ABSTRACT

The amplification of seismic ground motion due to surface topography is a significant factor in earthquake hazard analysis, particularly in regions characterized by complex terrain such as hills, valleys, and slopes. This study aims to systematically evaluate the effects of topographic features on ground motion characteristics by conducting two-dimensional elastic wave simulations using the spectral element method in SPECFEM2D. To isolate the role of topography from other geological variables, all models were configured with homogeneous material properties and included a consistent soft surface layer extending up to 100 meters depth. A range of sinusoidal topographies with amplitudes of 50 m, 100 m, and 150 m were tested alongside a flat surface model for baseline comparison.

The simulations examined the vertical component of ground motion (Z-velocity) across various seismic input conditions, including three source angles- vertical (0°), oblique (45°), and horizontal (90^0) and three frequencies: 10 Hz, 20 Hz, and 30 Hz. The results were analyzed using waveform overlays, Hilbert envelope interpretation (only in earlier stages), and quantitative parameters such as Peak Ground Velocity (PGV) and Root Mean Square (RMS) velocity ratios to measure amplification.

Findings reveal that topography significantly influences both the amplitude and duration of seismic signals. Hill crests exhibited strong amplification due to wave focusing, with PGV ratios as high as 2 times compared to flat surfaces, especially at oblique incidence angles. Valley geometries displayed prolonged shaking and waveform complexity attributed to wave trapping and internal reflections, while sloped surfaces showed spatially variable amplification driven by refraction and incidence-angle-dependent interactions. These effects were found to be frequency-dependent, with greater amplification observed when the seismic wavelength was comparable to the scale of the topographic feature.