On the seismic damage in historical building archetypes

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Summary. The present paper concerns about the historical seismic damage records of the 1763 Komárom earthquake regarding a method for the estimation of the magnitude of historical earthquakes that uses the damage in real structures. To carry out this study, general masonry building archetypes are modelled as planar SDOF and MDOF systems calibrated with the help of a multilinear spring. Afterwards dynamic structural analysis (DSA) is developed to attain fragility curves.

Introduction

The most commonly used methods for the estimation of the magnitude of historical earthquakes [1, 2] belong to the domain of seismology and benefit from the cooperation between geophysicists and historians [3]. A new method applies the background of probabilistic seismic hazard analysis (PSHA) and uses the nonlinear structural damage from historical seismic damage records translated in fragility curves obtained either through DSA or capacity spectrum method (CSM) [4]. The present work, studies the development of fragility curves for historical buildings with the help of a simplified macro-model using a multilinear spring [5] calibrated with generally defined mechanical parameters for historical masonry structures [6, 7, 8].

Historical seismic damage and dynamic structural analysis

The 1763 Komárom earthquake: damage & archetypes

The use of the method in [4] implies stressing the seismic modelling work, which for real historical structures usually reveals to be a complex case dependent task. An alternative route is to generate archetypes using the knowledge of the buildings of interest [9] usually available in bibliography and local historical building surveys [10]. This option is particularly relevant when records of real affected buildings are not available, or exist but do not provide a representative sample of the damaged buildings. Historical sources identify the most affected buildings as two storey rigid buildings, made of burnt clay bricks, rather than simple and more flexible peasant houses, made of earthen or adobe masonry. In total, out of 1169 houses in total, 279 ended completely destroyed, 353 partially collapsed, 213 needed expensive repair and 219 cheap repair [2]. Furthermore, an anonymous painter depicted the damage in the city of Komárom after the 1763 earthquake, enabling the identification of specific failure modes in structures, such as shear failure (fig. 1).

Figure 1. Shear failure in structural masonry walls due to the 1763 earthquake (anonymous' depiction)

Structural and material modelling

The knowledge of the dominant failure modes may lead to simplifications in the modelling work of masonry walls. Assuming shear as dominant, a nonlinear spring can be associated to an isostatic SDOF or MDOF planar frame (fig. 2) [11] in order to carry out the DSA. In turn, a nonlinear spring is calibrated regarding the mechanical parameters of earthen, adobe and burnt clay masonry [6, 7, 8].

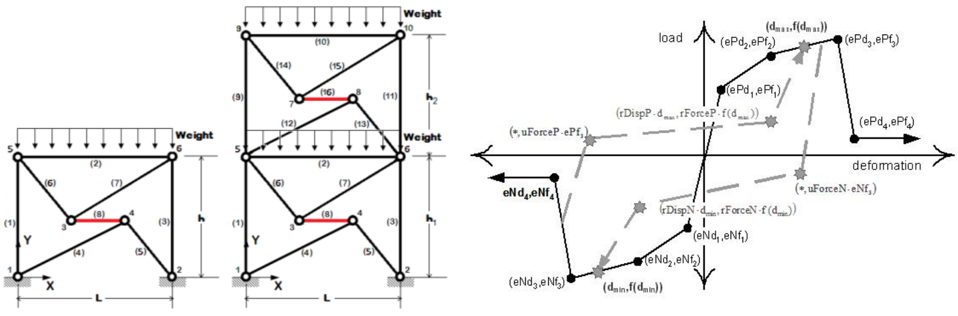

Figure 2. a) SDOF and MDOF structural models, b) *OpenSees* "pinching4" material model [5]

DSA and fragility curve fitting

The dynamic analysis of the systems (fig. 2a) enables the calibration of fragility curves *P(DM|IM,M,R)*. They give de probability of a damage measure DM given an intensity measure IM, a magnitude M and a distance R, and are usually lognormally fitted (median μ and standard deviation β) to the damage points from DSA given a seismic demand:

$$P\left(DM \mid IM, M, R\right) = \Phi\left(\frac{\ln\left(x/\mu\right)}{\beta}\right) \tag{1}$$

As can be seen in fig. 3, the input of the parameters of the lognormal CDF enables the comparison of earlier achieved fragility curves (μ, β) with the new results incorporating uncertainty in the strength parameters (μ', β'):

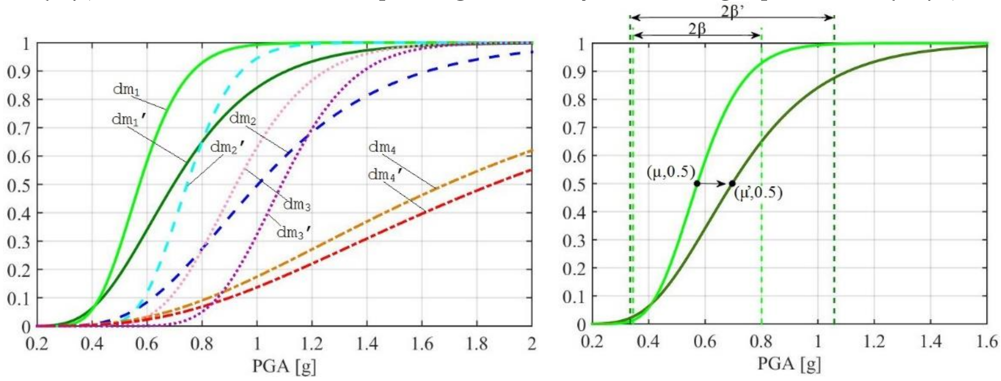

Figure 3. Adobe masonry wall: a) earlier and new results for damage states (dm_i) 1-to-4 and b) evidence of the shift of the fragility curve for damage state 1.

Conclusions

This study focussed on the use of a simplified approach to model the shear behavior in historic seismic damaged structures using a multilinear spring and aiming for DSA. Therefore, it extends results from previous works [11] in respect to the uncertainty in the mechanical parameters of adobe and burnt clay historical masonry [7, 8], and assuming a geometry and relatively simple structural archetypes. Although, assumptions related to the frame geometry and the material model, which are not here adressed, are still of great relevance. Future developments are expected considering more complex structural and mechanical models for the dynamics of adobe and clay maosnry structures.

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