Field load transfer characteristics of geotexile-pack micropile

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ABSTRACT: This paper presents a comparison study for load-transfer characteristics of two different types of micropiles. In general, structural components of micropile are thread steel bar or hollow-steel-pipe and surrounding cement grouts and its bearing capacity is mostly estimated from frictional resistance between grouts due to the small tip diameter. In this study, compressive bearing characteristics of two types of micropiles are compared to each other. Two types are (1) thread bar reinforcement with gravity grouting and (2) hollow-steel-pipe reinforcement with pressure grouting using geotextile pack surrounding micropile. Field test results showed that pressure-grouting micropile using geotextile pack provides better load transfer mechanism in that it makes surrounding soil strength to be fully mobilized upon loading.

Keywords: micropile, geotextile pack, field load test

1 INTRODUCTION

Micropile is cast-in-place small pile with diameter less than 300mm. It is applicable to repair and reinforce geotechnical structures due to its ease of construction method and wide applicability. It has advantages of easy connection with other pile method, In the case of Japan and the United States, it is actively used for reinforcement of bridge piers or strengthening of seismic capability for geotechnical structures (Lee et al. 2009). However, only few field load test were performed to understand load-transfer mechanism of micropile. This fact causes the lack of understanding field behavioral characteristics of micropile subjected to compressive or tensile loading condition.

In order to find in-field behavior and frictional resistance developed along the perimeter of micropiles, a set of field loading tests were performed for two different types of micropile. The first one is a conventional micropile in which thread bar reinforcement is inserted to a bored hole and surrounding grout is injected with gravity force. The other one is a recently developed micropile in which a hollow-steel-pipe reinforcement wrapped with woven geotextile pack is inserted to a bored hole and gravity grout and subsequent pressurized grout are applied to increase the inter-frictional bonding between surrounding ground and grout (Choi et al. 2009). It was enforced that the cross-sectional area of steel reinforcement for the two types was identical to ensure the same amount of steel ratio. The test piles were only installed for soil layers to obtain the information for frictional resistance of the two types of piles. This paper introduces the conceptual description of micropiles used for this study, field installation, field load test results and analysis.

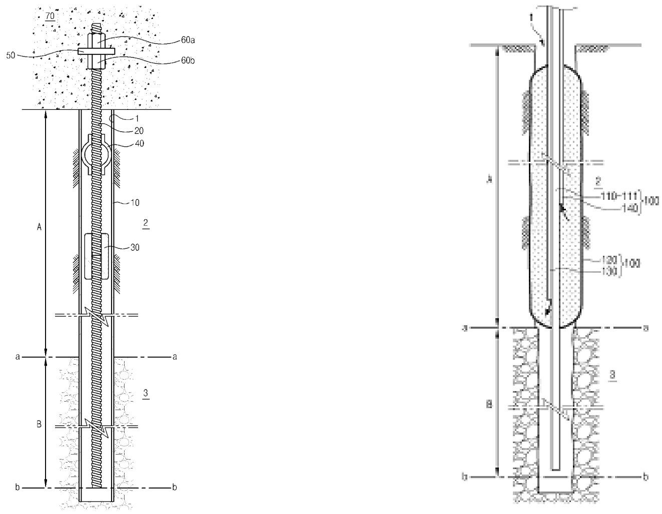
2 FIELD INSTALLATION

2.1 Conceptual description of micropiles

According to FHWA(2005) classification a conventional micropile studied herein is classified as Type-A and the geotextile-pack micropile is similar to Type-C and, hereafter, they are referred as TAM(Type-A-

Micropile) and GPM(Geotextile-Pack-Micropile), respectively. Basically, the FHWA definition for micropile classification is founded on grouting methods. Figure 1 shows TAM and GPM micropile concepts installed for this study.

Figure 1(a) shows TAM schematic in which a steel casing is inserted to ground for the purpose of preventing the hole-collapse and it is pulled out during gravity grouting process. The numbers, '30' and '40', in the figure represent the spacer which takes role of having reinforcing-rebar and rebar-connector to be centered in the hole. Design bearing capacity for this type is mainly obtained from skin friction between ground and pile perimeter in rock-socketing zone. Figure 1(b) presents the GPM schematic in which the pressured grouting technique for upper soil layer is involved during construction process and this process enables to maximize frictional resistance between loose soil and pile structure via wrapping the pile perimeter with woven geotextile and preventing the loss of grout. Grout is injected to the hole and inside pack with two steps; i) gravity grouting and ii) pressurized grouting. Pressurized grouting process makes the tight contact between pile perimeter and surrounding loose soil layer and, as a result, higher frictional resistance to be mobilized in the interface. The numbers, '130' and '120', of the figure show a hollow steel pipe for second-stepped pressure grouting inside and a pack tightly contacting to a hole together with expansion due to pressurized grout, respectively.



(a)TAM (conventional type) (b)GPM(pressure grouting type)

Figure 1. Schematics of two type micropiles

2.2 Field construction

Figure 2 presents the reinforcing rebar used for TAM and the reinforcing hollow steel pipe used for GPM, respectively. The dimension of threaded-rebar was 50mm of outside diameter, pitch of 8mm, yield strength of 700 MPa, and unit length of 3.0m for TAM. The dimension of hollow steel-pipe reinforcement was 82.5mm of outside diameter, thickness of 11mm, and yield strength of 482 MPa. The cement used for grout is Portland-cement (Korea Standard L 520-1) manufactured by Hanil-Cement in Korea. One percent of additive was used to increase workability of grouting material and water-cement ratio (w/c) was 45%.

The GPM installation requires several on-site works for the preparation. They are, i) D=10mm punching holes with 90° for one cross section with 70cm interval along steel-pipe length for pressure grouting, ii) taping the holes for preventing reverse flowing from outside of steel pipe to inside during gravity grouting, iii) wrapping geotextile-type pack outside of pipe and binding the pack with temporary steel-band.

Bored holes were drilled to the depth of 8.0m with water-rotary casing drill. The dimension of the drill casing was ID=155mm and OD=180mm. TAM micropile was constructed with the procedures of 1) boring hole with temporary casing, 2) inserting thread-rebar reinforcement, and 3) injecting grout with gravity in the manner of bottom-up together with removal of temporary casing. GPM micropile construction procedures consist of 1) boring hole, 2) gravity grouting-filling hole, 3) inserting reinforcement, 4) removing drill casing, 5) temporary casing removal, and 6) pressure grouting($\Delta p = 0.1 \sim 0.2MPa$).

(a) Thread bar for TAM

(b)Hollow steel pipe for GPM

Figure 2. Reinforcement used for field installation

3 FIELD LOAD TEST RESULT

3.1 Load-test method

For the field load test, the verification test method in FHWA (2005) was employed for the loading schedule which includes cyclic loading and unloading process. Equipment and load testing method were set up to meet the standards for ASTM D1143, ASTM D3689, and ASTM D3966. To minimize intervention between the pile and the anchor in the test process, a distance of at least 2m was spaced between the pile and the anchor.

3.2 Load-transfer mechanism

The distribution of axial load along depth for TAM and GPM is presented in Figures 3 and 4, respectively. Transferred loads were obtained using ten strain gauges with the interval of 70cm along pile length. Non-linear tangential elastic constants corresponding to Fellenius(2001) was used to evaluate the force from the measured strain. For all cases, the piles tend to behave as conventional friction-type-pile in that the load transfer into the ground before reaching the yielding load is evenly distributed along pile length. Because 50%~70% of the yielding load was supported by the friction between the pile and surrounding soil within a depth of 6m, the applied load reaches to almost zero at the end of pile. It means that end bearing capacity did not develop at the pile tips.

For TAM load transfer near the ground surface varied considerably. Former research reported that non-uniform pile diameters or non-uniform adhesion between pile and ground might be a main cause for this fact (Cadden et al. 2004). It is compared to the load transfer of GPM shown in Figure 4 in that applied loads tends to be evenly distributed along depth. In the case of GPM, idealized load distribution was observed for all load steps in that the curves are overall straight up to the depth of 3~5m where ground condition changes from soft to stiff. This fact reveals that GPM distributes applied loads evenly well along depth. Most stiff soil condition at the depth of 3m (highest SPT value was observed during site investigation) might cause more load to be born in this area.

It is interesting to note that the overall shape of load transfer curves for two different micropiles are comparable each other. Closer look to Figures 3 and 4 tells that the overall shape of GPM curve appears to be downside concave which contrasts upside concave for TAM. This observation suggests that GPM micropile exhibit higher stiffness and load carrying performance in the soil layers at this site.

3.3 Load bearing capacity

The field load tests were performed to study the load bearing capacity of micropiles subject to different installation procedure. Frictional resistance developed by bond strength between grout and surrounding soil takes most part of load-bearing capacity of micropile. It means that end/tip support was not considered during pile design because the diameter of micropiles is comparably small to pile length. Especially, the piles in this study were not socketed into the bedrock and end bearing resistance was negligible.

Ultimate load bearing capacity in this study was obtained when the settlement rate for unit load corresponds to FHWA(2005) guideline such as

$$\dot{S} = 0.15\ \text{mm/kN} \tag{1}$$

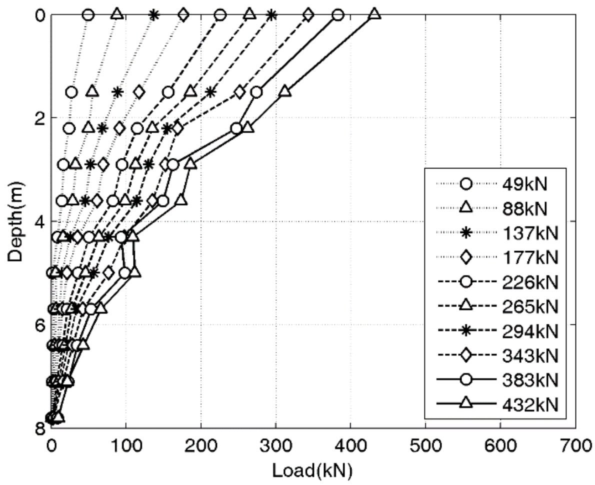


Figure 3. Load transfer behavior for TAM micropile under compressive loading

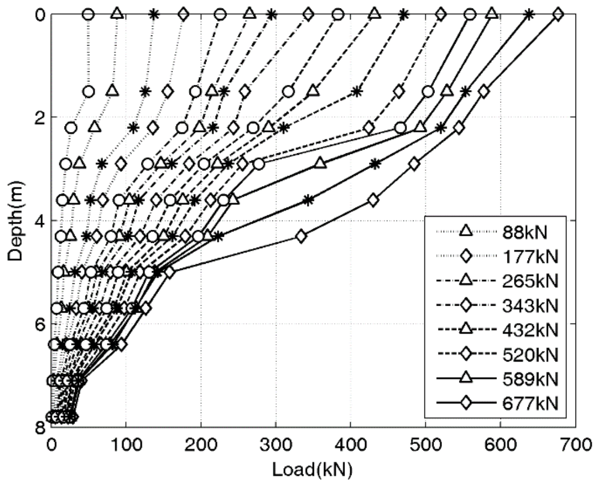


Figure 4. Load transfer behavior for TAM micropile under compressive loading

Figure 5 shows the direct comparison of load-displacement curves for TAM and GPM subjected to axial compressive loading condition. The trend load-displacement curve was obtained via curve-fitting with exponential function given in Eq. (2).

$$S = A\, e^{\lambda L} \quad (2)$$

where S and L are settlement and load data set, respectively, and A and λ are coefficients obtained from curve fitting. The ultimate loads (when *dS=0.15mm/kN*) were obtained at 276kN and 590kN for TAM and GPM, respectively. Direct comparison of the ultimate bearing load denotes that the ultimate load of GPM is more than 200% of that of TAM. This higher bearing capacity might be attributed to the pressurized grouting method and better bonding quality between pile structure and surrounding ground. Based on the analysis of the bearing capacity and load transfer characteristics, GPM pile provides higher bearing capacity with good status of load transfer characteristics along the entire pile length.

3.4 Frictional characteristics

In order to observe frictional resistance, unit skin friction was estimated for ultimate loading stage. Figure 6 shows the analysis results of the unit bond strength distribution along depth. It is clearly shown that the axial load distribution characteristics along depth depends on the pile type. In case of GPM with '◇', the unit bond strength develops highly along full length of the pile. However, the unit bond strength for TAM with '○' is much less than that of GPM. This higher friction for GPM is attributed to the pressurized grouting procedure during installation. The pressure grouting procedure enabled the grout-soil bonds to be increased. It was also observed that the compressive strength of cured grout for GPM is much higher than that of TAM. Based on these observations, it can be inferred that GPM provides better micropiling technique in that it provides better load distribution along effective pile length for soil layer.

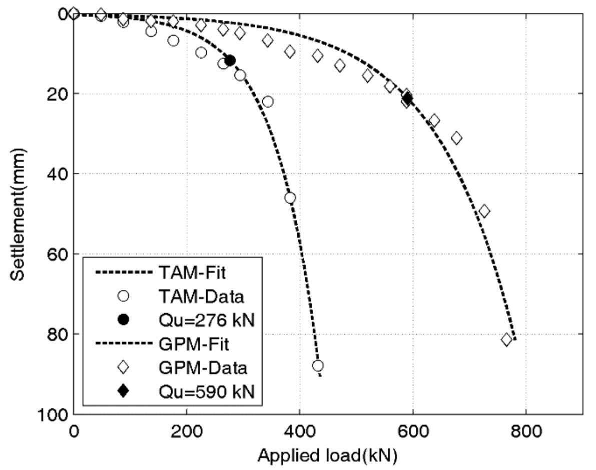


Figure 5. Load vs. displacement curves under axial compressive loading condition

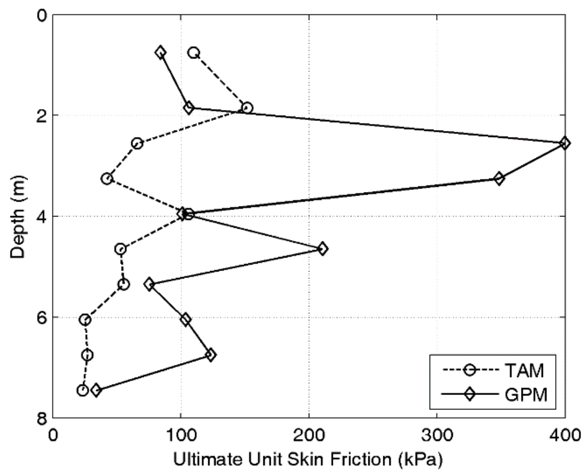


Figure 6. Unit skin friction along depth at the ultimate compressive loading condition

Now, the ultimate skin friction value for GPM was directly compared to SPT value at the site. Because friction value and SPT-N are different type of properties, N-value at 5m and skin friction of GPM at 4.7m are used as scaling factor as

$$\text{Factor} = \frac{N_{at\ 5m}}{f_{at\ 4.7m}} \tag{3}$$

The unit skin friction of GPM in Figure 6 is multiplied with Eq. (3) and plotted in Figure 7 together with SPT-N value. It appears that the ultimate skin friction for GPM develops with similar trends to soil strength. That is, the pressure grouting method for cast-in-place pile provides better load carrying characteristics. GPM micropile makes the surrounding soil strength to be fully mobilized upon load application. Of course, TAM result was compared to SPT value in the same manner, but they were not comparative.

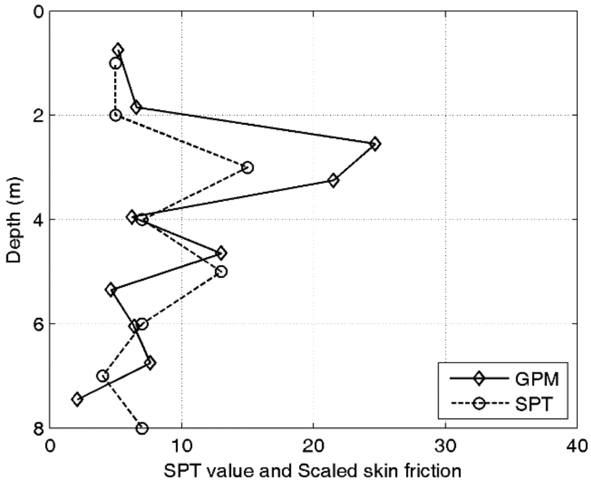


Figure 7. Comparison of ultimate skin friction for GPM and SPT-N value

4 CONCLUSION

This study was performed to evaluate the load bearing characteristics of two different types of micropiles, gravity grouting micropile and pressure grouting micropile. Based on a set of field load tests, the followings are concluded.

- ✓ The pressure grouting micropile provides better load transfer mechanism in that it makes surrounding soil strength to be fully mobilized upon axial loading. This fact attributes to the better mutual bond between pile structure and surrounding ground due to step-by step pressurized construction.
- ✓ The ultimate loads obtained from axial compressive loading condition indicate that the pressure grouting micropile sustains almost 200% ultimate load of gravity grouting micropile.
- ✓ The unit skin friction developed in pressure grouting micropile was scaled to be compared with SPT value. The result showed that the developed ultimate skin friction varies with similar trend to soil strength. Based on this observation, it is concluded that the pressure grouting micropile is a good method for micropile installation.

REFERENCES

Cadden, A., Gomez, J., Bruce, D. and Armour, T. (2004), Micropiles: Recent Advances and Future Trends, Geotechnical Special Publication 131: Deep Foundation, ASCE.

Choi, C., Goo, J-M., Lee, J-H, and Cho, S-D. (2009), Development of New Micropiling Method Enhancing Frictional Resistance with Geotextile Pack, ISM(International Society for Micropiles) 9th Workshop on Micropiles, London.

FHWA (2005), Micropile Design and Construction Guidelines : Implementation Manual.

Fellenius, B.H. (2001), From Strain Measurements to Load in an Instrumented Pile, Geotechnical News Magazine, Vol. 19, No. 1, pp35-38.

Lee, J-H., Lee, K-H., Cho, H., Jeoung, J., and Choi, C. (2009), A Case Study of Micropiling in the Urban Environment, ISM(International Society for Micropiles) 9th Workshop on Micropiles, London.