REDUCING VULNERABILITY TO MOUNTAIN HAZARDS BY LOCAL STRUCTURAL PROTECTION

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INTRODUCTION

Despite the long tradition of technical mitigation on a catchment scale in European mountain regions, losses due to mountain hazards are still considerable high in number and monetary loss. Therefore, the concept of technical mitigation had been supplemented by land-use planning and – more recently – local structural protection. Local structural protection includes measures directly implemented at or adjacent to endangered objects, and has proven to be particularly cost-effective with respect to integral risk management strategies. However, the effect of local structural protection in reducing the susceptibility of elements at risk, and the associated consequences with respect to a reduction of structural vulnerability have not been quantified so far. Moreover, there is a particular gap in quantifying the expenditures necessary for local structural protection measures.

LOCAL STRUCTRUAL PROTECTION AND VULNERABILITY REDUCTION

Even though the theory of vulnerability has been subject to extensive research and numerous practical applications over the past decades, considerable gaps still exist with respect to standardized functional relationships between impacting forces due to occurring hazard processes and the structural damage caused. For a major part these gaps result from the overall lack of data, in particular concerning: (1) losses caused by mountain hazards as a result of outstanding empirical classifications of damages; and (2) measurements of impact forces that caused these losses. Recently, promising approaches for a quantification of vulnerability have been made with respect to snow avalanches and rock fall processes, respectively. However, sound suggestions for landslides and torrent processes are still outstanding, even if these processes caused major losses in the Alps in recent years. Although such empirical relationships become increasingly important in determining vulnerability of structural elements at risk, the results only mirror the average expected systems behaviour (expected destruction due to impacting forces) for a specific setting, e.g., the entire area of a torrent fan presumably affected by a defined 1 in 150 year event.

In addition, the analysis of empirical data had shown that the vulnerability of buildings affected by medium hazard intensities (e.g., 1.00–1.50 m deposition height for torrent processes) is highly dependent on whether or not the entrained material harms the interior of the building (Fuchs 2009). Consequently, local protection measures such as deflection walls and specially designed closure structures for at-grade openings definitely play a major role in reducing the vulnerability of buildings, particularly with respect to low and medium process intensities (Holub & Hübl 2008)

Local structural protection measures which are implemented directly at or adjacent to endangered objects might therefore be a valuable and serious alternative with respect to reducing vulnerability within the concept of integral risk management. Local structural protection additionally seems to be economically efficient, as recently shown by Holub & Fuchs (2008) with respect to torrent hazards. Taking these findings as a basis, we will present a prototype of residential building typical for European mountain regions and adapted to mountain hazard processes. In particular, this prototype is equipped with various constructional elements which are able to resist the impact forces of hazardous events, i.e. fluvial sediment transport related to torrents, and snow avalanches. Therefore, we will

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focus on (1) possible loads emerging from these hazardous processes and impacting the building envelope, (2) the constructive design necessary to resist the loads, and (3) the amount of additional costs necessary for such an adaptation.

ADAPTED BUILDING DESIGN

In general, building design criteria have to rely on the following set of design loads, (1) in order to take into account the dead load of the structure; (2) to take into account the maximum possible live load; (3) load assumptions resulting from the impact of wind storm, and (4) the assumed static snow load with respect to the design criteria of the truss. Furthermore, (5) the design loads resulting from fluvial sediment transport and (6) the design loads for snow avalanches (dense part and powder part) have to be calculated to meet the requirements of adapted building design.

Taking into account the loads on the building envelope, a prototype for a contemporary reinforced building was developed. This prototype represents a typical alpine residential building in the European Alps. Due to topographical constraints, residential buildings in mountain areas are commonly constructed in a hillside situation. The characteristic building includes a basement as well as first floor (ground floor) and second floor (upper floor). The average effective floor space equals 70 m^2, which amounts to approximately 210 m^2 in total. Supporting walls consist of masonry while the baseplate and the ceilings are constructed from reinforced concrete, respectively. Timber is used for the roof truss, as well as the frame connectors for windows and doors. The roof truss is covered by copper sheet; the roof area is of projecting type in order to better protect the outside walls. Due to the hillside situation, the basement serves usually as a quasi-first floor towards the valley. At the hillside, light wells are installed to allow for an utilisation of the basement.

The structural reinforcement of the building in terms of increased protection against the impact of natural hazard processes was achieved by different constructive approaches. Possible adaptations included the reinforcement of the foundation, the structural levels (first and second floor), the roof construction, as well as additional design elements such as building openings, or mobile protection elements. Apart from a structural reinforcement, the protection of the building was supplemented by constructive measures adjacent to the building envelope.

The amount of construction costs were opposed to the additional expenditures necessary for an adapted design. The price basis is related to the average standard construction prices in Austria, which equals approximately the price indices in European mountain regions. A comprehensive overview on absolute prices used for the sets of calculation provided insight that the average construction costs were above the costs for unprotected buildings. Nevertheless, the ratios differed for individual measures: While the additional expenditures for the construction of a structural slab amount to an increase of one third, and the implementation of avalanche-proof windows result in an increase of two thirds (calculated in terms of the individual costs needed for this respective measure), the reduction of eaves leads to a decrease in construction costs of approximately 16 %. In total, the design adaptation of the prototype building under consideration lead to an increase in construction costs of 8 %, compared to an unprotected standard building. In absolute number, the increase in construction cost due to the implementation of structural mitigation outlined above amounts to approximately € 17,000. If this amount is compared to available data related to direct losses resulting from torrent events and snow avalanches, the savings potential becomes obvious. In principle, this concept is also applicable to a protection model for a group of buildings ("functional protection"), however, necessary quantifications are subject to ongoing research.

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