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Mechanics-based earthquake loss scenarios: what benefit and what uncertainties?

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Developing earthquake scenarios for cities in areas with a moderate seismicity is a challenge due to the limited amount of available data, which is a source of large uncertainties. This concerns both the seismic hazard, for which only recordings for small earthquakes are available and the unknown earthquake resistance of pre-code structures that constitute the vast majority of the building stock. An objective modelling of earthquake scenarios in such case is best performed through methods based on the ground motion physics and the dynamics of structures. The goal of the present study is to develop coherent probabilistic mechanics-based scenarios for a mid-size building stock including a comprehensive analysis of the uncertainties.

We studied the losses to the 121 public school buildings in Basel for 3 scenario events of different sizes based on history and on the de-aggregation of the Swiss Hazard Model for 475 years return period. The computations were run with the Openquake software, propagating all the recognized uncertainties.
The hazard analysis benefitted from the new Swiss Probabilistic Seismic Hazard Model of 2015 computed at a well-defined reference rock velocity profile. The city of Basel is located in the Rhine Graben, where sedimentary deposits up to several hundred meters thickness influence the ground motion. This ground motion amplification has been estimated at high spatial resolution using different methods, including recordings of small events on a dense strong motion network, and its estimation benefitted from 20 years of geophysical investigations and a large number of numerical simulations of earthquake ground motion.
The school buildings have been classified according to a specifically developed typology. Displacement-based analyses have been performed to calculate capacity curves representing the behaviour of the different types. Based on these capacity curves, fragility and vulnerability curves were derived following a new method to propagate the uncertainties. The fragility curves have been checked against empirical curves to ensure that the analysis method yielded realistic results and further improved. The scenarios allow us to quantify the number of casualties, the number of pupils without school and financial losses that such events would cause including their uncertainties.

The results show that the largest uncertainties come from the ground motion prediction equation while the vulnerability is also an important contributor. Computations not accounting for uncertainties are shown to lead to strongly biased estimates. The effect of the correlation of uncertainties is also investigated. Although improved data and models are still necessary to be developed, probabilistic mechanics-based models outperform deterministic and/or empirical models for retrieving realistic earthquake loss distributions.