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Free vibration of piles embedded in soil having different modulus of subgrade reaction

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Abstract

The soil that the pile is embedded in is idealized by a Winkler model and is assumed to be two layered. The part of the pile extending above the ground is called the first region, and the parts embedded in the soil are called the second and the third regions, respectively. The dynamic displacement function of the pile subjected to an axial force is obtained as a fourth order partial differential equation by taking account of the effects of bending moment and shear force. It is assumed that the behavior of the material is linearly elastic and axial force along the pile length to be constant. Shear effects are included in the differential equations by the second derivative of the elastic curve function with respect to shear deformation. Normalized natural circular frequencies of the pile are calculated using a carry-over matrix and the secant method for non-trivial solution of the linear homogeneous system of equations obtained for a specific value of the axial force, and for two combinations of boundary conditions:

1. One end fixed, and the other end free in displacement, but constrained against angular motion (henceforth referred to as a "sliding boundary condition");
2. One end fixed, and the other end simply supported.

Rotary inertia is considered. The results are presented in graphs.

Keywords: Carry-over matrix; Free vibration; Shear effect; Rotary inertia

1. Introduction

The piles partially embedded in the soil that are under the effects of bending moment, axial and shear forces, are very often used in highway, railroad, marine and harbour structures. Calculation of free vibration has a great importance for structural, geotechnical and foundation engineers.

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As in this study, for the bending analysis of a beam on a linear elastic foundation or of partially supported piles, soil is idealized mostly by the Winkler model. Many researchers have studied the behavior of the beams on an elastic foundation in the past [1]. Doyle and Pavlovic have solved the partial differential equation for free vibration of beams partially attached to elastic foundation using variable separating method and neglecting axial force and shear effects [2]. Boroomand and Kaynia have studied dynamic analysis of pile–soil–pile interaction for vertical piles in a homogeneous soil by using a Fourier expansion of variables [3]. Aviles and Sanchez-Sesma have studied the usefulness of a row of rigid piles as an isolating barrier for elastic waves. They have formulated the problem as one of multiple scattering and diffraction [4]. West and Mafi have solved the partial differential equation for free vibration of an elastic beam on elastic foundation that is subjected to axial force by using initial value method [5]. A theoretical analysis has been presented to solve the problem of foundation isolation, using a row of elastic piles as an isolating barrier for elastic waves by Aviles and Sanchez-Sesma [6]. Yokoyama has studied the free vibration motion of Timoshenko beam on two-parameters elastic foundation [7]. Liao and Sangrey have employed an acoustic model for the use of rows of piles as passive isolation barriers to reduce ground vibrations [8]. Lai et al. have obtained the mass and stiffness matrix of the beams on elastic foundation [9]. Catal and Alku have obtained the members of the second order stiffness matrix of the beam on elastic foundation [10]. Catal have calculated natural circular frequencies and relative stiffness of the pile for non-trivial solution of linear homogeneous system of equations obtained due to the values of axial forces acting on the pile, the shape factors, and the boundary conditions of the pile with both ends free and both ends simply supported by neglecting rotary inertia [11].

2. Differential equation for free vibration of partially embedded pile

A pile partially embedded in the soil is presented in Fig. 1. The pile part above the soil is called the first region and the parts embedded in the soil are called the second and the third region, respectively. If the soil

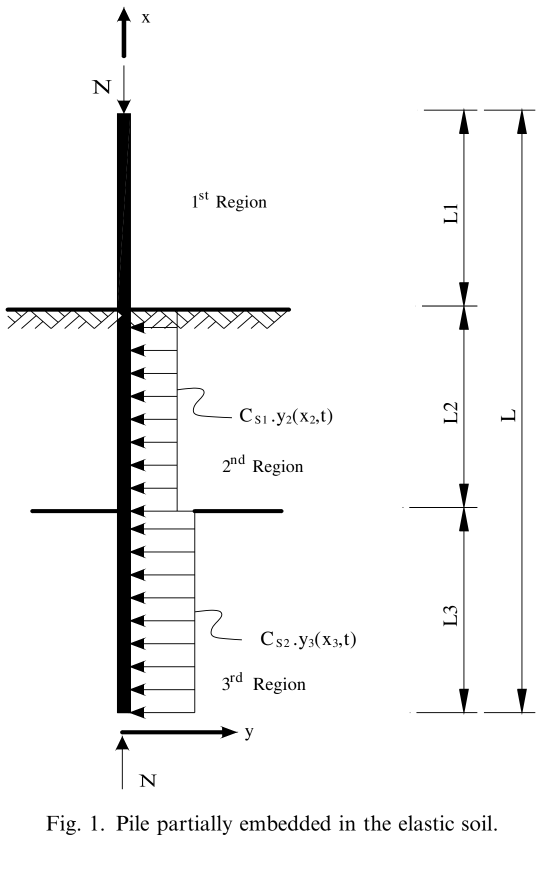

Fig. 1. Pile partially embedded in the elastic soil.