STATE OF THE ART OF MICROPILES IN JAPAN

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1. INTRODUCTION

The state of the art of micropiles in Japan was described in the First International Workshop on Micropiles by Tsukada and Ichimura of Pubic Works Research Institute of the Ministry of Construction, in Seattle in 1997[1)]. According to it, the first application of the micropile in Japan was the foundation of a lookout tower in 1980. Since then, micropiles have been used to reinforce slopes, embankments, and foundations of structures and so forth. Classification of the application of the micropile was summarized in Figure 1. And the ratios of the application fields were as shown in Figure 2. It seems that the tendency has not changed though Figure 2 was made two years ago. Typical examples of the application of micropiles drawn by them are also shown here from Figure 3 to Figure 8. The change afterwards will be briefly described in this report except applications in the tunneling engineering field because professor Nakagawa of Yamaguchi University will explain about them[2)].

The micropile has been called "route pile", " needle pile", "mini pile", "soil nailing", and "pin piling", etc. and the word of "micropile" was not necessarily popular in Japan. However, the research activity relevant to micropiles has become active after the first workshop, and the session of the micropile came to be gained in the annual meeting of the Japan Society of Civil Engineers, and the national conference on geotechnical engineering of the Japanese Geotechnical Society. Now, the word of "micropile" is considerably popular in Japan.

2. COMMITTEE ACTIVITIES AND PUBLICATIONS

After the First International Workshop on Micropiles, there was a consignment from the Japanese Association of Micropiles (JAMP) to the Advanced Construction Technology Center (ACTEC) to start the committee to investigate the application technology of high capacity micropiles (HCMP) in Japan. In this committee, design and construction methods were examined based on the reports published by Federal Highway Administration[3)] in the United States. Technical problems were extracted in application of micropiles in Japan, and at the same time discussed how to solve them. The earthquake-proof reinforcement and retrofitting of existence foundation structures were main issues in the discussion because Japan is an earthquake prone country. The activity of the committee was reported by ACTEC in April 1999[4)].

In parallel with this, parametric experimental study on bearing capacity of micropiles using small model were performed in Hokkaido University, and in situ tests using full scale micropiles were also conducted by Pubic Works Research Institute and JAMP, respectively. The test results on HCMP are reported by JAMP. In addition, "Tentative manual of design and implementation of HCMP" and "Materials for estimation of HCMP construction method" were issued from JAMP in April 1999 [5), 6), 7)]. They are purchasable.

Separately, Geo-Front Research Association has been studied applications of micropiles mainly in tunneling engineering for several years prior to the committee in ACTEC. The fruit of research activity of the association will be reported by professor Nakagawa in this Workshop[2)].

3. RESEARCH ACTIVITIES

The research activity on micropiles in Japan is now very active. The subjects are extending over ① case studies, ② element tests, ③ small model tests, ④ a full-scale in-situ load tests, ⑤ centrifugal tests, ⑥ theoretical stability analysis, ⑦ dynamic response analyses, and so forth. They will be reported in this Workshop and summarized in Table 1. Brief explanation of them will be given below.

3-1 Case study

Hoshiya et al.[8] surveyed the damage inspections done by many researchers for pile foundations after the 1995 Hyogoken-nanbu (Kobe) earthquake and showed that all structures reinforced by root piles were sufficiently flexible and highly earthquake resistant.

Watanabe and Sakamoto [9] report the projects in which steel pipe micropiles were used to reinforce the foundations at very narrow construction site as shown in Figure 9.

3-2 Element test

Murata et al.[10] developed high capacity steel tube core applicable to micropiles as shown in Figure 10. In order to conform fundamental load performance of the core, they conducted laboratory loading tests such as compression, tensile, bending and bond tests.

Yamane and Togawa[11] conducted laboratory tests for micropile system to confirm feasibility and efficiency of the system as shown in Figure 11 and showed that the pile body possessed sufficient bending deformation capacity and the specimens with a coupling joint also had enough strength.

3-3 Small model test

Tsukada et al.[12] carried out a series of model loading tests to clarify the mechanism of improvement of bearing capacity of a footing reinforced with a group of micropiles. The circular footing were reinforced with a group of micropiles with variety of the arrangement of micropiles as shown in Figure 12, and were subjected to vertical load. They discussed the influence factors on the improvement of bearing capacity based on the comparative examinations of the observed load-displacement behaviors.

3-4 Full scale in-situ load test

Fukui et al.[13] reported the trial execution and horizontal and vertical loading tests of micropiles, which was conducted to study the applicability of micropiles as a foundation retrofitting method. Figure 13 shows the soil profile at the site and the general view of the full scale test pile. The results of the trail calculation showed that although a relatively large number of piles were needed, even micropiles with small diameter provide a degree of the effects of foundation retrofitting.

Ichimura et al.[14] conducted full scale vertical loading tests to clarify the vertical bearing capacity of micropiles reinforced with steel pipes. Furthermore, they compared the results of statnamic loading test (Figure 14) with the results of static loading test of micropiles to judge the applicability of the statnamic load testing.

Nakata and Kishishita[15] also performed field tests of vertical compression loading tests and alternating vertical loading tests. They assessed the structural strength of anchorage zones of micropiles, and the ultimate skin friction stress working between the grouting material and ground in a vicinity of the anchorage zones of steel pipes.

3-5 Centrifugal test

Research team in PWRI started centrifugal loading tests for micropiles. Sagara et al.[16] outlined the large centrifugal loading test apparatus (Figure 15) which they used and explained the model experiment apparatus for the centrifugal model test of micropile foundations (Figure 16) and also explained models of micropile foundations. Morikawa et al[17] reported the part of test results of the bearing capacity of micropiles. They tested the effect of angle of micropiles and arrange pattern on the bearing capacity of the footing.

3-6 Theoretical stability analysis

Zhu and Miura[18] studied the critical load against buckling of a single pile foundation with initial displacements. First, they derived the set of geometrically nonlinear equations for the problem. Then they performed a series of parametric study to examine the critical loads. They showed that the initial displacements affected a little on the critical loads but the reduction of the soil spring coefficients was significant.

3-7 Dynamic response analysis

In order to study the dynamic response of structures supported by micropiles and dynamic effectiveness of micropiles Kishishita et al.[19] performed dynamic response analyses using 2-D finite element method (Figure 17). From the analysis results they proved that micropiles were effective if they facilitated construction of raking piles and produced high bending strength like high capacity micropiles.

Kawamura and J.Q.Jiang conducted dynamic response analyses of group of piles with the soil-pile interaction considered, and investigated the effect of dynamic stiffness of pile foundation on the response, including axial, lateral and rocking components, due to different pile distribution, pile diameters as well as soil conditions. They employed finite element method of an axisymmetric model under axisymmetric/anti-axisymmetric loading conditions (Figure 18).

4. SUMMARY

It can be said that this Second International Workshop on Micropiles is exactly the state of the art of micropiles in Japan. After the workshop, there was good news that the application of micropiles for retrofitting a substructure was determined. This may be a trigger of the application of micropiles as a component of permanent structures in Japan.

On the other hand, based on the lessons from the 1995 Hyogoken-nanbu (Kobe) earthquake, almost all the seismic design codes in Japan have been revised. Seismic design standards for railway structures are not the exception. The standards explicitly require the designer to take the ground deformation into consideration in designing pile foundations[21]. This implies that the pile should sustain the ground deformation, which requires piles with flexibility. Micropiles meet the requirements.

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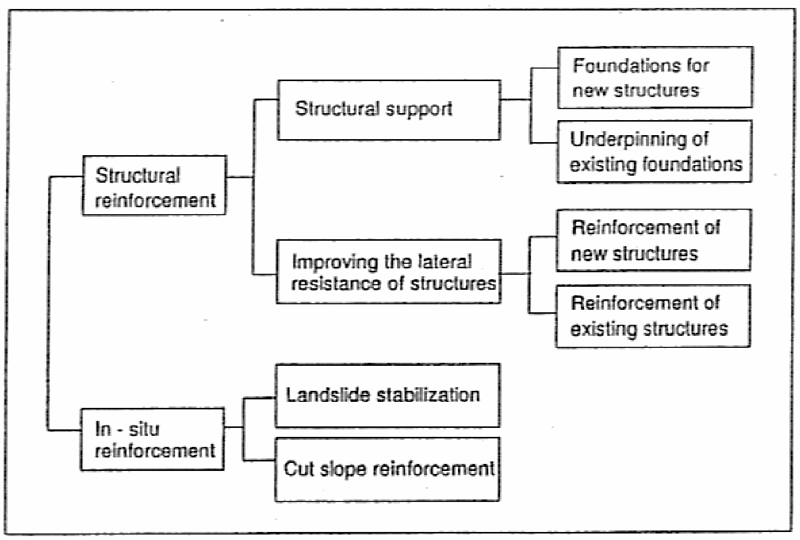

Figure 1 Classification of micropiles applications in Japan[1].

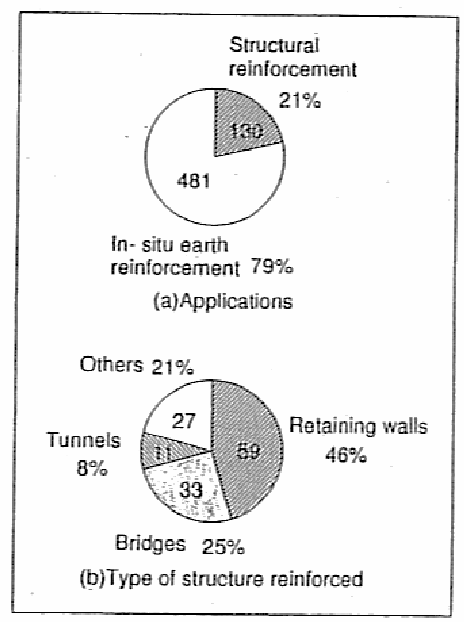

Figure 2 Ratios of micropile works in Japan by work category[1].

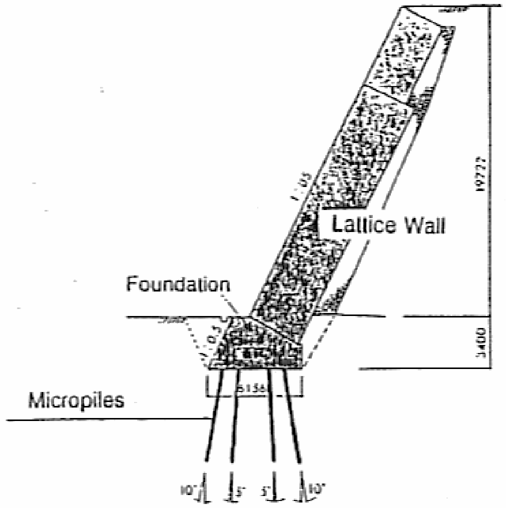

Figure 3 New retaining wall foundations[1).

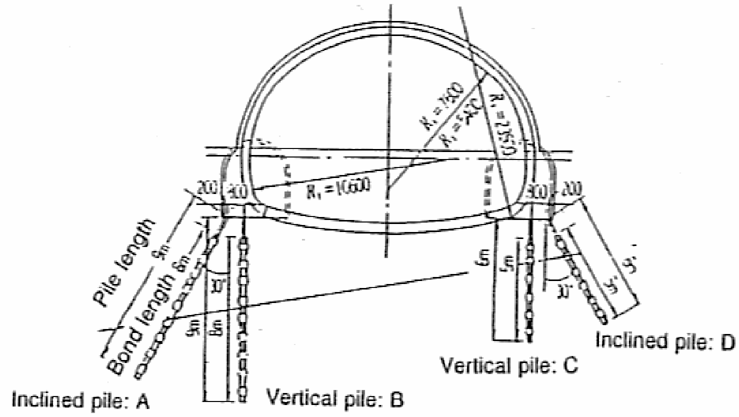

Figure 4 Tunnel foot reinforcement[1).

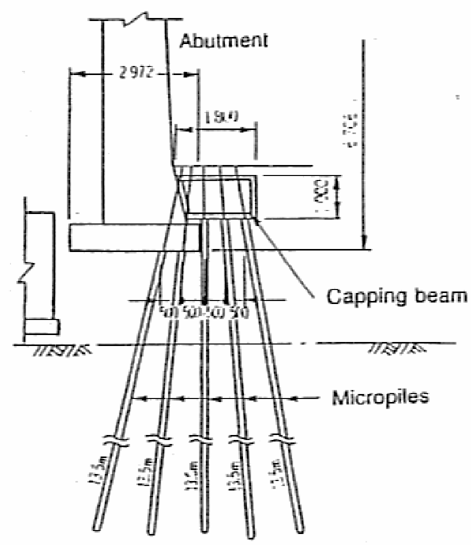

Figure 5 Underpinning of an existing abutment[1).

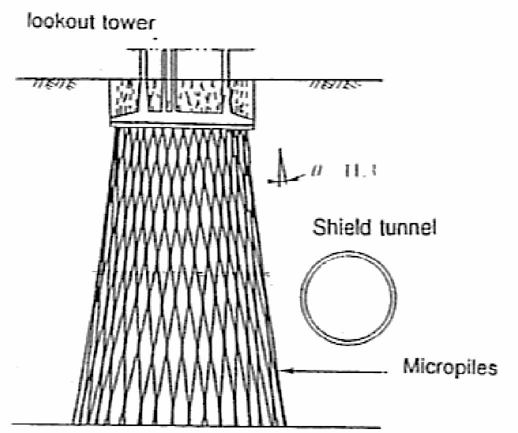

Figure 6 Protection of an existing structure[1).

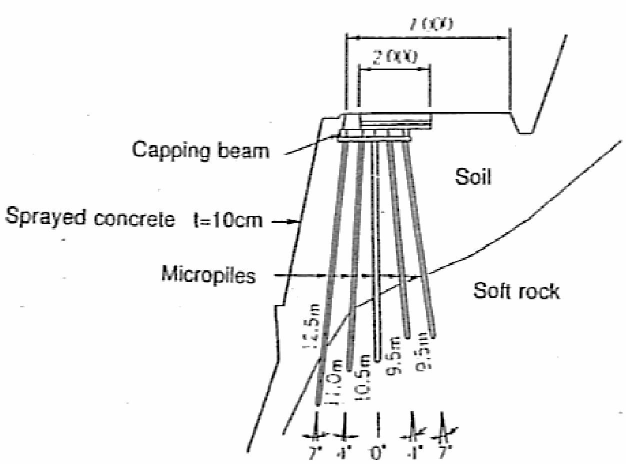

Figure 7 Landslide stabilization[1).

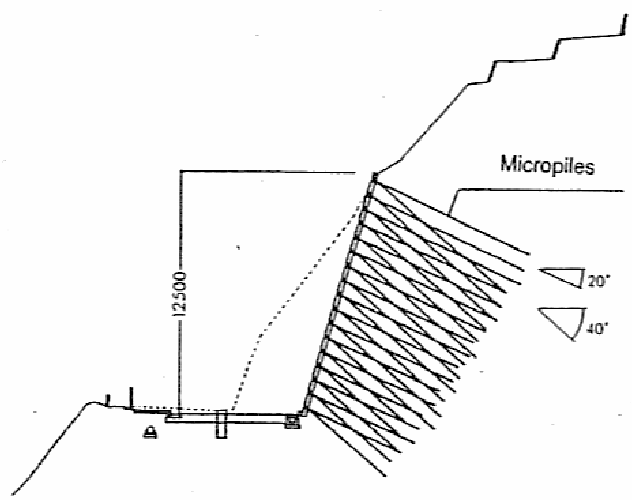

Figure 8 Cut slope reinforcement[1).

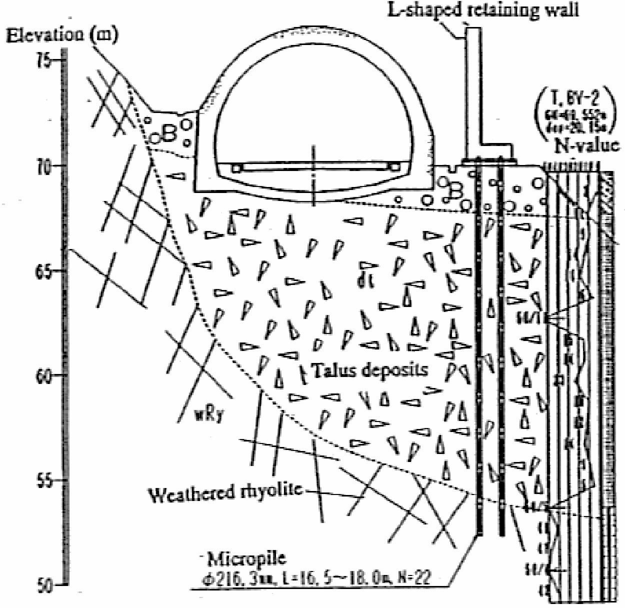

Figure 9 General view of the site [9].

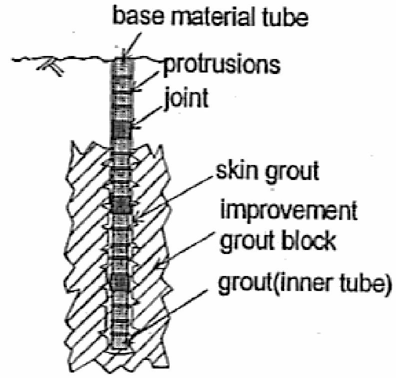

Figure 10 Feature of the proposed core[10].

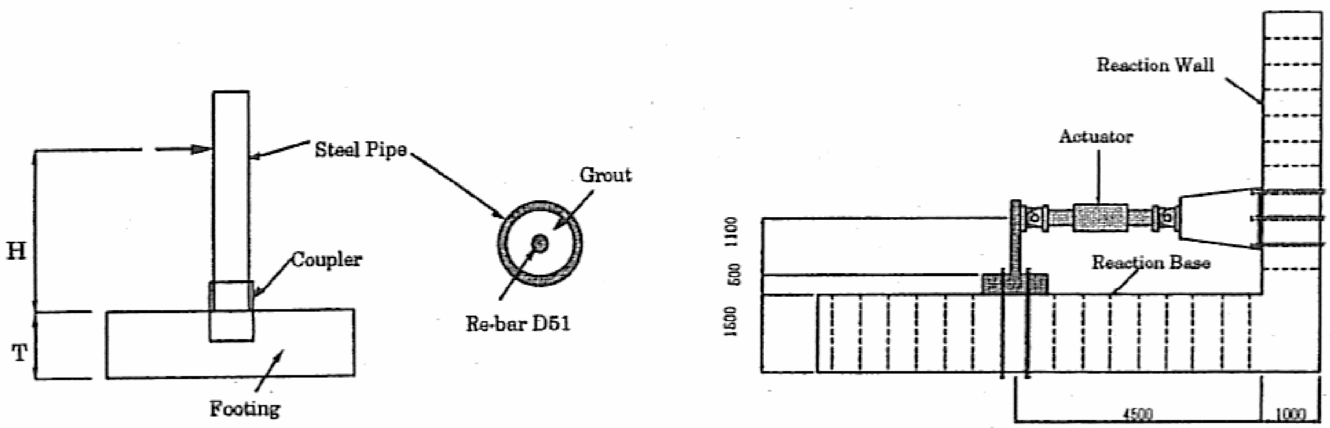

Figure 11 Test specimen and test setup[11].

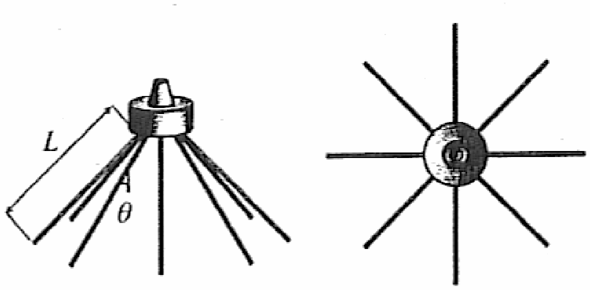

Figure 12 Model micropile foundation[12].

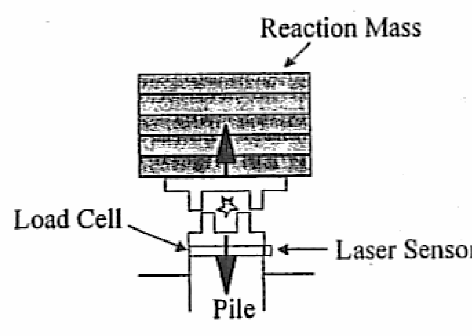

Figure 14 Principle of statnamic loading test [14].

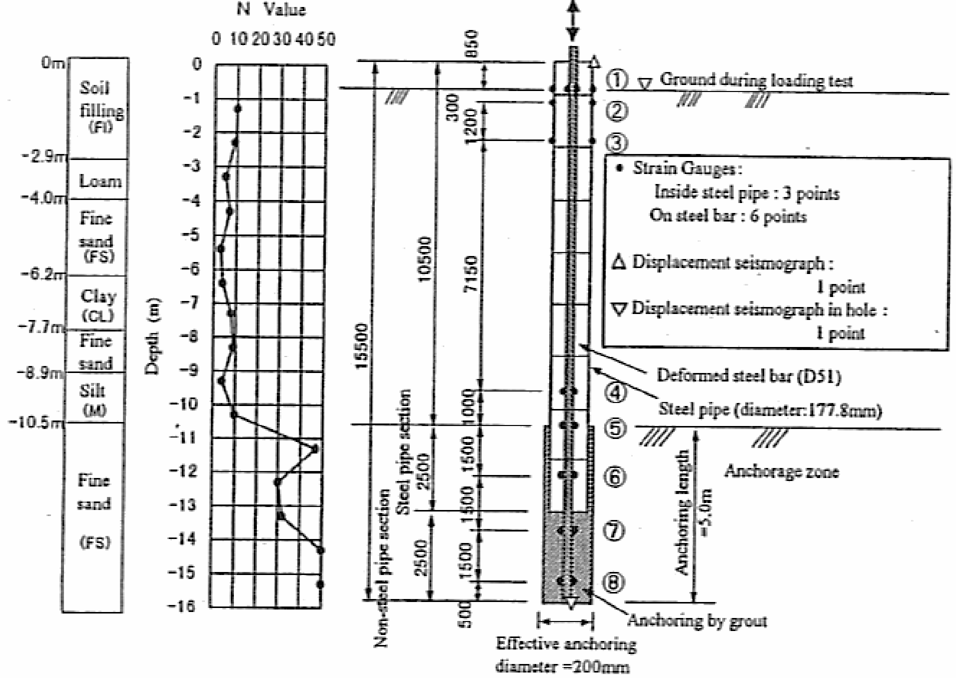

Figure 13 Soil profile at the test site and the general view of the test pile [13].

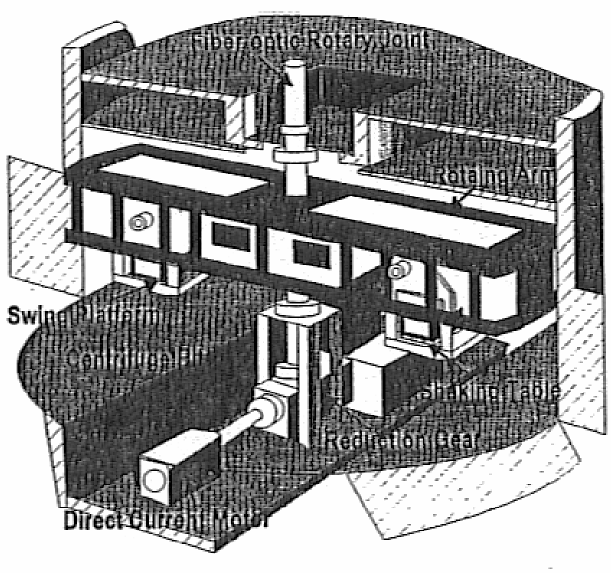

Figure 15 General view of the geotechnical centrifugal loading test system[16].

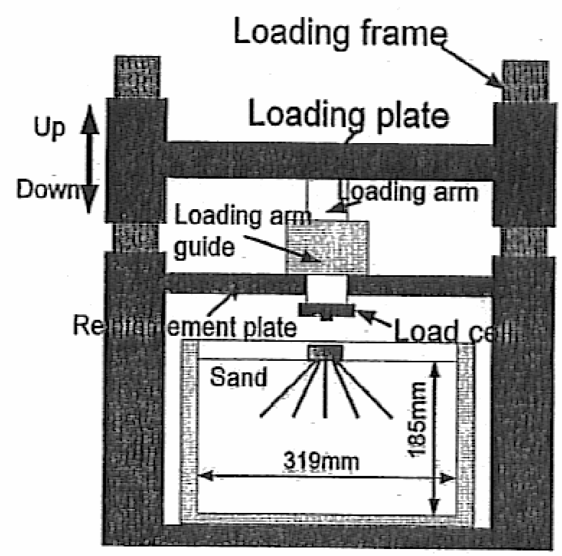

Figure 16 Schematic diagram of model experiment[16].

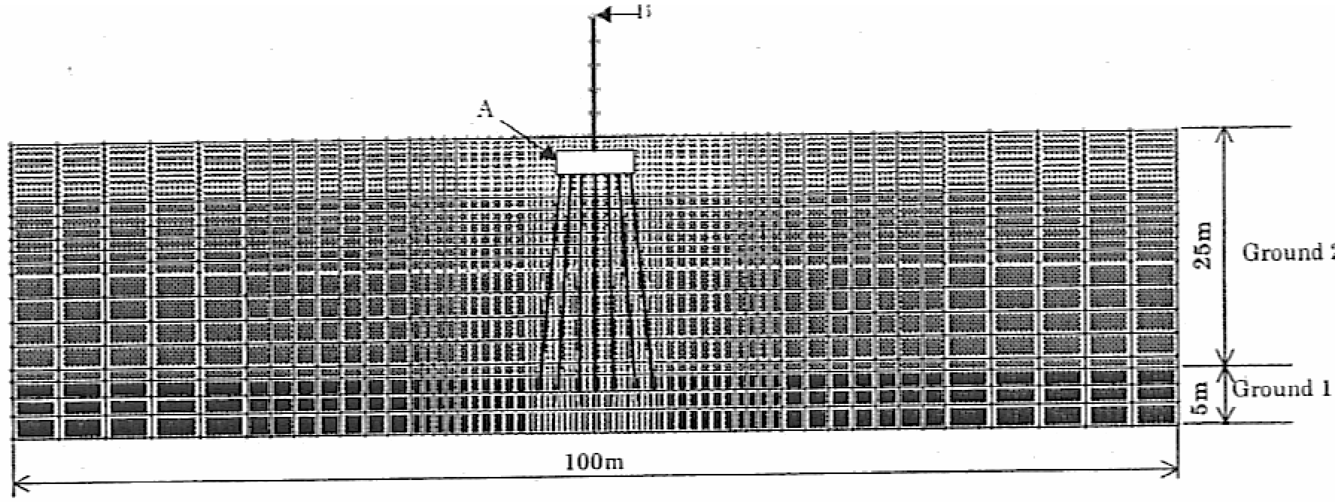

Figure 17 Finite element model for the numerical analyses[19].

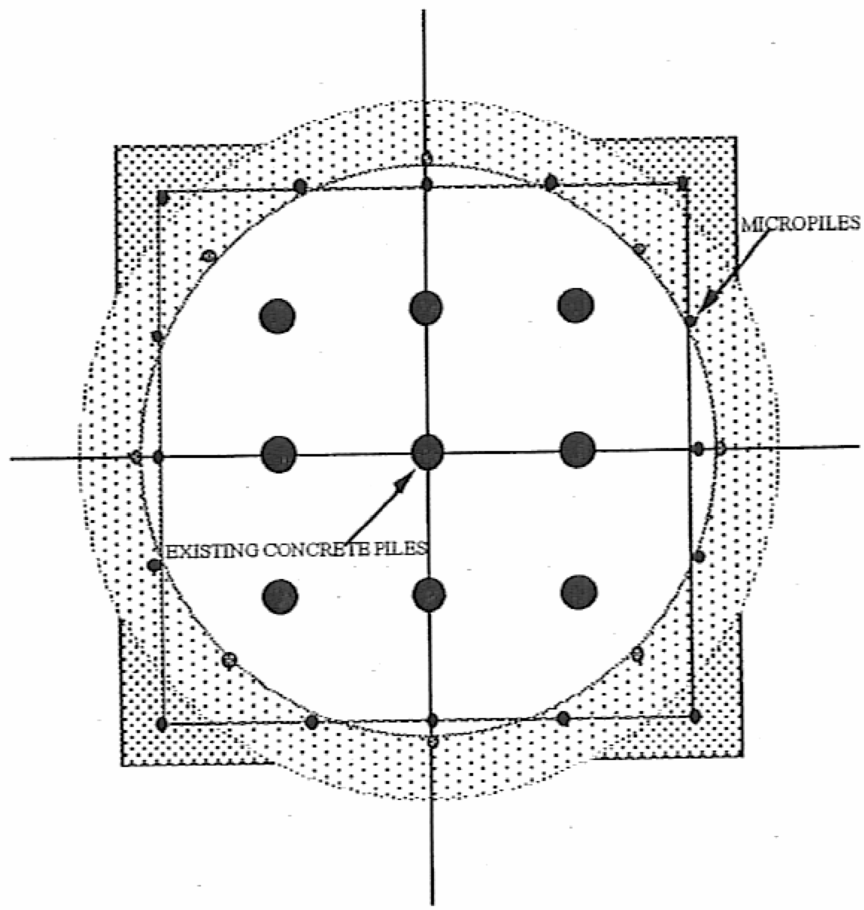

Figure 18 Actual pile arrangement and equivalent ring piles[20].