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Estimated Peak Ground Velocity Variability in the Kyoto Basin from Scenarios Earthquakes on the Hanaore Fault

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Introduction

Ground motion estimation is performed using either physics-based or empirical-based approaches. The physics-based approach involves detailed modeling of how a fault ruptures and how seismic waves travel through the earth, requiring detailed information about the source and subsurface structure. The empirical-based approach employs ground motion models (GMMs), which are based on the regression of observed ground motion data of earthquakes of the past.

In this study, we aim to identify how the ground motion varies by using two different approaches for the Hanaore fault in the Kyoto basin. The Hanaore fault, running from Imazu Town in Takashima District, Shiga Prefecture, through Kyoto City to Uji City in Kyoto Prefecture, has three sections: northern, central, and southern segments. We performed ground motion simulations on the central and southern segments, which are estimated to have occurred between 2800 and 1400 years ago with an average activity interval of approximately 4200 to 6500 years. The northern and central segments are right-lateral strike-slip faults, while the southern segment is a reverse fault with uplift on the east side. We calculated the peak ground velocity (PGV) on the engineering bedrock based on 243 scenarios using the physics-based approach and also estimated the ground motion using the empirical-based approach to discuss the ground motion variability .

Physics- and Empirical-based Ground Motion Estimation

In the physics-based approach, ground motion simulations of the central and southern segments were performed separately by changing the locations of strong motion generation areas (SMGAs) and rupture starting points, and then the predicted results were combined. The rupture transfers at the closest point between the central and southern segments. Earthquake scenarios for the Hanaore fault, provided by the Japan Seismic Hazard Information System (J-SHIS), were used as references and followed the recipe for ground motion prediction by the Headquarters for Earthquake Research Promotion (HERP) for fault geometry. New scenarios were considered by changing the locations of SMGAs and the rupture starting points in relation to the SMGAs; 81 cases for SMGA location and 162 cases for rupture starting location, thus 243 scenarios in total. For the subsurface structure, the deep subsurface structure provided by J-SHIS was adopted. To calculate low-frequency waveforms (≤ 1.2 Hz), the 3D Finite Difference Method was employed using the fourth-order spatial finite difference method with a discontinuous grid on the Ground Motion Simulator (GMS). For high-frequency waveforms (≥ 1.2 Hz), the Stochastic Green’s Function (SGF) Method was utilized. Both software programs are provided by the National Research Institute for Earth Science and Disaster Resilience (NIED). The waveforms obtained from the two calculations were combined using a matching filter (matching frequency of 0.85 Hz) to obtain the broadband ground motions on the engineering bedrock. In the empirical-based approach, we used the GMM by Si and Midorikawa (1999) to predict the ground motion on the engineering bedrock and compared the results with those from the physics-based approach.

Ground Motion Variability Estimated by the Physics- and Empirical-based Approaches

In this research, ground motions were simulated for 800 stations in and around the Kyoto basin. The PGVs estimated by GMS were categorized into inside or outside the basin (323 stations for inside and 477 stations for outside), corrected to the PGVs at the layer of the AVS30=350 and 600 m/s, respectively, and averaged in 13 bins which increase logarithmically in size. The averaged PGVs of inside and outside of the basin were compared with the GMMs at layer of AVS30=350 m/s and 600 m/s. Inside the basin, the average PGVs are lower than the GMM at AVS30=350 m/s, but they match with the GMM at AVS30=600 m/s, except at the further stations with distances ≥10 km, which are lower than the GMM. The stations between 3 km and 6 km distance and the furthest stations around 15 km to 19 km exhibit large variation, which is caused by the radiation pattern of scenarios which start rupture from the northern side of the central segment and the subsurface structure of the stations. For stations outside the basin, the stations closer to the fault (≤6 km) have larger uncertainty, but farther stations are consistent with those of GMM at AVS30=600 m/s.

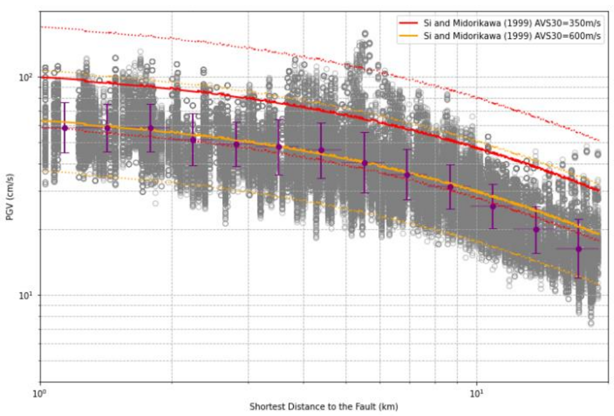

Fig 1. Comparison of PGV results: Physics-based approach using 243 scenarios (Grey circles) versus GMM at AVS30=350m/s for stations inside the basin

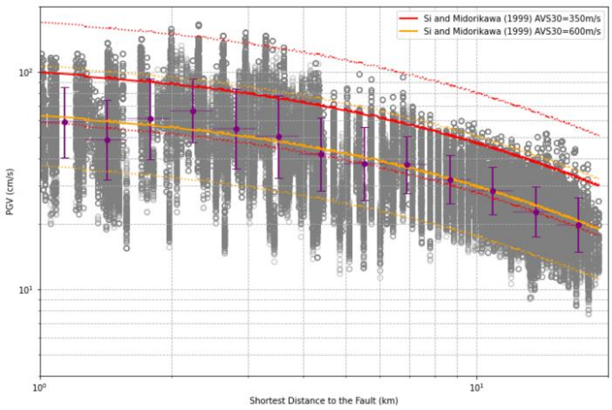

Fig 2. Comparison of PGV results: Physics-based approach using 243 scenarios (Grey circles) versus GMM at AVS30=600m/s for stations outside the basin

Summary

In this study, PGVs on the engineering bedrock were estimated by using two different approaches on the Hanaore fault. The estimated PGVs by 243 scenarios earthquakes were compared to the GMM to identify the consistency and inconsistency between the two approaches for stations inside and outside of the basin. For the stations inside the basin, the physics-based approach generally resulted lower than the GMM at AVS30=350m/s, but aligned more closely with the GMM at AVS30=600m/s. We still need to identify the reason why the stations inside the basin have less PGV compared to GMM at AVS30=350m/s. For outside the basin, the results were more consistent with GMM at AVS30=600 m/s, especially at farther distances.

References

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