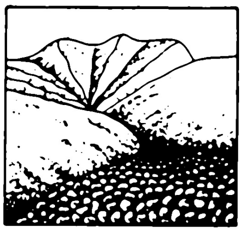
Труды Международной конференции

СЕЛЕВЫЕ ПОТОКИ: катастрофы, риск, прогноз, защита

Пятигорск, Россия, 22-29 сентября 2008 г.



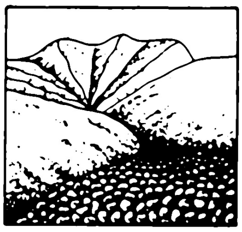
Ответственный редактор
С.С. Черноморец

Институт «Севкавгипроводхоз»
Пятигорск 2008

Proceedings of the International Conference

DEBRIS FLOWS:
Disasters, Risk, Forecast, Protection

Pyatigorsk, Russia, 22-29 September 2008



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

Simulation of debris flow runout before and after construction of mitigation measures: an example from the Swiss Alps

C. Graf, B.W. McArdell

WSL Swiss Federal Research Institute, Birmensdorf, Switzerland

Моделирование селевого потока до и после строительства защитных сооружений: пример из Швейцарских Альп

К. Граф, Б.В. Мак-Арделл

Швейцарский федеральный институт исследований снега, леса и ландшафтов, Бирменсдорф, Швейцария

Недавние изменения в активном очаге зарождения селевых потоков около Преонцо, Швейцария, привели к непредвиденному изменению селевого русла. Русло стало проходить в обход существующего селезащитного сооружения, в том числе крупного бассейна-селехранилища. Две новых отклоняющих дамбы были построены, чтобы перенаправить новые сели в старое русло и прежнее селехранилище. Численное моделирование может использоваться, чтобы оценить эффективность таких мер по уменьшению ущерба. Используя программное обеспечение RAMMS («Быстрые Массовые Движения»), которое описывает селевой поток с использованием двумерных уравнений потока и соотношения Воэллми для силы трения, мы описываем ход моделирования и оцениваем эффективность новых отклоняющих дамб. Сначала модель была калибрована, используя данные по селю 2004 г. Затем дамбы были включены в состав рельефа, используя модель RAMMS. Наконец, было проведено моделирование с использованием нового рельефа, сформировавшегося после селя 2007 г. Результаты показывают, что новые селеотклоняющие дамбы должны штатно функционировать для селей приблизительно такого же размера, как в 2004 г.

Recent changes in the source area of an active debris flow torrent near Preonzo, Switzerland, resulted in an unanticipated change in the flow path which bypassed existing mitigation structures, including a large debris flow retention basin. Two new debris flow deflection dams were built in the source area to re-direct new debris flows back into the old channel and the old debris flow retention basin. Numerical simulation can be used to evaluate the effectiveness of such mitigation measures. Using the RAMMS (Rapid Mass Movements) simulation software, which describes the flow of debris using the 2D shallow water equations and a Voellmy relationship for the friction, we describe simulations where we evaluate the effectiveness of the new deflection dams. First the model was calibrated using data from an event in 2004, then the dams were incorporated into the topography using the RAMMS model, and finally the model was run over the new topography using data from an event that occurred in 2007. Results indicate that the new deflection dams should function as intended for debris flows of about the same size as the event in 2004.

1 Introduction

Simulation models provide useful information on potential future events and help to optimize the construction or performance of planned or existing mitigation measures. The debris flows process is complex and many details are not yet fully understood. Many existing simulation models use a single-phase approach to describe the frictional behaviour of the flowing debris, thereby simplifying the real mixture of water and solid material consisting of a wide range of different grain sizes. Due to the gaps in our understanding of the process and the variety of flow types found in nature, the results need to be checked carefully and should be compared with existing field data. We performed post-event simulations of a debris-flow event originating from an activated rock avalanche zone in the southern part of Switzerland, taking into account structural measures realized after this event. Newer event data was used to evaluate if the new structures are capable of performing as designed.

2 Field site

The Frana (slide or rock avalanche) di Roscero drains into the Riale (creek) Valegiòn south of the village Preonzo, near Bellinzona in the Canton of Ticino in Switzerland (Fig. 1). Since the mobilization of an unstable zone in the upper catchment in the late 1990's, several debris flows have occurred. After the disastrous debris-flow events in 2001 a new retention basin with a capacity of 70 000 m^3 has been built 2002, replacing the older and smaller one from the 1990's. In May 2002 a new rock avalanche of about 150 000 m^3 occurred in the debris flow source area and the new loose material, consisting of large blocks deposited in the upper catchment, is expected to move down to the valley bottom in the form of minor debris flows, as has been observed previously. However the large addition of new debris flow in the source area has modified the channel network, resulting in a re-direction of the channel into an adjacent channel, located south of the main torrent channel, which bypasses the existing mitigation structures. Another 700 000 m^3 of potential debris is present in the rock-avalanche initiation zone, and because this mass movement is actively moving, it must be accounted for in the future. The rock avalanche site is instrumented and has been continuously observed by the forestry service of the Canton of Ticino since 1997.

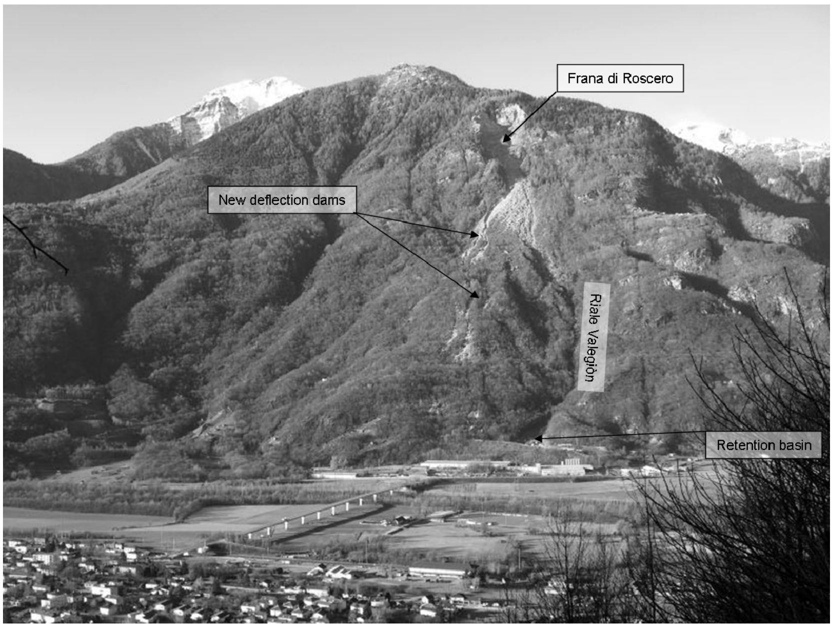


Fig. 1. Riale Valegiòn in Preonzo, Canton of Ticino, Switzerland. Photo by C. Graf, WSL.

In 2004 a debris flow initiated and went down the new channel, south of the Valegiòn. To anticipate similar or perhaps larger damages than caused by that flow, additional structures have been built up close to the debris flow initiation area of potential future debris flows. These two deflection dams control the water runoff and force the channel to return to the Riale Valegiòn and the existing retention basin (Fig. 1). Since 2002 the WSL has operated an automated debris-flow observation station in the Riale Valegiòn (similar to the stations described by Huerlimann et al., 2003) using geophones for triggering front velocity measurement, a radar sensor to measure flow depth and two video cameras for visual control. Recent debris-flows were observed in 2004 and in 2007. Unfortunately they have bypassed the observation station until the end of 2007 because of the new flow paths south of the Riale Valegiòn, described earlier.

3 Simulation

RAMMS is a modelling system for natural hazards research and practice developed by the avalanche, debris flows and rock fall unit of WSL, Switzerland (Christen et al., 2005). In the field of natural hazards there is a strong need for process models or tools where both the process and interaction with proposed mitigation measures can be evaluated. This software package combines flow avalanches, debris flows, rock fall, and mitigation measures in one tool, allowing partial evaluation of mitigation structures designed for other processes (e.g. the functioning of avalanche protection dams for debris flows). The graphical user interface incorporates many GIS functions, to rapidly define the boundaries of the computational grid and the definition of the initiation area for avalanches (RAMMS website, 2007). The module used – RAMMS::DEBRISFLOW – works with a one-phase approach (similar to RAMMS::AVALANCHE, Voellmy-friction) at the moment. The friction relation is frequently-used, depth-averaged and describes the debris flow resistance as the sum of a dry Coulomb-type friction (μ) and a viscous resistance which varies with the square of the flow velocity (ξ). A finite volume scheme is used to solve the 2D shallow water equations in general three-dimensional terrain (e.g. Christen et al., 2005).

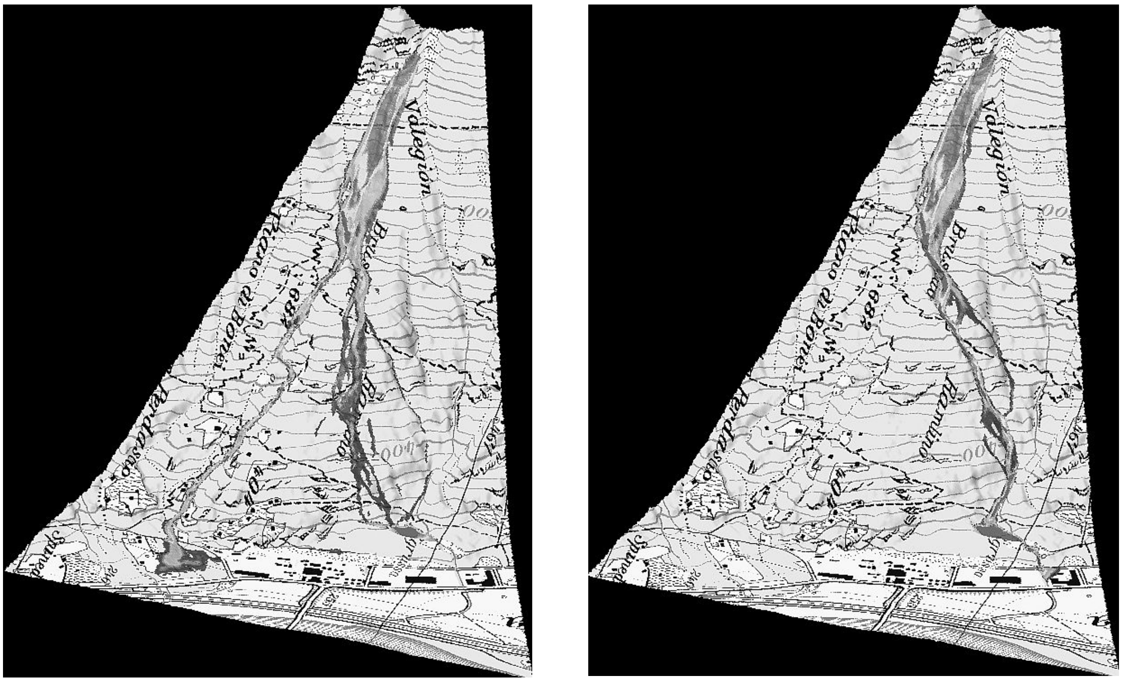


Fig. 2. Simulation of the 2004 debris flow event in Valegiòn a) without and b) with structural measures. Flow paths and heights correspond to the observations after the event and similar deposition zones result. Events as large or even larger than the 2004 event may partially bypass the mitigation structures, indicating that some additional construction work may be necessary.

The debris flow event in July 2004 was simulated using parameters estimated after a field survey one day after the event. The total volume was estimated at about 10,000 m^3, frontal velocity in the range of 6 to 10 m/s and flow depths in the order of 2 m. Calculations were made using a high-resolution terrain model (DTM-AV), with the starting volume estimated from the field data. The digital terrain model (DTM) shows the topography after the 2004 event and contains all active channels, including those formed by the event. Accurate representation of the topography in the grid is essential to obtain a reasonable replication of the observed deposition patterns (Rickenmann et al., 2006) and flow paths. For the two friction parameters in the Voellmy relation, no universally valid combination has been defined for debris flows. For RAMMS, we propose to start with $\xi = 200$ [m/s^2] and $\mu = 0.1$ [-] (Scheuner, 2007). The coefficient ξ may be varied from 100 up to 400 m/s^2, and μ from 0.1 up to 0.3. In the areas of the two dams the DTM was locally elevated by the heights of the structure. New small debris-flow events in 2007 happened after construction of the two dams and followed the new channel, as anticipated. These events confirm the physical design of the deflection dams; these events have also been parameterized and are used herein.

4 Results

Simulated flow paths, without taking into account structural measures, resemble the observed tracks in the field (Fig. 2a). The different deposition zones could be reproduced and flow heights as well as frontal speed reach approximately the same values as observed in the field. After adding the two dams to the DTM, results show the designated deflection to the north and to the original Valegiòn channel which includes the retention basin. Some residual discharge to the south could be observed (Fig. 2b) and indicates that the structures could be further optimized. The small debris-flow events in 2007 did not show any outbreak to the south due to their small volume. To re-direct larger flows, a third deflection dam or other measures at the initiation zone would be necessary.

5 Discussion

RAMMS is able to reproduce the observed flow paths and deposition patterns of the 2004 event. The estimated parameters derived from the field work after the event appear to be adequate, and observed and reproduced deposition patterns are similar. The location of the initiation zone is not exactly known and had to be optimized to generate the proper flow path in the upper catchment. Initiation zones need to have the right geometry to match the observed flow behaviour. Ideally a DTM from before an event should be used, however for back-calculation are only rarely available. A high resolution of the topographic data on the order of a few meters is necessary to achieve reasonable results. Potential location of structural measures could be easily derived from the flow paths simulated for the 2004 debris-flow event. Exact dimensioning of new construction measures would be more difficult and indicates the need for a detailed study at the corresponding locations. New structural measures for hazard mitigation, such as deflection dams or retention basins, are easy to integrate in the DTM with the user interface, providing a tool that can help to optimize the design of such structures. It is more difficult to define dimensions and exact position of modification of these measures from simulation results, especially because the debris flow process is only approximated by the use of single-phase friction relations such as the Voellmy relation used herein. Depending on the resolution of the DTM, structural measures have to been implemented somewhat larger than they are in nature to effect the desired behaviour, which has should be accounted for in the planning of the construction measures.

6 Acknowledgements

We are grateful to the support by the Canton of Ticino and the BAFU for financial support of the observation station, which was designed and maintained by WSL staff including Bruno Fritschi and Daniel Näf. Dieter Rickenmann supported the initial stages of this project. Melissa Swartz assisted in the data collection and analysis of the 2004 debris flow. We also thank the reviewers for constructive comments which helped to improve the manuscript and for translation of the title and abstract to Russian.

References

BWG. Hochwasserschutz im Fluss. Bern, 2002 (in German, French, Italian).

Christen M., Bartelt P., Gruber U. Numerical calculation of snow avalanche runout distances. – Computing in Civil Engineering. Proceedings of the 2005 International Conference, July 12–15 2005, Cancun Mexico, 2005.

Huerlimann M., Rickenmann D., Graf C. Field monitoring data of debris-flow events in the Swiss Alps. – Canadian Geotechnical Journal, v. 40, 2003, p. 161-175.

Rapid Mass Movements (RAMMS) - A modeling system for natural hazards research and practice. (website access: 17.12.2007). www.wsl.ch/hazards/ramms/

Rickenmann D., Laigle D., McArdell B.W., Huebl J. Comparison of 2D debris-flow simulation models with field events. – Computational Geosciences., v. 10, No. 2, 2006, p. 241-264, doi: 10.1007/s10596-005-9021-3.

Scheuner, T. Modellierung von Murgangereignissen mit RAMMS und Vergleich durch GIS-basiertes Fliessmodell. Zurich: University of Zurich, 2007, 106 p. (in German).