INTEGRATED HAZARD MAP OF AXEN ROAD

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The national road N 4 (Axenroad) and the Swiss Federal Railways-line (SBB Axen-Gotthard-line) are passing along the eastern shore of the Urnersee (eastern part of Lake of Lucerne, Switzerland) often below steep rocky cliffs. Between Brunnen and Flüelen these two major traffic routes are highly exposed to natural hazards, especially to rockfall processes. Over 70 occurred events have been recorded, extending from frequent rockfalls up to rockslides of 6'000 m^3 (1932). With the constructions of rockfall galleries in 1968, direct hits on the road by low energy events could be minimized. However, the galleries do not provide protection for high energy events and were damaged or partially destroyed several time by rockfall events (fig. 1). Statistically every second year a potentially harmful rockfall event has to be expected.

Fig. 1: Gallery destroyed by rockfall event (500-600 m3) in 1970.

Both transportation routes are part of the international north-south transit line via the Gotthard, connecting Switzerland and Italy. The transit frequency is very high with a daily average of 11’800 car/truck/bus movements and 200 trains per day, respectively. Consequently the safety requirements as well as the availability of these traffic lines are of high importance.

To investigate the 8.3 km long section from Mositunnel-Nord (Brunnen) to Gumpisch (Usser Tellen) for its exposure to gravitational natural hazards, the “Civil Engineering Office of the canton Schwyz” in cooperation with the “Swiss Federal Railways” and the “Civil Engineering Office of the canton Uri” conducted a two-phase project: The first phase should focus on the present gravitational hazard potential and is subject of this publication. In a second phase, the present collective and individual risks, including evaluation of measures to be taken, were considered. The consortium “Louis Ingenieurgeologie GmbH Weggis, Ingenieure Bart AG,

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The hazard analysis included detailed field mapping of the rockfall source and deposit areas, as well as the evaluation of all existing mitigation measures and protection structures. Numerical rockfall modelling was conducted to investigate the expected impact energies on the traffic lines.

Due to differences in the source rock areas (i.e. lithology, bedding, joints, spacing of joints, decomposition, failture mechanisms, registered events or observed tracks), the slopes and rock faces were divided into a total of 58 different release zones, for which scenarios (expected block volumes) for the following 5 intervals had been defined:

- Highly frequent occurrence: interval of recurrence 1 - 3 years
- frequent occurrence: interval of recurrence 3 – 10 years
- less frequent occurrence: interval of recurrence 10 – 30 years
- scarce occurrence: interval of recurrence 30 – 100 years
- very scarce occurrence: interval of recurrence 100 – 300 years.

Numerical 2D rockfall simulations were conducted in 44 slope profiles. The simulations were performed for the five scenarios, according to the different block volumes expected. Most of these slope profiles included several release zones positioned on different altitudes, so that more than one simulation run per slope profile and scenario was demanded.

This procedure resulted in a total amount of about 500 single rockfall simulations. To deal with the high computational effort, a batch procedure for the simulation run as well as pre- and post-processing tools were applied. For this, the used software Rockfall 6.1 was slightly modified.

The Slope profiles are based on a digital surface model and the surface elevations were extracted along predefined paths. As the resolution of the surface model was very high, it turned out to be necessary to smoothen the slope profile and overlay it afterwards with an appropriate roughness. This process was incorporated in the pre-processing procedure.

Regarding all these parameters, the amount of calculation results was overwhelming. Nevertheless the results of the rockfall trajectory calculation had to be checked and verified for plausibility for every single simulation. But for the use and the evaluation of the results for the further steps of impact and risk analysis the usual form of result presentation in single sheets for every single simulation run is not feasible.

To integrate the results into two-dimensional maps the following post processing procedure was conducted: In all slope profiles the calculation probed every 10 meters for the full statistics of kinetic energy and jump height. From this the 90% value was evaluated and exported into the two-dimensional presentation. Thus the simulation results of the effect of rockfall events for each release zone are charted in a map of intensity, graded in 9 level of impact energy.

On the basis of the intensity maps, the risk analysis (phase two) was conducted, including evaluation of measures to be taken to reduce existing risks to an acceptable level considering the principles of cost-efficiency.

It is shown that large amounts of simulations in single slope profiles can be processed and finally evaluated into areal presentations. Pre-condition is the a-priori identification of rockfall paths which lead to the slope profiles in which the simulations are done. In general they are following the steepest gradient downhill. The huge amount of calculations which are necessary to obtain detailed and in a statistical aspect valid results, requires a rather sophisticated system of pre-, post-processing and batch procedures. Otherwise the task at hand is not only consuming time and lots of manpower but also highly error prone.

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