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ORIGINAL RESEARCH ARTICLE

# Effect of Thermal Coating on Design parameters

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***Abstract***

*A comprehensive literature review was conducted to examine the current state of knowledge regarding passive piles which specifically focused on the recently adopted design methods for landslide prevention. Of all the publications compiled and reviewed for passive loading on piles, numerous efforts were found starting from over the last three decades, where major emphasis was placed on the various approaches ranging from theoretical and analytical to finite element methods. These methods have been adapted to predict the response of the piles, which also incorporates the influence of group interaction factors. Although research on passive piles subjected to lateral soil movement seems to be recent, there seemed to be a missing gap in research for pile groups used as landslide stabilizing piles. The authors believe that all of these state-of-the-art methods are widely accepted as it is supported by comparison with both field and laboratory data. Based on the review, the authors would like to highlight that further three dimensional (3D) modeling would offer another excellent alternative to study the response of those piles for landslide mitigation purposes.*

***Keywords:*** *lateral soil movement, reinforced slope, small diameter steel piles, slope stabilizing piles, passive piles.*

## 1. Introduction

Existing design methods for slope stabilizing piles can be categorized into pressure or displacement-based method[1] Ito [2] and numerical methods. In the first case, the pile is subjected to a presumed slope displacement. This, along with the distribution with depth of the soil modulus and the limiting values of pile-soil contact pressure, has to be pre-specified. In the second case (i.e. numerical methods), the problem is analyzed by employing finite elements or finite differences. These methods can presently tackle the entire 3D problem, taking into account of the exact geometry, soil-structure interaction and pile group effects. Although such methods are in principle the most rigorous, the 3D application is computationally intensive and time consuming.

### *1.1 Pressure or Displacement Based Methods*

In these methods, the pile is modeled as a beam connected with the soil through nonlinear springs, at the support of which the displacement of the slope is imposed. Hence, the assessment of pile lateral capacity is accomplished by solving two differential equations in which y1 = pile deflection above the sliding surface (assumed to lie at z=0) and EI = pile's bending stiffness. The force intensity, q(z), is calculated using the principle of plastic deformation of soil.
Despite its simplicity, this approach requires predetermining the slope-displacement profile and the distribution of lateral soil modulus (the assessment of which may require extensive field measurements), as well as the limiting lateral pile-soil pressure with depth [3]. A number of analytical approaches have been developed for the determination of the latter. Among the most widely accepted are the approaches of Poulos, and Reese et al.[4] These methods assume a single laterally loaded pile and correlate the ultimate soil-pile resistance with the

undrained shear strength for clays and with the overburden stress and friction angle for sands. A drawback of these methods is that group effects are simplistically taken into account by the application of reduction factors. Ito and Matsui [5]developed a plastic extrusion-deformation model for rigid piles of infinite length (and not closely spaced) to estimate the shear resistance offered by a row of piles embedded in a slope. Their approach presumes that the soil is soft and deforms plastically around piles. Despite its rigor, the method neglects pile flexibility, pile limited length, and soil arching-phenomena that may all have a substantial effect . This approach has formed the basis of a number of design methods.

### *1.2 Numerical Method*

Because of the dramatic progress in computing and software power over the last few years, the finite element (FE) and finite difference (FD) methods are increasingly popular. These methods provide the ability to model complex geometries and soil-structure interaction phenomena such as pile-group effects. Moreover, they are able to model the three dimensionality of the problem, and may well capture soil and pile non-linearity. As early as 1979, Rowe and Poulos [2] developed a two dimensional (2D) finite element approach that, in a simplified way, accounted for the three dimensional (3D) effect of soil flowing through rows of piles.

## **2. Recent Development on Slope Stabilizing Piles**

Hereafter, some of the current research pertaining to slope stabilizing piles undertaken by some researchers are discussed, taking into consideration the aspects of the newly adopted techniques available in the field at present namely the hybrid method of analysis, uncoupled method of analysis and also the coupled method of analysis.

### *2.1 Hybrid Method of Analysis*

This method was proposed by Kourkoulis [2] which develop a hybrid method for designing slope-stabilizing piles, combining the accuracy of rigorous three dimensional (3D) finite elements (FE) simulation with the simplicity of widely accepted analytical techniques. It consists of two steps: (1) evaluation of the lateral resisting force (RF) needed to increase the safety factor of the precarious slope to the desired value, and (2) estimation of the optimum pile configuration that offers the required RF for a prescribed deformation level. The first step utilizes the results of conventional slope-stability analysis. A novel approach is proposed for the second step. This consists of decoupling the slope geometry from the computation of pile lateral capacity, which allows numerical simulation of only a limited region of soil around the piles. A comprehensive validation is presented against published experimental, field, and theoretical results from fully coupled 3D nonlinear FE analyses. The proposed method provides a useful, computationally efficient tool for parametric analyses and design of slope stabilizing piles.

### *2.2 Uncoupled Method of Analysis*

The uncoupled method of analysis for slope stabilizing piles stems for the fact that the pile response (i.e. pile displacement, bending moment, shear force and also pile deflection) and slope stability are considered separately according to their specified method of analysis. A study conducted by Jeong et al., [5] describes a simplified numerical approach for analyzing the slope-pile system subjected to lateral soil movements. The lateral one-row pile response above and below the critical surface is computed by using load transfer approach. The response of groups was analyzed by developing interaction factors obtained from a three-dimensional nonlinear finite element study. The nonlinear characteristics of the soil-pile interaction in the stabilizing piles are modeled by hyperbolic load transfer curves. The Bishop's simplified method of slope stability analysis is extended to incorporate the soil-pile interaction and evaluate the safety factor of the reinforced slope. Numerical study is performed to illustrate the major influencing parameters on the pile-slope stability problem. Through comparative studies, it has been found that the factor of safety in slope is much more conservative for an uncoupled analysis than for a coupled analysis based on three-dimensional finite element analysis.

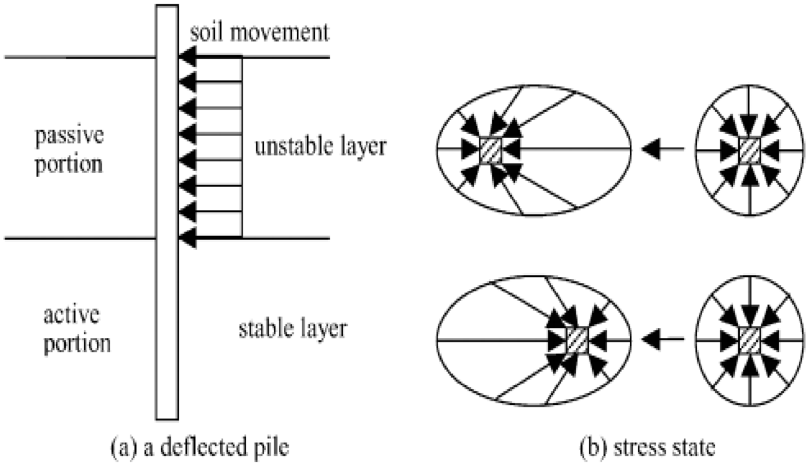


Figure 1: A pile undergoing lateral soil movement

Table 1: Weight from inputs to hidden layer

| Weight from inputs to hidden layer | | | | | bias {1} |
|---|---|---|---|---|---|
| -12.8441 | 20.50278 | -15.5231 | -3.11923 | 4.49661 | 21.47516 |
| -18.7561 | 7.291488 | -0.70412 | 0.353977 | -0.47013 | 24.87071 |
| 0.687205 | 0.890272 | 5.426286 | -8.8521 | -2.76763 | -2.32015 |
| -0.59351 | -0.61689 | 3.240572 | 13.79844 | 2.490056 | -0.66864 |
| -6.69662 | 4.196722 | 41.84173 | 14.72279 | 0.29078 | 0.478036 |
| 22.86743 | -6.45144 | -11.0188 | 3.009632 | -3.71165 | -20.87 |
| -0.39003 | -0.60865 | 3.487829 | 1.250031 | 3.010849 | 3.881527 |
| 0.155606 | 0.177922 | -0.26915 | -0.4196 | -0.91266 | -1.09495 |
| -25.5709 | -0.7389 | 4.654554 | -1.52011 | -17.6461 | -17.9528 |
| -5.65354 | -1.76028 | -7.76329 | -5.84226 | -3.01687 | 3.352388 |
| -4.23849 | -0.55612 | 0.234111 | -2.33927 | 6.767685 | -4.96711 |
| 0.119874 | 6.354606 | -16.5281 | -19.8093 | -23.6356 | -10.8796 |
| -3.31287 | 22.76426 | 8.615496 | -0.72317 | 1.425839 | -39.4266 |
| -1.34297 | -0.86946 | 4.300653 | 18.72181 | 4.853103 | -1.39389 |
| 4.857575 | -7.19375 | -4.68344 | 0.950667 | 11.97972 | -1.46213 |

**3. Results and Analysis**

This section will address the analysis's outcomes of the Objects consisted of 50 respondents. A survey tool was created to determine the important usages of public spaces in Jalan Wang Ah Fook, the physical qualities of public spaces in the study area and the reasons and the factors influencing it. To discover the symbolic value of study area, the quantifiable researches and the qualitative interviews were adopted. At the first, Data were collected by filling-out the survey forms. As mentioned survey questions are divided into three parts. The Socio-demographic background is composed of variables that may affect the common space, such as gender, age. Respondents differ in functional, cultural and social characteristics. Among 50 respondents, between male and female using the public space, female registered as the majority (56%) of users of public space in Jalan Wong Ah Fook and the distribution of participants according to their age. The majority of the participants' age was 19 to 25 with percentage 42%.

*3.1 The respondents' familiarity with public places located at Jalan Wong Ah Fook*

People go to the places that are familiar with or at least know where they are. On the other hand, those places which are memorized by users concern as places with significant identifications to make users use them. Due estimating the most distinctive public places and spaces and the amount of people's familiarity with mentioned public places, respondents were asked to specify that do they know those mentioned places in Jalan Wong Ah Fook. As shown in figure 2, City Square is the most well known public place for users. On the other hand, sidewalk between buildings and street curb is the less notable place for users. Regarding the information from this part of analysis, City Sauer (98%), Hindu Temple (68%), Public Bank Building (66%), Chinese Temple (62%), The Sungai Segget River (56%), Masjid India (50%), Shop houses areas (42%), Sultan Ibrahim Building (38%) and sidewalk between buildings and street curb (32%) are registered from the most well-known places to least. As next step of analysis, this study is going to evoke which places have most usage for respondents as public places and spaces.

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