Wen *et al. Earth, Planets and Space* (2018) 70:178
https://doi.org/10.1186/s40623-018-0937-y

Earth, Planets and Space

PREFACE

Special issue "Effect of surface geology on seismic motion: challenges of applying ground motion simulation to seismology and earthquake engineering"

Kuo-Liang Wen[1], Pierre-Yves Bard[2], Francisco-José Sánchez-Sesma[3], Sadanori Higashi[4], Tomotaka Iwata[5*] and Takuto Maeda[6]

In the past few decades, numerous studies on the modification of seismic ground motion by surface geology and subsurface structures (Effects of Surface Geology on seismic motion, ESG) have been carried out for improving both our understanding of strong ground motion characteristics during destructive earthquakes and our ability to perform reliable ground motion predictions of future events. This has been enabled by increasing amounts of strong motion data and computing power. Research into the quantification of ESG, and accounting for those effects in everyday design and engineering practice is a key element in the mitigation of earthquake disasters, which are still occurring all over the world.

ESG International Conferences have been held in 1992 (Odawara, Japan), 1998 (Yokohama, Japan), 2006 (Grenoble, France), 2011 (Santa Barbara, USA) and 2016 (Taipei, Taiwan). This 5th International Conference on the Effects of Surface Geology on seismic motions (ESG5) was successful in several respects. It gathered an important number of researchers, field engineers and graduate students from all over the world. The ESG5 proceedings include a large amount of significant information. In order to offer the research community a collection of peer-reviewed contributions, the ESG5 Organizing Committee arranged for the publication of a special issue on recent advances into ESG research in Earth, Planets and Space (EPS), a journal published by Springer. This follows the last special issue on ESG published in 1992 in the Journal of Physics of the Earth (a journal which was merged with EPS in 1998).

This new special issue is a compilation of 18 papers on ESG research, including topics such as seismic ground motion observation; analysis and interpretations, including nonlinear site response; utilization of microtremors; and development of simulation methodologies for strong ground motion prediction.

Seismic observation analysis has always been a key research topic of ESG. Uetake (2017) reports interesting behavior in long-period ground motion recorded in the Kanto area, Japan. He demonstrates that the observed long-period ground motions significantly differed among several distant earthquakes, although they had similar locations, sizes and mechanisms. He shows that the details of the velocity structure in the earthquake source region were the cause of the observed large waveform packet, demonstrating the importance of considering structural inhomogeneities in the source side for long-period ground motion prediction. Bijukchhen et al. (2017) use the observed strong ground motions in the Kathmandu valley during the 2015 Gorkha mainshock and aftershocks, to derive a one-dimensional velocity structure model beneath the observed stations and to compare them with the theoretical earthquake H/V ratios. A unique strong ground motion study was conducted by Sbaa et al. (2017), who performed six-degrees-of-freedom observations using translational and rotational sensors at two nearby sites in Kefalonia Island, Greece, located on rock and soft soil conditions,

*Correspondence: iwata@egmdpri01.dpri.kyoto-u.ac.jp
[5] Disaster Prevention Research Institute, Kyoto University, Uji, Japan
Full list of author information is available at the end of the article

respectively. They found that the dependence on site conditions is stronger for torsional motion (rotation around the vertical axis) than for rocking motion (rotation around horizontal axis), which they interpreted as being a result of more energetic Love waves on soft site conditions compared to Rayleigh waves. Kagawa et al. (2017) compare the observed ground motion variations in the source region of the 2016 Central Tottori earthquake to the map of predominant site period derived from dense microtremor observations in the area. They show that larger peak ground accelerations correspond to shorter predominant periods, and also report significant period shifts at some intermediate period sites during the main shock, which they interpret as being related to nonlinear site response.

Effects of nonlinear site response and/or liquefaction significantly impact strong ground motion characteristics. Ren et al. (2017) quantify the amount of soil nonlinearity by using various indices based on the horizontal-to-vertical spectral ratio applied to strong ground motion records obtained during and after the 2008 Wenchuan earthquake, China (Ms8.0), and investigate their correlation with loading or site parameters. Similarly, Chen et al. (2017) analyze the amount of nonlinear site response in the (estimated) strong shaking area in relation to the loading and site parameters for the 2016 Meinong earthquake and propose a method to incorporate the resulting nonlinear frequency shifts in otherwise linear stochastic ground motion simulations. Lu et al. (2017) investigate the degree of damage to low-rise buildings as a result of soil liquefaction in the superficial layer during the 2016 Meinong earthquake, Taiwan, and emphasize some nonconservative limitations of existing methods, linked to poor accounting of the underlying site conditions. Dhakal et al. (2017) transpose these nonlinear site response estimates based on H/V ratios to the ocean bottom seismogram sites of the Sagami Bay K-NET, Japan. Their observations show that the degree of nonlinearity is generally larger at the OBS sites due to the smaller threshold motions that cause a nonlinear site response, compared with the available data at land sites.

The use of microtremors has been a permanent feature of ESG studies for many decades. Recently, building on advances in the methodology of seismic interferometry of ambient noise or microtremors, Sánchez-Sesma et al. (2011) and Kawase et al. (2011) use the diffuse field theory to propose new relationships between an underground velocity model and microtremor H/V, or earthquake H/V, respectively. Sánchez-Sesma (2017) investigate the nonuniqueness issue of 1D velocity model inversions based on the H/V spectral ratio only, by inverting jointly the H/V ratio and the dispersion curves of fundamental modes of Rayleigh and/or Love waves. Kawase et al. (2018) use statistical analysis to compare microtremor (M) and earthquake (E) H/V spectral ratios from a large set of permanent strong ground motion stations to derive simple, frequency-dependent correction factors to estimate EHVSR from easily obtainable MHVSR and propose a relatively simple method for the derivation of 1D velocity profiles from corrected microtremor H/V ratios. Matsushima et al. (2017) observed a directional dependence of microtremor H/V at the Onahama station, Fukushima, Japan. The directional analysis of dense, single-point microtremor measurements allowed them to identify the presence of a shallow, wedge-like lateral heterogeneity, parallel to the direction of the axis of the larger microtremor H/V amplitude, consistent with the strong motion observations. Meanwhile, Wu et al. (2017) propose a simplified approach to invert the 1D velocity structure directly from the microtremor H/V ratio, on the basis of the locked mode ("cap-layer") approximation allowing the use of the residue theorem.

Asano et al. (2017) obtain long-period inter-station Green's function in the Osaka sedimentary basin, Japan, using ambient noise (microtremor) cross-correlation functions. The fairly good match with the simulated inter-station Green's functions based on the present Osaka sedimentary basin model (Sekiguchi et al. 2016) shows the applicability of noise cross-correlation for velocity model validation. Salameh et al. (2017) propose, using a case study from Beirut (Lebanon), the combination of microtremor observations at ground surface with those within buildings, coupled with a background model based on extensive site and building response calculations, to provide urban-scale damage estimates on the basis of easily available dynamic parameters (soil and building frequencies, H/V amplitude). Kleinbrod et al. (2017) show the usefulness and repeatability of ambient vibration on rock slopes to characterize unstable areas from the directional dependence and the amplitude of the H/V spectral ratios.

Finally, in order to optimize the efficiency of ground motion prediction equations and building code provisions, site characterization issues should be addressed continuously. Derras et al. (2017) use the KiK-net data to investigate the performance of several parameters as site condition "proxies" to reduce the aleatory variability of GMPEs and recommend the use of pairs of proxies. They also identify significant site response nonlinearities and discuss the ability of various site proxies and loading to account for them. The objective of Stambouli et al. (2017) is similar, i.e., to identify optimal site condition proxies, but their approach is based exclusively on 1D, linear numerical simulations, together with the use of a special kind of neural network to derive appropriate relationships between various site parameters and site amplification functions.

This special issue presents a representative selection of recent advancements in ESG studies, including topics such as strong motion observation, field investigation of microtremor and/or seismic ground motions, their analysis using a wide variety of processing and inversion techniques, and their interpretation and comparison with forward simulation models. These studies reflect the ongoing efforts to improve strong ground motion prediction for future earthquakes. We expect new challenges and further advances of ESG studies that contribute to the reduction in earthquake disasters all over the world.

Authors' contributions

All authors of this article served as guest editors for this special issue. All authors read and approved the final manuscript.

Author details

[1] Department of Earth Sciences, National Central University, Chungli, Taiwan, ROC. [2] ISTerre, IFSTTAR, CNRS, IRD, Bâtiment, OSUG C, Grenoble-Alpes University, Grenoble, France. [3] Instituto de Ingeniería CU, Universidad Nacional Autónoma de México, Coyoacán, Mexico. [4] Central Research Institute for Electric Power Industry, Abiko, Japan. [5] Disaster Prevention Research Institute, Kyoto University, Uji, Japan. [6] Graduate School of Science and Technology, Hirosaki University, Hirosaki, Japan.

Acknowledgements

We express sincere thankfulness to the authors who contributed to this special issue, and reviewers who evaluated the contributions and gave helpful comments and suggestions.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 3 October 2018 Accepted: 3 October 2018
Published online: 15 November 2018

References

Asano K, Iwata T, Sekiguchi H, Somei K, Miyakoshi K, Aoi S, Kunugi T (2017) Surface wave group velocity in the Osaka sedimentary basin, Japan, estimated using ambient noise cross-correlation functions. Earth Planets Space 69:108. https://doi.org/10.1186/s40623-017-0694-3

Bijukchhen SM, Takai N, Shigefuji M, Ichiyanagi M, Sasatani T, Sugimura Y (2017) Estimation of 1-D velocity models beneath strong-motion observation sites in the Kathmandu Valley using strong-motion records from moderate-sized earthquakes. Earth Planets Space 69:97. https://doi.org/10.1186/s40623-017-0685-4

Chen C-T, Chang S-C, Wen K-L (2017) Stochastic ground motion simulation of the 2016 Meinong, Taiwan earthquake. Earth Planets Space 69:62. https://doi.org/10.1186/s40623-017-0645-z

Derras B, Bard P-Y, Cotton F (2017) VS30, slope, H800 and f0: performance of various site-condition proxies in reducing ground-motion aleatory variability and predicting nonlinear site response. Earth Planets Space 69:133. https://doi.org/10.1186/s40623-017-0718-z

Dhakal YP, Aoi S, Kunugi T, Suzuki W, Kimura T (2017) Assessment of nonlinear site response at ocean bottom seismograph sites based on S-wave horizontal-to-vertical spectral ratios: a study at the Sagami Bay area K-NET sites in Japan. Earth Planets Space 69:29. https://doi.org/10.1186/s40623-017-0615-5

Kagawa T, Noguchi T, Yoshida S, Yamamoto S (2017) Effect of the surface geology on strong ground motions due to the 2016 Central Tottori Earthquake, Japan. Earth Planets Space 69:106. https://doi.org/10.1186/s40623-017-0689-0

Kawase H, Sánchez-Sesma FJ, Matsushima S (2011) The optimal use of horizontal-to-vertical (H/V) spectral ratios of earthquake motions for velocity structure inversions based on diffuse field theory for plane waves. Bull Seismol Soc Am 101:2001–2014

Kawase H, Mori Y, Nagashima F (2018) Difference of horizontal-to-vertical spectral ratios of observed earthquakes and microtremors and its application to S-wave velocity inversion based on the diffuse field concept. Earth Planets Space 70:1. https://doi.org/10.1186/s40623-017-0766-4

Kleinbrod U, Burjánek J, Fäh D (2017) On the seismic response of instable rock slopes based on ambient vibration recordings. Earth Planets Space 69:126. https://doi.org/10.1186/s40623-017-0712-5

Lu C-C, Hwang J-H, Hsu S-Y (2017) The impact evaluation of soil liquefaction on low-rise building in the Meinong earthquake. Earth Planets Space 69:109. https://doi.org/10.1186/s40623-017-0693-4

Matsushima S, Kosaka H, Kawase H (2017) Directionally dependent horizontal-to-vertical spectral ratios of microtremors at Onahama, Fukushima, Japan. Earth Planets Space 69:96. https://doi.org/10.1186/s40623-017-0680-9

Ren Y, Wen R, Yao X, Ji K (2017) Five parameters for the evaluation of the soil nonlinearity during the Ms8.0 Wenchuan Earthquake using the HVSR method. Earth Planets Space 69:116. https://doi.org/10.1186/s40623-017-0702-7

Salameh C, Bard P-Y, Guillier B, Harb J, Cornou C, Gérard J, Almakari M (2017) Using ambient vibration measurements for risk assessment at an urban scale: from numerical proof of concept to Beirut case study (Lebanon). Earth Planets Space 69:60. https://doi.org/10.1186/s40623-017-0641-3

Sánchez-Sesma FJ (2017) Modeling and inversion of the microtremor H/V spectral ratio: physical basis behind the diffuse field approach. Earth Planets Space 69:92. https://doi.org/10.1186/s40623-017-0667-6

Sánchez-Sesma FJ, Rodríguez M, Iturrarán-Viveros U, Luzón F, Campillo M, Margerin L, García-Jerez A, Suarez M, Santoyo MA, Rodriguez-Castellanos A (2011) Theory for microtremor H/V spectral ratio: application for a layered medium. Geophys J Int 186:221–225

Sbaa S, Hollender F, Perron V, Imtiaz A, Bard P-Y, Mariscal A, Cochard A, Dujardin A (2017) Analysis of rotation sensor data from the SINAPS@ Kefalonia (Greece) post-seismic experiment—link to surface geology and wavefield characteristics. Earth Planets Space 69:124. https://doi.org/10.1186/s40623-017-0711-6

Sekiguchi H, Asano K, Iwata T, Yoshimi M, Horikawa H, Saomoto H, Hayashida T (2016) Construction of 3D velocity structure model of Osaka sedimentary basin. In: Proceedings of the 5th international symposium for effects of surface geology on seismic motion, Taipei, 15–17 August 2016

Stambouli AB, Zendagui D, Bard PY, Derras B (2017) Deriving amplification factors from simple site parameters using generalized regression neural networks: implications for relevant site proxies. Earth Planets Space 69:99. https://doi.org/10.1186/s40623-017-0686-3

Uetake T (2017) Effects of subsurface structures of source regions on long-period ground motions observed in the Tokyo Bay area, Japan. Earth Planets Space 69:71. https://doi.org/10.1186/s40623-017-0655-x

Wu H, Masaki K, Irikura K, Sánchez-Sesma FJ (2017) Application of a simplified calculation for full-wave microtremor H/V spectral ratio based on the diffuse field approximation to identify underground velocity structures. Earth Planets Space 69:162. https://doi.org/10.1186/s40623-017-0746-8