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Improving Station Characterisation for the Accelerometric Network of the National Observatory of Athens

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Abstract

The accelerometric network of the National Observatory of Athens (NOA) covers most Greek territory with 164 strong-motion stations. For few of those, site conditions are known in detail through measurements. However, most of them are still characterised merely through 1:50,000 geological maps. Considering: 1. the progress made in recent years with sophisticated ground motion models, 2. the move towards large open-access strong-motion databases, and 3. that Greek-provenance data represent a significant percentage of European seismic data, better site characterisation of this network's stations has become imperative. In-situ-characterisation campaigns impose unattainable time/budget constraints, so we implement alternative approaches using the recordings themselves. We consider triggering-mode stations with an adequate number of recordings and use the empirical horizontal-to-vertical spectral ratio technique to estimate amplification. The computed transfer functions show that the response within site categories as defined by seismic design codes (e.g. Eurocode 8) is often not homogeneous. The results shed light onto the seismic behaviour of particular stations and hope to aid in the quest for a more harmonised site characterisation throughout Greece.

Background and Objectives

The accelerometric network of the Institute of Geodynamics of the NOA had its first strong-motion stations installed in the 1970s, and today covers most of the country's territory with 164 strong-motion stations (https://accelnet.gein.noa.gr,). In March 2019, the network consists of 91 stations operating in continuous mode with live data transmission and 73 stations operating with low-resolution instruments in triggering mode. For a few of these stations, site conditions are known in great detail thanks to nearby boreholes, geophysical in situ and/or geotechnical laboratory investigations. For some others, Vs_{30} values have been inferred from proxies, such as topography. Margaris et al. (2014) provide a brief history of the characterisation of Greek stations with boreholes, geophysical campaigns and microtremors, while Stewart et al. (2014) compile values of Vs_{30} and other geological data for some of the stations. However, to date, most of these stations are still characterized merely through 1:50,000 scale geological maps. Today, characterising the network's stations has become a necessity, not only due to the upgrade of the instrumentation leading to more and better-quality data, but also given the state of the art in ground motion prediction and simulation, where the prevalent type of classification used up to now (geological maps) has become obsolete.

Methods

Despite the strong need for site characterisation, performing in-situ measurements (boreholes, geophysical campaigns, geotechnical testing) at all stations imposes unattainable time/budget constraints. Hence, we turn to alternative approaches and estimate amplification functions (aka transfer functions), with the horizontal-to-vertical spectral ratio (HVSR) introduced by Lermo and Chavez-Garcia (1993), the empirical technique available in the absence of a reference station. Here we focus on the triggering-mode accelerometric stations. At the end of 2018, over 1000 strong-motion recordings had been processed and individually inspected for quality assurance. Recordings up to 1999 are included in the unified Hellenic Accelerogram Database HEAD (Theodulidis et al., 2004), while recordings from 2000 to 2018 are not in public databases so far. We begin with the best-populated stations choosing a minimum number of 10 events per station, resulting in 19 stations and about 700 usable recordings. Few of these stations appear in the Vs compilation of Stewart et al. (2014). After standard corrections and processing, ratios of the Fourier amplitude spectra (FAS) of acceleration were computed between the horizontal components and to the vertical. For each station these were logarithmically averaged per component, yielding amplification functions for the longitudinal and transverse component. An additional set of analyses was performed in order to assess the sensitivity of the amplification to orientation. We followed the procedure of Ktenidou et al. (2015), incrementally rotating the pairs of components, and recomputing the transfer functions.

Results

Fig. 1 shows the mean transfer functions computed for each station and their directional dependence per rotational increment. The shaded areas represent values of HVSR between 0.5 and 2.0, which considering typical uncertainties are practically equivalent to unity. An example of considerable directional dependence/sensitivity of the HVSR is ARGA, while an example of stability with orientation is VLSA. Around 3 Hz, ARGA exhibits statistically the same amplification in both components, if the as-installed recordings are rotated by 10°, but shows a difference of a factor of 2 if rotated by 40°. This is particularly interesting, as ARGA is one of the few stations on rock (class-A site as per EC8, CEN, 2003). Considering the high number of recordings at the site, and the significant separation of the standard error bands, this is not likely to be an artefact and so further investigation is recommended. On the other hand, VLSA exhibits considerable stability with orientation, and also remains flat and close to unity over the entire range of frequencies below 6 Hz. Of the rock stations studied, VLSA is the only one that may be considered a reference station, at least out to 6 Hz. Of the 2 stiff soil sites, AIGA exhibits the typical behaviour of a B-class site, while the fact that no strong directionality is observed there seems to confirm previous conclusions that topographic effects are not prominent at Aegion (Ktenidou, 2010); MALA, on the other hand, does not exhibit significant amplification. Finally, of the soft-soil (class C) sites, site AMAA shows a clear peak around 1 Hz, much as expected, while PATA is interesting due to its stability with orientation and its lack of significant amplification.

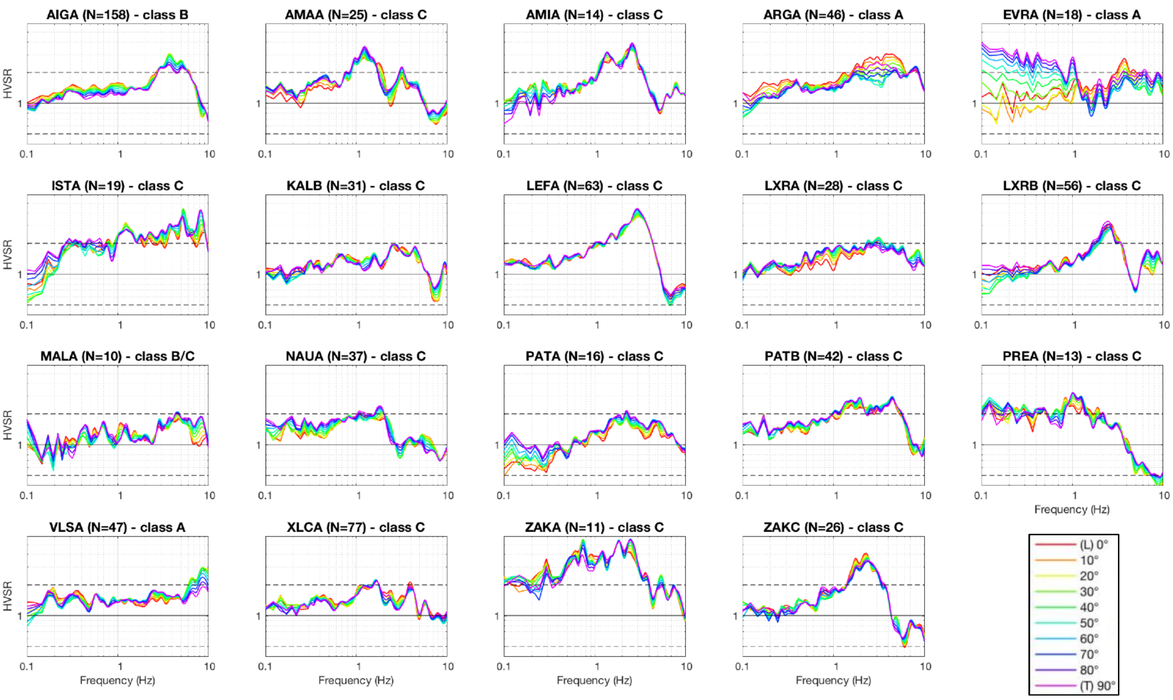

Figure 1. Mean HVSR and directional sensitivity at stations that recorded more than 10 earthquakes.

Conclusions

The hard sites in this subset do not behave in the same way, nor is their response independent of orientation. This calls for further investigation into the local site conditions and an effort to understand the provenance of any directional dependence. The majority of sites studied are soft-soil sites, and again their response exhibits variability: some stations have an identifiable resonance, others have more complex or broadband amplification patterns, while others show no significant amplification. We do not focus on absolute amplitude, as HVSR has often been shown to yield unreliable amplitudes (Field & Jacob, 1996). Finally, low-frequency uncertainties are likely due to the fact that some of the recordings came from analog instruments (Kinemetrics SMA-1) or from low-resolution digital Kinemetrics QDR or Teledyne A800 sensors, whose low-frequency content is known to be limited.

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