A Research about Correlation between Similarity of EHVSRs and that of HSAFs

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Under ideal conditions, the horizontal site amplification factor (HSAF) is a ratio of the horizontal Fourier amplitude spectrum (FAS) on the Earth's surface with respect to the horizontal FAS on the seismological bedrock straightly beneath the surface. HSAF reflects the profile of local sedimentary soil and rock formations, standing for site effects. In actual engineering, such ideal HSAF is significantly difficult to be directly measured in many cases. Thus, how to well evaluate HSAF is a curial mission in the strong-motion amplification estimation over the last century. This research found the correlation between the similarity of earthquake horizontal-to-vertical spectral ratios (EHVSRs) and that of HSAF, giving a new perspective for evaluating HVSR in terms of the correlation. Fig. 1 shows the flow chart of the proposed method.

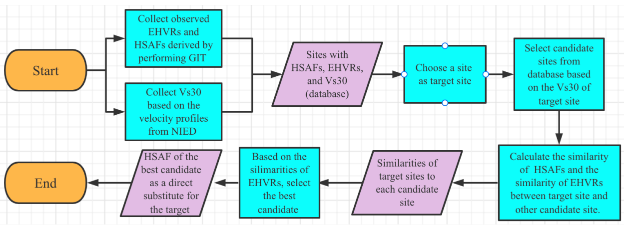

Fig. 1 Flow chart of the proposed method

Herein, all the sites are those of K-NET and KiK-net of National Research Institute for Earth Science and Disaster Resilience (NIED) (Aoi et al., 2000). The total number of sites is 1588, and this investigation applied the HSAFs and EHVSRs, which were separated using Generalized Inversion Technique (GIT) at those sites in a previous study by Nakano et al. (2015), as well as Vs_{30} based on the velocity profiles from NIED. In additional, the extrapolation functions by Boore et al. (2011) were utilized to derive the Vs_{30} at those sites where borehole survey data did not reach 30 meters.

Both the average residuals over the whole frequency range of interest (0.12–15 Hz) and Pearson product-moment correlation coefficient (PPMCC) are utilized to design the functions as an index for the similarity between two spectra (e.g. R_1 and R_2) in terms of goodness-of-fit. Since we would like to pay more attention to peaks and troughs of the spectra, a linear coordinate system was applied on the vertical axis in Eq. (1), giving larger weight to sharper peaks and troughs than logarithmic systems. Supplementing a weight on the denominator of Eq. (1) in terms of average R_2 means a higher tolerance is given to those spectra whose average is larger. Different from the degree of difference (DoD) proposed by Wang et al. (2021), which represents the average distance between two spectra on logarithmic axes, the *Res* herein has no geometric meaning due to the weight considering average R_2 on the denominator of Eq. (1).

$$Res(R_1, R_2) = \frac{\sum_{i=1}^{n} \left| \frac{1}{f(i)} (R_1(i) - R_2(i)) \right|}{\sum_{i=1}^{n} \frac{R_2(i)}{f(i)}} \quad (1)$$

$$\bar{R} = \frac{\sum_{i=1}^{n} log_{10} R(i)}{n} \quad (2)$$

$$\sigma_R = \sqrt{\sum_{i=1}^{n} (log_{10} R(i) - \bar{R})^2} \quad (3)$$

$$Cor(R_1, R_2) = \frac{\sum_{i=1}^{n} (log_{10} R_1(i) - \overline{R_1}) \cdot (log_{10} R_2(i) - \overline{R_2})}{\sigma_{R_1} \cdot \sigma_{R_2}} \quad (4)$$

$$Gof(R_1, R_2) = \frac{Cor(R_1, R_2) + 1}{Res(R_1, R_2)} \quad (5)$$

In these equations, R_1: spectrum of target sites, R_2: spectrum of candidates, *Res*: average residual between

R_1 and R_2, n: total number of data, f : frequency, $\bar{R}$: average of R, σ_R: standard deviation of R,$Cor(R_1,R_2)$: PPMCC between R_1 and R_2. Finally, the function standing for similarity is Eq. (5).

As shown in Fig. 2, the correlation between the similarity of EHVSRs versus that of HSAFs was considered without other additional restrictions, meaning that 1588-1=1587 blue dots representing each candidate were plotted here, except for the target site itself (Here it is AIC014). Following the flow chart shown in Fig. 1, the site denoted as MYZ020 was selected as the best candidate among 1587 sites, meaning that the HSAF of MYZ020 was found to be the direct substitute of HSAF for AIC014. The correlation is obvious, yet the best candidate selected in terms of the similarity of EHVSRs is not the best choice from the aspect of the similarity of HSAFs, which should be IWT013.

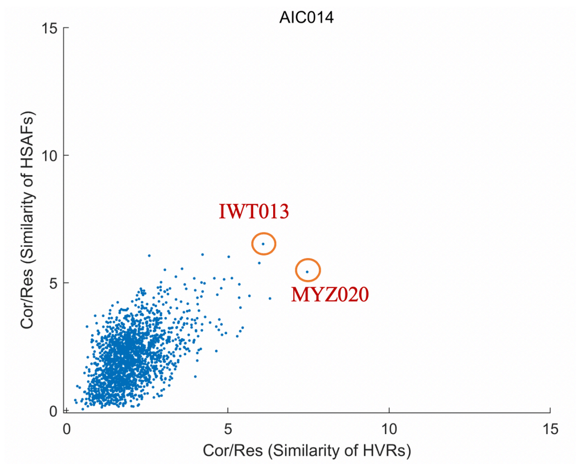

Fig. 2 Correlation between the similarity of EHVSRs and that of HSAFs without V_{S30}

The pre-selection shown in Fig. 3 means that 1587 sites (except for the target site) are sequenced based on Vs_{30}, then a certain number of sites are chosen by referring to the Vs_{30} akin to the target site. As shown in Fig. 3, the number of candidates is 150, meaning that 150 sites with the most similar Vs_{30} to the target were selected among 1587 sites. As shown in Fig. 3, the range of candidate Vs_{30} is 343–389 m/s, and Vs_{30} of the target site is about 367m/s. Moreover, the use of pre-selection also met our expectation that MYZ020 was eliminated and IWT013 was picked, which was the most desirable choice from the view of vertical axes, as the direct substitute of AIC014.

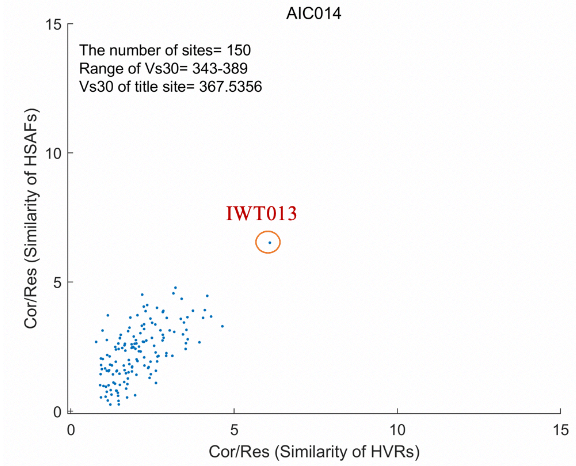

Fig. 3 Correlation between the similarity of EHVSRs and that of HSAFs considering Vs_{30} for pre-selection

Fig. 4 shows four types of HSAFs and the average residuals (average distance on the logarithmic system) of GIT with respect to other methods. Obviously, the results from our correlation method or Vertical Amplification Correction Function (VACF) are much better than using EHVSRs as a direct substitute. Yet, there is no significant difference in effectiveness between VACF and the proposed correction method in this study. In the case of AIC014, the correlation method gave better results than VACF at low frequencies, but is worse at medium frequencies. As for the high-frequency range, both these two methods have ample space for improvement, yet the correlation method chose a better HSAF in this example.

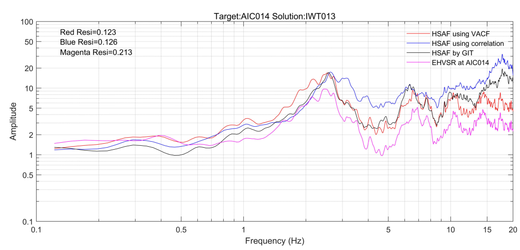

Fig. 4 Four types of HSAF and their average residuals with respect to GIT