FORMAL SNOW AVALANCHE RISK ASSESSMENT TO BUILDINGS AND OPTIMAL DESIGN OF DEFENSE STRUCTURES

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INTRODUCTION

Long term avalanche mitigation generally involves considering high return period avalanches as reference events for hazard zoning and the design of defense structures. However, standard engineering procedures such as using high return periods as reference events can hardly handle the multivariate nature of snow avalanches. Furthermore, they do not explicitly take into account the elements at risk and/or possible budgetary constraints.
Since the work of Keylock et al. (1999), formal risk evaluation is known as in interesting alternative to overcome these limitations. The principle is to combine the model describing avalanche hazard in terms of magnitude/frequency relationship with a quantitative assessment of its consequences for one or several elements at risk, mainly people, buildings and traffic roads. Furthermore, it is then possible to perform cost-benefit analyses of different competing mitigations strategies taking into account the full variability of snow avalanches on the considered case study instead of only a few scenarios.

DETAIL OF THE WORK

Fully usable risk and optimal design models remain, for the moment, seldom applied in practice, mainly because they are computationally intensive, and nevertheless oversimplified in terms of modelling assumptions, both for avalanche hazard and vulnerability of the elements at risk. The aim of this work is therefore to combine state of the art sub-models for the probabilistic description of avalanche flows and the numerical evaluation of damages to buildings, so as to evaluate the risk with a reasonable compromise between precision and computational costs. To do so, a numerical approach has been developed to evaluate the physical vulnerability of concrete buildings to avalanche loadings (Bertrand et al., 2010). It is illustrated in Figure 1 representing the consequences of avalanche loading for buildings of different sizes and mechanical properties. In a second time, passive defense structures have been included in the framework, and an optimal design procedure has been developed (Eckert et al., 2008; 2009). Illustration is provided with the case of an avalanche dam reducing the risk for buildings situated in the runout zone of a French alpine path (Figure 2).

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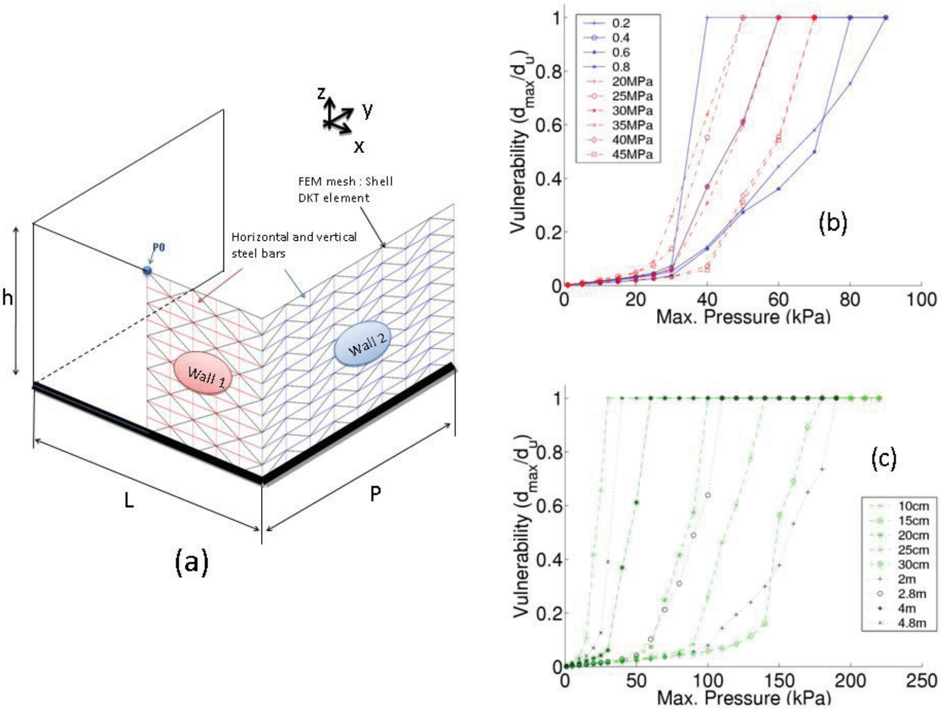

Fig. 1 Physical vulnerability defined as a damage ratio for reinforced concrete civil engineering structure from Bertrand et al. (2010). a) Finite Element Model (FEM) of the u-shape reinforced concrete structure where shell DKT elements have been used. b) Vulnerability as a function of structure's mechanical properties: reinforcements density (steel density) from 0.2% to 0.8%. c) Vulnerability as a function of structure's dimensions: L (form 2m to 4.8m) and wall thickness (from 10cm to 30cm).

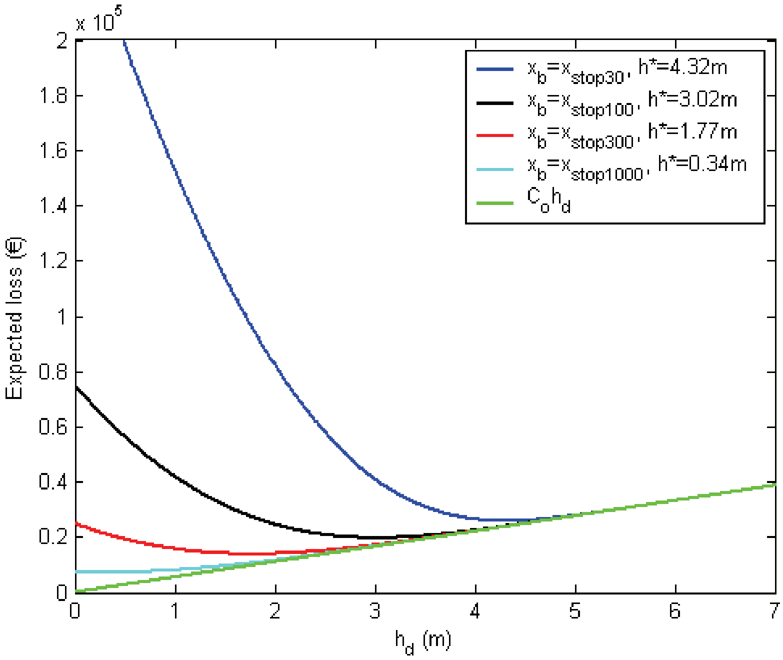

Fig. 2 Risk function and optimal design of an avalanche dam. Optimal design model and case study from Eckert et al. (2008a). Risk functions are given for a single building situated at abscissa positions x_{stopT} corresponding to return periods ranging from 30 to 1 000 years without dam in the runout zone.

Keywords: snow avalanches, formal risk, physical vulnerability, optimal design of defense structures