Study for Seismic Microzoning in Damascus City, Syria, from Strong Motion Simulation Considering Local Site Amplification

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Abstract:

Damage patterns in past earthquakes show that the local site conditions have a major effect on the level of ground shaking. Seismic microzonation, which is a methodology for mapping the seismic hazard at local scales to incorporate the effects of local site conditions, can provide input for urban planning and for assessment of the vulnerability of the building stock for different hazard levels. Site characterization, which is an essential component for microzonation, was performed for Damascus city based on short-period microtremor exploration technique. The phase velocities were estimated at each site from the vertical components of recorded microtremor data by using the Spatial Autocorrelation method. Then, Genetic Simulated Annealing Algorithm technique was applied for inversion of the phase velocities to estimate 1-D S-wave velocity structures beneath the sites. The inverted VS profiles are not uniform in Damascus city and the city can be divided into three different regions. The inversion results show that the depth to the engineering bedrock (~750 m/s) is very shallow along the foothills of Mt. Qasyoun in the north-west. Then the depth increases towards the east and south-east of Damascus city. The maximum depth to the engineering bedrock was observed in the southern part of the city. The resultant profiles also show that a shallow soft layer (~200 m/s) appears only in the eastern part of the city as well as the central part along Barada River. To validate the results of the inversions, the spectral ratios between the horizontal and vertical components (H/V) of the recorded microtremor data at the central seismometer were compared with the computed ellipticities of the fundamental-mode Rayleigh-waves based on the respective VS structure.

Site amplification factors were calculated by following one-dimensional shear wave

propagation theory for vertical incident S-wave using the inverted VS structure. To validate the applicability of the NEHRP site classification in the case of Damascus city, averaged site amplification was compared with the averaged S-wave velocity for the top 30 and 10 meters of soil (VS30 and VS10). VS10 shows a better correlation with the averaged site amplification than VS30. That indicates VS10 as a better proxy for site amplification in the case of Damascus city. We also compared the site amplification with the topographic conditions. We performed a multiple regression analysis with the averaged amplification factor as the criterion variable and defined by different independent parameters (Elevation, Slope, Distance from rivers, and Site classification). A fairly good correlation between the averaged site amplification and Elevation as well as Distance from rivers was found in the case of Damascus city. These relationships can be used for seismic hazard assessment in Damascus city even though they need to be improved.

The seismic hazard potential for Damascus city is mainly controlled by earthquakes along Serghaya Fault which is a branch of Dead Sea Fault System. Through the last 2000 years, many destructive earthquakes occurred in the region and caused much causality in Damascus city and its vicinity; one of the most destructive events occurred in November, 1759 with a magnitude of ~7.4. Strong ground motions due to the November 1759 Earthquake along the fault of Serghaya, were estimated with a numerical simulation technique. In the simulation, the Kostrov-like slip-velocity function was used as an input to the discrete wave number method to simulate the strong ground motions in a broadband frequency range. In order to model the incoherent rupture propagation which can excite large high-frequency waves, random numbers are added to arrival time of circular rupture front. For source modeling of the 1759 Earthquake, MMI intensities calculated from the synthetic ground motions are compared with the observed values by Ambraseys & Barazangi (1989). The calculated intensities are in good agreement with the observed ones at the most sites that validate appropriateness of the proposed source model.

A grid system with 1.0 km * 1.0 km cells was adopted in Damascus city. We simulated the ground motions at the top layer of VS = 1600 m/s at each grid point using the most appropriate source model of the 1759 Earthquake. The peak ground velocities at the ground surface (PGVS) were calculated by considering the effects of shallow soil layers overlain the layer of VS = 1600 m/s. The microzonation maps with respect to peak ground velocity at ground surface (PGVS) were estimated for Damascus city. The highest values of PGVS were obtained at the central and eastern parts of the city and the smallest values were obtained at the southern parts of Damascus due to the local site effects. We then followed the equivalent linear approximation of nonlinear response to estimate the free surface ground motions at different sites in Damascus city. Acceleration response spectra were estimated and compared with the design response spectra defined by the Syrian building code. The simulated high frequency (1.0 – 6.0 Hz) ground motions for the sites in the Damascus city are higher than the design requirements defined by the code. We also simulated the ground motions at two sites in the epicenter region of the 1759 Earthquake. Acceleration response spectra were calculated and compared with the design requirements defined by the Syrian codes. The simulated high frequency ground motions for sites in the focal region are bigger than the design requirements in the case of the near-fault factors are not considered. That demonstrates the appropriateness of considering the near-fault factors for a site near focal region as introduced by the new building code.