Development of unmanned caisson type pile installing system

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ABSTRACT

Small diameter caisson type piles have been used for the foundations of the structures built in mountainous areas, such as bridges, power lines and so on. Therefore, those piles will continue to be important foundations of the structures built in mountainous area. The small diameter caisson type piles, however, have been constructed by manpower mostly under dangerous and terrible situations. For example, digging, assembling retaining wall, spraying shotcrete, assembling rebar, and compaction of placed concrete are all carried out by manpower at the bottom of the small diameter pile hole. Furthermore, the dug soil is conveyed from the pile hole to outside, retaining wall and rebar are carried into the pile hole, in the situation that the workers are working at the bottom of the pile hole. Due to the poor construction situation, decreasing the number of young workers who take care of the future construction of piles has been accelerating. Therefore, improving the construction situation of the small diameter caisson type pile is an urgent issue, which has to be solved rapidly. The authors have proposed an unmanned construction system for the small diameter caisson type pile, in which workers do not need to go into the pile hole during the pile construction. The applicability of the system has already confirmed from test constructions of three real piles, which were performed at the two construction sites of expressway. The applicability confirmed from the test constructions as well as the details of the proposed system are summarized in this paper.

Keywords: small diameter caisson type pile, unmanned installing

1 INTRODUCTION

Small diameter caisson type piles, which are constructed by manpower mostly, have been used for the foundations of the structures built in mountainous areas, such as bridges, power lines and so on, because delivering large construction machines to the mountainous area is difficult. The construction, however, is conducted under dangerous and terrible situations. Fig. 1 shows a picture taken from the bottom of the pile hole, 3.0 m in diameter and 30 m in depth. The workers work here in the case of small diameter caisson type pile construction. For example, digging, assembling retaining wall, spraying shotcrete, assembling rebar, and compaction of placed concrete are all carried out by manpower at the bottom of the small diameter pile hole. Furthermore, the dug soil is conveyed from the pile hole to outside, retaining wall and rebar are carried into the pile hole, in the situation that the workers are working at the bottom of the pile hole. Due to the poor construction situation, the decrease in the number of young workers who take care of the future construction of the piles is accelerating. Therefore, the improvement of the construction situation of the small diameter caisson type pile is an urgent issue, which has to be solved rapidly.

Fig. 1. Working space of small diameter caisson type pile.
from test constructions of three real piles, which were performed at the two construction sites of expressway. The applicability confirmed from the test constructions as well as the details of the proposed system are summarized in this paper.

2 SUMMARY OF PROPOSED SYSTEM

The proposed system consists of following five components.

a) Remote control excavation: Excavating by digging machine set at the tip of retaining wall, which is remote controlled from an operating room outside the pile hole, as shown in Figs. 2, 6 and 7.

b) Dug soil conveyance: Conveying dug soil from the pile hole to outside by vacuum system, as shown in Figs. 2 and 8.

c) Inserting and pulling out retaining wall: Assembling the retaining wall at the top of the pile hole and inserting it with using jacks depending on excavation. Pulling out the retaining wall with using jacks depending on placing concrete and taking apart it at the top of the pile hole, as shown in Figs. 2, 9 and 10.

d) Assembling and inserting of rebar cage: Assembling rebar cage at the top of the pile hole with using jacks, and inserting it, as shown in Figs. 3, 11-13.

e) Placed concrete compaction: Compacting placed concrete by the vibrators set at the bottom of retaining wall. This work can be possible because the retaining wall is pulled out in the proposed system, as shown in Figs. 4 and 14.

Fig. 2. Excavation, inserting and pulling out retaining wall.

Fig. 3. Assembling rebar cage.

3 TEST CONSTRUCTIONS

The applicability of the system has already confirmed from test constructions of three real abutment piles of 2.5 m in diameter, which were performed at two construction sites of expressway in 2012 and 2014, as shown in Fig. 5. Table 1 presents the confirmed applicability of the components composed of the proposed system through the two test constructions.

Table 1. Applicability confirmed in the test constructions.

| Target component | (a) | (b) | (c) | (d) | (e) |
|------------------|-----|-----|-----|-----|-----|
| Test in 2012     | X   | X   |     |     |     |
| Tset in 3014     | XX  | X   |     |     | X   |

X: conducted one, XX: improvement and conducted one

3.1 Remote control excavation and dug soil conveyance

Fig. 6 shows a picture of test construction appearance conducted in 2012. In this test construction, the space for assembling and taking apart of retaining wall, 4.0 m in diameter and 1.5 m in depth, was constructed at first, then a caisson type pile of 2.5 m in diameter was constructed at the center of the space.

Excavation is conducted by the digging machine attaching at the tip of retaining wall shown in Fig. 7(a), which is remote controlled from the operating room shown in Fig. 6 with watching the monitor shown in Fig. 7(b). In this test, the excavation speed of 0.75 m per 7 hours was confirmed despite the ground that is
decomposed granite with large gravel of more than 1.0 m in diameter. This speed is not faster than the previous construction, but if it were considered that the excavation could be possible by three workers in the proposed system, this speed would be enough applicable for real practice.

In the excavation working, excavation itself is critical pass, so conveying dug soil with using vacuum had no problem in the test construction, as shown in Fig. 8.

3.2 Setting and removing retaining wall

Fig. 9 shows the procedure of assembling and inserting retaining wall depending on the excavation, pulling out and taking apart of it depending on placing concrete. And Fig. 10 shows pictures of assembling and inserting retaining wall in the test construction conducted in 2014. Liner plate attaching steel plate at the side of the ground was adopted as retaining wall in the test construction.

![Fig. 8. Conveying dug soil from pile hole to outside.](image)

![Fig. 9. Procedure of setting and removing retaining wall.](image)

![Fig. 10. Setting retaining wall (test construction in 2014).](image)
5-divided retaining wall was adopted in the test construction conducted in 2012 though; it took about 20 minutes to take apart it. Because this speed becomes critical pass for placing concrete of the pile, in the test construction conducted in 2014, 2-divided retaining wall after assembling 12-divided retaining wall at outside of the pile hole was adopted, as shown Fig. 10(a). However, the speed of taking apart it was not able to be shrunk from 20 minutes, namely, the effect of improvement could not be confirmed. So this issue has still been a future issue. Meanwhile, inserting retaining wall has no problem as shown in Fig. 10(b).

3.3 Assembling and inserting rebar cage

Rebar cage is assembled from the following procedure, as shown in Fig. 3.

a) Least weight rebar cage, which can be hang by crane existing in the site, as shown in Fig. 11, is kept at the top of the pile hole.

b) Hoop rebar is set with raising the rebar cage by jack, as shown in Fig. 12.

c) Residual main rebar is set and connected to hoop rebar with downing the rebar cage by jack, as shown in Fig. 13.

d) Inserting completed rebar cage into the pile hole.

If assembling plural rebar cage, two or three rods for instance, was needed, it could be assembled from repeating the works of a) to d).

As the result of test construction of assembling and inserting rebar cage, the same speed of setting rebar cage as the present construction could be confirmed. If improvement of turning accuracy of multi-jacks’ stroke moving was achieved, it would be considered that the speed would progress.

3.4 Unmanned compaction of placed concrete

The applicability of unmanned placed concrete compaction system shown in Fig. 4 was confirmed, as shown in Fig. 14.

4 PROGRESSING STUDY

This study has been progressing about the future issue obtained from test constructions, such as the speed of removing retaining wall and improving tuning accuracy of multi-jacks’ stroke moving, by using the subsidy of MLIT (Ministry of Land, Infrastructure and Transportation). The result will be published in future.

5 CONCLUSIONS

The applicability of unmanned caisson type pile installing system, which the authors have developed from a decade ago, was confirmed through two test constructions of three real piles. Furthermore, several issued found through the test constructions are improving by using the subsidy of MLIT.

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