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Evaluation of Kinematic Bending Moment of Piles subjected to Seismic Motions

Mahdy Khari*, Khairul Anuar Bin Kassim, Azlan Adnan, Saied Yaghob Zoalfeghary
Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor Barhu, Malaysia

*Corresponding Author's E-mail: kmahdy2@live.utm.my

Abstract
Dynamic response of pile foundations is a very complex phenomenon consisting of kinematic and inertial interaction among soil, pile and superstructure. Piles experience kinematic bending moments caused by the soil deformations due to the passage of the seismic waves through the surrounding layered soil. These moments are increased in the interfaces of alternating the soil layered with the different modulus. This paper presents the main results of parametrical study on single piles obtained by a 2D finite element computer code with the exiting design methods for evaluating the kinematic interaction between soil-pile subjected to the seismic excitations. The shear strain and the shear stress are evaluated by the linear equivalent method of the free field site response analyses. The results show that the kinematic bending moment at the interface is affected by the soil nonlinearity behavior and the frequency content of the seismic motion even in absence superstructure.
Keywords: soil-pile interaction, interface, kinematic bending moment, simplified methods, site response

1. INTRODUCTION

Significant damages of structures supported by deep foundations due to complete or partial collapse has been observed in the past earthquakes. The 1964 Niigata Earthquake, the 1964 Alaska Earthquake, The Loma Prieta Earthquake in 1989, and recently during the 1995 Kobe Earthquake have been demonstrated paramount importance of the Soil-Pile-Superstructure Interaction in the seismic behavior of structures (Meymand, 1998). The Soil-Pile-Interaction (SPI) does play a significant role in the structure design. As this complex phenomena and highly coupled has received considerable attention. (Cairo and Dente, 2005; Sica et al., 2007; Castelli and Maugeri, 2010)

The soil-pile-superstructure interaction (SPSI) is included of the two sources: Inertia and Kinematic Interaction. The kinematic interaction is due to the presence of pile foundation on or in the ground surface that causes the ground motions deviate from free-field notions. it is mentionable that the method of the dynamic site analysis and soil conditions effect the free-filed site response(Khari and Bazyar;2008). Inertia interaction is due to the kinematic interaction transmitted to the superstructure (Castelli and Maugeri, 2010). While, the inertial loading effects are only considered in professional design offices, but impotence of the kinematic Interaction has been recognized by some building codes such as Euro code 8 that states the kinematic information should be taken into account under several conditions. (Kavvadas and Gazetas, 1993; Mylonakis, 2001)

Evaluation of the soil-pile interaction has developed by several investigators. Exiting methods can be classified into numerical approaches, Beam on Nonlinear Winkler Foundation method (BNWF), and simplified formulations. In the numerical approaches – so-called Direct Approaches-SPSI is completely modeled and the seismic response is assessed in one-step. Maheshwari et al. (2004), Kimura and Zhang, 2000, and Wu and Finn (1997) implemented the Finite Element Method (FEM) in their researches, whereas Cairo and Dente, 2007; Kaynia and Kausel (1982) used the Boundary Element Method (BEM) for the seismic behavior of pile foundations. Although, the above two methods are versatile technique as SSPI analysis can be performed coupled and independent from the site response analysis, but they are very expensive from a calculation viewpoint. The Beam on Nonlinear Winkler Foundation(BNWF) method (studies of Nogami et al.,1992;El Naggar et al.2005;Maheshwari and Watanabe,2006)and simplified formulations (researches of Dobry and O'Rourke,1983; Mylonakis,2001; Nikolaou et al.2001;Liyanapathirana and Poulos 2005;Castelli and Maugeri,2009)are widely used in research practices. It is worthy of note the results of the two last methods are in a good agreement with the mathematical analyses. In this paper presents the results of different types of dynamic numerical analysis to determine the kinematic bending moments at interface between the two soil layers. An overview of these methods will be described in the later section. The main objectives of this paper are: 1).To evaluates the influence of soil properties and