Numerical Analysis of Flaw Sizes Detection in a Bored Pile Using Surface Reflection Method

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ABSTRACT

The main purpose of this paper is to investigate the ability of the surface reflection method, namely the sonic echo method and impulse response method, for flaw size assessment in a pile. Three dimensional axisymmetric finite element models were performed to investigate the effects of the flaw size, flaw depth-to-pile diameter ratio, and pile-to-soil stiffness ratio on the response of the surface reflection test. According to the results from the numerical simulations, some useful formulas for flaw size assessment in a pile are proposed, considering these factors simultaneously. Some other factors, such as the flaw length and pile diameter and length, were also discussed to show their effects on the proposed formulas.

KEY WORDS: pile; flaw size; simulation; surface reflection.

INTRODUCTION

Nowadays, large diameter bored piles are widely used to support heavy loading structures, such as bridges and high-rise buildings. In Taiwan such piles are generally long, and even reach up to 70 m (Lin et al., 2004). Flaws in bored piles, such as cracks, necking, soil intrusion, honeycombing, and soft bottoms, might occur both during and after construction (Hassan and O’Neill, 1998; O’Neill and Reese, 1999). Such flaws, especially when they are sufficiently large, severely decrease the loading capacity and performance of bored piles, causing significant safety problems. Therefore, such flaws should be identified as soon as possible prior to incorporation into the final foundation work in order to ensure safety.

The NDE methods for pile integrity tests can be classified into two main types (Davis, 1998), namely the surface reflection and borehole methods. In particular, sonic echo (SE) and impulse response (IR) methods, which are classified as surface reflection methods, have been used extensively to check the lengths and integrity of piles, and are more cost-effective than borehole methods (Higgs, 1979; Ni et al., 2006). Among the related studies, only a few focuses on the identifiable flaw size in a pile and is summarized in Table 1. Of these studies, Kim et al. (2002) and Hartung et al. (1992) seem to provide the most systematic investigations on the surface reflection method for flaw detection. Based on the impulse response test, Kim et al. (2002) demonstrated that the flaw size should greater than 50% to be detectable, while Finno and Gassman (1998) indicated that a 25% flaw size can be detected successfully. When the sonic echo method was used for pile integrity detection, flaw sizes of more than 10% were indicated to be detectable in research of Hartung et al. (1992). However, Lin et al. (1991) and Baker et al. (1991) show that a 15% flaw size is not always detectable and Kim et al. (2002) show that a flaw can be detected by SE method when the size of it is larger than 30%. Obviously, an explicit limitation for both SE and IR methods in flaw size detection has not been unified in previous research. The successful use of the surface reflection method for the flaw detection depends on whether the energy, which reflects from a source of the impedance change, can induce a sufficiently large vibration in the pile head (Fukuhara et al., 1992; Liao and Roesset, 1997). Usually, three factors would affect the amount of reflection energy. They are the flaw size and depth in a pile, and the soil stiffness around it. However, the published research does not seem to have systematically investigated the reciprocal effects of these factors in detail and this might be a reasonable interpretation why the detectable flaw size of a pile in literature is inconsistent.

The purpose of this paper was to investigate the effect of the influence factors on the flaw size evaluation by using the SE and IR methods. Since it would be really impractical to perform a series of small scaled model piles or full size piles, numerical simulations seem to be a good solution to this problem. Normalized factors, namely the flaw depth-to-pile diameter ratio ($R_D$), the flaw size ratio ($A_f$), and the pile-to-soil stiffness ratio ($k_{R_E}$), were used in the constructed models. The $R_D$ varies from 3.33 to 26.67, $A_f$ varies from 8 to 100% (100% flaw size means a collapse pile), and $k_{R_E}$ varies from 39 to 277. Flaw length, pile diameter, and pile length, which might affect the applicability of the surface reflection methods, were also discussed.

SURFACE REFLECTION METHOD

The surface reflection method uses the reflecting wave from the location of the impedance change to detect the integrity of the piles. Sonic echo and impulse response methods are the most popular ways for pile nondestructive tests due to the advantages of fast, economy,