# Comment on “Effect of surface wave inversion non-uniqueness on 1D seismic ground response analysis” by Roy et al.

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**Short title: Comment on “Effect of SW inversion non-uniqueness on 1D seismic GRA”**

# Comment on “Effect of surface wave inversion non-uniqueness on 1D seismic ground response analysis”

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## Abstract

We discuss a study on the effect of surface wave solution non-uniqueness on 1D seismic site response analysis. The 1D ground response approach used in the considered paper may lead to an overestimation of the variations in amplification spectrum. We also address the numerical simulation of seismic site response. We apply a consistent framework to one real record of the same earthquake to show that, contrary to what is claimed in the considered study, the solution non-uniqueness has negligible effect in amplification and acceleration response spectra.

## Comment

Roy *et al.* (2013) study the impact of solution non-uniqueness of surface wave inversion on seismic site response of soil column using near-source and far-source earthquake records.

They refer to a previous study (Foti *et al.*, 2009) in which it was shown that the impact of solution non-uniqueness on seismic response simulations is negligible for profile having high impedance contrast. They also refer to another study (Boaga *et al.*, 2011) in which it was reported that, in the case of a gradual velocity increase with depth, solution non-uniqueness deeply affects the accuracy of seismic response analyses: for low impedance contrast the effect is much more pronounced than for high impedance contrast, for which the equivalent solutions have a very little influence. The latter was already discussed by Socco *et al.* (2012), highlighting the importance of a correct procedure in ground response analysis: errors in the selection and application of input motions in seismic response simulation can indeed affect the obtained results.

Roy *et al.* claim that the inversion uncertainty has a pronounced effect on the 1D ground response analysis particularly for the far-field earthquake scenarios: this can mislead the calculations for design ground motions if these uncertainties are not properly addressed.

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We think that some issues in Roy *et al.* (2013) approach require further clarifications. The main concern is the selection of the input motion and the procedure used to its implementation in the seismic site response analyses.

Input motions in the equivalent one-dimensional ground response study considered by Roy *et al.* were defined such as “five records of the same earthquake at epicentral distances of 37, 50, 103, 150 and 202 km... Recorded data of an earthquake of magnitude 6.6 occurred on 2012/03/27 (Latitude 39.80°N, Longitude 142.33°E) in Japan are collected from K-NET database and used for the analysis”. Considering the time histories reported by Roy *et al.*, it seems that input earthquakes are recorded in borehole. As no details are presented for the deconvolution procedure, it is assumed that these time histories were used directly in the site response analysis by Roy *et al.*, probably as “within” motion at the base of the model. This assumption has been verified by the Authors against the results provided in the paper by Roy *et al.* Such a procedure can mislead the obtained results because borehole records heavily depend on the associated Vs profiles. Vs profiles beneath the five stations cited in Roy *et al.* are indeed different from each other and different from the ones adopted in the study of site response (see Figure 1): consequently, recorded accelerograms can not be implemented directly in the analyses (Kramer, 1996).

One-dimensional ground response analyses are based on the assumption that all boundaries are horizontal and that the response of a soil deposit is predominantly caused by S-waves propagating vertically from the underlying bedrock: therefore a correct input motion, corresponding to a “bedrock motion”, has to be applied at the base of the model. Procedures based on this assumption have been shown to predict ground response that is in reasonable agreement with measured response in many cases (Kramer 1996).

A conventional time history is in general recorded at a station on surface: if the station is located on outcropping, the recorded time history is used as input in the convolution analysis for a 1D site response. Otherwise it should be reduced to outcrop through deconvolution procedure (Kramer, 1996), which is not specified by Roy *et al.* in their paper. In any case, for the deconvolution it is necessary to know the depth of the seismic bedrock and this issue is not addressed in Roy *et al.* (2013). In real cases, if the investigation depth of surface waves does not reach the seismic bedrock, this information should be introduced into the process as an a priori information inferred on the basis of other surveys (e.g. seismic reflection/refraction) as done for instance by Foti *et al.*, 2009.

Applying this procedure we implemented a 1D equivalent linear elastic site response analysis, carried out using the software EERA (Bardet *et al.*, 2000), considering the same 15 best fitting profiles adopted by Roy *et al.* and the same earthquake occurred on 2012/03/27: the selected time history is the surface EW record of the Tarou station at epicentral distance of 37 km. Input motion was obtained using a deconvolution procedure at bedrock outcrop beneath the Tarou station considering the Vs profile reported in Figure 2 (details in K-NET and KiK-net database) and with modulus reduction and damping curves taken from the literature (Seed and Idriss, 1984).

The adopted methodology is showed in Figure 3. The ground motion at the surface of a site (point A, i.e. Tarou station) depends on subsurface conditions of the sites beneath it. The recorded motion is then deconvolved through the soil profile beneath the surface to determine the time history of bedrock motion (at point B) that would produce the time history of motion at point A. The corresponding rock at cropping motion produces the bedrock motion applied at the base (point D) of the soil profile at the site of interest. A conventional ground response analysis is then performed to predict the motion at the surface of the soil profile of interest (point E). This motion, which is consistent with the local site conditions, can be used to compute site-specific design parameters (i.e. peak acceleration and velocity, amplification spectrum, response spectral ordinates). According to this procedure, we calculated the rock outcrop waveform from the surface record at Tarou station applying the recorded input motion at the top of the related 1D model: the output at the base of the model was then implemented as input motion at the base of all the 15 best fitting profiles in the site response analyses.

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To evaluate the amplification functions for the equivalent Vs profiles (Figure 1-f) seismic bedrock should be introduced: we assumed it at a depth of 60 m and with Vs equal to 1240 m/s as bedrock in Tarou (Figure 2). Similar results are obtained with the bedrock at higher depth (i.e. 80 m or 100 m). Therefore we performed a set of simulations using the code EERA considering the 15 shear wave velocity profiles in Figure 4. Other input data (Poisson ratio’s, densities, modulus reduction and damping curves) were the same used by Roy *et al*.

Results in terms of amplification are reported in Figure 5-a: the amplification curves (ratio between the surface motion and the input/base motion), obtained for the set of equivalent shear wave velocity profiles, are very similar in terms of peak amplification as well as in peak frequency. Figure 5-b shows the coefficient of variation (CoV = $\sigma/\mu$, where $\sigma$ is the standard deviation and $\mu$ is the mean) of amplification spectra for equivalent profiles with respect to frequency: the maximum value of CoV is about 9.51%, with a mean value of 4.85%, much lower that one obtained by Roy *et al*.

Little variations can be observed for acceleration response spectra (Figure 6-a). Variation in peak acceleration is between 0.499g and 0.614g. For response spectra, the CoV observed (Figure 6-b) is lower than those observed for amplitude spectra, with a maximum value of about 6.34%, and mean equal to 2.40%.

These results confirm the conclusion of the study reported by Foti *et al.*, 2009, showing that the impact of solution non-uniqueness on seismic response simulations is indeed negligible following the correct procedure for site response analysis.

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# Figure captions

Figure 1 – a) Vs profile beneath the Tarou station; b) Vs profile beneath the Yamada station; c) Vs profile beneath the Touwa station; d) Vs profile beneath the Nakasen station; e) Vs profile beneath the Honjoh station; f) 15 best fit Vs profiles used for the site response analyses.

Figure 2 – a) Vs profile beneath the Tarou station: general soil stratigraphy and related modulus reduction and damping curves; b) recorded acceleration time history at Tarou station, earthquake of magnitude 6.6 occurred on 2012/03/27 (Latitude 39.80°N, Longitude 142.33°E); c) acceleration time history at seismic bedrock after deconvolution analysis.

Figure 3 – Procedure for modifying ground motion parameters to account for the effects of local site conditions (deconvolution and convolution analyses)

Figure 4 – Fifteen best fitting shear wave profiles considered in the site response analysis with seismic bedrock at 60 m of depth.

Figure 5 – a) Variation of amplification spectra of equivalent profiles; b) Variation of CoV of amplification spectra for equivalent profiles with respect to frequency

Figure 6 – a) Variation of acceleration response spectra of equivalent profiles; b) Variation of CoV of acceleration response spectra for equivalent profiles with respect to period.

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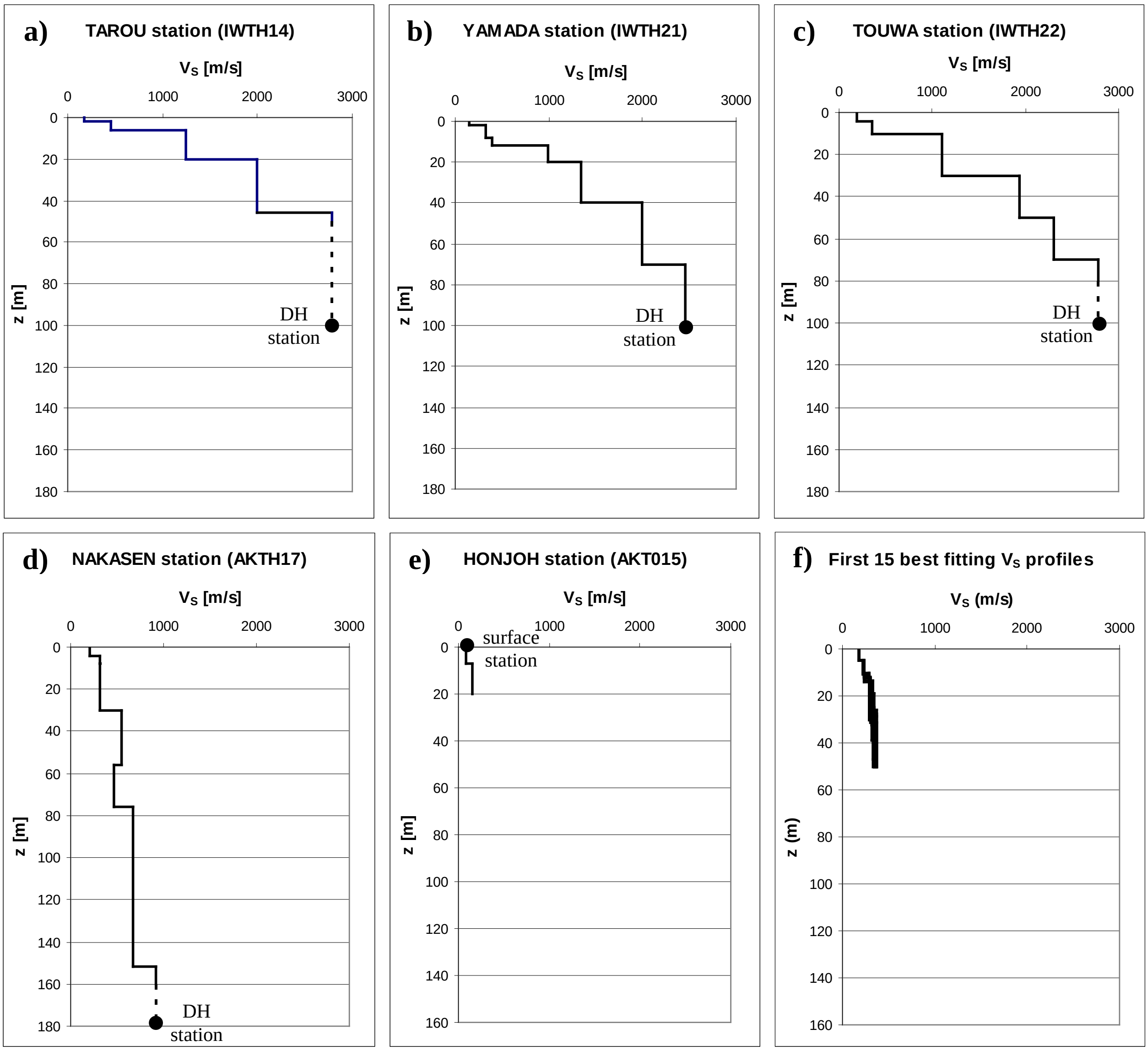

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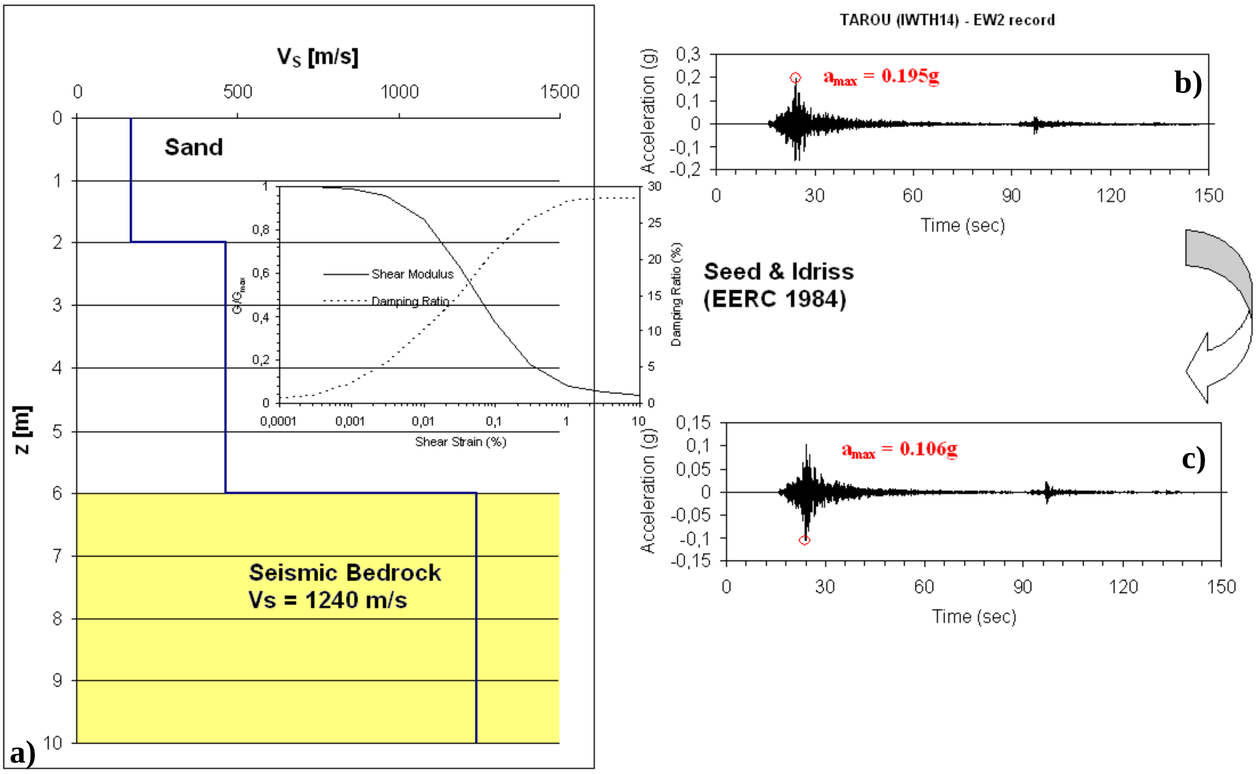

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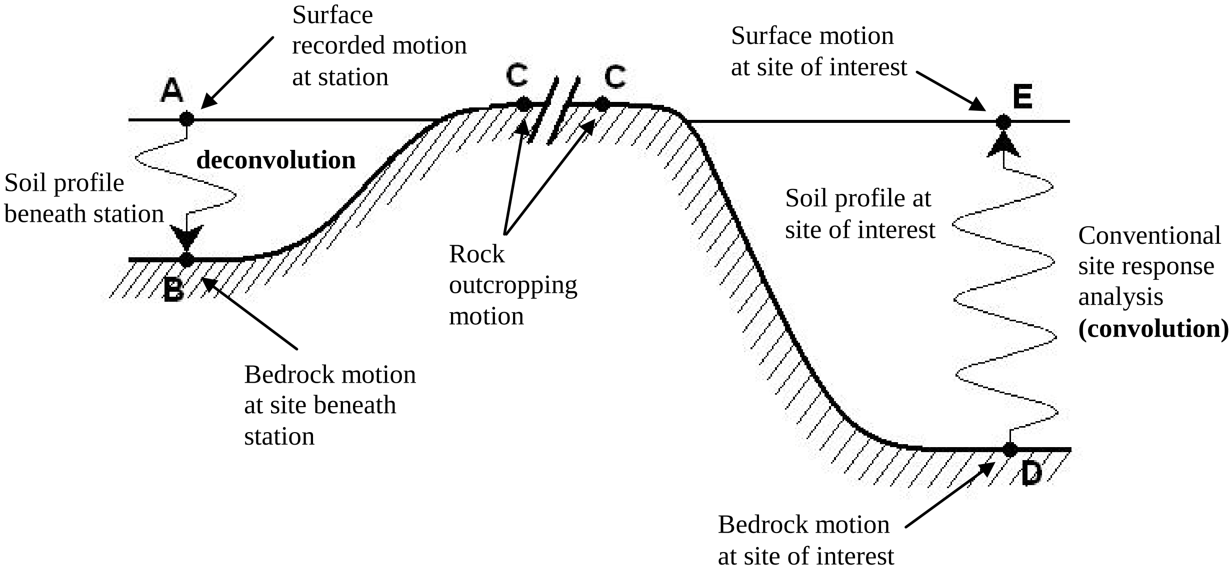

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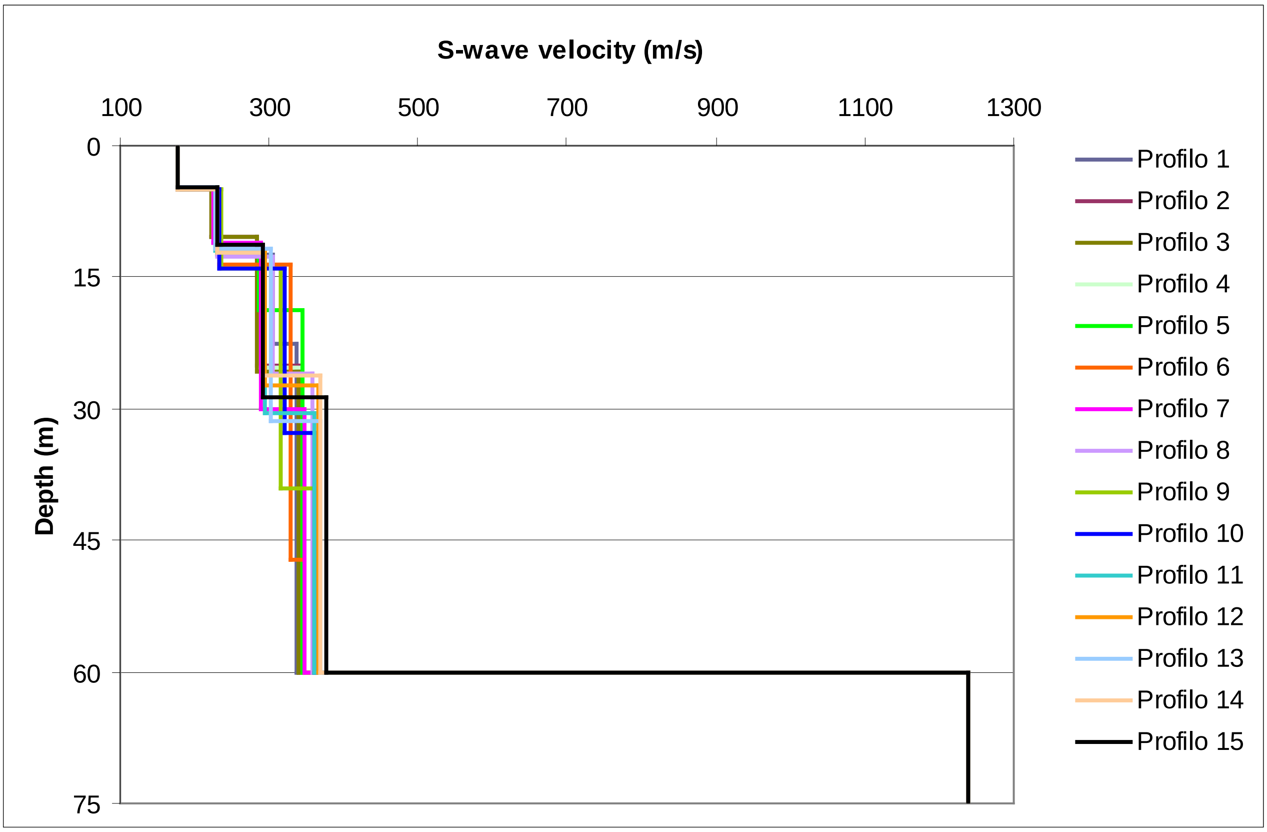

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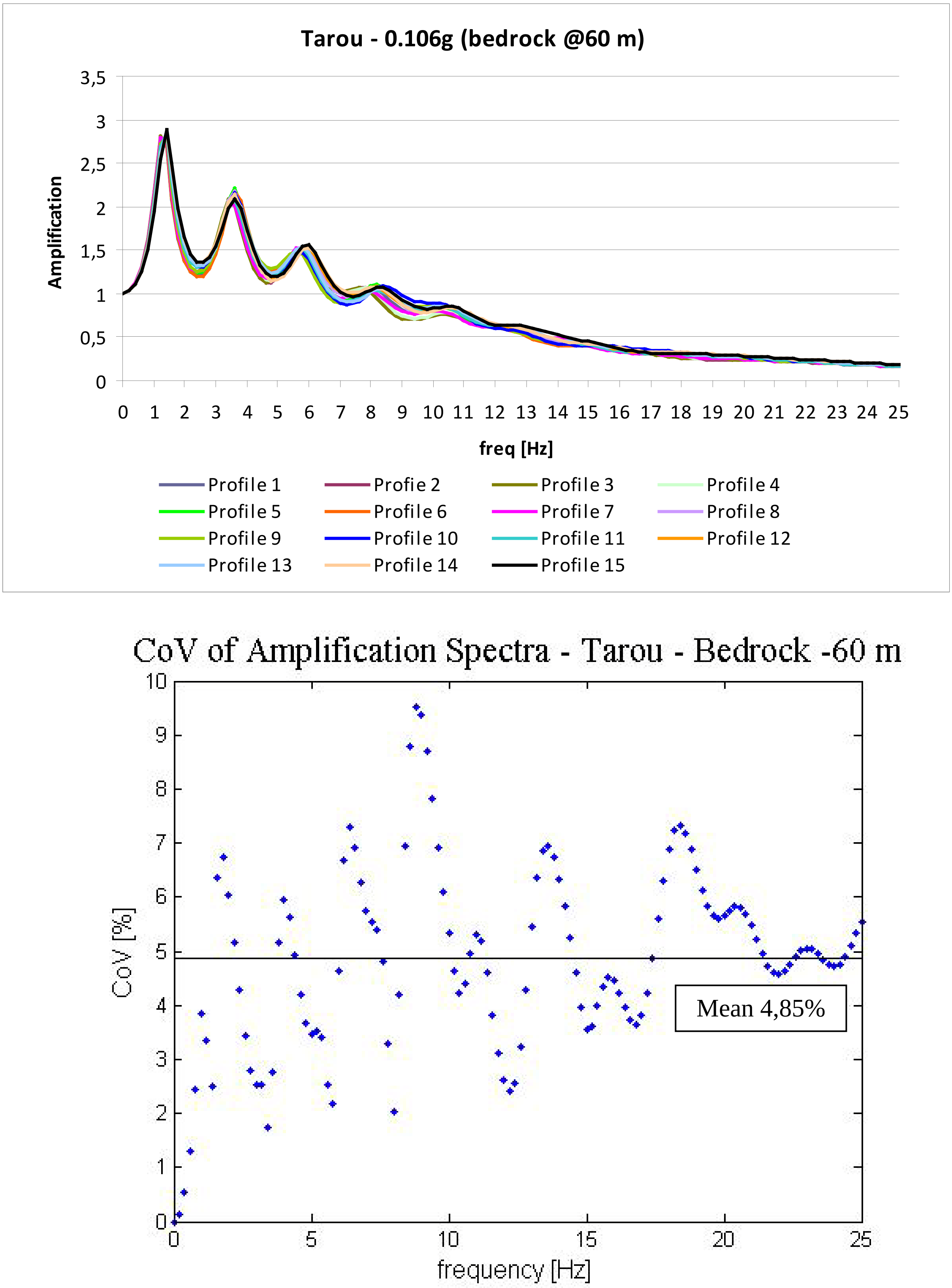

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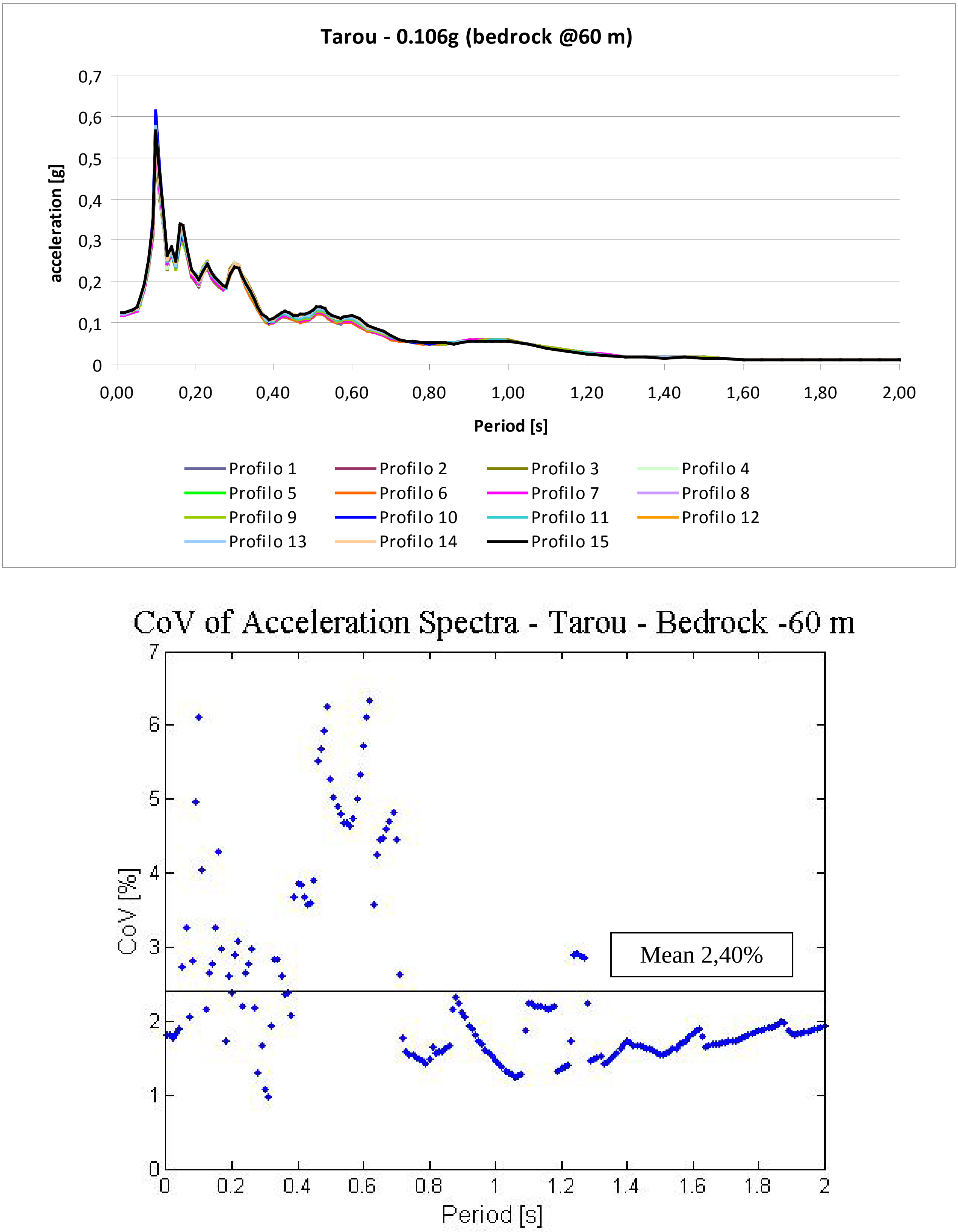

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