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INFLUENCE OF PULLING OUT EXISTING PILES ON THE SURROUNDING GROUND

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ABSTRACT: Teardowns of social infrastructure, including civil structures, have been increasing in number in recent years because these structures have aged and their utilization has decreased along with the decrease in population. The number pile foundations being pulled out is now far greater than that being newly installed. However, after a pile foundation is pulled out, the mechanical characteristics of the surrounding ground may be affected by the existence of the resulting hole formed by pulling out. There are no regulations yet on injecting fillers into pull-out holes, and the influence of filler strength on the surrounding ground is yet to be elucidated. This study considers the influence of a pull-out hole on the static and dynamic characteristics of the surrounding ground using two-dimensional dynamic finite-element analysis. The special qualities required by fillers injected into such holes are also clarified.

Keywords: Existing pile, Pull-out hole, Surrounding ground, Two-dimensional dynamic finite-element analysis

1. INTRODUCTION

In Japan, many cities are located on soft ground, and many structures use pile foundations. Therefore, for land to be reutilized in places where existing structures are present, it is necessary to remove the existing piles supporting the structure as well as the structure itself for construction of a new structure. Further, existed piles and concrete husk become industrial waste, be left of these industrial wastes in the ground is a very difficult problem. In addition, the presence of such piles remaining in the ground is seen as a hidden defect in land transactions [1]. Accordingly, it can be said that the removal of existing piles is essential.

Methods of removing existing piles include the pull-out method and the crushing-removal method [2]. The crushing-removal method suffers from vibration, noise and environmental problems, and hence, the pull-out method is more widely used. However, the pull-out method also has certain problems; in particular, a hole is formed when an existing pile is pulled out of the ground, and if this hole is left unattended, it is possible that the ground surface may subside as earth and sand collapse into the hole. Therefore, it is necessary for filler to be injected into the pull-out hole. Conventionally, mountain sand or sand recycled from construction is used as filler, as these materials are simple and inexpensive. However, as such materials cannot ensure reliable filling or stable strength, the use of processing soil and cement–bentonite has increased in recent years. However, there are no regulations yet on the filler that are injected into pull-out holes, and the influence of filler strength on the surrounding ground is yet to be elucidated.

This study considers the influence of the pull-out holes of pile foundations on the static and dynamic characteristics of the surrounding grounds using two-dimensional dynamic finite-element analysis. The special qualities required by fillers for being injected into pull-out holes are also clarified in this study.

2. DYNAMIC FINITE-ELEMENT ANALYSIS

The tasks involved in this study are described in points (1) to (5) (as shown in Fig. 1).

(1) Select the study cross section and the input ground-motion waveform.
(2) Create an analytical model based on the cross section selected in point (1), and set the mesh division of the analytical area.
(3) Select an analytical constant. Set the application configuration model and material parameters in the initial stress analysis and the dynamic total stress elastic plastic analysis.
(4) Perform the initial stress analysis. The analysis technique used is total stress analysis. In this study, an HD model for the ground material and an elastic model for the hollow portion are applied.
(5) Took over the calculated ground in stress at (4), perform dynamic total stress analysis. Again, as with the initial stress analysis, the HD model for the ground material and the elastic model for the hollow portion are applied. Enter the seismic acceleration at the bottom of the analytical model.

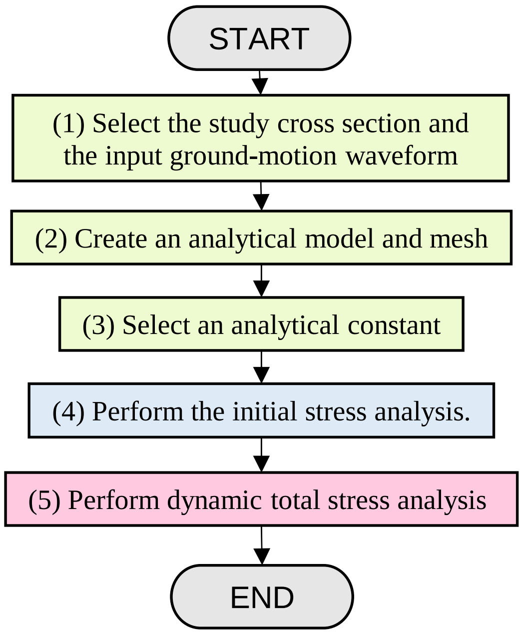
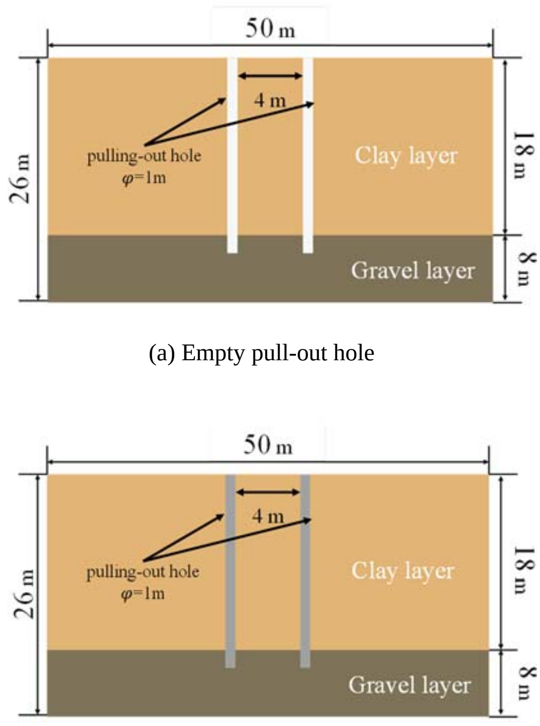


Fig. 1 Analytical procedure

2.1 Analytical model

In the analysis, the analytical cross section has two layers. The upper layer has clay as a soft stratum, for which the N-value is approximately 4. The lower layer consists of a strong formation of gravel serving as a support layer, for which the N-value is approximately 50. The width of the analytical cross section is set at 50 m, the thickness of the clay layer is 18 m, the thickness of the gravel layer is 8 m and the total depth of the cross section is 26 m. Two pull-out holes exist in the model at a spacing of 4 m; the pore diameter is 1 m, depth is 20 m and the depth of embedment in the gravel layer is 2 m. To improve the accuracy of the analysis, a finer mesh spacing is used near the pull-out hole. This finer mesh continues to be used even when the pull-out holes are filled in order to examine the behavior of the filling. As a boundary condition, in the dynamic analysis, the bottom is a 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 whether the stratum has spread to the left or right.

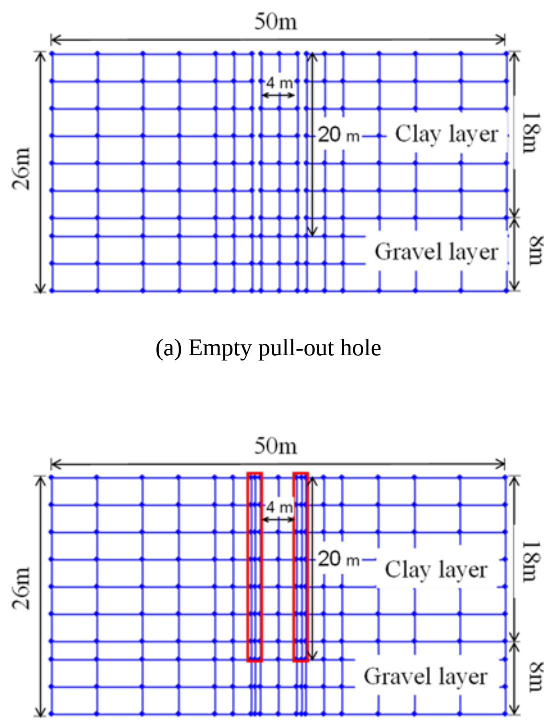
Analysis is performed on three types of ground: one with no pull-out holes, one with empty pull-out holes and one where the pull-out holes are filled. The analytical cross-sectional view of the ground is shown in Fig. 2. A similar analytical model is shown in Fig. 3. In the case of filled pull-out holes in Fig. 3, the portion surrounded by a red frame is the pull-out hole portion. The parameters of the HD



(a) Empty pull-out hole

(b) Filled pull-out hole

Fig. 2 Sectional view



(a) Empty pull-out hole

(b) Filled pull-out hole

Fig. 3 Analytical model

Table 1 HD model parameters

Parameters	Clay layer	Gravel layer
G_0 (kPa)	27900	298485
σ'_m (kPa)	90	234
ν (-)	0.45	0.40
c (kPa)	25	0
ϕ (°)	0	50

Table 2 Elastic model parameters

Parameters	Pull-out holes (filler)		
	Filler 1	Filler 2	Filler 3
q_u (N/mm^2)	0.1	0.5	1.0
E (kN/m^2)	25280	126400	252800
ν (-)	0.48	0.46	0.44

Table 3 Element parameters

Parameters	Clay layer	Gravel layer	Pull-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

model in the clay and gravel layers are shown in Table 1. Table 2 shows the parameters of the elastic model of the pull-out hole.

2.2 Constitutive Law and Material Parameters

The parameters in the clay and gravel layers used in the analysis as well as the soil parameters in the pull-out hole are shown in Table 3. In this analysis, a fluidization treated soil is used as a filler; experimental values of its properties can be seen in the literature [3], [4]. In addition, three fillers with different elastic moduli and different Poisson ratios are analyzed in order to examine the effect of filler strength on the ground. The strengths of the fillers increase in the order filler 1, filler 2, filler 3. Parameters used in the analysis is to determine the anamnestic literature reference [5].

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

2.3 Input Ground-motion Waveform

In the analysis, the waveform of the El Centro 1940 NS earthquake (which was provided by the Building Center of Japan) is exerted on the substrate's surface. The maximum acceleration is 341.7 cm/s^2.

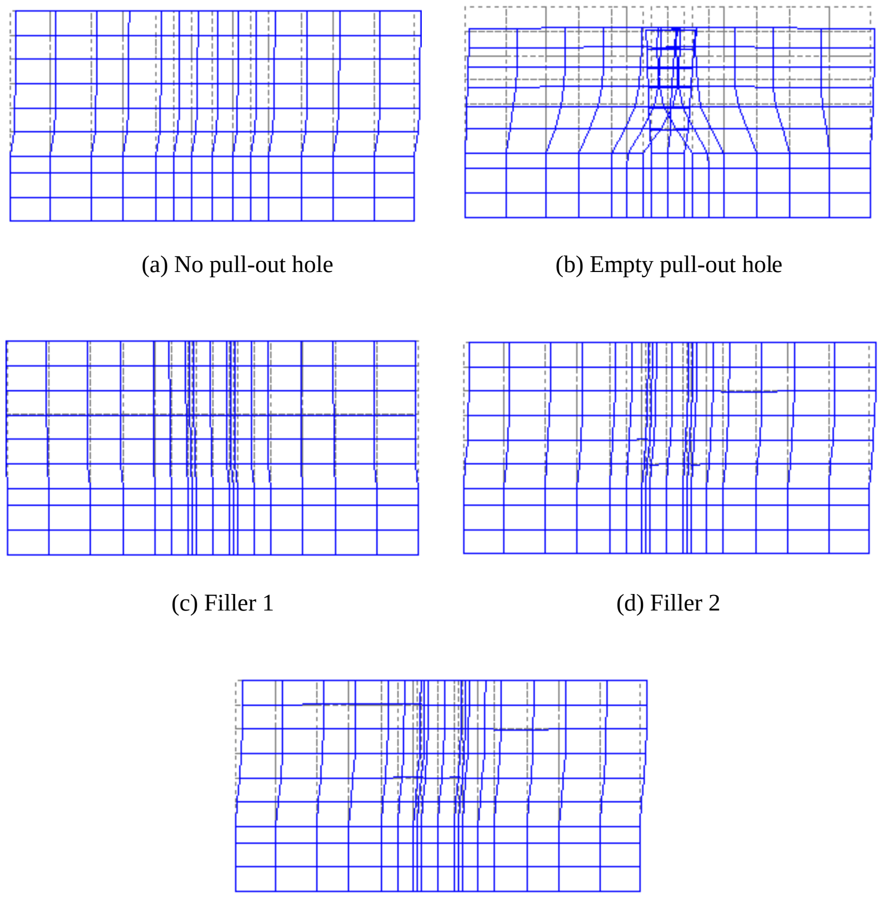
3. RESULTS AND DISCUSSIONS

Figure 4 shows the diagrams of the maximum displacement for each of the three ground types. In addition, Fig. 5 shows the X-direction displacement contour diagrams, and Fig. 6 shows the Y-direction displacement contour diagrams. Figure 7 shows the time history view of the X-direction displacement of the ground center in the cases where no pull-out holes are present and where the pull-out holes have been filled.

It can be seen that the ground wave causes significant horizontal displacement in all cases when it is allowed to act on the base surface. From Fig. 4, it can be seen that a large ground subsidence occurs in the vertical direction when the pull-out hole is empty. The maximum subsidence in ground surface is approximately 60 cm, which is very dangerous. However, this subsidence does not occur in the case where the pull-out holes are filled. Thus, it can be said that filling the pull-out hole is an effective way to prevent subsidence.

From Fig. 4, it can be seen that, using filler 1, the maximum horizontal displacement is on the left side, unlike in the other cases. Figure 5 clearly shows that the behavior of the horizontal displacement under filler 1 is different from that of the other cases.

In the other cases, displacement to the right occurs rapidly at approximately 5 seconds and displacement have continued while the displacement remained. However, if the displacement at 5 seconds is small, then the system will soon return to its original configuration. From this fact, it is believed that the behavior of the horizontal displacement of the ground varies greatly when the filling material strength is too small. From Fig. 5, it can be seen that the horizontal displacement is greatest in the case where filler 3 is used and the displacement is approximate in the case where no pull-out holes and filler 2 are used. Figure 8 shows a comparison of the horizontal displacements of the ground center line. From Fig. 8, it can be seen that rapid displacement of the clay layer bottom occurs in all cases. In addition, the behavior of the ground with holes filled by filler 2 is considered to be closest to the behavior of the ground without pull-out holes. In the vertical direction, bulging occurs on the left side of the filling portion and subsidence occurs on the right side when fillers 2 and 3 are used. Furthermore, it can be seen that the displacement increases as the

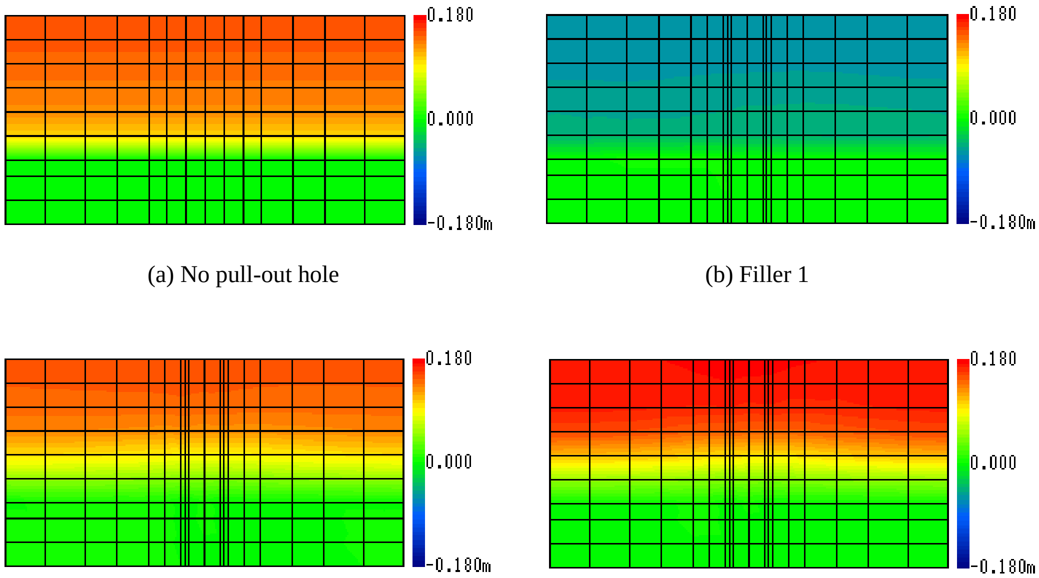


(a) No pull-out hole (b) Empty pull-out hole

(c) Filler 1 (d) Filler 2

(e) Filler 3

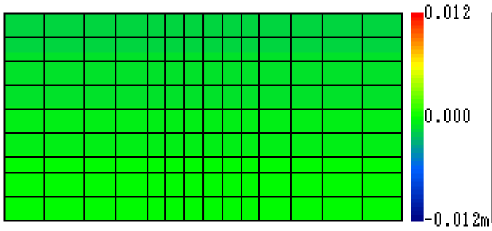
Fig. 4 Displacement diagram (The amount of displacement is three times)



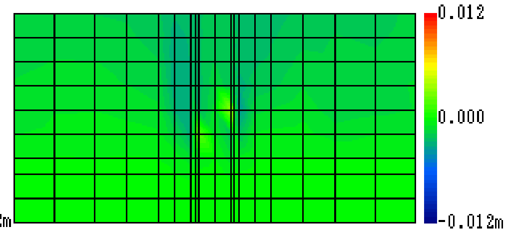
(a) No pull-out hole (b) Filler 1

(c) Filler 2 (d) Filler 3

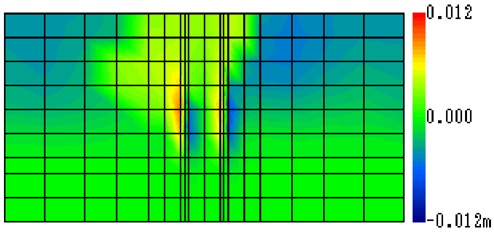
Fig. 5 X-direction displacement contour diagrams



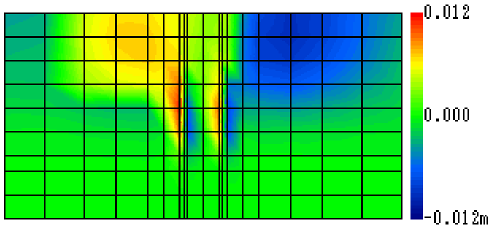
(a) No pull-out hole



(b) Filler 1

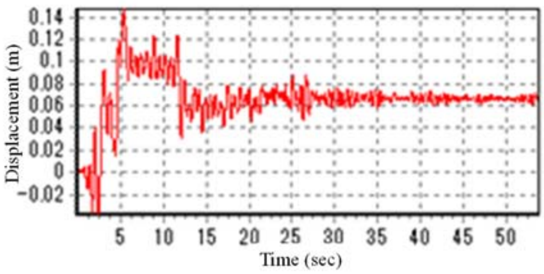


(c) Filler 2

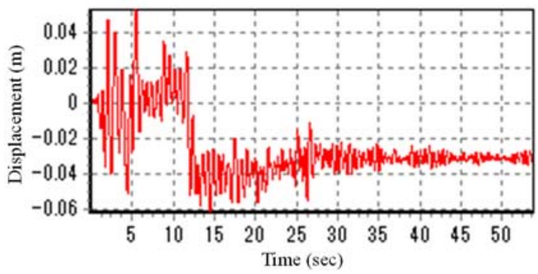


(d) Filler 3

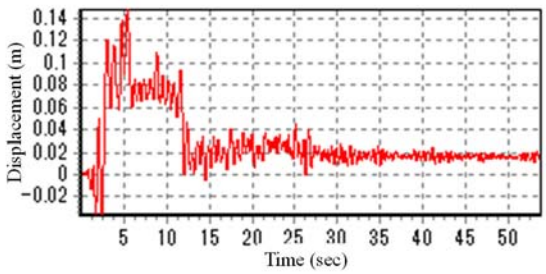
Fig. 6 Y-direction displacement contour diagrams



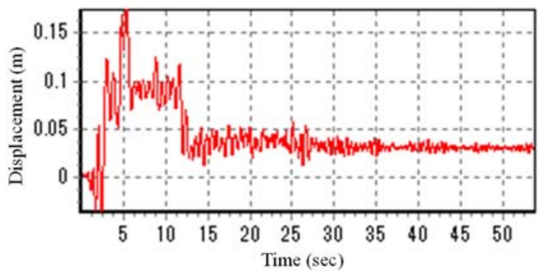
(a) No pull-out hole



(b) Filler 1



(c) Filler 2



(d) Filler 3

Fig. 7 Time history view of the X-direction displacement of the ground center filler strength increases.

4. CONCLUSIONS

In this study, two-dimensional dynamic finite-element analysis was used to elucidate the effect of pull-out holes of foundation piles on the dynamic behavior of the ground.

The results obtained from the analysis are shown below.

(1) Ground subsidence occurs in the vicinity of a pull-out hole when the hole is left empty, particularly in the area sandwiched between two pull-out holes. A very large subsidence occurs in a wide range of ground surfaces if earthquake ground motion occurs.
(2) When the pull-out holes are filled, ground subsidence does not occur in the dynamic or static analyses. For this reason, it is clear that filling pull-out holes is effective.
(3) When the filling strength is too small relative to the strength of the original ground, the ground may behave in a significantly different way from the case with no pull-out holes. For this reason, it is necessary to change the filler strength to suit the ground conditions.

This study has not taken account of the influence of different compounding filler materials or different hole shapes. Therefore, there is a need to investigate these conditions as the subject of future analysis.

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