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INVESTIGATION OF NON-LINEAR SITE AMPLIFICATION AT TWO DOWNHOLE STRONG GROUND MOTION ARRAYS IN TAIWAN

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SUMMARY

Non-linear seismic response of soil is studied by comparing the spectral ratios of surface to downhole horizontal accelerations on weak and strong motion. Data from two boreholes are analysed. One is drilled in the alluvial deposits in the south–west quadrant of the SMART1 array. The second one penetrates Pleistocene terrace deposits in the northern part of the SMART2 array. Observed weak and strong motion spectral ratios are compared with the theoretical ones predicted by the geotechnical soil model which postulates a hysteretic constitutive law. A significant non-linear response is found at the first site for the events with surface peak acceleration exceeding roughly 0·15*g*. Deamplification of the strong motion occurred in the frequency range from approximately 1 to 10 Hz. The maximum observed difference between the average weak and strong motion amplification functions of an 11 m-thick near-surface stratum is a factor of 2·3. Non-linear response characteristics are in qualitative agreement with the model. An additional corollary is that the amplification function calculated from the shear wave coda is equivalent to the average amplification calculated over the ensemble of small earthquakes. No statistically significant non-linear response is detected on the second array, that is tentatively accounted for by the stiffer soil conditions and weaker accelerations achieved at the SMART2 site. The results indicate that the non-linear amplification can be detectable at certain soil conditions above a threshold acceleration level.

INTRODUCTION

Non-linear soil response in strong ground motion caused by earthquakes has long been a controversial subject in seismology and earthquake engineering. It has been known theoretically since the pioneering works carried out by Idriss and Seed[1] that non-linear effects in near-surface deposits can be manifested in increased damping and reduced shear wave velocity (V), both occurring as the excitation strength increases from low to high. Since $V = 4Hf$, where f is the fundamental frequency of the surface layer and H is its thickness,[2] the decrease in shear wave velocity should be associated with the downward shift in the resonance frequency of the layer. The above non-linear effects are caused by the typically hysteretic nature of soil shearing deformation, as revealed from vibratory and cycling loading tests performed on soil samples under laboratory conditions.[3–5] A threshold acceleration level beyond which there is an appreciable departure of the ground response from linear prediction, expected in geotechnical engineering, is approximately 100–150 Gal (cm/s^2).[1,6–8]

It is also known that low-impedance superficial layers amplify the upcoming seismic waves.[2,9,10] As non-linear effects increase the effective damping in soils, they work against the common amplification. Thus, one of the characteristic symptoms of non-linear ground response is deamplification of strong motion compared with the weak motion.

Reliable demonstrations of the non-linear ground response derived from seismological data did not exist until very recently and seem to be scarce. That is why non-linearity was never taken seriously in seismological

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