Site effects : Impact, advances and challenges

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This topic dealing with effects of «shallow» site conditions on ground shaking is indeed at the interface between different disciplinary fields (seismology, geophysics, soil and structural dynamics) and between different communities (academic / engineering / regulatory). The talk is intended to present a short overview of the today status of both knowledge and practice, with a special focus on the recent advances and on the major remaining issues for a more satisfactory accounting fro an improved risk reduction.

The basic physics of underlying wave propagation phenomena will be addressed first, in view of capturing the actual space scale, and introducing a few present challenges, such as: the relevancy of the classical separation between independent source, path and site effects (in other terms, the sensitivity of site effects to incident wave-field characteristics), a better assessment of surface topography effects and their links to weathering, the effects and amount of non-linearity in sediments, including at large depth, which calls for larger amounts of soil/rock pairs and/or vertical arrays, the more systematic quantification of effects on duration (and not only on amplitude) of ground motion, and the respective roles of wave-field complexity and soil short wavelength heterogeneities – natural or anthropic - on the spatial variability of ground motion – which calls for a larger number of permanent dense arrays.

The main tools for site effect studies are complementary : observations, numerical simulation, and shallow geophysics and geotechnics. Some significant efforts have been made recently in Europe to densify the (permanent and temporary) observations and complement them with richer metadata on site conditions, but they still remain modest as compared to Japan or even US. The usefulness of a dedicated large pool (several hundreds) of compatible mobile stations at the European level (for temporary, very dense studies on small, typically ct-scale areas) will be promoted. Numerical simulation has been, and is still an invaluable tool in understanding the physics of site effects, but still faces big challenges for actually predicting them for complex 3D structures. Numerous sophisticated codes do exist, but their use without due caution can be harmful; recent verification and validation studies resulted however in promising results, showing that the prediction of ground motion in complex 3D structures is at reach up to frequencies around 4-5 Hz. The main frontier indeed comes now from the capability of shallow geophysics and geotechnics to provide the needed resolution with enough reliability at an affordable cost : the propagation medium at shallow depth is indeed extremely heterogeneous (large contrasts over very short vertical and lateral distances), and its imagery is a major challenge. Recent years have seen significant advances, especially with non-invasive, both active and passive techniques. Major breakthroughs are needed however for in-situ measurements of some parameters such the soil non-linearity and soil damping (including their possible frequency dependence).

The last part of the talk will address more specifically the engineering and regulatory interface. Non-site specific assessment techniques recommended in building codes, or in large scale hazard and risk maps, use «proxies» to site conditions. The relevancy of those which are presently used worldwide (i.e. VS30 in codes, and slope for hazard and risk maps) will be discussed: serious warnings will be issued on their possible misuse, and alternative directions will be indicated. Site specific assessments – for instance for critical facilities - may use the 3 tools listed in the previous section, and could thus benefit from the significant recent advances; it is amazing however how the instrumental approach is most often completely neglected in Europe, despite the drastic drop in instrumentation and data storage costs, while it could have a major impact on the reduction of uncertainties, and therefore hazard levels at large return periods.