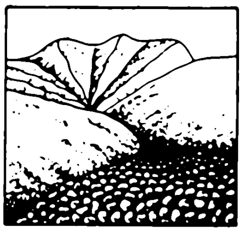
Труды Международной конференции

СЕЛЕВЫЕ ПОТОКИ: катастрофы, риск, прогноз, защита

Пятигорск, Россия, 22-29 сентября 2008 г.



Ответственный редактор
С.С. Черноморец

Институт «Севкавгипроводхоз»
Пятигорск 2008

Proceedings of the International Conference

DEBRIS FLOWS: Disasters, Risk, Forecast, Protection

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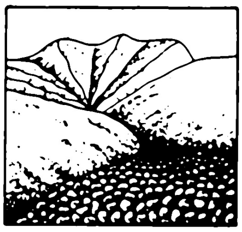

Edited by
S.S. Chernomorets

Sevkavgiprovodkhoz Institute
Pyatigorsk 2008

УДК 551.311.8
ББК 26.823

Селевые потоки: катастрофы, риск, прогноз, защита. Труды Международной конференции. Пятигорск, Россия, 22-29 сентября 2008 г. – Отв. ред. С.С. Черноморец. – Пятигорск: Институт «Севкавгипроводхоз», 2008, 396 с.

Debris Flows: Disasters, Risk, Forecast, Protection. Proceedings of the International Conference. Pyatigorsk, Russia, 22-29 September 2008. – Ed. by S.S. Chernomorets. – Pyatigorsk: Sevkavgiprovodkhoz Institute, 2008, 396 p.

Ответственный редактор: С.С. Черноморец
Edited by S.S. Chernomorets

Редакция английских аннотаций: К. Маттар и О. Тутубалина
English versions of abstracts edited by K. Mattar and O. Tutubalina

При создании логотипа конференции использован рисунок из книги С.М. Флейшмана «Селевые потоки» (Москва: Географгиз, 1951, с. 51).
Conference logo is based on a figure from S.M. Fleishman's book on Debris Flows (Moscow: Geografgiz, 1951, p. 51).

ISBN 978-5-91266-010-8

ROCCO® barrier systems for debris flows control

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Барьерные системы ROCCO® для контроля селевых потоков

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Селевые потоки – естественная опасность, которая похожа на сочетание наводнения и оползня. Селевые потоки – причина регулярных серьезных убытков в горных областях. Традиционные меры уменьшения ущерба от селевых потоков могут включать сооружений дорогостоящих жестких конструкций, таких как селезадерживающие дамбы. Гибкие барьерные системы, состоящие из соединенных колец, являются новой дешевой альтернативой и уже успешно использовались для того, чтобы сдерживать селевые потоки. Многоуровневые (каскадные) барьеры для контроля селевого потока были установлены и успешно использованы для многократного увеличения задерживающей емкости.

Debris flows are a natural hazard which look like a combination of flood, land and rock-slide. Debris flows regularly cause severe damage in mountainous areas. Traditional mitigation measures against debris flows may involve construction of expensive rigid structures such as sediment retention dams. Flexible ring-net barrier systems provide a new low-cost alternative and have already been successfully used to control flows. Multi-level (cascade) debris flow control barriers were installed and performed successfully in order to multiply the retention capacity.

1 Introduction

After the successful result of the introduction of the Geobrugg ROCCO® ring-net several years ago, in the Rockfall Protection Systems, and as a result of the necessity of the avalanche control of materials dragged by the action of the water (rocks, mud, trees, etc.), Geobrugg was studying the possibilities of placing properly braced, this type of ring-net within the natural channel of these flows, obtaining with it to stop the heavy and dangerous blocks, trees and let pass the water. During the last years, several events of trawling materials (rock blocks, mud, remnants of trees and snow), which were successfully intercepted by barriers dynamic ring-net, originally set for rockfall protection. In February 1995, a debris flow of 60 m^3 was held back by a rockfall barrier of BRUGG Cable Products Inc. (BCPI) along California State Road 41 (County of San Luis Obispo). The road was not affected by the natural hazard. As a result of this event detailed studies were carried out in the year 1996 by the United States Geological Survey (USGS), the California Polytechnic State University (CALPOLY) and the California Department of Transportation (CALTRANS). On the test flume of H.J. Andrews Experimental Forest, Blue River, Oregon the debris flow load on different protection barriers under different conditions was analyzed. In 1.998 the RX-150 system (1.500 kJ) installed in Aobandani, Japan stopped a debris flow with a volume of 750 m^3. In March 2.000

a 200 m^3 debris flow hit a RX-075 barrier (750 kJ) in Seewalchen, Austria. In November of 2001 in Fikushima, Japan, happened a snow sliding of a volume of 400 m^3, that was stopped by a barrier RX-075. In 2002 in Japan the Tabata's project was made, which has stopped events that have been recorded of more of 3.000 m^3 of blocks and mud.

Fig. 1. Tateyama. Tabata´s project.

After storms of the winter of 2002 in Santa Cruz de Tenerife in the Canary Islands, Spain, Geobrugg designed and installed a solution of debris control by means of two lines of barriers, with capacity of 850 m^3. In 2004 was installed in the port Gaviota the South of California, Highway 101 (Fig. 2), barriers for debris flow control. In June happened an event that dragged a volume 300 m^3, it was contained successfully by the installation. Since 2002 Geobrugg has continued installing several ring–net barriers to protect against debris flows, which have worked properly.

Fig. 2. Illustration of filled barriers at Gaviota Pass and The Narrows (CA, USA).

2 The barrier system

The Geobrugg VX/ UX Protection System against Debris Flow is based on the approved and from independent institute certified RX Protection System against Rockfall. Due to the aerial load of debris flows some adaptations are necessary: stronger support ropes, brake elements with higher capacities and weaker ROCCO® ring-net because of the distributed load; stronger anchorage; protection of the top support ropes against abrasion (Roth, 2003). The permeable construction of a Geobrugg VX/ UX ring-net barrier an impacting granular debris flow is drained as a result of the retention of rougher material and the passing of water and fine parts. Through this dewatering a certain length of the debris flow is stopped which stops afterwards the rest of the flow. The energy of a debris flow is mainly absorbed by the brake elements. The task of the ring-net is to carry the load to the support ropes. The

ROCCO ring-net has a proven capacity to absorb punctual impacts and has therefore ideal features for debris flow impacts because most of the large blocks in a granular debris flow are transported at the front of the flow. Experiences show further that the links between ROCCO rings are stronger than the clips of wire rope nets. For the location of a barrier a torrent section as straight as possible should be chosen. The inclination should be as small as possible to reduce the impact velocity and to enlarge the retention capacity. The location should further be well accessible to ensure an immediate inspection and a cleaning of the barrier, if necessary. The bed at the barrier location has to be stable enough to withstand the anchor loads; otherwise additional protective measures have to be carried out. The abrasion protection has to be investigated accurately, if the barrier is intended to remain filled with debris. For location of a barrier a torrent section as straight as possible should be chosen. The inclination should be as small as possible to reduce the impact velocity and to enlarge the retention capacity. The barriers should be checked regularly and cleaned and repaired if necessary immediately after an event. Experiences show that the cleaning of a barrier is easily practicable. Engaged brake elements have to be replaced. This is the only repair effort to be done even after big events. If the barrier is intended to remain filled with debris, static loads and corrosion have to be considered. Debris flows mostly occur as a result of heavy rainfall but can also be triggered by other events such as melting snow or dam failure. The pre-conditions for the appearance of debris flows are mainly steep slopes, enough material which is easy to mobilize and enough water to trigger the flow. Under a mechanical point of view debris flows can be divided in two main types: *Mud flows*, which mainly consist of water and fine material, which is more or less uniformly distributed and *Granular debris flows*, which consist of water, fine and rougher material. The larger components are mostly accumulated at the front of the flow and play an important role in the overall flow behaviour of a granular debris flow. Observations of debris flows show that they mostly occur in surges. The observations show further that the velocity and the consistency of the surges may vary from surge to surge. Therefore it is important to use load parameters always with a sufficient variation. Although debris flow load parameters are crucial input data to dimension protection systems, only few research projects were carried out on this subject so far. This is a result of the still limited understanding of the mechanics of debris flows. It is further hard to measure debris flow parameters adequately during real events. Several mechanical and rheological models were proposed to analyze and predict debris flows. Due to the lack of field data for comparison, (Rickenmann, 2001) suggests to use empirical relationships. At the location of the barrier the stopped debris flow has to be modelled in the cross section. In most of the cases there are inclined banks and the experiences show that the maximum depth of the accumulated material is in the middle of the torrent. For simplifying it is assumed that the width of the flow corresponds to the average bed width. The idealized cross section of the stopped flow should have more or less the same area than the expected flow face. In order to dimension the barrier the energy is transformed to a quasi-static force. In doing so a linear deceleration is assumed. The dimensioning energy may not be compared with design energies of RX rockfall protection systems. The reasons for that are given in the following table:

Table 1. Debris flow flexible barrier compared to a rockfall barrier.

	Rockfall	Debris Flow	Influence of a debris flow on a flexible barrier compared to a rockfall
Load	Punctual (1 section)	Distributed (several sections)	positive due to smaller local loads
Impact time	0.2 – 0.5 s	1 – 4 s	positive due to smoother deceleration
Type of impact	single impact	in surges	negative due to static loads in the system after the first impact
Braking distance	5 – 8 m	2 – 3 m	negative due to higher dynamic forces

During 2005, within the scope of a CTI project (Commission for Technology and Innovation), began a field campaign to evaluate the performance of flexible ring-net debris-flow barriers, to provide data for use in developing design guidelines (Wendeler et al., 2006), and to investigate the impact and dewatering processes in detail. Inside this project a computer program was developed to simulate the impact of rocks into flexible ring-net barriers. The project was executed with collaboration of the ETH Zurich (Federal Institute of Technology) and the WSL Birmensdorf (Research Institute for Forest, Snow and Landscape). The software is called FARO (falling rocks) and was calibrated by using the data resulting from static pull tests of the single elements and 1:1 field trials. Using this simulation program is possible to model punctual impacts, and it's also possible to use for distributed impact loads. The figure 3 shows an impact of a debris flow into a UX system. It's assumed that the debris flow only hits the middle section and that it hits the barrier first in the bottom part and then fills up the whole system.

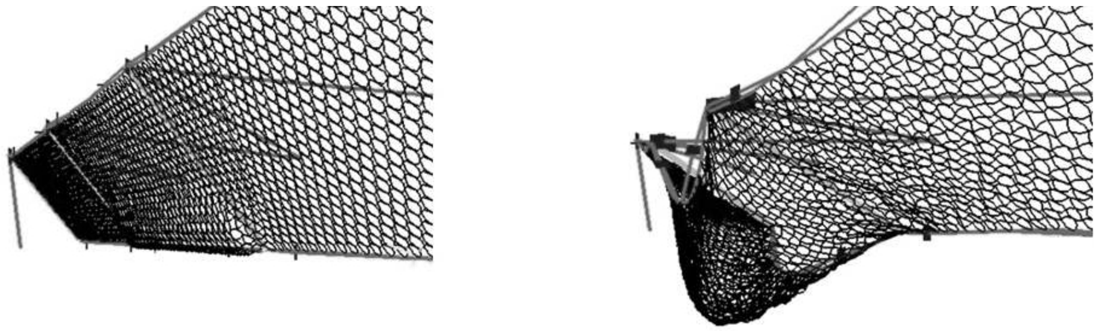

Fig. 3. Impact of the debris flow into the UX barrier (modelled with FARO)

3 Conclusions

The last results show that the debris flows, can be stopped using flexible barriers of steel ring-nets. For such cases, it has been possible to confirm that these flexible systems are an alternative to rigid systems, due to their great capacity of deformation, ideal to stop dynamic impacts. Due to the slight construction of the flexible barriers, they do not require of execution of access way, reason why they are easy to install and its cost in general is reasonable. Geobrugg VX/ UX Barriers can be used for two aims: *Debris flows stopped* halting of active detritus flows, retention of solid components within the flow to protect infrastructures, separation of the water and the solid material and *Debris flow control* substitution of concrete check dams, passive reduction of the erosive energy of the flow. Installed in series of several barriers in staggered form, it allows modification of the cannel average angle, as well as clear advantages by the significant lower cost of installation in difficult zones, and less affection to the environment. The steel rings net of the barriers are transparent and fit better in landscape than the massive steel or concrete structures.

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