Development of a Comprehensive Seismic Risk Model for Heraklion (Crete)

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Seismic risk is determined by the combination of the probability of occurrence of a specified level of ground motion in a specified period of time (seismic hazard), the degree of damage expected to occur in structures after an earthquake (seismic fragility) and the assets exposed in a given area (economic exposure). Seismic risk assessment can provide critical information to stakeholders for the development of efficient risk reduction measures. However, in many cases observed ground motions are found to be underestimated by seismic hazard maps, due to lacking experience of strong earthquakes near urban areas and hence a questionable awareness of building stock endurance. In this work we present a physical risk model for the old part of Heraklion city (Crete). Crete is located in one of the most seismically active domains of eastern Mediterranean, marking the tip of the southern Hellenic subduction zone. Crete is considered also to be of high importance for the Greek tourism, estimated that contributes at around 47% of the GDP.

Heraklion, is the third most populated city of Greece. It is situated at the north-central coastal area of Crete, thus it is prone to strong earthquakes as manifested by the seismic history of the area (Papadopoulos, 2011) and the presence of several active faults in its vicinity. During the history of the city, several shallow and intermediate depth damaging earthquakes have occurred. Although instrumental and historical evidence does not indicate that Heraklion was damaged by earthquakes triggered by nearby shallow faults producing adverse effects to the city, a future incident cannot be excluded (Papazachos, 1995). According to the effective Greek seismic code (EAK-2000), Heraklion belongs to seismic hazard zone II for which predicted peak ground acceleration is PGA=0.24g. However, the above consists only an abstract approach, neglecting local conditions that may largely alter the effects of natural phenomena at a site. Therefore, a modern plan taking into account local conditions is required to facilitate effective interventions and mitigation policies.

To this aim, we develop a comprehensive seismic assessment by combining the exposure and vulnerability model of the old part of Heraklion city with the SHARE seismic zones (Giardini *et al*., 2014) and site response deduced from geotechnical data and microtremors measurements in order to acquire both probabilistic and deterministic earthquake loss assessments. The GEM OpenQuake-engine (OQ - www.globalquakemodel.org/openquake) was used to identify the regions with the highest risk within the target site, the most vulnerable assets, and the expected economic losses for a number of return periods and also for the most hazardous seismic sources in the vicinity of the city. The public-private Global Earthquake Model (GEM) foundation is an international pioneer that hosts an open initiative to develop state-of-the-art, widely accepted datasets, models and open-source tools/software for seismic risk assessment.

The herein work is organized as following. Path-effects were assumed after empirical GMPEs; site effects were approximated by experimental Horizontal to Vertical Spectral Ratios - HVSRs (Nakamura, 1989) obtained during an in-situ survey of microtremors measurements (ASPIDA, 2015) and geotechnical data (Auto-Seismo-Geotech, 1998). The census exposure model was available by EPANTYK (2009) and the corresponding fragility/vulnerability functions from the OpenQuake-platform (www.globalquakemodel.org/oq-platform). To assess the impact of soil response, the loss model was calculated with and without taking into account site amplification functions. Results were mapped using GIS tools.

Fig. 1 presents the resolved Probabilistic Seismic Hazard Assessment (PSHA) for the old city of Heraklion using OQ, SHARE Area Sources (AS), attenuation laws from the literature and site amplification. Site amplification was approximated by V_{S30}, derived from ambient noise HVSR (ASPIDA, 2015) and geotechnical borehole NSPT measurements (Auto-Seismo-Geotech, 1998). V_{S30} was obtained by inversion of the HVSR curves using ModelHVSR (Herak, 2008) and empirical relations (Tsiambaos & Sabatakakis, 2011) for the two data types, respectively. Probabilistic PGA values were found to range from about 370 to 470 cm/s^2, somewhat higher than values predicted in the global maps of the SHARE project (http://www.efehr.org/en/hazard-data-access/hazard-maps) calculated for rock conditions (V_{S30}=800 m/s), being of the order of 350 cm/s^2. Moreover, these are significantly larger than the value of 0.24 g predicted for the area by the national seismic code (EAK-2000). Fig. 2 illustrates the outcome of a scenario-damage calculation regarding a M_w6.5 earthquake on a N-S trending, east-dipping normal fault source located west of Heraklion (SHARE-GRCS740 fault source). The scenario, appears relatively amenable for the building stock implying a small percent (6%) of the buildings prone to undergo extensive damage or collapse, corresponding to 220 buildings out of the ~4000 ones in the target site available from the census data. In conclusion, the ongoing analysis manifests a robust methodology that yields consistent seismic risk assessments, which could be of use of stakeholders towards decisions on mitigation measures.

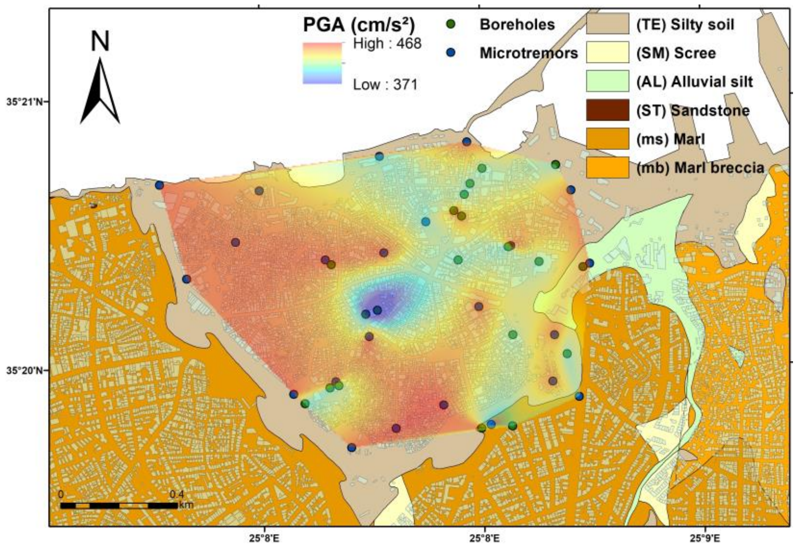

Figure 1. PSHA for the old Heraklion city using OQ, SHARE-AS and site amplification. PGA is calculated for 10% probability of exceedance within the next 50 years. Geology and buildings' footprints are also plotted.

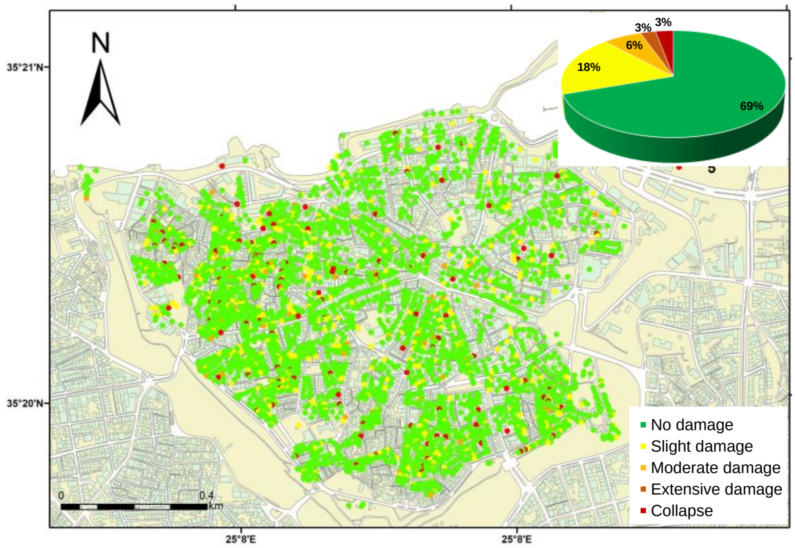

Figure 2. Damage distribution in Heraklion for an M_w6.5 scenario earthquake.

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