Numerical and Theoretical Investigation on the Origin of the Multiple Peaks of the H/V Ratio Curve

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Despite the popularity of the horizontal to vertical spectral ratio (HVSR) method in site effect studies, the origin of the H/V peaks has been controversial since this method was proposed. Many previous studies mainly focused on the explanation of the first or single peak of the H/V ratio, trying to distinguish between the two hypotheses — the S-wave resonance and ellipticity of Rayleigh wave. However, it is common both in numerical simulations and practical experiments that the H/V ratio exhibits multiple peaks, which is essential to explore the origin of the H/V peaks.

The cause for the multiple H/V peaks has not been clearly figured out, and once was simply explained as the result of multi subsurface layers. Therefore, we adopted numerical method to simulate the ambient noise in various layered half-space models and calculated the H/V ratio curves for further comparisons. The peak frequencies of the H/V curves accord well with the theoretical frequencies of S-wave resonance in two-layer models, whose frequencies only depend on the S wave velocity and the thickness of the subsurface layer. The same is true for models with varying model parameters. Besides, the theoretical formula of the S-wave resonance in multiple-layer models is proposed and then supported by numerical investigations as in the cases of two-layer models. We also extended the S-wave resonance to P-wave resonance and found that its theoretical frequencies fit well with the V/H peaks, which could be an evidence to support the S-wave resonance theory from a new perspective. By contrast, there are obvious differences between the higher orders of the H/V ratio peaks and the higher orders of Rayleigh wave ellipticity curves both in two-layer and multiple-layer models. The Rayleigh wave ellipticity curves are found to be sensitive to the Poisson's ratio and the thickness of the subsurface layer, so the variation of the P wave velocity can affect the peak frequencies of the Rayleigh wave ellipticity curves while the H/V peaks show slight change. The Rayleigh wave ellipticity theory is thus proved to be inappropriate for the explanation of the multiple H/V peaks, while the possible effects of the Rayleigh wave on the fundamental H/V peak still cannot be excluded.

Based on the analyses above, we proposed a new evidence to support the claim that the peak frequencies of the H/V ratio curve, except the fundamental peaks, are caused by S-wave resonance. The relationship between the P-wave resonance and the V/H peaks may also find further application.