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Assessment of gravitational hazards and risk analysis along the Axen national and international traffic lines (Central Switzerland)

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The national highway A4 as well as the Gotthard railway line (N-S transit-line) are passing along the eastern shore of the Urnersee (southern part of Lake of Lucerne) often below steep rocky cliffs. Both infrastructures are highly exposed to gravitational natural hazards, principally rockfall, avalanches and debris flows. The record of occurred events is exhaustive. It is extending from frequent rockfalls up to rockslides of 6'000 m^3 (1932). Since the construction of rockfall galleries in 1968 (figure 1), direct hits on the road by low energy events could be minimized. But despite galleries and additional protective measures (e.g. rockfall barriers), statistically every second year a potentially harmful rockfall event has to be expected.

Although the last fatal casualty is dated back to 1956, authorities are fully aware of presumably high, inacceptable risks along the approximately 10 km long section between Brunnen and Flüelen. Beside the risk of casualties, also the question of availability of important traffic lines is a point at issue. In order to accurately assess hazards and risks, the authorities of Schwyz and Uri, the SBB transport company and federal authorities started a two-phase project, that should focus on the following items:

Phase 1: Present hazard potential along the 8 km long section between Brunnen and Gumpisch (site south of Flüelen).

Phase 2: Actual collective and individual risks in respect to the analysed gravitational hazards for car drivers and users of the railway transportation system.

Evaluation of measures to be taken to reduce risks to an acceptable level, considering the principles of cost-efficiency.

How are risks managed, if protective measures are beyond the limits of actual cost-efficiency standards?

Within phase 1, detailed field work was carried out. Concerning rockfall hazard, the steep slopes and cliffs have been analysed intensively, including roping down a great number of profiles. Since lithologies, tectonization (especially structures of brittle deformation), weathering and exposition vary substantially, 58 individual source areas for rockfall processes have been identified. For each area, scenarios for different return periods (3, 10, 30, 100, 300 years) of rockfall events have been determined, based on source rock characterization (i.e. lithology, bedding, joints, failure mechanisms, decomposition, registered events or observed traces). For all scenarios, the rockfall-intensities have been determined, using 2D-modelling.

Referred to the highway, almost 5.4 km (65%) are exposed to rockfall. Some sections of the highway are threatened simultaneously by up to 4 different source areas. Even the galleries (approx. 1.3 km total length) are providing limited protection, since the structure itself can be seriously damaged or fail by hits exceeding approximately 300 kJ. This corresponds with events of a return period of 10-

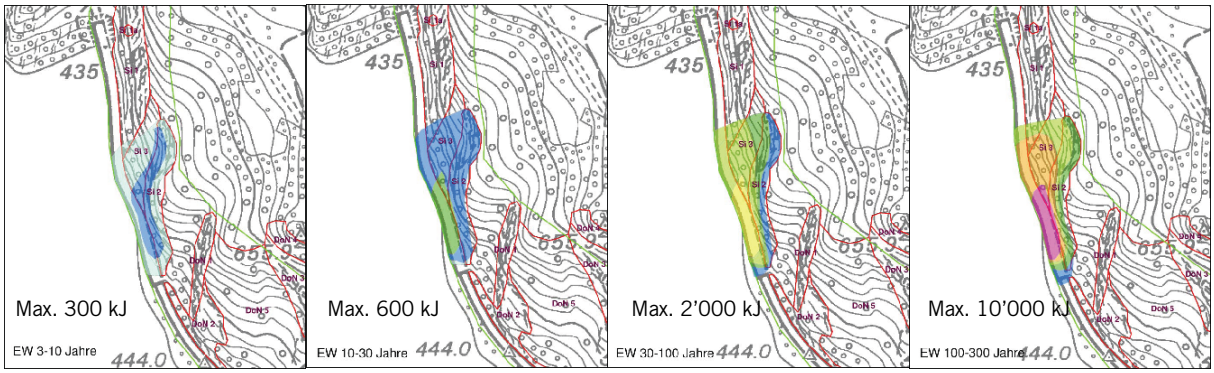
30 years (what already occurred more than once since the construction of the galleries). Events with a return period of 30-100 years mostly exceed energies of 300 kJ, and on a length of roughly 1.5 km energies of 3000 kJ. Maximal energies are beyond the limit of 10'000 kJ. These data clearly display the fact, that the applicability of active protective measures might be restricted (technical/financial feasibility).

Other natural hazards have been analysed accordingly to the rockfall processes. Compared to rockfall events, they are of minor significance (relatively rare, and – in the case of snow avalanches - predictable).

The risk profile of the railway is slightly better, because the tracks are situated either in tunnels or they are "sheltered" by the highway.

Figure 1
Aerial view of a part of the Axen national highway with rockfall protection gallery.

Figure 2
Sequence of rockfall intensities from an isolated source area at 4 given scenarios (return periods)



Phase 2 is still in progress. Risks will be quantified by summer 2007, and the appropriate measures by the end of autumn 2007. These data will be integrated in the submitted presentation.

From the present point of view it must be taken into account, that the risks along the Axen cliffs probably can't be fully managed based on cost-efficient measures. Then, the crucial question has to be posed, how authorities and the society will cope with a risk, that might be settled below the threshold of acceptability.

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