ANALYSIS OF TORRENT PROTECTIVE STRUCTURES AS A BASIC ELEMENT OF THE HAZARD MAPPING PROCESS

DETERMINING THE AS-IS-STATE OF 100 YEARS OLD CHECK DAMS MADE OF NATURAL STONE MASONRY

Bernd Kister[1], Markus Zimmermann[2], Gabi Hunziker[2], Bruno Zimmerli[3] and Walter Fellmann[4]

INTRODUCTION

The natural hazard map for the villages of Schwanden, Hofstetten, Brienz and Brienzwiler (Bernese Alps, Switzerland) had to be revised as a consequence of large debris flows and flooding in August 2005, which caused huge damage. The Lammbach, which is one of the six mountain torrents in the area, showed no significant activity at that time, although this torrent is known for its huge debris flows, well documented for several centuries. The more than 20 torrent control structures in the Lammbach gorge (natural stonework, constructed approximately 100 years ago) play a vital role for today's safety on the fan of the Lammbach with extended housing estate and small-scale industry.

THE LAMMBACH, A HAZARDOUS TORRENT

The mountain torrents of the Brienz area are well known for their flooding and debris flows for hundreds of years. In the year 1896 disastrous debris flows occurred in the Lammbach valley, which destroyed several houses in the village Kienholz and interrupted the main road and a railway line. The volumes of the last three incidents have been reported as approximately 300'000 m^3 of material covering land along a shoreline length at Lake Brienz of 120 m with an average debris thickness of about 2.5 to 4.0 m.

In consequence of those disastrous debris flows, torrent control measures had been installed in the Lammbach gorge to raise the streambed and stabilize the slopes. In particular 20 check dams had been constructed in the period 1896 to 1913. Those dams consist of natural stone masonry and have remarkable dimensions in part. The largest one, check dam IVa, has a span of 90 m and the visible height at the downstream face is still 13 m today.

Major debris flows did not occur in the Lammbach since the construction of those dams. But on the other hand some 500'000 m^3 of debris has been accumulated immediately behind the torrent control structures and more than 500'000 m^3 debris are deposited in large talus slopes, mainly on the left side of the gorge. There is a potential for large debris flows, especially if one or more of the dams would fail. The structural safety of the old torrent control structures is therefore of utmost importance.

ASSESSMENT OF THE LAMMBACH DAMS WITHIN THE HAZARD MAPPING PROCESS

Since more than 10 years the hazard mapping process has been done in a standardized way in Switzerland consisting of 3 the individual steps:

1. identification of hazards,
2. assessment of hazards and
3. transfer of scenarios into a hazard map.

[1] Dr. Bernd Kister, Lucerne University of Applied Sciences and Arts, Technikumstrasse 21, CH - 6048 Horw, Switzerland
[2] Dr. Markus Zimmermann, NDR Consulting GmbH, Riedstrasse 5, CH - 3600 Thun, Switzerland
Gabi Hunziker, NDR Consulting GmbH, Riedstrasse 5, CH - 3600 Thun, Switzerland
[3] Prof. Dr. Bruno Zimmerli, Zimmerli Bauingenieure GmbH, Fliederstrasse 8a, CH – 6010 Kriens, Switzerland
[4] Walter Fellmann, Fellmann Geotechnik GmbH, Bruchmatthalde 3, CH – 6003 Lucerne, Switzerland

New discussions came up in the last years to take into account the effectiveness of safety measures. According to PLANAT (2008) a 5 step procedure has been applied for integrating the effectiveness of safety measures into the hazard mapping process. The steps are as follows:

1. basics (existing documents, visual analysis, surveys, main parameters of structures and subsoil),
2. process assessment (overall assessment of the torrent system, failure mechanisms),
3. arrangement assessment (structural safety, fitness of purpose, durability and aging),
4. outcome assessment (uncertainties, effects of protective structure on hazard scenarios),
5. implementation of results into planning

The course of action used in the project follows this 5 step procedure.

In the first step the available documentation has been analysed, a geodetic survey has been done and the check dams' as-is-state has been mapped. The last one has been done by using a special rating system for natural stone masonry, which has been developed at the Lucerne University of Applied Sciences and Arts in the last years (Kister et al, 2008). The new rating system for natural stone masonry has been developed based on our experience with rating systems in rock mechanics on the one hand and our experience with natural stonework on the other. Combining both and additionally taking into account aspects of the surrounding area as topography, geology, groundwater and plant-cover, the assessment and rating of old natural stonework has been put on a less subjective base.

In the second step the potential failure mechanisms and hazard scenarios had to be detected and the impact forces acting on the constructions had to be determined. One of those impact forces is the stress due to fluid shear when an overflow of a debris flow occurs at a dam. Two different models have been studied in the project.

The 3rd step deals with the estimation of the functional capability of the adopted measure. The structural safety as well as the fitness for purpose of the structures has to be checked. Because of the complexity in geometry and material behaviour for 2 of the large dams, check dam IVa and check dam III, 3D-Finite-Element calculations had been done.

The outcome assessment, the 4th step of the procedure, handles the evaluation of uncertainties and the resulting risks. Uncertainties are given for example by incomplete project documentation of the constructions and by variation in material parameters.

Based on the results of the previous 4 steps different scenarios had been analysed. The most likely scenario acts on the assumption of the failure respectively partial failure of several dams. The scenario starts with a large landslide in the middle of the Lammbach gorge. Approximately 50'000 m^3 material of this landslide will form a debris flow running down the valley and eroding further debris masses. This will result in:

- An overflow of approximately 220'000 m^3 of debris at check dam IVa, but the dam itself will remain stable.
- A debris flow of approximately 325'000 m^3, which will reach the fan apex.

In comparison to a scenario taking into account the failure of all dams, the scenario shows a significant smaller so called "red area" in the hazard map, which is the area where the construction of new buildings is prohibited. To choose this scenario as the most likely scenario was only possible due to the engineering assessment of the as-is-state of the 100 years old Lammbach check dams.

REFERENCES

Kister, B.; Zimmerli, B.; Fellmann, W. (2008): Über die Problematik einer systematischen Bewertung des Zustandes von älteren Stützbauwerken aus Natursteinmauerwerk, 6. Kolloquium Bauen in Boden und Fels, Technische Akademie Esslingen

PLANAT (2008): Wirkung von Schutzmassnahmen, www.planat.ch/de/infomaterial-listenansicht/

Zimmermann, M. (2006): Prognose von Murganggefahren: Wie sicher ist sie? Bull. angew. Geol., Vol. 11/2: p. 65-73

Keywords: identification of risk, risk assessment, natural hazard map, torrent control structures, potential failure mechanism, natural stone masonry, as-is-state of structures and rating, 3D-FEM