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A probabilistic boundary element method applied to the pile dislocation problem

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ABSTRACT

In this paper a probabilistic approach is presented where the boundary element method is efficiently used to study the effect of a random shift of a given pile within a particular pile cap from its original position – the so-called *pile dislocation* problem – on selected output design parameters such as pile loads and bending moments in the pile cap. A new circular internal element is developed to simulate the true geometric modeling of piles. The boundary element method for the shear-deformable (thick) plate theory is employed to analyze the pile cap. The plate–pile interaction forces are considered to have constant variation over the circular pile domain. The probabilistic approach presented herein incorporates a Monte Carlo simulation technique for generating random shifts in the original position of a given pre-selected pile. The procedure has been applied to some exemplar pile caps with given pile layouts typically adopted in bridge construction.

The results demonstrate that the random dislocation of piles within practical ranges/values as customarily encountered for example in pile caps pertinent to bridge applications will cause limited variations in the output design parameters investigated herein and mentioned above. In other words, it has been illustrated that the resulting dispersion in the output values due to random dislocation of piles is less than the possible intrinsic dispersion that may be practically triggered in the pile locations due to common construction inaccuracies and/or unanticipated problems during pile driving process. The study further emphasizes the efficiency and reliability of the Boundary Elements Method adopted herein for such application.

1. Introduction

Effects of pile dislocation on the safety of bridges' pile caps under a bi-axial loading state are of utmost importance to the bridge design community. Pile dislocation is occasionally occurring due to frequent and highly likely construction inaccuracies expected on site for this somehow large civil structures. Such inaccuracies are not uncommon due to often harsh construction conditions usually encountered on site for large bridges crossing profound valleys or deep waters. The current paper is a step forward aiming at studying the pile dislocation effects on some selected design parameters/straining actions including the pile load and bending moments in the pile cap, and hence demonstrating whether such effects are of much importance to the overall safety of the as-designed structure or not. The present work is conducted in the context of a probabilistic investigation using the Boundary Elements Method (BEM) to model both piles and pile cap, along with Monte Carlo (MC) simulation techniques to mimic possible random dislocation (geometric shift) of a particular pile within a given pile cap featuring a certain configuration of piles. MC techniques have been extensively and effectively used in the literature to model randomness and uncertainties in a variety of civil and structural engineering applications (e.g., [1–4]).

The efficiency and reliability of the BEM in such application is due to the fact that each time the pile is randomly assumed to be slightly shifted from its original location, a complete re-meshing of the whole domain depicting the case-study problem is not required. Conversely, a sophisticated re-meshing is generally a must for the re-analysis of such dislocation situations with other conventional and well-established methods of analysis such as the Finite Element Method (FEM). Moreover, even with the availability of advanced software providing automatic mesh/re-mesh generation techniques for FEM analysis, the outcome of the analysis is not able to isolate the effect of the randomness in pile dislocation on the variability in the piles/pile cap response from the effect of the intrinsic uncertainty (namely, the *epistemic* modeling uncertainty) coming from the variability and randomness in the different meshes resulting from the adopted re-meshing technique.

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