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RISK-BASED SEISMIC PERFORMANCE ASSESSMENT OF A TYPICAL MASONRY BUILDING IN THE URBAN AREA OF ZAGREB

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1. Introduction: Seismic risk assessment in post-earthquake Zagreb

The Zagreb 2020 earthquake has damaged many historical buildings within the old city centre despite its medium intensity. Damaged buildings were mostly typical masonry buildings in aggregates built in the first half of the 20th century when seismic codes were not developed. Simultaneously, seismic risk assessment has been carried out for the city of Zagreb indicating these typical masonry buildings as high-risk in case of an earthquake. Since then, efforts have multiplied to improve risk inputs and performance assessments of buildings in Zagreb. The present study is a case study of a typical masonry building in the urban area of Zagreb and a risk-based assessment of its seismic performance.

2. Case study: Typical masonry building in the urban area of Zagreb

2.1 Model definition

Several similar typical unreinforced masonry buildings (URM) from the Zagreb historical centre area have been analyzed and joined into a simplified model of a four-storey building without basement using ETABS, as shown in Fig 1. Material nonlinearity has been introduced as plastic in-plane shear hinges in the center of shear walls using parameters from detailed studies of similar buildings [1].

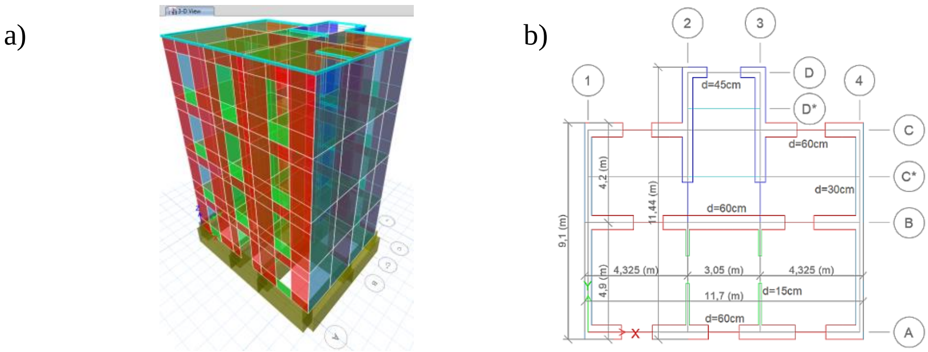

Figure 1. a) 3D numerical model in ETABS; b) Building plan

2.2 Incremental dynamic analysis (IDA) results

Performance assessment has been carried out using 13 ground motion records selected according to local seismotectonic conditions (active shallow crustal earthquakes, reverse thrust and strike-slip faulting) linearly scaled to 7-9 intensity levels of PGA in range 0.1g-0.3g in X direction (scale factor of X direction used for scaling in Y direction) and applying time-history analyses with both horizontal components simultaneously on the 3D model for each record thus generating 13 IDA curves up to collapse and 96 performance points in total. Average maximum inter-storey drift is used as engineering demand parameter (EDP) and average spectral acceleration in range of periods 0.5s-0.8s as the optimal

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intensity measure (IM) for this type of buildings [2]. Each IDA run has been assigned a damage state by direct visual inspection of the 3D model state after each run based on EMS-98 damage classification using nonlinear hinge states as main criteria for the assessment of wall damage states and damage spread [3]. The performance points and their inspected damage states are shown in Fig. 2. a).

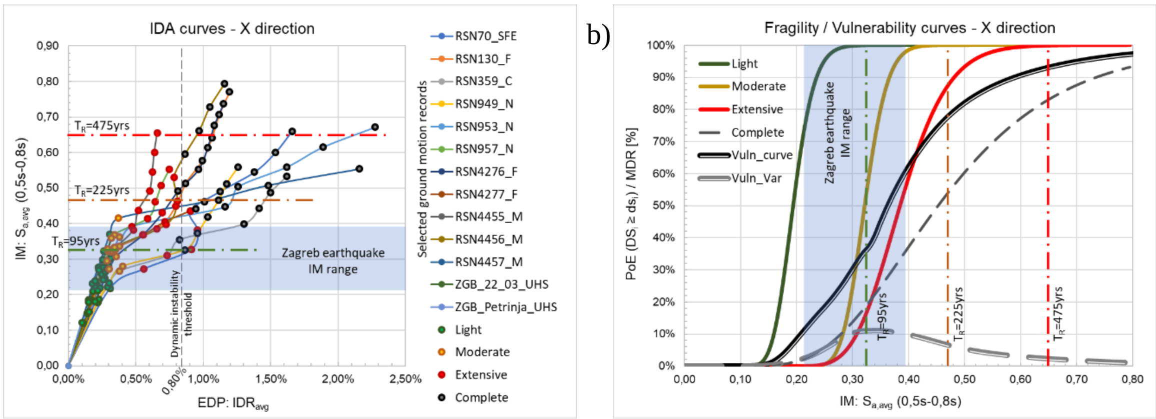

Figure 2. a) IDA curves and performance points for X direction; b) Fragility and vulnerability curves for X direction; Zagreb 2020 earthquake IM range is marked along with IM values for return periods T_R=95, 225 and 475 years (elastic EC8 spectrum, type 1, soil type C, $a_{g,ref}$ value from Croatian national seismic hazard map)

2.3 Risk-based seismic performance assessment

Fragility curves have been derived for slight, moderate, extensive and complete damage states using IM-based approach, but instead of EDP thresholds, visual inspection results have been used for each IDA curve. The only exception is complete damage threshold which has been set to EDP value 0.8% according to IDA results (limit that keeps lognormal distribution of EDP results). Vulnerability curves have been developed using MDR (mean damage ratio) values of 10%, 30%, 60% and 100% for slight, moderate, extensive and complete damage states respectively [4] for URM buildings. Fig. 2. b) shows the fragility and vulnerability curves with marked IM values corresponding to Zagreb 2020 earthquake components and code-based return periods. Results show that the building reaches slight damage state for T_R=95 years. For T_R=225 years moderate damage levels are already exceeded and for T_R=475 years extensive and complete damage can be expected. Zagreb 2020 earthquake IMs already fall into the peak derivative of the vulnerability curve although the earthquake is only of medium intensity according to hazard and losses up to 60% can be expected, indicating extensive damage. This building type is therefore very vulnerable according to code-based hazard and should be retrofitted in order to increase its seismic performance.

Acknowledgements

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