SSS25-P07 Room:Convention Hall Time:May 25 18:15-19:30

Relations between seismic intensity by linear and nonlinear site responses using empirical transfer functions

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In order to estimate broadband source models or predict strong motions to agree with intensity scale of historical earthquakes such as the 1923 Great Kanto earthquake and Nankai Trough earthquakes, intensity scale or seismic intensity should be calculated considering into nonlinear site responses. However, strong motions calculated by the stochastic Green's function method using empirical site responses derived from weak motions or the empirical Green's function method are not considered into nonlinear site responses. The site responses estimated by nonlinear seismic response analyses depend on subsurface structure models and the dynamic property models as well as the methods. In this study we develop an empirical relation between seismic intensity by linear and nonlinear site responses using many KiK-net records.

Firstly, we select strong motion records with peak ground accelerations greater than 300 cm/s^2 of 68 earthquakes observed at 124 KiK-net stations and the weak motion records of 520 earthquakes there. Then we remove some records affected by rocking or uplifting vibrations of seismometers, basements or structures from the selected records. The record most strongly affected by such vibration was the strong motion records observed at KiK-net Haga with equivalent intensity scale of 7 during the 2011 Tohoku earthquake.

Then we calculate empirical transfer functions which are defined by spectral ratios of ground motions at a surface to vertical motions at a borehole for weak motions to those for strong motions. The strong motions by linear site responses are estimated from strong motion records multiplied by the empirical transfer functions, which are complex Fourier spectra, in the frequency domain. The strong motions in the time domain are calculated by the Fourier inverse method. This idea means that we use empirical transfer functions instead of theoretical transfer functions by the one-dimensional linear and equivalent linear analyses. The empirical transfer functions are not influenced by the assumptions of dynamic property models and subsurface structure models.

The seismic intensity by nonlinear site responses I_{NON} is modeled by seismic intensity by linear site responses I_{LIN} and the equivalent predominant frequency fe=PGA_{LIN} /(2$\pi$$PGV_{LIN}$). Here PGA_{LIN} and PGV_{LIN} are the calculated peak ground acceleration and the peak ground velocity. The regression relation derived by the constrained least square method with $I_{LIN} \geqq I_{NON}$ is,

I_{NON} - I_{LIN} =6.155-1.669 I_{LIN} + 0.110 I_{LIN}^2-0.688$\log_{10}$fe.

Figure shows the relation between I_{NON} and I_{LIN} and the regression relations. The maximum I_{NON} of data was 6.6 observed at KiK-net Hino during the 2000 Tottoriken Seibu earthquake. The range of I_{LIN} used in the regression analysis is from 4.5 to 7.0. The number of transfer functions is 192. In the empirical equation, I_{NON} becomes smaller than I_{LIN} beyond I_{LIN} of about 5.0. We show that fe is better than Vs30 as a parameter of the equation because fe is influenced by not only site effects but also source and path effects. The higher fe is, the bigger the difference between I_{NON} and I_{LIN} is. This feature reflects that amplification factors in the high frequency range decrease stronger than those in the low frequency range by the increase of damping factors due to nonlinearity of soil. In the obtained equation, INON is 6.4 in the case of I_{LIN} =7.0 and fe=5Hz. I_{NON} is 6.7 in the case of I_{LIN} =7.0 and fe=2Hz. Since I_{LIN}^2 term is added in the equation in order to represent the saturation of dynamic properties on the strain, the empirical equation of I_{NON} has the slight saturation effect on I_{LIN}.

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