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Research Article

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Predication of Bending Moment and Horizontal Load of Micropiles using Mathematical Models

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Abstract Micropiles are small in diameter (less than 300 mm) implemented as cast in situ replacement or injected grout which can be installed at various angles from vertical and are capable of resisting both axial and lateral loads. In this paper, the results have been obtained from the laboratory test for micropile model with different length to diameter (L/D) ratios (13, 15, 27, 42, and 50)are used as a statistical data to drive mathematical models for a maximum bending moment and ultimate horizontal loads and to achieve this goal, the Computer program (STATISTICA) was used. The mathematical models can be predicted the maximum bending moment and ultimate horizontal load as a function of as a function of frequency of lateral load, length to diameter ratio, relative density of sand and time for any values of parameters studied. The models are very simple and a considerable saving in effort to predict the maximum bending moment and ultimate horizontal loads within the data range used in this study. Mathematical models provide a good predictive performance when compared the values of maximum bending moment and ultimate horizontal load obtained by mathematical models with values obtained by experience way.

Keywords Micropile, Lateral Load, Displacement, Moving Rate

1. Introduction

Micropiles are defined as small diameter piles (generally, less than 300mm),implemented as cast in situ replacement or injected grout. They are used as underpinning elements to enhance the bearing capacity of existing foundations and to prevent an excessive settlement; they can also be used as foundations for new structures and land stabilization.

The impacts of constant piles on the stability of a slope are prophesied by the Three-Dimensional elasto-plastic shear strength diminution limited radical mode. The soil - pile interplay is pretended with zero density elasto-plastic interconnected components. The numerical consequences are compared with those achieved by Bishop’s Common Method, where the reaction force of the piles is resolved Ito- Matsui’s equation. The impacts of the piles spacing, pile head situations, slanting stiffness and pile position on the preserved elements are evaluated [1].

Bruce et al [2] studied the numerical modelling of micropiles to optimize the micropiles’ depth and spacing. This case study was focused on a 16 m high embankment fill in southern Ontario, Canada. Two slopes; slope 1 and slope 2 are located near the CN rail tracks, occasionally experience significant distress. Micropiles were considered the best alternative solution for the following reasons:

- They can be placed in the embankments’ upper region, minimizing the removal of tress,

- The cost is less than the available method alternative,
- Disruption is minimized.

A technique for stability analysis of the pile-reinforced slopes has been inferred by broadening the friction circle method of slant stability investigation in conjunction with the pile stability examination proposed by Ito and Matsui. The issue has been thrown into a mathematical programming. The arrangements have been segregated by planning the issue as one of non-linear programming. The appreciation of this advancement method will be useful for analyzing the slope stabilized with a line of piles and furthermore prompting an ideal arrangement of the pile location for a wanted factor of safety [3].

Centrifugal experiment was conducted by Choo et al [4] for the obtainment of quality data regarding lateral behavior of the large-diameter monopile. Numerical results based on the p-y analysis were compared to centrifuge experimental results and showed that the vertical load effect on lateral displacement was much greater in experimental results than in numerical analysis results.

The attributes of the bearing capacity of a micropiled raft were examined by performing model tests what's more a numerical examination. While micropiles are utilized as a part of numerous geotechnical ventures, as ground reinforcement instead of as basic complements. The help conduct of the micropiled raft is assessed for different conditions, such as pile length, soil type, and installation angles. It is discovered that the micropiles change the disappointment conduct of the ground significantly, what's more that the bearing resistance can be upgraded by examine about the suitable failure mode, pile length and installation angle [5].

2. Geotechnical Capacity of Micropiles

Most researches assumed that micropiles derive their capacity entirely by friction or adhesion along the interface between the grout and the surrounding soil, and that the tip capacity is negligible.

As with most other types of deep foundation elements, prediction of the shaft resistance of micropiles is not an exact science. The bond strength along the micropile depends on the characteristics of the geological media that surround it, the material characteristics of the micropile, and the micropile installation process. In addition, typical design procedures incorrectly assume a uniform distribution of bond stresses along the bonded zone. The bond stress distribution will vary relative to the stiffness of the pile and the geologic medium, as well as the stiffness of the pile-medium interface [6-7].

The load transfer from the micropile to the adjacent ground requires some relative movement. The latter is controlled by the elastic modulus of the composite-reinforced micropile and the load transfer mechanism [8].

Table 1: Properties of the river sandy used

estate	Value			Standard Specification
Active sizes: D_{10}, D_{30}, D_{50}, D_{60} [mm]	0.12, 0.19, 0.24, 0.27			ASTM D 422 and ASTM D 2487 (2007)
Coefficient of uniformity [Cu]	2.25			ASTM D 422 and ASTM D 2487 (2007)
Coefficient of curvature [Cc]	1.12			ASTM D 422 and ASTM D 2487 (2007)
Classification [USCS]	SP			ASTM D 422 and ASTM D 2487 (2007)
Specific gravity [Gs]	2.67			ASTM D 854 (2006)
Max. dry unit weight, [kN/m^3]	15.99			ASTM D 4253 - (2000)
Min. dry unit weight, [kN/m^3]	13.14			ASTM D 4253 - (2000)
Max. void ratio	0.99			....
Min. void ratio	0.63			....
Relative density [RD],%	35	55	75	....
Dry unit weight natural [γ_d] kN/m^3	14.02	14.6	15.17	....
Voids ratio [e]	0.86	0.79	0.72	....
Friction angle, degree	28	30	33	ASTM D3080 -11

3. Experimental Work

3.1. The properties of sand, micropile model and container

The dry river sandy used in this survey is raise from the Baghdad City at a depth of (2-4 m).According to the unified soil classification system, the soil used is classified as poorly graded sand (SP) as shown in Table 1.

The micropile model used in this study has different length to diameter (L/D) ratios (13, 15, 27, 42, and 50). The dry sand is compacted in steel container which has the inner lengths of the box are (750×750×750 mm). The container was made from five separated parts; the five part of the box was made by using 6 mm thickness steel platelet.

3.2. The system of lateral load

Ellwei [9], manufactured system of horizontal hydraulic jack and screw steel shaft connected with each other to exert a horizontal load which applied to the load cell from one side as shown in Figure (1)

a. Horizontal movement device

b. Model Setup

Figure 1: Horizontal movement device

4. Numerical Model Test Results

Depending on the test results obtained from the experimental work carried out on the models of micropiles used in this study and to relate the pile parameters considered in this work, mathematical relations in form of nonlinear will introduce using The Computer program (STATISTICA).

4.1. Numerical models for estimating ultimate horizontal load

To determine ultimate horizontal load (H_u) for micropile embedded in sandy soil within the range of data obtained, Equation (1) is established and examined in Figure (2) which gives a coefficient of determination (R^2) equal to (94%).

$$H_u = 9882.4 * \left(\frac{L/D}{F}\right)^{0.0067} + 1.06 * RD - 0.13 * T - 10091 \quad (1)$$

Where,

H_u: Ultimate lateral load.

L/D: Embedment length to diameter ratio.

F: Frequency.

RD: Relative density.

T: Time.

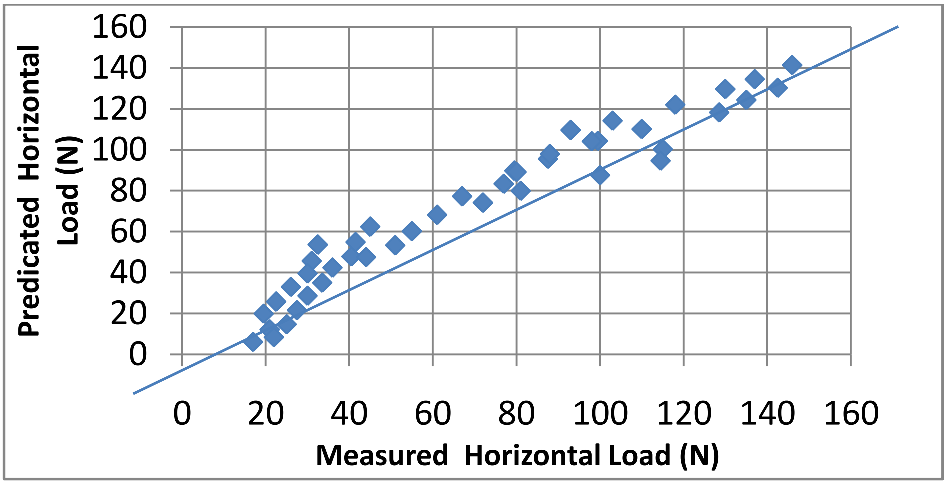

Figure 2: Relation between the measured and predicted ultimate horizontal load of micropiles

4.2. Mathematical models for estimating maximum bending moment

Figure (3) a propounded an equation to establish the maximum bending moment of micropiles. The equation is depending on the results acquired from the experimental work of (45) models of micropiles installed in sandy soil are expressed below. And also, Figure (3) which gives a coefficient of determination (R^2) equal to (83%).

$$M_{max} = -20 * F + 0.000197 * \left(\frac{L}{D}\right)^{2.77} + 0.122 * RD + 0.015 * T + 8.52 \quad (3)$$

Where,

M_{max}: Maximum bending moment.
L/D: Embedment length to diameter ratio.
F: Frequency.
RD: Relative density.
T: Time.

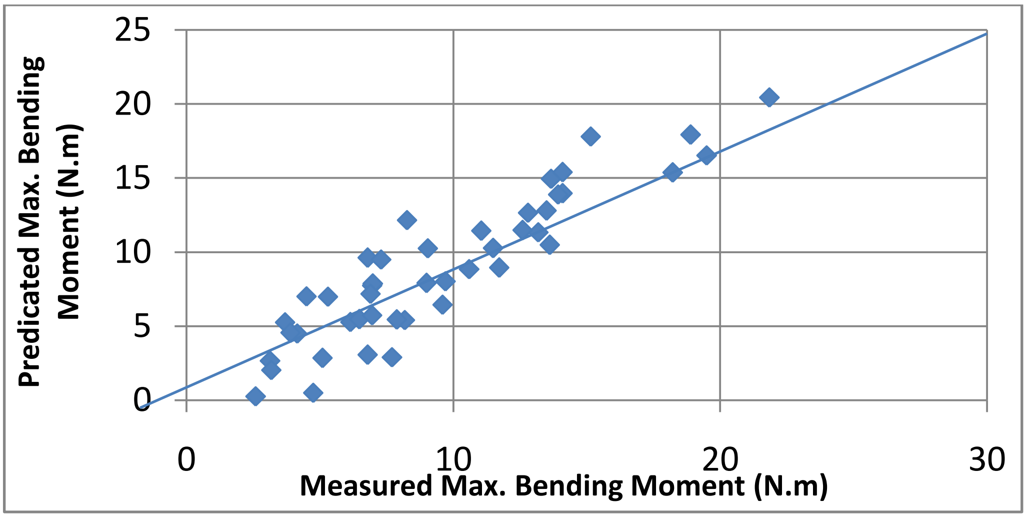

Figure 3: Relation between the measured and predicted maximum bending moment of micropiles

5. Conclusions

From this study, the following conclusions can be drawn:

1. The study conducted that the use of statistical ways are viable to predict the maximum bending moment and ultimate horizontal load of micropile.
2. The relationship between the measured and predicted ultimate horizontal is approximately linear for all studied cases of numerical models.

3. The values of predicted ultimate horizontal load increase with increase length to diameter (L/D) ratio and also, with increased relative density at the same frequency.
4. The relationship between the measured and predicted maximum bending moment is nonlinear for all studied cases of numerical models.
5. The values of predicted maximum bending moment increase with increase length to diameter (L/D) ratio and also, with increased relative density at the same frequency.
6. Mathematical models provide a good predictive performance when compared the values of maximum bending moment and ultimate horizontal load obtained by mathematical models with values obtained by experience way.
7. Mathematical models can be used as a function of soil properties and can be used for any values ranges in between the properties of soils studied.

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