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AMBIENT VIBRATION TESTS AND NUMERICAL MODELLING TO EVALUATE SEISMIC RETROFITTING

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This contribution presents the assessment of the retrofitting measures that were performed in a 6-storey stone masonry residential building in Switzerland (Fig. 1). To this end, field measurements (ambient vibration recordings) as already proposed by Michel et al. (2008) or Snoj et al. (2013), and numerical nonlinear dynamic modelling (Karbassi and Nollet 2013) are used. The retrofitting work mainly includes adding (i) reinforced concrete footing under the walls, (ii) horizontal steel beams to link the walls together, and (iii) an RC slab at each floor.

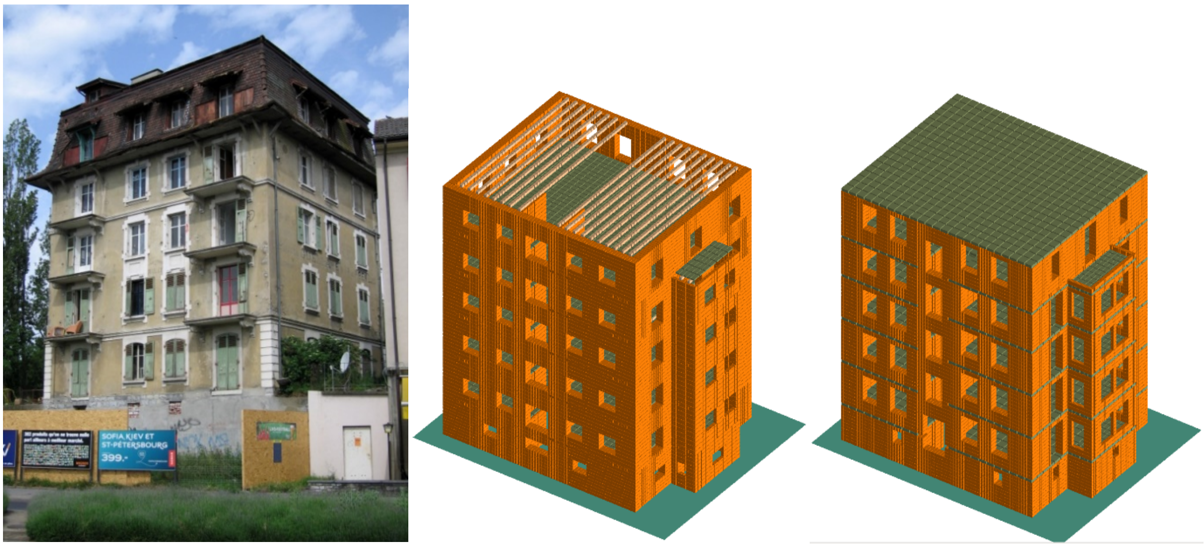

Figure 1. Study-building, numerical models before and after the retrofit work

The ambient vibration recordings were performed before, during, and after the retrofitting work (4 in total). The recordings have been processed using the Frequency Domain Decomposition (Brincker et al., 2001) in order to compute the resonance frequencies, modal damping and modal shapes of the structure. Moreover, numerical models representing the state of the building before and after the retrofit work (Fig. 1) have been developed to perform nonlinear dynamic analyses using the Applied Element Method.

Ambient vibration recordings show a shift in the resonance frequencies towards higher values of about 25% (Fig. 2), whereas the numerical model show a negligible increase due to the balancing between the increase in the stiffness and in the mass. The numerical models have not been tuned to the observed frequency because of the large uncertainties in the modeling of unreinforced masonry (URM).

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Both assessment methods show a shift in the structural behavior of the floors from non-rigid slabs with in-plane deformation to rigid floors with diaphragm effects. This diaphragm effect is shown to also slightly increase the torsion in the building, though, but without a major effect on the overall structural behavior of the building. The absence diaphragm effect before the retrofit led to out-of-plane failures, whereas the RC slabs prevent this kind of failure in the retrofitted building as shown by the model.

The assessment methods also show a change in the distribution of the seismic actions on the structure. Before the retrofit, the structure behaves more like a cantilever beam (Fig. 2) with lower drifts at the ground floor, considered as the most sensitive. After retrofitting, the stiff RC floor make the building behave more like a shear beam with increased drifts at the ground floor (see also Michel et al. 2012).

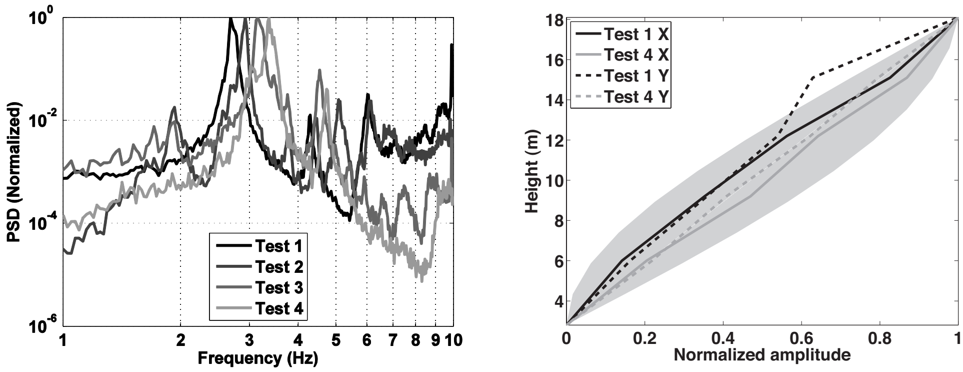

Figure 2. PSD spectra of recordings at the top of the structure throughout its retrofit (left). The increase of the resonance frequency with time is clear to be noticed. Modal shapes in elevation before (test 1) and after (test 4) retrofit. The grey shaded area delimits the range between the pure shear beam (lowest limit) and the cantilever beam (upper limit). The observed modal shapes behave more in shear after the retrofit due to the RC slabs.

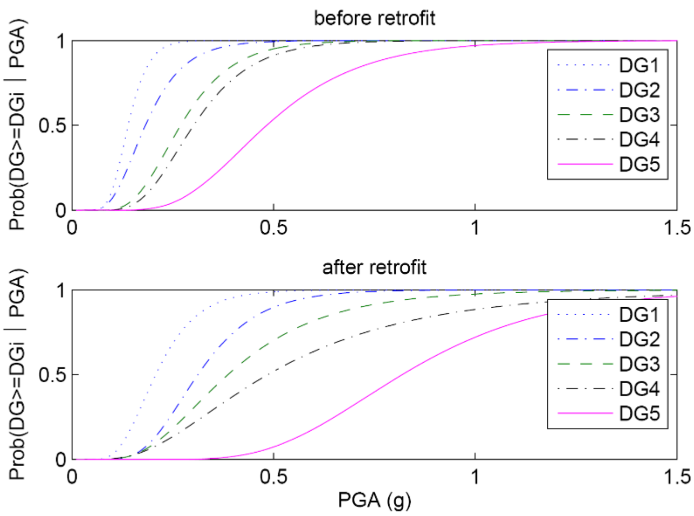

Figure 3. Fragility curves for the study-building before and after the retrofit

We also computed the fragility curves of the structure before and after the retrofitting to quantify the change in its seismic vulnerability. For each model, the damage grades are estimated (EMS98) after 50 non-linear time history analyses with input from a database of recorded strong ground motions. The results (Fig. 3) show that, overall, the seismic capacity has noticeably increased.

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