Geo-Environmental Engineering 2017
Seoul National University
Seoul, Korea
May 19-20, 2017

DEVELOPMENT OF PULLING-OUT OF EXISTING PILES AND INFLUENCE OF THE PULLING-OUT HOLES ON SURROUNDING GROUND

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Abstract**:** The teardowns of social infrastructures including the civil structures have been increasing because of aging them constructed in a period of high economic growth and decrease in their utilization with a population decrease, in recent years. The number of pulling-out existed pile foundations has been becoming a lot more than that of newly installing pile foundations. However, after pulling-out a pile foundation, mechanical characteristics of surrounding grounds is concerned due to existence of the formed pulling-out hole. There are no regulations yet on fillers injected into a pulling-out hole, and the influence by which the strength of the fillers gives it to the surrounding grounds is not also elucidated. This study considers the influence by which a pulling-out hole of a pile foundation gives it to static and dynamic characteristics of surrounding grounds by using two-dimensional dynamic finite element analysis. The special qualities required for fillers injected into a pulling-out hole are also clarified in this study.

Keywords: Pile Foundation, Pulling-out Method, Pulling-out hole, Finite Element Method

1. Introduction

In Japan, many of the city located in the soft ground, there are many structures using a pile foundation. Therefore, to achieve a new land utilization at the place where existed structures are present, it is necessary to remove existed pile supported the structure as well as existed structures for construction of a new structure. Further, existed piles and concrete husk become industrial waste, be left of these industrial waste in the ground is a very difficult problem. In addition, it is seen troubles many as "hidden defect" in the sale of land transactions. Accordingly, it can be said that the removal of existed pile is essential.

The removal method of existed pile, there is a pull-out method and crushing removal method, and the like. But the crushing removal method are having such as vibration, noise and environmental problems. The pull-out method has been widely used from this thing. However, there are also problems in the pull-out method. The pulling-out hole is formed when pulling out the existed pile. If the pulling-out hole is left, the collapse of the empty drilling part of the earth and sand, and there is a possibility that the subsidence of the ground surface by the gap widening in the ground occurs. Therefore, it is necessary to fill the pulling-out hole by injection of the fillers. About fillers, conventionally, in many cases to construction in mountain sand and recycled sand from construction it is easy and inexpensive. But, by cannot ensure a reliable filling and stable strength, in recent years the flow of processing soil and cement-bentonite use has increased. However, there are no regulations yet on fillers injected into a pulling-out hole, and the influence by which the strength of the fillers gives it to the surrounding grounds is not also elucidated.

This study considers the influence by which a pulling-out hole of a pile foundation gives it to static characteristics of surrounding grounds by using two-dimensional static finite element analysis. The special qualities required for fillers injected into a pulling-out hole are also clarified in this study.

2. STUDY SUMMARY ABOUT THE STATIC BEHAVIOR OF THE PULLING-OUT HOLE AND THE ORIGINAL GROUND

Describe the study content to ① ~ ④ (Fig. 1).

① To select the study cross-section.

② To create the analysis model, based on the selected cross-section in the ①. And the analysis area to mesh division.

③ To select an analysis constant. To set the application configuration model and material parameters in the initial stress analysis.

④ Perform the initial stress analysis. Analysis technique is a total stress analysis. In this study, HD model for the ground material and elastic model for the hollow portion has been applied.

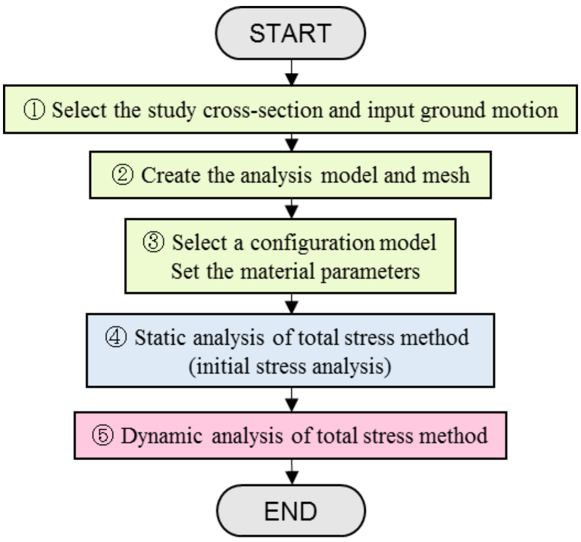


Figure 1 Analysis procedure

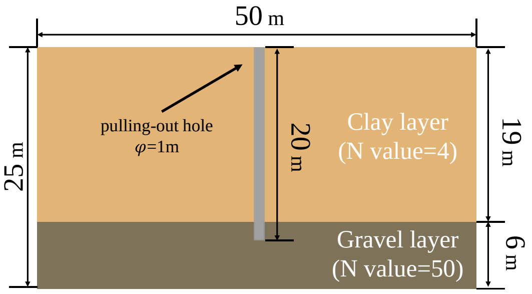


Figure 2 Sectional view

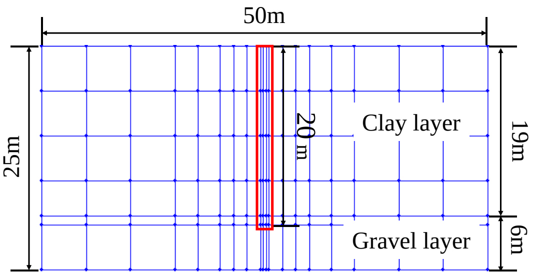


Figure 3 Analysis model

3. ON THE STATIC BEHAVIOR OF THE PULL-OUT HOLE AND THE ORIGINAL GROUND, ANALYSIS MODEL AND INPUT GROUND MOTION WAVEFORM

3.1 Analysis model

In the analysis, the analysis cross-section has a two-layer, upper layer part is clay layer as soft strata, which N value is about 2. And under layer part is gravel layer as strong formations serving as a support layer, which N value is about 50. The width of the analysis cross section is set to 50m, the thickness of the clay layer is 19m, the thickness of the gravel layer is 6m, and the total depth of the cross section is 25m. About pulling-out holes, the number is one, pore diameter is 1m, depth is 20m, and embedment depth into the gravel layer is the 1m. For mesh division, improve the accuracy of analysis by finer mesh spacing near the pulling-out hole. Also, even when filled with pulling-out holes, it is finer mesh in order to examine the behavior of the filling portion of the pulling-out hole. As a boundary condition, the bottom was fixed fulcrum, and the lateral boundary is the equal displacement boundary. When the moving node on the side of the left side, node of the other side to the displacement is the same movement as the node on the side of the left.

Therefore, it is possible to express that stratum has spread to the left and right.

In the analysis, filler material is fluidization treated soil. The analysis cross-sectional view of the ground shown in Figure 2. Also shown a similar analysis model in Figure 3. In the figure at the time of filling material injection in Figure 3, portion surrounded by a red frame is a pulling-out hole portion.

3.2 Constitutive law and material parameters

Parameters in the clay layer and gravel layer used for the analysis and soil parameters in the pulling-out hole are shown in Table 1. In this analysis, using a fluidizing processing soil that many of the experimental value. In addition, it analyzes in ten fillers with different elastic modulus and Poisson's ratio of the fluidizing process soil in order to examine the effect of filler strength has on the ground. From having a small strength, the filler 1, filler 2, …, filler 10. Parameters used in the analysis is to determine the anamnestic literature reference.

Table 1 Element parameters

Parameters	Clay layer	Gravel layer	Pulling-out holes (filler)
γ_t (kN/m^3)	15	21	15
γ_w (kN/m^3)	9.8		
Constitutive law	HD model	HD model	Elastic model

Table 2 HD model parameters

Parameters	Clay layer	Gravel layer
G_0 (kPa)	26985.77	173722.74
σ'_m (kPa)	67.5	201
ν (-)	0.45	0.40
c (kPa)	19.6	0
φ (°)	0	42

Table 3 Elastic model parameters

Parameters		q_u (N/mm^2)	E (kN/m^2)	ν
Pulling-out holes (filler)	①	0.1	15700	0.479
	②	0.2	31400	0.476
	③	0.3	47100	0.472
	④	0.4	62800	0.468
	⑤	0.5	78500	0.464
	⑥	0.6	94200	0.460
	⑦	0.7	109900	0.456
	⑧	0.8	125600	0.452
	⑨	0.9	141300	0.448
	⑩	1.0	157000	0.444

γ_t represent unit volume weight of the soil. γ_w represent unit volume weight of water. G_0 represent initial shear stiffness. σ'_m represent initial average active confining pressure. ν represent Poisson's ratio. c represent adhesive force. φ represent internal friction angle. q_u compressive strength. E represent elastic coefficient.

4. ANALYSIS RESULTS AND STUDY ON THE DYNAMIC BEHAVIOR OF THE PULLING-OUT HOLE AND THE ORIGINAL GROUND

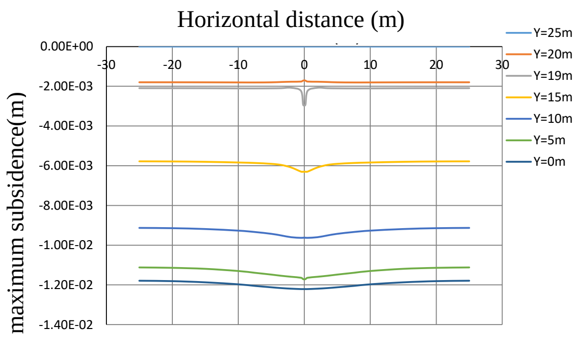
In this study, to compare the ten types of ground used deferent filler, in the static analysis. The results are shown in the following.

4.1 Results of the analysis

Figure 4 and 5 show the results about the effect of 10 types of fillers with different strength on the surrounding ground by this study. Figure 4 is maximum subsidence amount in analysis section when each filler with different strength is used. Figure 5 is the graph comparing maximum subsidence amount at each depth when each filler with different strength is used.

4.2 Study on the results of the analysis

From Figure 4, the maximum subsidence is the largest in the filler central portion in the case of the strength of the filler is 0.1N/mm^2, 0.2 N/mm^2. So that, it can be said that the surrounding ground subsids into the filler part in the existing pile pull out hole, it is because of



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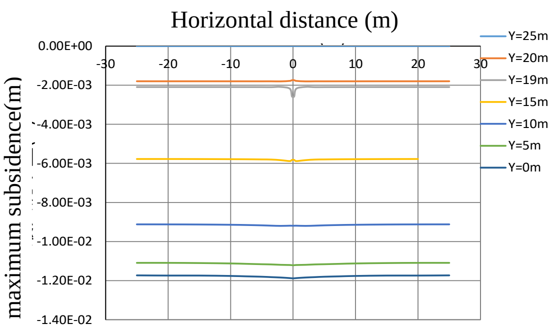

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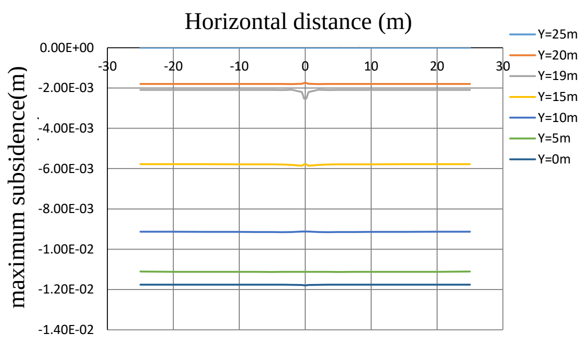

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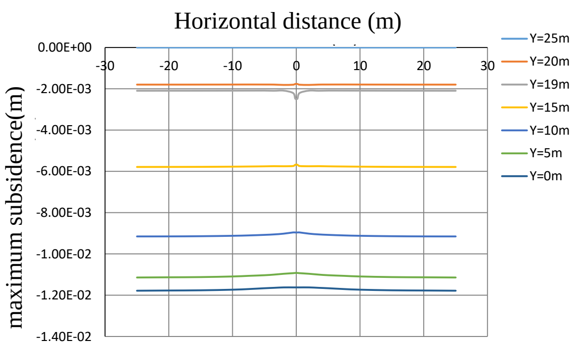

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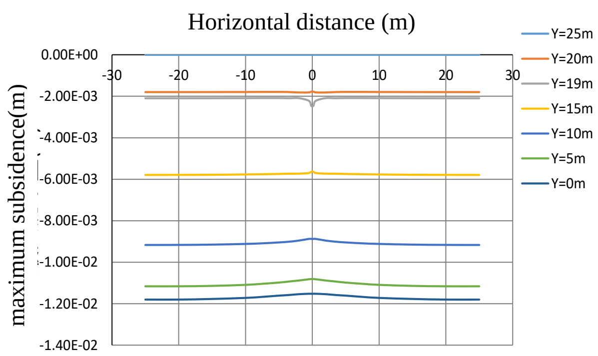

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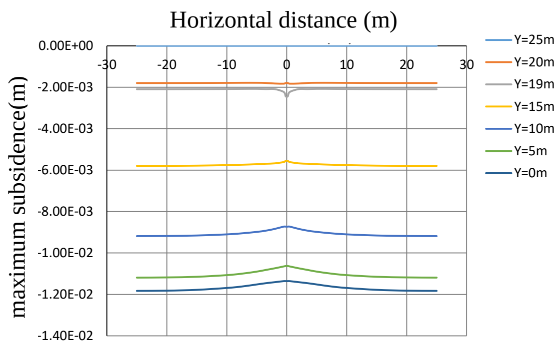

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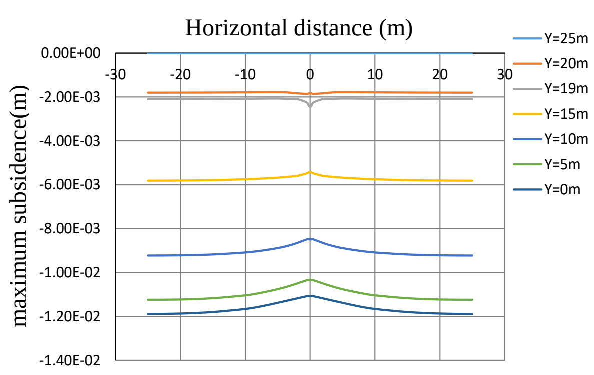

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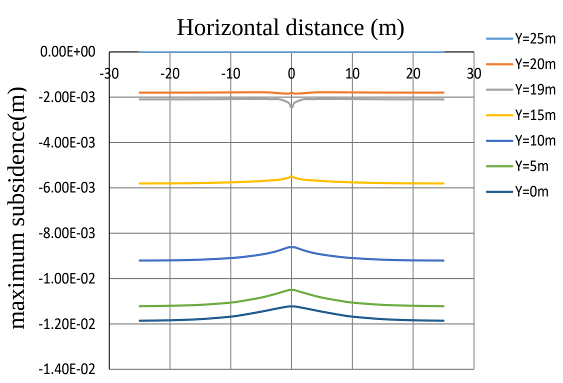

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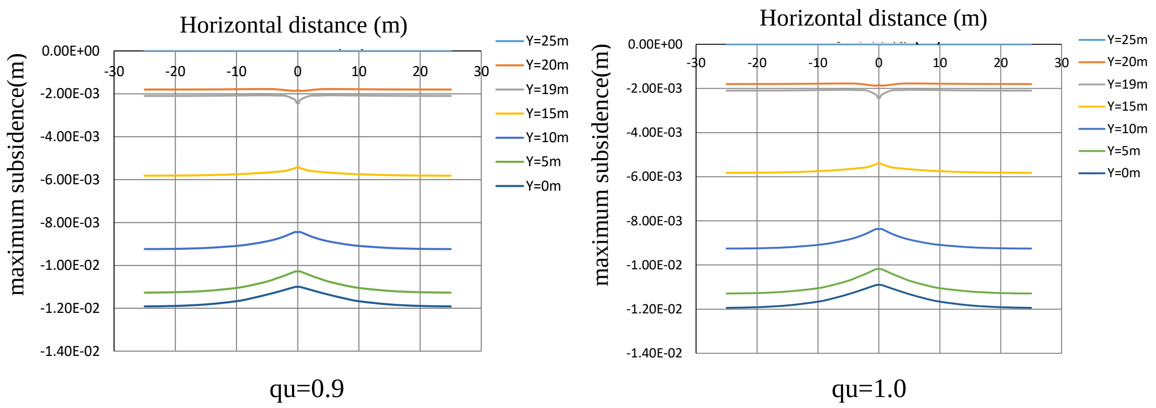

Figure 4 Maximum subsidence amount when each filler with different strength is used

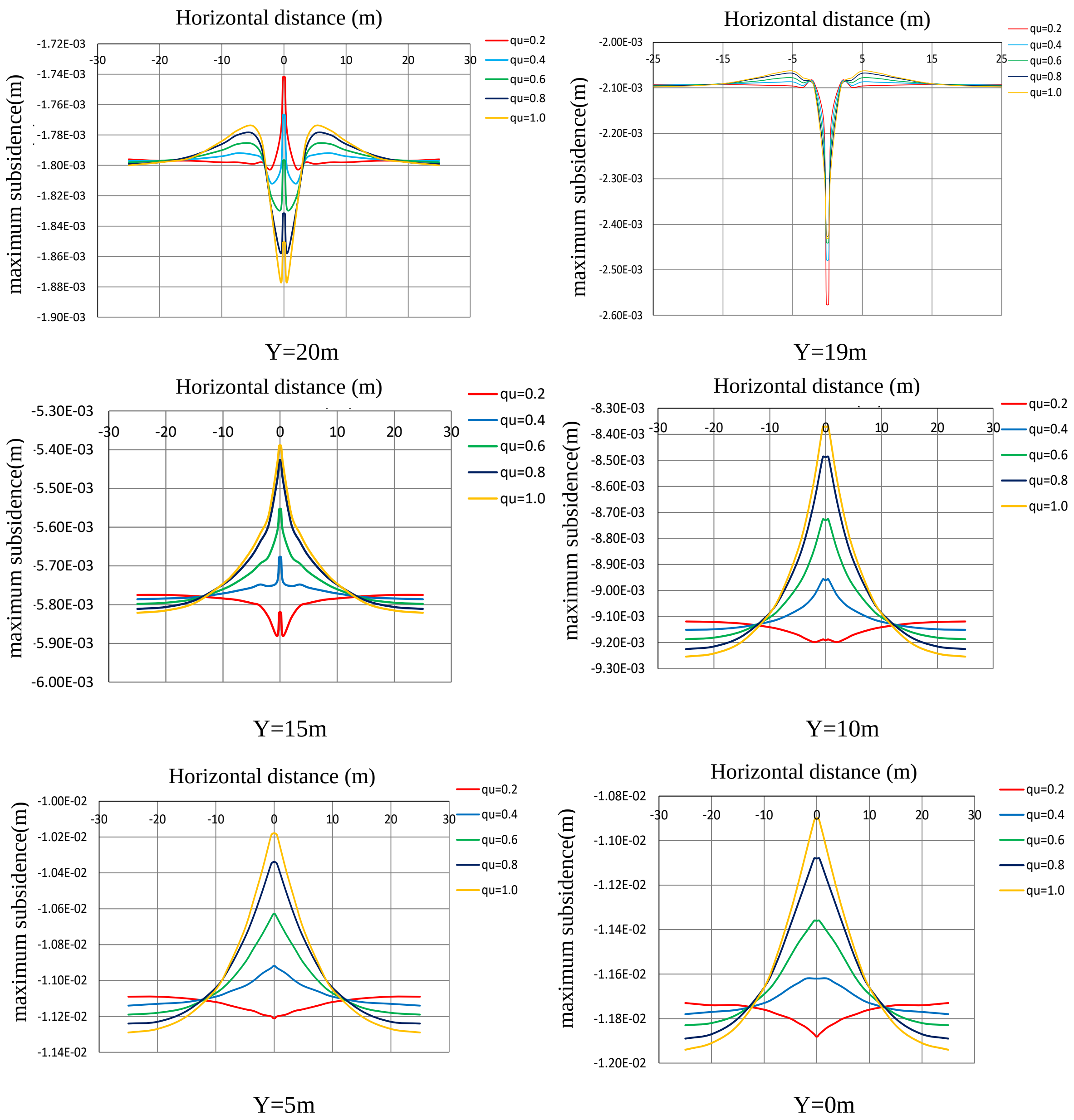

Figure 5 The graph comparing maximum subsidence amount at each depth when each filler with different strength is used

insufficient strength of filler. In the case of the strength of the filler is 0.4N/mm^2, the maximum subsidence is the smallest in the filling material the central part. So that, it can be said that surrounding ground subsides, because the filler strength is higher than the strength of the surrounding ground. In the case of the strength of the filler is 0.3N/mm^2, the maximum subsidence amount is almost evenly occurring, and it shows the behavior closest to the field panel than other fillers in this study. It is because of the strength of the filler is closest to the strength of the surrounding ground.

Furthermore, Figure 5 shows that the maximum subsidence amount is larger as the strength of the filler is higher in the position of the depth of 20m from the ground surface. However, the maximum subsidence amount is smaller as the strength of the filler is higher at the place other than filler part. The maximum subsidence amount is larger as the strength of the filler is lower in the filler part, and the maximum subsidence amount is about the same in the other horizontal position, which is in the position of the depth of 19m from the ground surface. In the position of the depth of 15m, 10m, and 0m from the ground surface, the maximum subsidence amount is smaller as the strength of the filler is higher at the place other than filler part, the maximum subsidence amount is smaller as the strength of the filler is lower after the distance from the center is around ± 12m. It is because of the relationship between strength of filler and strength of surrounding ground. Moreover, it is presumed that it is subsided toward the center of the analysis section from result of the maximum subsidence amount is smaller as the strength of the filler is lower after the distance from the center is around ± 12m.

From the above, in this study's analysis section, the strength of the filler to the pulling-out hole of existing pile is 0.3 N/mm^2 or more. It is because of that there is no subsiding toward the filler part.

5. Conclusions

In this study, the influence of the pulling-out holes on surrounding ground was evaluated by two-dimensional static FEM analysis for development of pulling-out of existing piles. From this, it was founded that if the strength of the filler to the pulling-out hole of existing pile is lower than the strength of the surrounding ground, the surrounding ground subsided towards the filler part. So it is conceivable that it suffices for the filler to the pulling-out hole to satisfy the minimum strength according to each ground condition.

As this study's future work is that it is necessary to examine the influence of this analysis compared with this analysis result when changing ground conditions.

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