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Ground Motion Analysis in the Geometrically Complex Sedimentary Basins of the Dead Sea Transform

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In this research we performed a ground motion analysis in the Dead Sea Basin (DSB) using a finite-difference code (E3D - Larsen et al., 2001) capable of simulating seismic wave propagation in a 3-D heterogeneous earth. Two cross-sections transecting the DSB were compiled based on currently available geological and geophysical data and were used for wave propagation simulations. The research introduces a systematic decomposition method for distinguishing between the individual contributions of each geometrical feature in complex basins.

Sedimentary basins are known to amplify and trap earthquake ground motions, thus, leading to longer ground shaking durations. In Israel, several sedimentary basins are associated with the Dead Sea Transform (DST). These basins are up to 10 km deep, structurally complex and typically bound by active fault zones. Both Israel and Jordan have important industrial facilities and many tourist resorts situated in and around the DST and its associated basins. The DST is the source for some of the largest earthquakes in the region including the 1927 MW 6.2 Jericho earthquake (Garfunkel et al., 1981; Shapira et al., 1993) and more recently the 1995 MW 7.2 Gulf of Aqaba earthquake (Hofstetter, 2003). For seismic hazard assessment it has been suggested that the DST is capable of producing earthquakes with magnitudes up to 7.5 with return periods of 50 years for $M \geq 5$ in the Elat area, 30 years in the Arava and Dead Sea area, and 25 years in the Jordan Valley (Shapira et al., 2007). The seismic hazard presented by the DST threatens the Israeli, Palestinian and Jordanian population alike.

The low seismicity rate of the DST combined with a sparsity of the seismic network in Israel, that provides low coverage of sedimentary basins, results in a critical knowledge gap. It is therefore necessary to compliment the limited instrumental data with synthetic data, based on computational modeling in order to study the effects of earthquake ground motions in these sedimentary basins and to bridge the gap.

Our results confirm that ground motion amplification in sedimentary basins occurs when a strong impedance contrast exists near the surface where Pleistocene lacustrine sediments of the Lisan-Samra Formation are overlying Pleistocene sediments of the Amora Formation with an impedance ratio ranging from $\sim$3.5 to $\sim$4. It is also shown that amplification of ground motions occur (i) in the vicinity of faults or other steep structures and (ii) when a geometrical feature focuses the seismic energy to a convergence zone near the surface. We successfully developed a systematic structural decomposition approach in order to recognize the Peak Ground Velocity (PGV) signature of the various geometric features in the model. Furthermore, we formulated an analytical approach for quantifying geometrical focusing effects based on the relationship between basin parameters, namely, aperture-to-depth ratio, velocity ratio and angle of incidence.

The results of this research add an important aspect in the assessment of earthquake risk, as the investigated scenarios outline areas with a high potential for damage of vital lifelines and critical infrastructure. These results will also contribute toward the improvement of future building codes and seismic hazard assessment. This type of ground motion forward computational modeling has never been performed in Israel.