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Vulnerability assessment of historical buildings in the city of Málaga (Southern Spain)

t. Goded (1), e. Buforn (1), and j. Irizarry (2)

(1) Dpto de Geofísica y Meteorología, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Avda. Complutense S/N, 28040 Madrid, Spain. Phone: +34 913944542, Fax: + 34 913944398, email: tgoded@fis.ucm.es, (2) Institut Geològic de Catalunya, C/ Balmes 209-211, 08006 Barcelona, Spain

The city of Málaga (Southern Spain), is located in one of the most active seismic areas in Spain. The region is characterized by the occurrence of low-to-moderate shallow earthquakes (h<40km) with magnitudes usually lower than 5.0, and the occurrence of sporadic large shocks. An important seismic activity is also present at intermediate depth (40<h<150 km) near the city of Málaga, with a N-S epicentres distribution. According to the Spanish Seismic Code (NCSE-02), the seismic hazard in Málaga for a 500 years return period is of 0.11g, equivalent to a MSK intensity of VII-VIII. Two large events heavily damaged the city in the past. In January 1494 (Imax=VIII), an earthquake destroyed the great majority of the houses in Málaga. But the largest event in the region was the one occurred on October 1680 (Imax=VIII-IX), causing 250 wounded and 70 killed in Málaga city and heavy damages to its building stock: 20% of the houses were completely destroyed and 30% were left uninhabitable. Of the 36 monuments described as damaged by the earthquake according to contemporary documents, 23 buildings suffered severe damage or were completely destroyed (EMS-98 damage grades 4 and 5). Focused on the preservation of the city's cultural, historical and artistic heritage, this study has been motivated by the heavy damages caused by historical earthquakes and the poor seismic risk conscience provoked by the lack of events with magnitudes higher than 5.0 for the past 50 years. A vulnerability analysis of the city of Málaga's historical and monumental buildings is presented. The vulnerability index methodology, based on statistical data taken from damages in Italian monuments for the past 30 years, has been applied. Soil effects in terms of intensity increments derived from a microzonation study of the city centre have been used. For each building, vulnerability curves have been obtained, and damage grades have been estimated. A comparison has been made between expected and observed damages in the past, enabling us a way of checking the feasibility of applying this methodology to Spanish monuments. This comparison has been possible due to the fact that the city of Málaga is one of the almost unique cases in Spain where a considerable amount of the monuments damaged in the past (a total of 19), still exist today. Results show a good consistency between expected and observed damages, especially for the churches typology. Two seismic scenarios have also been considered, one deterministic (based on the 1680 event) and one probabilistic (based on NCSE-02), where 54 historical and modern buildings have been analyzed. For the deterministic scenario, 13% of the monuments have a 40-50% probability of suffering collapse. For the probabilistic scenario, most of the buildings have low probabilities (<10%), of suffering severe damages or collapse. The most vulnerable buildings belong to the typologies of churches, chapels and towers. For these monuments, expected high probabilities of suffering very heavy damage or even collapse have been obtained. The results of this study may be applied for preservation and reinforcement measurements in the city's historical heritage. We highly recommend the necessary measurements to be taken, in the hope of trying to avoid possible damages in the future.