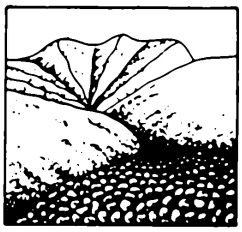
Proceedings of the International Conference

DEBRIS FLOWS: Disasters, Risk, Forecast, Protection

Pyatigorsk, Russia, 22-29 September 2008



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Sevkavgiprovodkhoz Institute
Pyatigorsk 2008

MDD 551.311.8
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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.

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English versions of abstracts edited by K. Mattar and O. Tutubalina

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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

Experiences with the Chain of Functions in debris flow control

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Контроль селей с помощью цепи функций: опыт применения

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In the last two decades of the past century systematic debris flow control and systematic torrent control has been developed in Austria. The countermeasures directly changed from protection to prevention, from object control to catchment management and integrated watershed management. In debris flow control you have two principles, active and passive countermeasures. The passive measures are mainly land-use planning keeping the endangered areas free of settlements and infrastructure to prevent economic damages. In Debris Flow Mitigation the systematic approach of the Chains of Functions has been developed. Active countermeasures start at the debris flow source area and are continued through the debris flow course down to the apex and the debris flow fan. These countermeasures cover various functions and their belonging structures. From top to bottom, from the debris flow source to the debris flow fan, the functions are chained.

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1 Introduction

The system of the chain of functions will be explained partially by the example of the Russ-Bach watershed and its tributaries. The catchments lay between 800 and 1800 m a.s.l. in the district Hallein south of the city of Salzburg in the limestone prealps. The tributaries Randobach and Rinnbach frequently damaged the village of Russbach by debris flow and bedload disasters.

2 Experiences with the chain of functions

A master planning in systematic control starts always with an environmental analysis. The environment analysis documents the links between geology, topography, vegetation, forestry, geomorphology, anthropogeneous influences and the torrentiality of the catchment. The case study shows areas with high runoff, landslides, soil creeping, debris input and bedload agglomeration. Depending on the environmental analysis necessary functions were derived. These functions are, to level down high runoff – afforestation, reforestation and runoff control and so one. To minimize or to stop landslides, soil creeping – landslide control, drainage, consolidation and revegetation by others are used. To control reaches of bedload agglomeration and development and debris input from slopes it is necessary to stabilize and to consolidate at least to control the banks.

The functions derived from the environmental analysis leads to functional structures and therefore to the chain of functions (Fiebiger, 1992). The case study Russbach explains for the tributary Randobach: flood dosing dam with integrated woody debris filter grill (bi-functional dam) – landslide control – debris flow breaker (energy dissipater) – bedload trap (sedimentation basin) with dosing facility. The second tributary Rinnbach shows another chain of function: reforestation – landslide control – sorting (sizing) dam – bedload dosing facility with two consolidation dams as inlet, two sedimentation basins with two dosing dams as outlet and a third dosing and consolidation dam (bi-functional dam) downstream. The difference between these two chains of functions lays in the difference of the subcatchment geology. The bedrock of the eastern tributary Randobach is the "Gosau formation" with layers of marl and cretaceous shists. In contrary the western catchment is build up by dolomites of the Trias period. The systematic control of the torrential watershed Russbach and its tributaries was very effective. In spite of some disastrous precipitations since the finish of the implementation of the master plan 1992 no torrential disaster damaged the village of Russbach. The next link in the physique of the functional chain of countermeasures is in the reach or the end of the debris flow channel. At least these are energy dissipating structures or diversion structures to lead the debris flow to areas where no damages are possible. Due to the lack of these areas near gorges and debris flow channels often the only possible is a debris flow breaker in the channel or at the apex of the debris flow cone. Downstream of the debris flow breaker sizing (sorting) dams and/or dosing dams are situated to convert the harmful debris flow into a harmless flow. The choice of the functional structure depends on the character of the debris flow. All these structures must be developed for excavation and maintenance after an impact by a debris flow.

The last link in the chain of functional structures in systematic debris flow control is a sedimentation trap or deposit basin for the debris flow load. This deposit basin should be able to catch the total capacity of the possible debris flow.

3 The functional structures in the debris flow origin

Surface drainage (runoff control) will be done to prevent infiltration from rainfall, springs, ponds, channels and gullies and other surface waters. If the debris flow origin is related to short-term rainfall surface water should be drained immediately. Also runoff control is necessary to guide the runoff out of crucial areas. Although the results cannot be calculated by slope stability analysis but drainage is in general effective as a countermeasure. Surface water drainage includes infiltration prevention and channelling.

Infiltration prevention knows two methods, filling of cracks and channel sealing. Many cracks and depressions are caused by landslide movements and surface water and runoff can easily infiltrate the sliding mass. Such openings should be filled with clay or cement or covered with vinyl cloth to prevent surface water infiltration. Channelling is installed to collect rainfall and storm runoff and divert it outside the landslide area. To plan the channel net a detailed survey of the landslide area topography should be performed and a topographical map should be made. There are two types of channels, catchment and drainage channels. The catchment channel is a type of a small channel which is attached to the drainage channel. It is wide and shallow and is made of asphalt, semi circle concrete or crockery pipes, etc. The drainage channel is installed to divert water outside the landslide area. This channel has a steep gradient. The discharge must be calculated. Stabilizing sills should support the channel in the steep slope and at the end of the channel. The drainage channel is made from stone, concrete U-shaped pipes, crockery pipes etc.

Groundwater near the surface (subsurface) is drained by opening a vacant space to intercept and divert the water. We differentiate in shallow and deep groundwater drainage.

Shallow groundwater drainage lies about 0.5–5.0 m below the surface and its velocity relatively slow. It drives from rainfall which is infiltrated near or at the concerned site. This type of groundwater usually causes a shallow landslide or the toe of a large – scale landslide.

Deep groundwater drainage is closely related to long-term rainfall or snow melt and is able to cause extensive landslides. Deep groundwater generally has a relatively high velocity (up to 1000 m/day) and is distributed to aquifers.

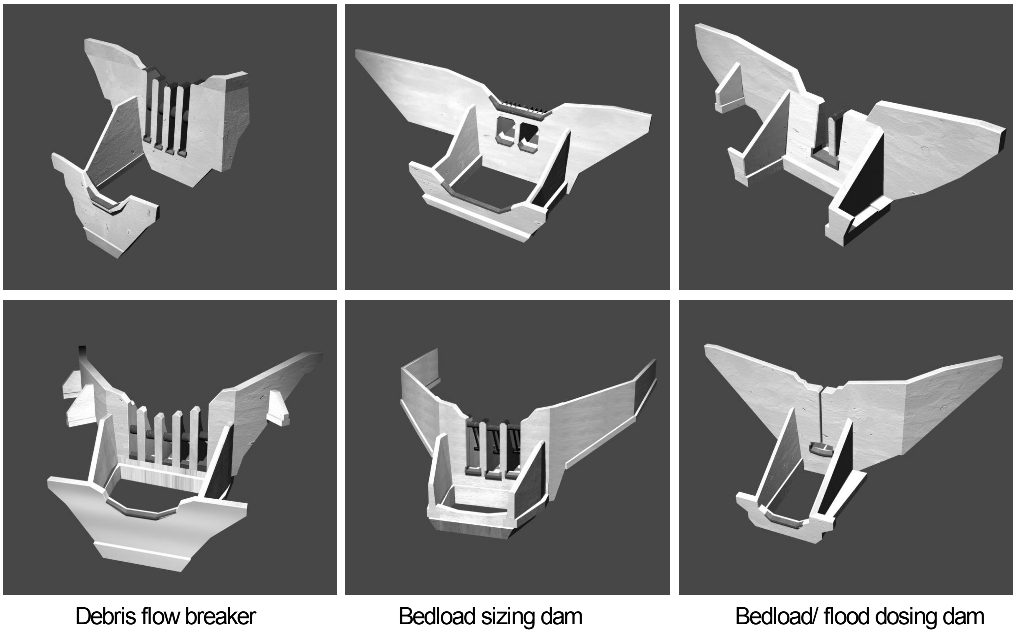

Fig. 1. Structures with different functional design. Front view without surrounding terrain (Leitgeb, 2002).

Retaining structures are established to directly resist the thrust of debris flow mass. This method is used to prevent small-scale debris flow or bank erosion and scouring. It may also be applied to part of a debris flow which has only small thrust. It is usually used combined with other methods, because it is not possible to control a debris flow with only a retaining structure. The design of these retaining structures has to done adequate to the standards. The items like, stability to fail, stability to glide, stability to slide, bearing capacity of the ground (bottom pressing), and last not least the safety of internal stress must be considered. During construction it is necessary to take care on excavating. Excavations in a debris flow channel increase the danger of activating the debris flow. Piles are installed to stabilize a debris flow source through resistance. There are inserted through the debris flow originating mass and fixed to bedrock. Usually steel piles approximately 300 mm in diameter are inserted through bores. When the debris flow source moves, the piles stabilize the mass by resisting the gliding force by bending moment and/or shear resistance. The pile is generally defined as bending pile since its length is long compared to its diameter.

An anchor is implemented to prevent landslide through the tensile strength of reinforcing steel which anchors the sliding mass to the bedrock. One end of the reinforcing steel is fixed to the bedrock and the other end is fastened to a bearing plate on the ground surface. The reinforcing steel is tightened and prestressed through the bearing plate. Important considerations for this method are the bearing capacity of the soil mass under the bearing plate and the bond strength between anchor grout and rock at the fixation part. Circumference friction and hole spreading friction are the two types of anchor fixation.

Slope reformation is done by soil mass removal. The volume of soil mass to be removed is determined by trial slope stability analysis taking the objective safety factor (F = 1,2) into consideration. Vegetation cover and surface drainage should be established on the surface of the slope after soil mass removal.

Erosion prevention leads to the more technical part in the chain of functions. In many cases landslides are caused by the lowering of torrent bed or lateral erosion by meandering. In such cases erosion control by structures is important. The construction used are stabilizing and consolidating constructions like sills, bars, ground sills, consolidation dams or other lateral constructions like revetments, dikes, embankments, groynes and spurs.

Revegetation is rehabilitation with vegetation cover. The expected functions of vegetation are, to reduce runoff and therefore surface erosion, to strengthen the surface and subsurface soils by the root system and to improve the hydrological conditions of landslides areas. Prevention and stabilization by revegetation is an important part of an integrated measure package. The revegetation will be done either by seeding or by planting. The various methods for seeding are, full surface seeding, mixed seeding, spaying (hydro seeding),vegetation matting, linear seeding, vegetation blocking and vegetation bagging. The planting mainly is done with seedling, piling sods, seedling after simple terracing, cover to protect the vegetation planted under, straw and brushwood and vegetation nets.

Reforestation as landslide prevention measure is performed about the sliding area in order to reduce the supply of infiltrated water into the sliding area. Slopes should first be covered with plants which are able to bear severe conditions. Primary trees are required, to grow in barren land, to bear dry conditions, to grow fastly, to have a root system which grows deeply and fixes soil and to have high budding potency.

4 The functional structures in the middle course and the apex of a debris flow

The various functional structures in the middle course and the apex of a debris flow depend also on the desirable function as the result of the environment analysis. These functional dam-types are sills, bed-sills, consolidation-dams, retention-dams and deposit-dams, which are defined also as bedload-strengthening structures as well as bedload storages structures (Leys 1973). The main target of these structures are primarily levelling down the energy-line of the debris flow and to prevent depth and lateral erosion, stabilizing the debris flow or torrent bed and to retain and filter harmful bedload and debris flow load and grant a more or the less continuous transport of the harmless bedload. The mainly used structures are sizing and sorting dams, ground sills, and revetments including soil-bioengineering works and drainage systems and landslide control and energy dissipaters. Their functions and the single types are descript and discussed earlier in this paper.

5 The functional structures on the debris cone and the lower course of a debris flow

The various functional structures on the debris cone and the lower course of a debris flow depend also on the desirable function as the synthesis of the environment analysis. These functional dam-types are sills, bed-sills, and deposit facilities like sedimentation basins and sediment traps and their obtaining dams, which are defined also as bedload-stabilizing and bedload-strengthening structures as well as bedload storages structures (Leys 1973). Their functions and the single types are described and discussed earlier in this paper.

6 Conclusion

After generally discussing the chain of functions in systematic torrent control and debris flow control the links to landslide control are described. Landslide control stands in the chain of functions of torrent control on the top of the systematic control together with afforestation reforestation and runoff control. On the other side there is landslide control for itself independent and not influenced by torrent or streams. Such landslide can influence torrents and torrential streams. seriously. The links of the chain of functions in systematic landslide control are drainage, retaining structures, piles, anchors and slope reformation and erosion prevention. Revegetation and reforestation is the rehabilitation of the landslide surface after technical treatment. The vegetation cover prevents the production of unstable debris on hillsides and slopes. At least the chain of functions in debris flow control and their related structures and treatment systems are specified.

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