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Nonlinear Homogenized Continuum Approach for Determining Peak Horizontal Floor Acceleration of Old Masonry Buildings

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Abstract : It is a well-known fact among the engineering community that earthquakes with comparatively low magnitudes can cause serious damage to nonstructural components (NSCs) of buildings, even when the supporting structure performs relatively well. Past research works focused mainly on NSCs of nuclear power plants and industrial plants. Particular attention should also be given to architectural façade elements of old masonry buildings (e.g. ornamental figures, balustrades, vases), which are very vulnerable under seismic excitation. Large numbers of these historical nonstructural components (HiNSCs) can be found in highly frequented historical city centers and in the event of failure, they pose a significant danger to persons. In order to estimate the vulnerability of acceleration sensitive HiNSCs, the peak horizontal floor acceleration (PHFA) is used. The PHFA depends on the dynamic characteristics of the building, the ground excitation, and induced nonlinearities. Consequently, the PHFA can not be generalized as a simple function of height. In the present research work, an extensive case study was conducted to investigate the influence of induced nonlinearity on the PHFA for old masonry buildings. Probabilistic nonlinear FE time-history analyses considering three different hazard levels were performed. A set of eighteen synthetically generated ground motions was used as input to the structure models. An elastoplastic macro-model (multiPlas) for nonlinear homogenized continuum FE-calculation was calibrated to multiple scales and applied, taking specific failure mechanisms of masonry into account. The macro-model was calibrated according to the results of specific laboratory and cyclic in situ shear tests. The nonlinear macro-model is based on the concept of multi-surface rate-independent plasticity. Material damage or crack formation are detected by reducing the initial strength after failure due to shear or tensile stress. As a result, shear forces can only be transmitted to a limited extent by friction when the cracking begins. The tensile strength is reduced to zero. The first goal of the calibration was the consistency of the load-displacement curves between experiment and simulation. The calibrated macro-model matches well with regard to the initial stiffness and the maximum horizontal load. Another goal was the correct reproduction of the observed crack image and the plastic strain activities. Again the macro-model proved to work well in this case and shows very good correlation. The results of the case study show that there is significant scatter in the absolute distribution of the PHFA between the applied ground excitations. An absolute distribution along the normalized building height was determined in the framework of probability theory. It can be observed that the extent of nonlinear behavior varies for the three hazard levels. Due to the detailed scope of the present research work, a robust comparison with code-recommendations and simplified PHFA distributions are possible. The chosen methodology offers a chance to determine the distribution of PHFA along the building height of old masonry structures. This permits a proper hazard assessment of HiNSCs under seismic loads.

Keywords : nonlinear macro-model, nonstructural components, time-history analysis, unreinforced masonry
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