主論文

New Ground Motion Prediction Equations for Saudi Arabia and its Application to Probabilistic Seismic Hazard Analysis

サウジアラビアにおける地震動予測式の構築と確率論的地震動予測への適用

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Abstract

Saudi Arabia is surrounded by several active tectonic regions, such as extension in the Red Sea, left-lateral strike-slip motion along the Gulf of Aqaba as known Dead Sea Transform Fault (DSTF), and the continental collision zone in the Zagros mountain belt. These tectonic environments produce numerous earthquakes that present a significant hazard to Saudi Arabia. Also, more than 15 continental, intraplate volcanic fields, locally called as "harrats", are spreading over more than 3,000 km from Yemen in the south through Saudi Arabia to Turkey in the north. Some of these volcanic fields are young and active, including Harrat Lunayyir where a seismic swarm consisting of 30,000 recorded earthquakes associated with dike intrusion occurred from April through June 2009. Along with historical evidence about volcanic activity accompanied by moderate to large earthquakes, this seismic swarm has caused the public in Saudi Arabia to recognize the risk of damage caused by a potential future volcanic eruption and associated large earthquakes around the volcanic fields in Saudi Arabia. This thesis contributes to better estimate of the national seismic hazard model in Saudi Arabia by developing new empirical ground motion relationship and its application to seismic hazard modeling in the rapidly growing urban area near the Harrat Rahat young volcanic field.

A recently developed dense seismic network in Saudi Arabia has enabled us to observe numerous seismic recordings. Using these collected seismograms, I have created a new ground motion database for Saudi Arabia. This database consists of 2,761 recordings, from 225 events and observed at 77 stations, in the range of magnitudes M_L 3 - 5.4 and distances from 1 to 400 km. The ground motion parameters included in this database are Peak Ground Acceleration (PGA) and Peak Ground Velocity (PGV) derived from the two horizontal components. Based on this newly created database, Ground Motion Prediction Equations (GMPEs) for Saudi Arabia are developed by employing a mixed effects regression model to modify one of the NGA-West2 Project GMPEs as the reference model. NGA-West2 addressed several key issues concerning GMPEs for shallow crustal earthquakes in active tectonic regions. However, the NGA-West2 results do not include many extensional earthquakes, such as those observed in Saudi Arabia. This deficiency is corrected by calculating a magnitude scaling of the new Saudi Arabia GMPEs compared to the reference model. Furthermore, there is a clear difference in distance scaling for the Arabian GMPEs in comparison with the reference GMPEs. This difference is especially significant at large distances and is mainly due to lower anelastic attenuation in the crystalline crust of western Saudi Arabia. The site residuals incorporated into the analysis due to the lack of site response

information, such as V_{S30} are derived during the regression. The obtained site residuals show a general agreement with the surface geologies and the site characteristics derived from H/V response spectral ratios. Our empirical data demonstrate that the GMPEs presented here are in good agreement with the observed earthquake ground motions in western Saudi Arabia.

Using the developed regional GMPEs for Saudi Arabia, we carried out Probabilistic Seismic Hazard Analysis (PSHA) for the region of the northern Harrat Rahat volcanic field in the middle west of the Arabian Peninsula. This young, active volcanic field has experienced multiple historical eruptions, including the 1256 CE eruption which occurred at ~20 km away from the Al-Madinah, the second holiest city in Islam, with 1.4 million population. We combined Saudi Arabian GMPEs with two results from volcanological studies in this area: 1. A return period of volcanic eruptions; 2. The spatial probability of the next vent opening. The calculated ground motion levels of PGA and PGV for 2% probability of exceedance in 50 years are expected to be about 0.13 g and 9 cm/s at the most probable vent opening location, about 0.10 g and 6 cm/s at the southwestern edge of the city of Madinah, respectively. These ground motions are higher than previous estimates which did not consider the nearby earthquakes associated with volcanic activity.