Defense Announcement

The Efficiency of Metamaterial-Based Seismic Isolation Barriers

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Seismic isolations are used to protect structures from earthquake disasters. This research aims to develop a new type of seismic isolation barrier adopting the technology of periodic metamaterial. This type of seismic isolation barrier is called periodic barrier.

Periodic metamaterial possesses a unique frequency-selective property that enables the periodic metamaterial to manipulate the wave propagation. A wave barrier, which is designed to mitigate either man-made or naturally caused vibrations by introducing a discontinuity in the soil, is made by infilling the 1D periodic metamaterial in the trench-type wave barrier. The research can be summarized as follow: (1) deriving the analytical frequency band gaps of periodic metamaterial for the Rayleigh wave, (2) establishing a finite element model for an extensive parametric study, and (3) conducting passive isolation tests and active isolation tests to evaluate the performance of the barriers.

First, the analytical frequency band gap of periodic metamaterial for the Rayleigh wave is derived. Second, the dynamic behavior of the periodic metamaterial is simulated with finite element models. The two-dimensional finite element simulations on trench-type wave barriers with various conditions are investigated for their screening effectiveness. The influence of key parameters, including the depth of barriers, infilled material, loading direction, number of barriers, and loading distance, on the screening effectiveness is understood. Third, a series of full-scale field experiments are conducted to investigate the screening effectiveness of both empty trench and periodic barriers. Two state-of-the-art hydraulic mobile shakers (T-Rex and Thumper) were used to generate excitations in the vertical, horizontal inline, and horizontal crossline directions for passive and active isolation tests. In addition to the effect of the barrier dimension, geometrical arrangement, and loading distance, it is found that the excitation direction significantly affects the performance of the barrier. Moreover, the presence of the underground periodic foundation can lead to a wider attenuation zone. The attenuation zones identified through the field tests match the theoretical frequency band gaps with the assumption of the dominant type of wave generated by the excitation in different directions.