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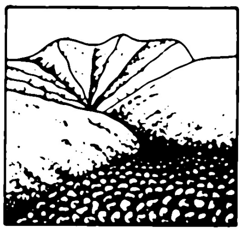

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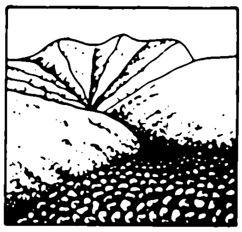

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При создании логотипа конференции использован рисунок из книги С.М. Флейшмана «Селевые потоки» (Москва: Географгиз, 1951, с. 51).
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Field observations in barrier systems against debris flows

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Полевые наблюдения за барьерными системами для противодействия селевым потокам

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В Швейцарии бассейн Иллграбен поставляет приблизительно 5 больших селевых потоков каждый год, которые сходят после интенсивных ливней. Измерения глубины и скорости потока, получаемые с регистрирующих устройств, в сочетании с данными о плотности позволяют определить объем селевой массы, отложенной выше задерживающего тестового барьера. В 2006 г. в 50 м ниже моста был установлен оборудованный приборами гибкий селезадерживающий барьер из сплетенных колец, имеющий высоту 4 м. Вскоре пространство за барьером было заполнено селевыми отложениями. Поверх заполненного барьера в последующие месяцы сошло много потоков. В данной статье приведены некоторые интересные заключения в отношении мероприятий на участке после нескольких селевых событий. События выше по течению после заполнения барьера позволяют выявить интересные особенности эволюции таких участков с барьерами во времени. Также рассказано о создании двух новых станций по измерениям селевых потоков в Испании, которые позволяют охарактеризовать потоки, формирующиеся при различных условиях.

In Switzerland, the Illgraben basin delivers approximately 5 large debris flows each year following intense rainfall events. Flow depth and velocity measurements combined with bulk density data from the logger system allow determination of the loads produced by debris flows as they approach the test barrier. In 2006 an instrumented 4m height ring-net barrier was installed, 50m downstream of the bridge, and was soon filled by a debris flow. The full ring-net was overtopped by many flows in the following months. This paper shows some interesting conclusions regarding the site measurements during some events. The over-topping events after the filling of the barrier are particularly interesting since this kind of systems must be lasting in time. Finally, we discuss the installation of two new measurement stations of debris flow in Spain, which allow the characterisation of flows under different conditions.

1 The Illgraben test site

Observations of debris flows at the Illgraben basin (area above the fan apex= 8,9 km^2), south-western Switzerland, began in 2000 for the purpose of collecting data for comparing and calibrating debris flow propagation models (Hurlimann et al., 2003, McArdell et al., 2003). The station has subsequently been expanded to provide additional information on the nature of the debris flow process. The mean volume for debris flows that reached the downstream end of the alluvial fan is around 25,000 m^3 based on 25 events observed from 2000 to 2005 and using the front velocity, channel cross-sectional geometry, and flow depth.

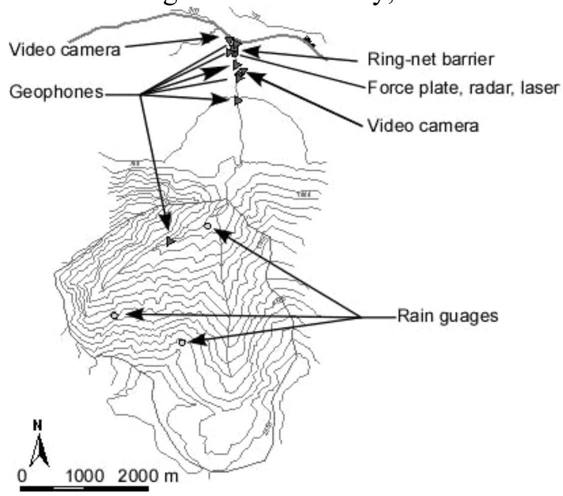

Fig. 1. Instruments location of at the Illgraben test site.

All the instrumentation at the Illgraben site is concentrated along the downstream 500 m of the main channel on a large 2 km long alluvial fan. The overall slope of the channel bed in this reach is about 8%, although it varies locally, especially through small abrupt decreases in bed elevation downstream of concrete check dams, which were installed to stabilize the channel. Instrumentation consists of geophones to measure debris flow arrival times at check dams for velocity measurement, depth measuring devices (ultrasonic, radar, and laser sensors) at several locations, video cameras to provide qualitative control on the nature of the flow, a force plate sensor for measuring normal and shear forces, and finally the test barrier immediately upstream of the confluence of the Illgraben channel with the main river in the valley. The force plate, an 8m^2 instrumented steel plate installed flush with the channel bed, allows us to determine the bulk density of the flow using from the flow depth and normal forces.

Fig. 2. Flexible ring-net barrier system at the Illgraben before and after filling.

The ring-net barrier tested at the Illgraben in 2006 it’s a Geobrugg Protection Systems VX-Barrier (without vertical support posts at the channel bottom), which is recommended for use on channels, such as the Illgraben, with channel widths smaller than 12 m to 14 m. The net used is made out of high tensile steel wire rings. The barrier is 4m height, with pairs of horizontal steel ropes at the top and bottom of the barrier, and additional pairs of steel ropes supporting winglet elements at the top of the net. Each steel rope is instrumented with a load cell (50 t capacity). Because large peak loads can be expected at the Illgraben due to large boulders (diameter > 2 m) transported at the debris flow front, special peak-energy absorbing brake rings have been integrated into the support ropes to absorb peak loads and protect the anchors, load cells, and support ropes.

2 Debris flow events during 2006

From mid-August 2006, were observed five important debris flows at the Illgraben observation station (Table 1).

Table 1. Debris flow events in 2006.

Date	Volume, m^3	Density, kg/m^3	Max flow height, m	Velocity, m/s	Comments
18 May	12,000	1.530	1.1	1.9	Watery front
24 June	50,000	1.520	3.2	4.8	Granular front
27 June	80,000	1.320	2.5	4.8	Watery front (granular body)
18. July	50,000	1.600	2.5	4.8	Watery front
28 July	10,000	2.130	1.4	2.0	Granular front

Debris-flow height is determined through the use of either the laser or radar distance measuring device mounted above the force plate (under the bridge). The debris flow volume is calculated from the front velocity, the cross-sectional area of the channel as a function of flow height at the force plate, and the flow depth at the force plate. Flow velocity for Table 1 was calculated over the 460 m distance between geophones fixed on two check dams. In comparison to debris flows with relatively distinct granular flow fronts, velocity errors (and consequently discharge and volume estimates) are somewhat larger for debris flows with significant pre-surge flow and watery flow fronts. The bulk density is calculated using the measured normal force values and the flow height. Because the force plate is relatively large, large non-lithostatic pressures resulting from strong vertical accelerations of boulders at the flow front are typically not observed with the force plate. These pressures would increase the bulk density values, which are occasionally observed with the force plate. The table summarizes the average bulk density calculated for flow depths larger than 90% of the maximum flow depth, because these values are representative of the head of the debris flow which is expected to deliver the largest forces when the flow reaches the barrier.

3 The filling and the overtopping of the debris flow barrier

The first event initially flowed under the barrier, which had roughly 0,5m gap between the bottom of the net and the channel bed, with subsequent surges or roll waves eventually catching on the bottom and starting the fill process.

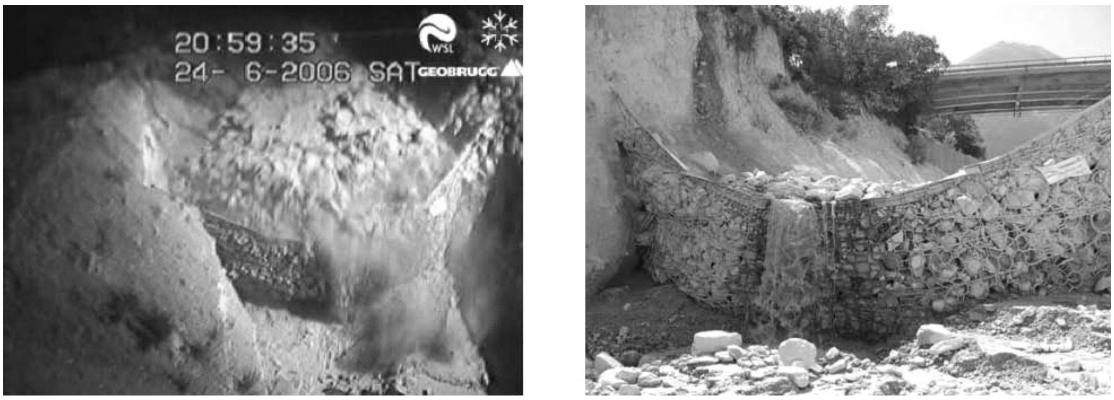

Fig. 3. ROCCO ring-net barrier during and after the 24 June debris flow.

During the several minutes it took to fill the net, substantial quantities of fine sediment and water flowed through the net, effectively retaining the largest grain sizes of sediment yet allowing significant volumes of sediment and water to pass. The maximum load was observed in the lowermost steel retaining rope; the uppermost ropes recorded significantly smaller maximum loads during the subsequent initial impact with the top rope as the barrier was filled. The 18 May event eventually filled the barrier, however the peak loads were observed when the debris flow first came in contact with the barrier. The major difference between the location of the loading from the initial barrier-filling flow and subsequent debris flows is that the location of the maximum loads is reversed: the passage of a flow front over an already filled barrier results in the largest load being distributed over the uppermost support ropes (closest to the base of the flow). The consolidation and dewatering immediately after the net-filling event of the initially-trapped deposit (approx. 1000 m^3) effectively forms a stable in-channel deposit, in the way that is not readily mobilized by subsequent debris flow events. The 24 June event, a large debris flow with a granular front, resulted in an increase from the residual load in the top rope. However the structure remained intact (Fig. 3). Measured forces in the lower support ropes increased somewhat in response to the deformation of the brake ring elements with the arrival of the peak impacts on the brake elements. The subsequent debris flows produced qualitatively similar results, roughly with increasing measured force values as the depth, velocity, or bulk density increase.

4 Observation stations in Spain

In Spain, at the end of 2006 Geobrugg, in collaboration with WSL, Forestal Catalana (the Catalan company Forestry) and the Department of Environment and Habitat of Catalonia, implemented a project for install of two measuring stations, in the areas of Erill and Galera, two site chosen because of their difference weather. The first case Pyrenean weather (it's assumed multiple events of medium intensity would occur) and the second Mediterranean climate (single events, but very high intensity). The main goal of this to stations is to demonstrate the feasibility of barriers UV / VX, for the hydrographic control of different kind of basins. In the case Erill, the barrier type placed was VX, due to the size of the natural channel, while in Galera was necessary place a UX type system with the post placement at the middle. During 2007, only there has been very low-intensity events, at the station located in the Pyrenees. At these events, just have mobilized small bulk, the amount was not sufficient to start the filled of the barrier; the sediments flowed under the barrier. In previous years had witnessed significant events often (more than two per year). In the case of the Galera the return period is about 5 years, estimating the likely 2008 as a base year of occurrence.

5 Conclusions

The Illgraben torrent observation station is ideal for testing ring-net barriers under natural conditions due to the relatively high frequency of large debris flows. This provides an opportunity to address questions of the stability of filled barriers. The preliminary results presented herein suggest that the material retained in the barrier is effectively stabilized. Excavation of debris flow deposits indicates a dense structure of interlocked particles, supporting our conclusion that the deposits are not readily remobilized as a mass-movement by subsequent flows. The effective long-term retention of the sediment in the barrier then depends on the continued integrity of the barrier system against abrasion from sediment transporting flows and debris flows. The abrasion protection elements were intact after the largest debris flow event, suggesting that such elements may survive periodic debris flows in applications with infrequent activity. To ensure structural stability, regular inspection of flexible barriers, as with most structural mitigation measures, is recommended.

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