EFFECTIVE SEISMIC INPUT THROUGH RIGID FOUNDATION FILTERING

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SUMMARY

The current practice in seismic analysis of structures, including structures with large foundations such as those in typical nuclear power plants, is to represent earthquake excitation by one translation input ground motion over the entire foundation area. This is generally based on the assumption that the near-surface seismic excitation consists of vertically propagating shear and compressional waves. This leads to a considerable simplification in the seismic analysis of structures. However, it has been demonstrated that seismic ground motion may consist predominantly of obliquely incident shear and compressional body waves in the near field of a shallow-focus earthquake, and may have significant contributions from horizontally propagating surface waves under certain conditions in the far field.

In the general case of a plane wave incident at an arbitrary angle, the motion at the soil-foundation interface will not be in phase, giving rise to an important class of soil-structure interaction effects. These effects are due to wave scattering and are manifested by the attenuation of high-frequency components in the translational motion of the foundation relative to the free-field motion, along with frequency-dependent torsional and rocking motion of the foundation. These effects are independent of effects caused by structural eccentricities and soil compliance. This raises some concern about the adequacy of current practice in seismic analysis, which ignores such phenomena.

This paper develops a simple yet realistic approach that will account for this important soil-structure interaction phenomenon of wave scattering. The foundation may be considered to act as a filter (or transducer), which partitions the imparted momentum into low-pass filtered translational motion together with frequency-dependent torsional motion (for horizontally polarized shear and Love waves) and rocking motion (for compressional, vertically polarized shear, and Rayleigh waves). These effects are evaluated to first order by extending the approximate approach used by Yamahara (1970) for horizontally incident, horizontally polarized shear waves. The results are expressed in terms of filtering functions for various foundation geometries and embedment conditions. The filters can be applied to horizontal and vertical free-field time histories to obtain the foundation input motion components, namely horizontal translation and torsion, and vertical translation and rocking, respectively. Numerical results of such filtering of a number of ground motion records are presented in the form of acceleration response spectra.

The formulas for these filters in the frequency domain show an interesting general relationship between the attenuated translation and torsion or rocking motions of the foundation: the two motions are 90° out of phase for a given free-field harmonic wave. This suggests the possibility of computing the responses of structures to the two foundation motion components independently and combining the results by the square-root-of-the-sum-of-the-squares method to obtain a reasonable estimate of the true combined response. Results of numerical analyses on several one-degree-of-freedom systems and a multi-degree-of-freedom system are presented in the paper to support this conclusion.