Soil Dynamics and Earthquake Engineering 31 (2011) 535–545

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

Analysis on multiple scattering by an arbitrary configuration of piles as barriers for vibration isolation

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ARTICLE INFO

Article history:
Received 7 July 2010
Received in revised form
26 October 2010
Accepted 30 October 2010

ABSTRACT

By introducing the multiple scattering of acoustic or electromagnetic waves by an arbitrary configuration of parallel cylinders, a new formal solution that is different from the traditional ones to solve the problem of plane elastic waves scattering by cylindrical solid piles as barriers for environmental vibration isolation has been established. The first order of scattering is generated from the excitation of each pile by incident waves, and the second order is resulted from the excitation of each pile by the first order of scattering induced by remaining piles. The rest to an infinite can be executed in the same manner. Suppose that each order of scattering satisfies continuity boundary conditions at the surface of each pile, the undetermined scattering coefficients would be figured out ultimately. By introducing the normalized displacement amplitude and transmissibility indices, some properties of vibration isolation by single or multi-row of piles are analyzed. Influences of specific parameters such as scattering orders, separations between piles and pile rows, normalized frequencies, number of piles, etc. are investigated. Several instructive results are derived and recommended for designing piles as barriers for environmental vibration isolation.

1. Introduction

The vibration induced by traffic, construction and blast not only has severe effects on vicinal structures and facilities, but also distresses the daily life of residents. Therefore, it becomes a major concern for engineers and researchers. The most valid way of environmental vibration isolation is to set up a barrier between the vibration source and protection area. Usually we use ways such as active and passive isolation to cope with the vibration. Generally, the passive approaches are widely used, which contains two methods: the continuous barriers and the discontinuous ones.

The continuous barriers such as open and in-filled trenches are considered to be the conventional ways. A large number of literatures referring to the subject can be turned to. Woods [1] proposed the criteria of open trenches on the basis of a series of experiments in situ and he raised the concept of A_{RC} evaluating the amplitude reduction of barrier for the first time. Haupt [2] developed a model test by comparing open and concrete in-filled trenches, he concluded that the isolation effectiveness has relationship with the depth of trenches. With numerical methods, Lysmer and Waas [3] employed the FEM to access the screening of trenches in layered soil by simulating the boundary conditions. Segol et al. [4] also applied FEM along with special non-reflecting boundaries to the trenches in the layered soil. Beskos et al. [5] utilized BEM combining with Fourier and Laplace transform and reached a conclusion that open trenches behave better than in-filled trenches. Al-Hussaini and Ahmad [6,7] studied time domain coupled BEM algorithm so as to apply it in the vibration screening by trenches.

Nevertheless, for incident waves with long wavelengths, and for the case in very soft ground or high water table level locations, this kind of method is circumscribed for some critical and restricted reasons such as stability and excavating depth of trenches. Rows of piles as discontinuous barriers are considered to be a better way for environmental vibration isolation consequently.

Since 1960s, lots of researches with respect to discontinuous barriers have been conducted. Through experimental ways Richarts et al. [8] investigated the performance of screening effectiveness by piles initially. By using holography technique, Woods et al. [9] pointed out that the effective isolation was under the circumstances that wavelengths were less than 6 diameter of piles and more than 4 separations between the piles. Avilés and Sánchez-Sesma [10,11] had reached a conclusion that rigid piles performed more effectively than flexible piles through the studies on scattering of plane wave by infinitely long piles, the effectiveness could be obtained when incident wavelengths were less than 4 diameters and 2 lengths of piles. Boroomand and Kaynia [12,13] analyzed a simplified foundation model to examine the efficiency of vibration reduction by one-row pile in homogeneities. In the recent past, Kattis et al. [14,15] developed a 3D frequency-domain BEM and applied the full-space Green′s function to study the efficiency of pile barriers. Gao [16] et al.

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doi:10.1016/j.soildyn.2010.10.008