Strain Wedge Model Capability of Analyzing Behavior of Laterally Loaded Isolated Piles, Drilled Shafts, and Pile Groups

Mohamed Ashour, M.ASCE[1]; Gary Norris, M.ASCE[2]; and Patrick Pilling, M.ASCE[3]

Abstract: This paper demonstrates the application of the strain wedge (SW) model to assess the response of laterally loaded isolated long piles, drilled shafts, and pile groups in layered soil (sand and/or clay) and rock deposits. The basic goal of this paper is to illustrate the capabilities of the SW model versus other procedures and approaches. The SW model has been validated and verified through several comparison studies with model- and full-scale lateral load tests. Several factors and features related to the problem of a laterally loaded isolated pile and pile group are covered by the SW model. For example, the nonlinear behavior of both soil and pile material, the soil-pile interaction (i.e., the assessment of the *p-y* curves rather than the adoption of empirical ones), the potential of soil to liquefy, the interference among neighboring piles in a pile group, and the pile cap contribution are considered in SW model analysis. The SW model analyzes the response of laterally loaded piles based on pile properties (pile stiffness, cross-sectional shape, pile-head conditions, etc.) as well as soil properties. The SW model has the capability of assessing the response of a laterally loaded pile group in layered soil based on more realistic assumptions of pile interference as compared to techniques and procedures currently employed or proposed.

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Introduction

The problem of a laterally loaded single pile and pile group has been under investigation and research for more than three decades. Many approaches, such as Broms' method (1964a, b), the elastic method (Poulos 1971a,b), and the *p-y* curve approach (Matlock 1970; Reese 1977; Murchison and O'Neill 1984; etc.), have been employed in the analysis of laterally loaded pile response. These methods consider some factors while neglecting others. Therefore, limitations exist with respect to all these approaches. As a result, designers have to switch from one method to another to best satisfy their needs.

The *p-y* method, which was developed by Matlock (1970) and Reese (1977), represents the most commonly used and convenient procedure for the analysis of laterally loaded piles. The confidence that designers have in this method derives from the fact that the *p-y* curves employed have been obtained (back calculated) from full-scale field tests, albeit only a very few tests. However, the *p-y* method does not account for some significant factors such as various pile properties and soil continuity which could affect the predicted results tremendously. Researchers have attempted to improve the performance of the *p-y* method by evaluating the *p-y* curve based on the results of the pressuremeter (Smith 1983; Briaud et al. 1984) or dilatometer test (Robertson et al. 1989).

The strain wedge (SW) model analyzes the response of laterally loaded piles based on a representative soil-pile interaction that incorporates pile and soil properties (Ashour et al. 1998a). The SW model allows the designer to predict the associated *p-y* curve at any point along the deflected part of the loaded pile. The effect of pile properties and the surrounding soil profile on the nature of the *p-y* curve has been presented by Ashour and Norris (2000a).

p multipliers for piles in different rows have been suggested by Brown et al. (1988) for analysis of pile interference effects. Recent tests (McVay et al. 1995, 1998; Rollins et al. 1998) indicate that such multipliers are a function of pile stiffness, pile spacing, load or deflection level, and soil type. Therefore, the *p-y* method is presently insufficient for the task of accurately evaluating pile group response. In contrast, the SW model utilizes the mobilized geometry of the passive wedge of soil in front of the pile (horizontally and vertically) to assess the interference of overlapping shear zones among the piles in the group. Consequently, the continually changing effect of pile group interference on the associated *p-y* curves and the modulus of the subgrade reaction (E_s) along every pile in the group can be evaluated.

The SW model has the capability of representing the undrained resistance of liquefiable soil (saturated sands) and the effect of the expected developing liquefaction on the behavior of laterally loaded piles as illustrated by Ashour and Norris (1998, 1999, 2002) and Norris et al. (1997). The profession still lacks a realistic procedure for the design of pile foundations in liquefying or liquefied soil. The most common practice employed is that presented by Wang and Reese (1998) in which a traditional *p-y* curve shape is used but based on the undrained residual strength

[1]Research Assistant Professor, Dept. of Civil Engineering, Univ. of Nevada, Reno, NV 89557. E-mail: ashourm@unr.edu

[2]Professor, Dept. of Civil Engineering, Univ. of Nevada, Reno, NV 89557.

[3]Vice President, Black Eagle Consulting, Inc., 1345 Capital Blvd., Suite A, Reno, NV 89502.

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