An Investigation of Element Size in a Numerical Simulation of Press-in Behavior by Discrete Analysis Method

The University of Tokyo Student Member ○Shunya Kimura
The University of Tokyo Regular Member Kohei Nagai
The University of Tokyo Regular Member Yuya Sakai

1. Introduction

To understand the soil behavior during the execution of press-in process of the steel pile, various researches have been done. Numerical simulation is one of the methods, where the discrete analysis method is suitable since it can simulate the steel pile penetration and soil movement directly. However, it is actually difficult to model each soil particle in the simulation because the soil particle size is very small so that large-scale analysis is needed. Therefore, it is realistic that the element in the simulation represents a certain area with assembled soil particles to reduce the calculation time. This paper reports the parametric simulation results to investigate the effect of element size on the press-in behavior by Discrete Analysis Method.

2. Analysis method

In this research, Rigid Body Spring Model (RBSM) is used. The analysis method was developed by Kawai [1]. RBSM is a method that considers the object to be analyzed as discrete rigid elements, with stresses transferred through set springs between the elements. Generally, RBSM is not suitable for presenting a large deformation behavior. Therefore, the simulation program for large deformation developed by Sakai is used in this research [2]. The shape of element is circular, to simplify the determination of the contact, as shown in Figure 1. The constitutive model of spring set between elements is shown in Figure 2.

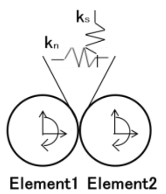

Figure 1: Element and spring in RBSM

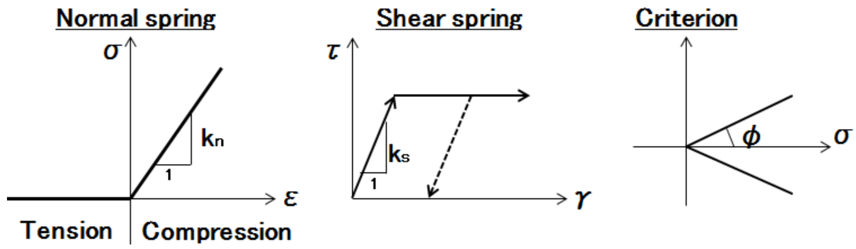

Figure 2: Constitutive model of springs

3. Analysis cases

In order to investigate the effect of the element size, numerical models were conducted. The width and the height of the models are 600mm and 500mm, respectively. The size of the element is set as the parameter in this study, i.e. 5mm, 10mm, 15mm and 20mm (Figure 3). In order to prepare the model, another program to carry out packing by free falling was used. In this model, a rectangular element, with 20mm width representing the pile, was pressed-in at a penetration rate 1mm/step. As the comparison, simulations with pile width 80mm are also conducted. Table 1 shows the dimension of the numerical models, and Table 2 shows the material properties of the numerical models.

Table 1: Dimension of the numerical models

Model	Element	Dimension		Number of
	Diameter(mm)	Width(mm)	Height(mm)	Element
1	5	600	500	11738
2	10			2927
3	15			1306
4	20			723

Table 2: Material properties

Material Properties	Input value
Normal spring k_n (MPa)	75
Shear spring k_s (MPa)	5
Angle of friction φ (degree)	27

4. Analysis Results

Figure 4 and 5 show the press-in depth and force relationships in the simulations. From these results, obtained press-in force becomes larger and scattered when the diameter of the element is larger than 10mm (Model 3 and 4). Press-in forces in case of model 1 and 2 are almost same. However, the scatter of the press-in force of model 2 is larger than that of model 1, because the gap area between elements became wider due to large sand elements. In case of pile width 80mm, the scatters of analysis results are smaller than in case of pile width 20mm. It is considered that the ratio of pile width and the element size is also an important factor for the stable solution of the numerical simulation. Figure 6 shows a contour diagram of the total displacement at penetration depth 300mm. The scatter of total displacement is larger if the

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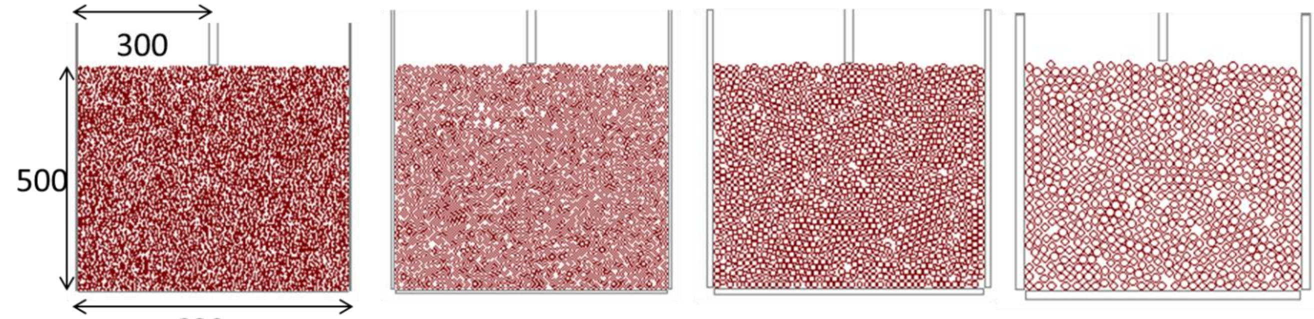
【Contact】Address: 4-6-1, Komaba, Meguro-ku, Tokyo, Japan 153-8505 Tel:03-5452-6655 Fax:03-5452-6395



(a) Model 1 (element size 5mm) (b) Model 2 (10mm) (c) Model 3 (15mm) (d) Model 4 (20mm)

Figure 3: Analysis models

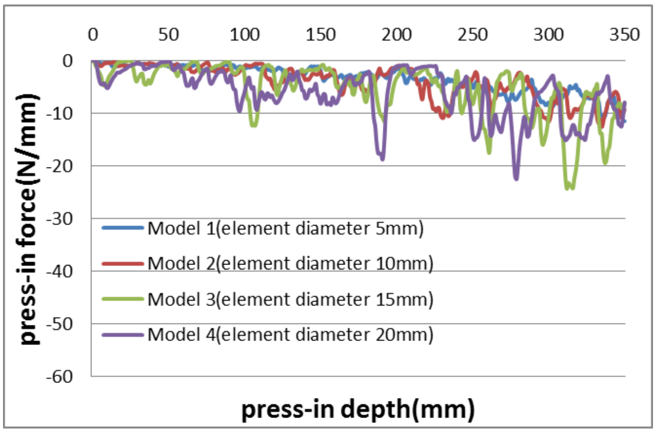


Figure 4: Press-in force (pile width 20mm)

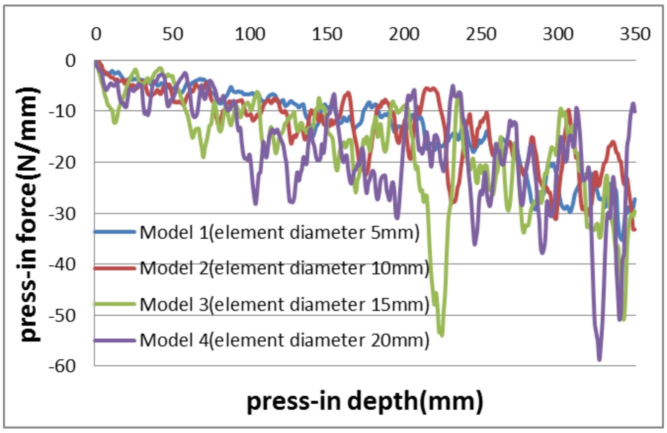
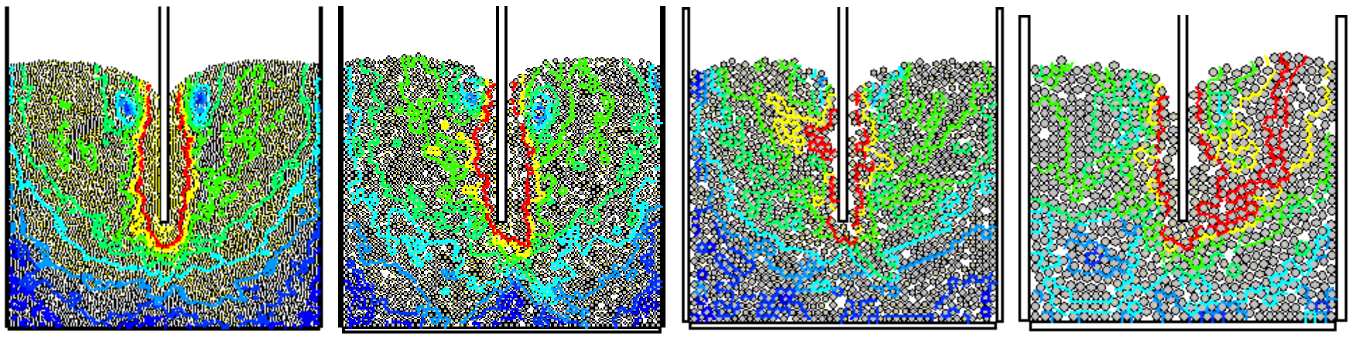


Figure 5: Press-in force (pile width 80mm)



(a) Model 1 (b) Model 2 (c) Model 3 (d) Model 4

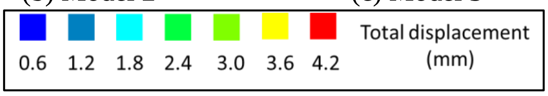


Figure 6: Contour diagram of the total displacement

diameter of the element is larger. Contour lines of model 1 are smoother than those of model 2, especially light-blue line. These figures also show larger scatter in case of larger elements. In addition, the range of the effect is different if the element size is changed.

5. Conclusion

From these results, it is considered that not only scatter of press-in force but also deformation of particles becomes larger if the element in the simulation becomes larger. Therefore, the choice of suitable element size is needed. In addition, the ratio of pile width and element size is also important.

Reference

1) Kawai, T. : New Discrete Models and Their Application to Seismic Response Analysis of Structures, Nuclear Engineering Design, 48, pp. 207-229, 1978.

2) Kohei NAGAI, Taro UCHIMURA, Yuya SAKAI, and Koichi MAEKAWA, NUMERICAL SIMULATION OF PRESS-IN BEHAVIOR IN A HETEROGENEOUS FIELD USING ALUMINUM RODS LAYER BY DISCRETE ANALYSIS METHOD, Press-in Engineering 2011: Proceedings of 3rd IPA International Workshop in Shanghai