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Ground Failure Mechanism of Micoropiled-raft

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ABSTRACT

The micropile of which diameter is 300mm or smaller has been mainly used under the concept of supplementing structural support or reinforcing soft ground. For the micropiled-raft which uses a micropile and a raft in combination in particular, it is generally considered as ground reinforcement rather than foundation components contributing to the bearing capacity of the micropile in many cases. This study conducted a physical model test to investigate the failure mode of the micropiled-raft. The test results have shown that the failure zone of micropiled-raft is strongly influenced by the installation angle of micropile. The failure area in the battered installation was significantly extended comparing to in the vertical installation, and consequently the bearing capacity has also considerably increased.

1. INTRODUCTION

A micropile is a small cast-in place pile with a diameter of 300mm or smaller, is installed in about 10 to 30m length in accordance with in-suit condition. Micropiles have been mainly used one of the underpinnig methods to increase the bearing capacity or to restrict the additional settlement of existing structures. And those have been also used for supporting the newly constructed structures, in recently.

A micropile consists of the steel bar and grout. In installation method, the steel bar is installed in the bore hole before grouting, the grout fills between the steel bar and ground. The raft is installed at the head of micropile (FHWA, 2005). Therefore the two elements are combined, it can be considered as the micropiled-raft in foundation system.

As the behavior of a piled-raft is determined by an interaction between the pile and the raft, the behavior of a micropiled-raft may not be greatly different in the short or compressive pile condition (Poulos and Davis, 1980). But the behavior of micropiled-raft may be different, in the slender pile condition (L/D>100). Because the contribution of a slender pile to bearing capacity is affected by the rigidity of the soil on which the pile is installed rather than by the length of the pile (Hoalley, et al.,1969; Meyerhof,1995;

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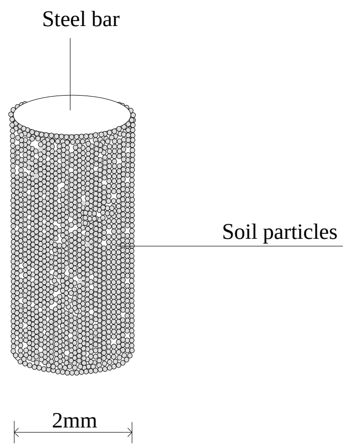
Randolph,1994). And Madhira, et al.(2009), Meyerhof and Yalcin(1993) reported that the installation length of a slender pile has almost no effect on bearing capacity.

The installation angle of micropile is not restraint unlike the existing pile, so a micropile can be installed by field engineer demands. The bearing behavior of micropiled-raft is varied by the installation angle, because the interaction of micropile and soil is different. According to previous studies on micropile and micropiled-raft(Lizzi, 1982; Tsukada, 2006), it is seen that the bearing capacity in the battered installation increased than in the vertical installation. And, according to You et al.(2003), Tsukada et al.(2006), and Shu and Muhunthan(2010), displacement develops to the ground surface around the foundation during a failure of a micropiled-raft system. In this case, the pile installation angle has an important factor on the bearing behavior. Thereby this study conducted the physical model test to investigate the failure mode of micrpiled-raft with the pile installation angles.

2. MODEL TEST

Fig. 1(a) shows the model tester to be devised in order to investigate the failure mechanism of a micropiled-raft in the soil. This main components of this tester were the soil box, sand rainer and loading equipment. The size of the soil box was 1200 × 400 × 800(length × width × height, mm). The soil in the soil box was homogeneously built to have about 50% relative density using a ‘soil rainer’. And a total of 49 micropiles to use in test are installed in a row.

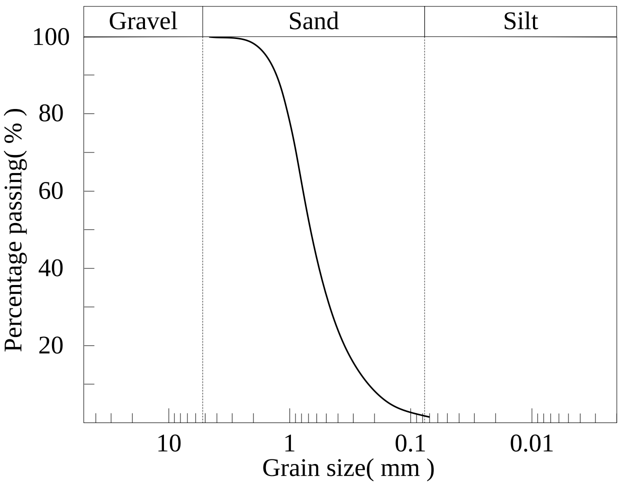
(a)



(b)

Fig. 1 Model test. (a) model test device , (b) model pile

Also a thin black sand layer was laid at a regular interval of 50 mm, to enable the failure mode of the soil beneath the foundation system to be observed visually, for the constructing process of soil layer. The soil used was dried sand with a uniformity coefficient, C_u of 1.62 and coefficient of curvature, C_g of 0.87. The properties of soil are shown in Fig.2.



Parameters	Sand
Gravity(G_s)	2.64
D_{50}	0.68
e_{max}	0.91
e_{min}	0.63
Dry unit weight(kN/m^3)	14.70
Cohesion(c, kN/m^2)	0
Shear resistance angle(φ, °)	31°

Fig. 2 Properties of soil to use in test

As the bearing characteristics of the pile is mainly dependent on the flexural rigidity of the pile, the diameter of the model pile was determined by considering the following relative rigidity to secure the similarity between the model and prototype.

$$\lambda_{EI} = \frac{E_p I_p}{E_m I_m} \tag{1}$$

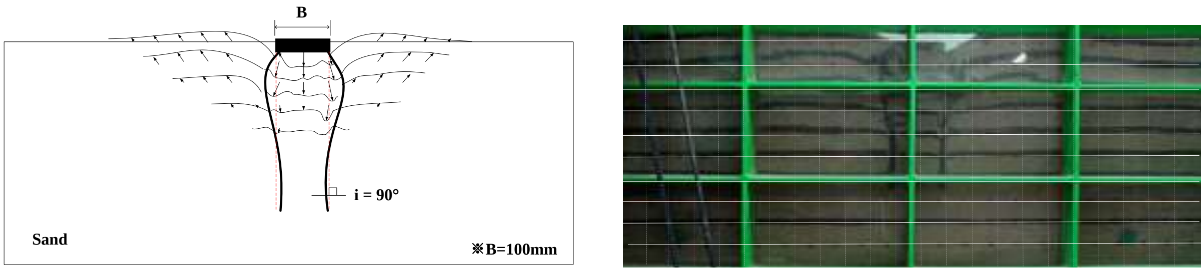
The subscripts p and m means the prototype and model respectively. According to Iai(1989), the λ_{EI} (bending rigidity scale factor) for the micropile is about 35. The model micropile simulates a prototype micropile with a diameter of 200 mm. To satisfy Eq.(4), the diameter of the model pile is set at 2 mm and the pile is made of steel. Soil particles are attached to the surface of the model micropile using glue as shown in Fig. 1(b) in order to introduce the frictional interface on the boundary surface between the soil and the micropile (Tsukada et al., 2006).

Model tests were conducted for the installation angle(i) of 45°, 60°, 75° and 90°. In each test, a load was applied until the ratio of vertical displacement to the width of the foundation, that is to say, the vertical strain, exceeded 10% which is considered as a state of failure (Han and Ye, 2006).

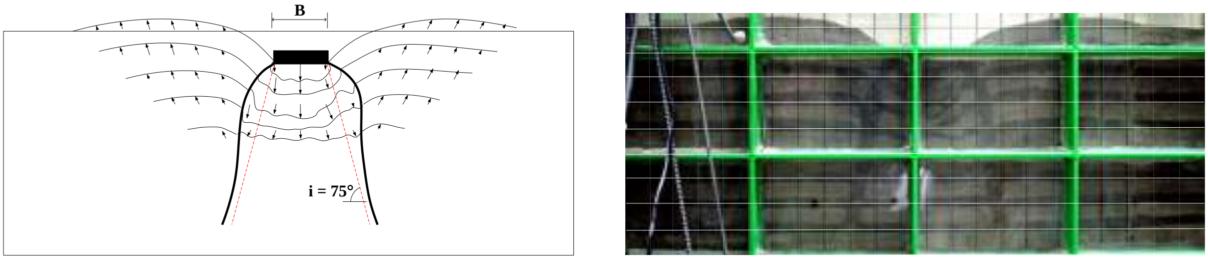
3. FAILURE MODES OF MICROPILED-RAFT

Fig.3 shows the failure mode of miropiled-raft with the installation angle after test. In results, the failure area showed a general shear failure mode similar to a shallow foundation, the failure zone of micropiled-raft varied depending on the installation angle. By comparing Fig.3(a) and Fig.3(b), it can be seen that the failure zone extended significantly in the battered installation comparing to the vertical installation.

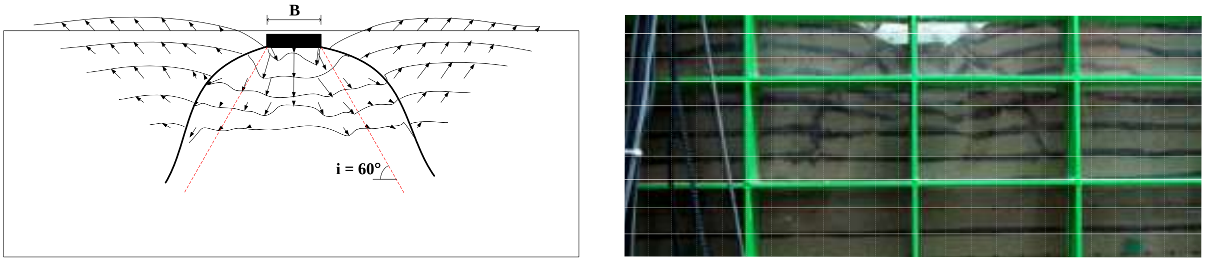
And the failure area in case of the battered pile conditions was extended as the installation angle derease. Especially, the failure area was significantly extended in the case of i = 60° comparing with the case of i = 90°. However it was similar to the case of i = 45°, as shown in Fig.3(c) and Fig.3(d).



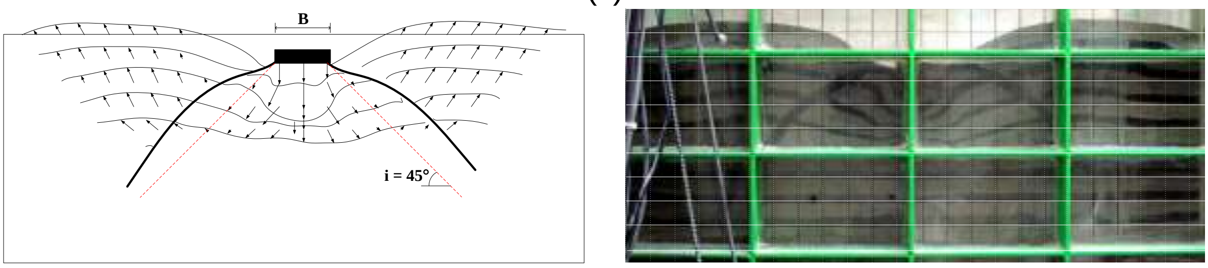
(a)



(b)



(c)



(d)

Fig. 3 Failure of micropiled-raft with the installation angle of micropile. (a) i = 90°, (b) i = 75° , (c) i = 60° , (d) i = 45°

Fig.4 compares the failure area and bearing capacity. In shows that, the failure width in the case of i = 90° was extended 2.3 times of B(= width of raft), and the failure depth was extended 1.5 times of B as shown in Fig.4(a). In the case of battered installation with i = 45° ~ 75°, it can be seen that the failure width and depth was extended considerably comparing with the case of i = 90°. Especially, the failure width and depth of the failure area in case of i = 60° were significantly extended. In comparing the case of i = 60° and i = 45°, the failure width was similar, while the failure depth for i = 45° decreased.

The load-displacement relationship for each test cases are shown in Fig.4(b). The maximum vertical load was about 1.15kN ~ 1.60kN, depending on the installation angles. And the vertical load in the case of i = 60° was greater than in other cases, while the load in the case of i = 90° was small. The results of model test confirmed that the bearing capacity of micropiled-raft is closely related to the failure area to be varied by the installation angle. Thus the installation angle is important factor in enhancing the bearing capacity.

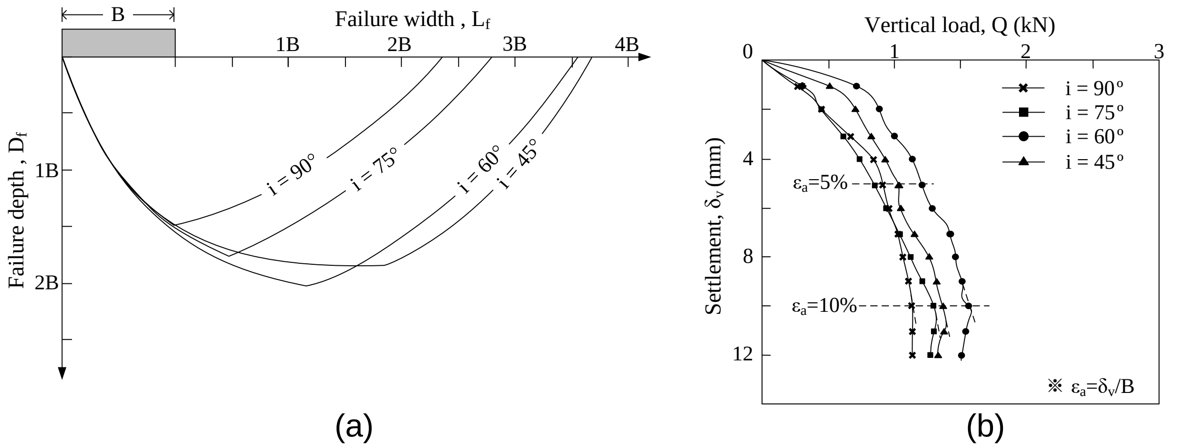


Fig.4 Comparison of test results. (a) failure area , (b) bearing capacity

Fig.5 shows the $L_{f(i<90°)}$ / $L_{f(i=90°)}$ and $D_{f(i<90°)}$ / $D_{f(i=90°)}$ - i relationship. Here, L_f and D_f is the failure width and depth, and the subscripts i = 90° and i < 90° represent the case of vertical and battered installation, respectively. The failure width ratio defined by $L_{f(i<90°)}$ / $L_{f(i=90°)}$ increased as the installation angle decreased, and became constant when i is less than 60°. The maximum failure width for i = 60° was strongly extended, which is about 1.5 times comparing to the case of i = 90°. While the failure depth ratio defined by $D_{f(i<90°)}$ / $D_{f(i=90°)}$ also increased as the installation angle decreased, but was decreased in exceeding i = 60°. In the case of i = 60°, the failure depth ratio was the maximum value, the failure depth is extended about 1.3 times comparing to the case of i = 90°.

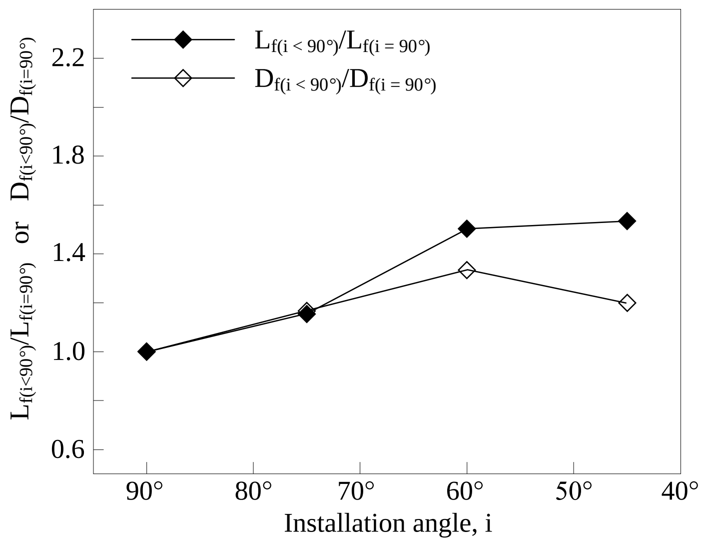


Fig.5 Effect of installation angle on the failure area

4. CONCLUSION

The failure modes of micropiled-raft with the installation angle were investigated by performing a model test. The results showed that the failure modes and bearing capacity were significantly influenced by the installation angle. It can be concluded that the failure mode and installation angle should be properly considered to enhance the bearing capacity of the micropiled-raft.

(a) The failure area of micropiled-raft in the case of battered installation is extended comparing with the case of vertical installation. The failure area is considerably extended with a decrease in the installation angle.
(b) The failure width increases as the installation angle decreases, and become constant when i is less than 60°. The failure depth also increase as the installation angle decrease, however it decrease when i exceed 60°.
(c) The failure width is the maximum in the case of i = 60°, and this is about 1.5times wider comparing to i = 90°. Meanwhile the failure depth is the maximum when i = 60°, and this is about 1.3times comparing to i = 90°.

ACKNOWLEDGEMENT

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