ABSTRACT

The presence of soft alluvial sediment-filled basins and valleys can significantly modify earthquake ground motion (EGM) characteristics. These so-called site effects are mostly considered in a seismic hazard assessment using simple site conditions proxies that implicitly refer to the local 1D structure of the site. This approach is not suitable for site-specific study, because for complex local surface sedimentary structures with pronounced 3D and 2D geometry potentially associated effects on the intensity and EGM characteristics are not taken into account. The reasons for inaccurate site-specific assessment of the earthquake hazard are the absence of well-determined site models due to excessive price of geological surveys, lack of empirical data and poor knowledge of the key controlling parameters of local surface sedimentary structures responsible for anomalous values of EGM characteristics. Therefore, numerical simulations are an irreplaceable tool for proper site-specific seismic hazard assessment.

We performed 3D, 2D and 1D finite-difference numerical simulations for 6 typical sedimentary valleys of various width and depth, and for a variety of modifications of these 6 ‘‘nominal models’’ to investigate the sensitivity of EGM characteristics to geometry and impedance contrast at the sediment-bedrock interface, attenuation, velocity gradient and small-scale random heterogeneities in sediments. We calculated amplification factors, and 2D/1D and 3D/2D aggravation factors for selected EGM characteristics using a representative set of recorded accelerograms to account for input motion variability. For each model, at least one EGM characteristic exhibits a significant 2D/1D aggravation factor, i.e. 1D estimates of EGM characteristics are not sufficient at any of the investigated sites. We identified the key structural parameters that are the shape ratio and overall geometry of the sediment-bedrock interface, impedance contrast at the sediment-bedrock interface, and attenuation in sediments. The amplification factors may largely exceed the values that are usually considered in GMPEs between soft soils and rock sites.

We performed 2D and 1D numerical simulations for 2D models to investigate the effect of small-scale random heterogeneities on EGM characteristics. We considered 3 different autocorrelation functions – Gaussian, exponential and von-Kármán, and 3 different values of standard deviation (5%, 10% and 20%) while assuming fixed values of

correlation lengths with a vertical-to-horizontal ratio 1:10. For each of the combinations of the standard deviation and autocorrelation function, we generated 10 modified models. We showed that at least 9 modified models with randomly perturbed material parameters are sufficient for further analysis effect of small-scale random heterogeneities on EGM characteristics. We concluded that the selection of autocorrelation function does not have a significant impact on the EGM characteristics of modified models. The larger is the standard deviation, the larger is the increase of 2D/1D aggravation factors.

Keywords: Earthquake ground motion, Amplification factor, Aggravation factor, Finite-difference numerical modelling, Small-scale random heterogeneities