Abstract

The resistance of masonry structures against earthquake action is limited by its low shear strength. Vertical prestressing is mainly considered in order to improve the shear capacity and the ductility of masonry. Experimental tests have already shown the suitability of this method in case of static and static cyclic action. By means of a risk based design, a theoretical investigation is presented that considers dynamic loading.

The basis for the management of seismic risk of masonry, that is considered in the present doctoral thesis, is a developed risk management chain with definitions of its important components as well as introductory statements about different risk types and possibilities to describe and classify them. An important advantage of this risk management concept is the separation of risk into categories. The first includes only physical damage of the structure, while the second category considers the consequences of the physical damage that may be loss of life, economic, historical, social or cultural loss. Generally, the estimation of such losses entails very high effort. Moreover, it can currently not be carried out completely and reasonably, since there is still considerable need for deeper research and further development. Thus, the user of the suggested risk management concept has the possibility to deal only with the risk related to the physical damage, as it is done in the present work. Demandable knowledge about earthquakes, their artificial generation and simulation in transient structural analyses is provided as well as their probabilistic description to take into account their probability of occurrence and scattering, exemplarily demonstrated for the region of Aachen, Germany. Essential basics regarding dynamic structural behaviour and modern demands for aseismic design are explained. Concerning its significance, special attention is given to ductility.

The main focus lies on the analysis of vulnerability of unreinforced and vertical prestressed masonry. Its results are physical damages that are used for the above mentioned risk estimation. In order to carry out such analyses in a profound and pursuable manner, the structural behaviour of unreinforced and prestressed masonry, failure mechanisms, influencing factors and the effect of prestressing are particularly discussed as well as experimental investigations and application examples. The impact of vertical prestressing and its dependency on practical methods of execution on the meaningful ductility is asserted, described and theoretically explained by an interaction between internal prestressing elements (tendons) and the wall itself. Numerical methods and three material laws for masonry are elucidated that are used for the extensive simulations regarding the in-plane behaviour. By means of the experimental tests, the numerical models are calibrated.

The impact of prestressing on the dynamic behaviour is pointed out. Furthermore, influencing factors on the structural behaviour and simulations results are investigated such as wall slenderness, support conditions, position of the tendons and numerical modelling techniques of prestressing. Also sensitivities and correlations are results of extensive probabilistic simulations which include loading as well as resistance uncertainties. However, the evaluation of probability density functions for different damage parameters is the main aim of the probabilistic simulations. As an outcome, vertical prestressing of masonry is only conditionally useful in case of seismic action. It depends on several factors, for instance properties of the structure and earthquake, degree of prestressing or considered damage parameter. In general, the mortar damage is reduced, but the unit damage increased. Thus, further ideas are taken into account and developed to reduce the damage of masonry in case of seismic action. A detailed investigation of such method was neither the purpose nor the intention of this thesis. It closes with the application of the suggested risk management concept to an example. By means of calculated damages and their probabilities, the risk is calculated and compared.

Keywords: Masonry, earthquakes, prestressing, retrofitting, probabilistic, risk management