

1982-2024: Four Decades of Accumulating (Scientific) Debt to “Japan-made” Engineering Seismology

Pierre-Yves Bard

ISTerre (Institute of Earth Sciences), University Grenoble-Alpes, Grenoble, France

As a sincere thanks for this honoring DPRI award, I will start my talk with listing several features of my professional career that benefitted a lot from inspirational exchanges with Japanese seismologists and engineers. As it might look as an indigest, “à la Prévert” catalog of apparently unrelated activities, I will detail one particular scientific topic that has been one of my constant concerns since the Guerrero-Michoacan 19985 event and its effects in Mexico City, i.e., the interaction between the building stock and the seismic ground motion in densely urbanized areas: this debated issue might find an in-situ, full-scale and real-world instrumental answer with accumulated strong motion gathered since almost three decades by the K-NET and KiK-net networks.

The list of my “Japan-inspired” activities is indeed quite long and broad, as it combines specific research topics, the approach to tackle them, and the way to use and communicate research results. I will shortly mention some of them:

- The involvement in the mid-eighties in the genesis of the IASPEI/EAGE working group on ESG, with smart Japanese and Californian leaders: the way they found a road for understanding the reasons of their different viewpoints on ESG, and for reaching a common understanding (from seismologists to engineers, and on each side of the Pacific Ocean...) left me a career-long example of how to (try to) bridge the multi-fold misunderstanding gaps between the different communities involved in engineering seismology
- Making me aware of the usefulness of long-term test sites coupled with benchmarking exercises: The Ashigara Valley and Turkey Flat blind predictions proved very instructive for me in strongly shaking my (by that time strong) numerical simulation bias, learning me the value of well-controlled data. This was actually the initial seed for the future establishment of several test sites in Europe and the organization of numerous benchmarking exercises.
- The use of microtremors (and microseisms) following the exponential world-wide spread of the H/V technique after the 1989 Nakamura's RTRI paper: this was really a major turn in my scientific career. Trying to understand the physical meaning of this H/V ratio, I discovered the richness of the Japanese literature, the variety of approaches and interpretations, and it was actually for me the initial impetus to introduce the ambient vibration approaches first in the European seismological community, and then in the engineering community. It took long time to convince both communities, but after three decades it is almost done, thanks to many exchanges with Japan, several European projects, dedicated experiments, many PhD students and international benchmarks...
- The new standards set up by K-net and KiK-net networks in producing large sets of high-quality strong motion data and making them freely available worldwide through internet: the post-Kobe, mid-nineties coincided with the time we were starting the French strong motion network, and struggling

with the "keep your data for you" policy, and the "kyoshin" web site was an excellent example to show and follow! Not to talk about the achievement of systematic site investigations and the availability of velocity and geological profiles, which were a fantastic opportunity for many previously impossible investigations, including with emerging AI tools. I will list several topics where actually this dataset was essential in my research activities over the last two decades

- Last but not least, I also enjoyed and benefitted from the beginning of my career, the human qualities of Japanese seismologists. Their humility, their respectful attentiveness, their quietness (and sometimes their silence) were indeed very useful for a young French professional, quite likely to give in to typically French (or Western style) arrogant, loud-speaking behavior.

The second part will focus on the site-city interaction issue, first with a quick overview of past, partial results, followed by an analysis of data from one of the most densely urbanized areas in the World, the Tokyo-Kanto area. The striking site response observations obtained in Mexico City during the 1985 Guerrero-Michoacan even triggered a series of investigations on multiple structure-soil-structure interaction, which later evolved with the concept of metamaterials. Up to very recently, such investigations relied largely on numerical simulations in 2D and 3D media, coupling soft surface soil layers and simplified building models, including also some theoretical developments using various mechanical concepts. They also relied on a number of laboratory experiments on reduced-scale mock-ups with diverse vibratory sources (shaking table, acoustic devices). The latest studies coupled full-scale experiments on mechanical analogs such as forests or wind turbine farms involving sets of resonators with similar frequencies, and numerical simulation to investigate their impact on the propagation of surface (Rayleigh) waves. Almost all such studies converge in predicting lower ground motion amplitude for sites located within the "urbanized" area, but none of them can be considered a "ground-truth" proof for a real earthquake in a real city. Thus, I took advantage of my 3-month stay in DPRI in Spring 2023, to investigate the possibility of temporal site response changes in areas of rapid urban changes, through an analysis of the event-specific site terms provided by the Generalized Inversion Techniques of Nakano et al. (2015) at all KiK-net, K-NET or JMA (Shin-dokei) located in the Kanto area. In short, it is found that the sites located in or near the priority redevelopment areas of the "urban renaissance" program in Tokyo, where many new high-rise buildings have been erected since the turn of the century, exhibit a significant reduction of the low-frequency amplification (up to a factor of 3 reduction at some sites). Considering the correspondence between high-rise building frequencies (below 1 Hz) and site frequencies (fundamental mode below 0.2 Hz in relation with very thick – around 3 kilometres – sedimentary deposits, and largest amplification between 0.5 and 1 Hz in relation to softer soils at shallow depth), such a decrease is consistent with the outcomes of all kinds of previous investigations carried over three decades about effects of multiple interaction between buildings and underground soil structure. Such a consistency, although intriguing, cannot be considered yet a definite proof that the observed reduction is actually due to "site-city interaction" effects: I look forward a further cooperation with Japanese colleagues to performing some additional investigations (that I will propose) to confirm (or eliminate) the SCI interpretation.