Centrifugal Model Tests on a Micropile Foundation

Part 1: Outline of the Large Centrifugal Force Loading Test Apparatus and Model Experiment Apparatus

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1. Introduction

Micropile (abbreviated as MP in this report) is a general term for cast-in-place piles and bored precast piles with a diameter of 300 mm or less. An MP is executed using a compact boring machine, its pile body is reinforced with either deformed steel bars or with steel pipe, and it is formed by injecting grout.

In Europe and America, MP are widely used as structural foundations, but rarely in Japan. To prepare for the use of MP as structural foundations or as a seismic reinforcement method, various research studies of MP have been conducted in Japan. But there is still much that is unknown regarding their bearing capacity properties.

This report describes the clarification of the bearing capacity properties of MP made with steel pipe. This was done by performing bearing capacity experiments on a model of a spread foundation reinforced with MP in a centrifugal force field. The following pages present an outline of the large centrifugal force loading test apparatus used primarily by the Public Works Research Institute of the Ministry of Construction, an outline of the model experiment apparatus used for this experiment, and an explanation of the experiment method.

2. Outline of the Large Centrifugal Force Loading Test Apparatus

Centrifugal force loading test apparatus are widely used as a powerful experimental method of performing model experiments that satisfy the law of similitude in a number of fields: primarily ground systems.

(1) Principles of a centrifugal model experiment

Confining pressure generated by the dead weight of the soil itself significantly influences the mechanical properties of soil. The ideal way to reproduce stress conditions identical to those of actual ground at a site is to perform full-size experiments, but this is actually extremely difficult. Scale models are, therefore, usually employed, but it is necessary to satisfy the law of similitude in order to recreate actual phenomena. It is possible to reproduce stress conditions that correspond to those of a full size specimen using model ground by performing a centrifugal model experiment: namely by subjecting model ground to centrifugal acceleration in order to increase its weight. Equivalency to a full-size specimen is obtained by a centrifugal acceleration nG (1G = 980 gal) and model scale 1/n.

(2) Principal specifications and properties of the large dynamic centrifugal force loading apparatus

Table 1 Principal Specifications of the Centrifugal Force Loading Test Apparatus [1)]

Centrifuge	Effective Rotor radius	6.6m
	Maximum Acceleration	Static test : 150G Dynamic test : 100G
	Maximum Payload	400ton・G
	Swing Platform	2 Static test : 2 Dynamic test : 1
Shaking Table	Maximum Shaking Acceleration	40G
	Maximum Velocity	90cm/s
	Maximum Displacement	±5mm
	Capacity	40ton・G
	Frequency Range	10～400Hz
Data Acquisition	Number of Channels	Static test : 100ch Dynamic test : 80ch

Its principal specifications are shown in Table 1 and its external appearance can be seen in Figure 1. This apparatus features the following properties.

[1] With an effective radius of 6.6 m, it is the world's largest centrifugal force loading test apparatus. [2] A high output shaking device capable of replicating a large earthquake is installed inside the centrifugal force field. It can produce vibration equivalent to the 800 gal that was observed during the Hyogo-ken Nanbu Earthquake in a centrifugal acceleration field of 50G. [3] By forcefully placing oscillation frames on the highly stiff rotating arm, it can be

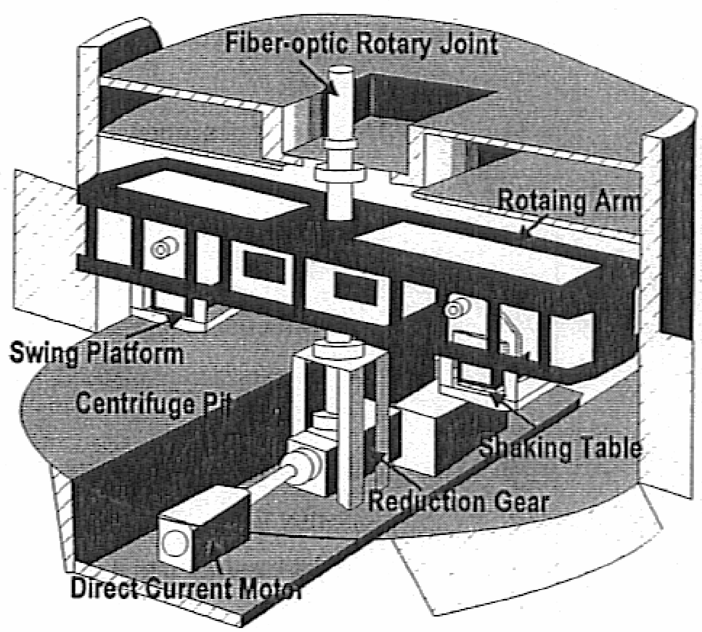

Fig.1 External View of the Geotechnical Centifuge

used to reproduce a large earthquake with high precision. [4] An extremely durable and reliable optical rotary joint that produces little noise is used to transmit measurement and control signals, permitting high speed and extremely accurate control of the earthquake motion and measurement of the deformation of the ground. [5] Thanks to the oscillation frames on the left and right ends of the rotating arm, it can be used to efficiently perform static experiments in which a long period of centrifugal loading is required to compact the model ground.

(3) Main Application

By providing the apparatus with increased shaking force and a large soil tank, it can be used to perform experiments regarding [1] soil liquefaction and flow of ground and [2] behavior of embankments, underground structures and earth-retaining structures during large earthquakes, and [3] effects of ground improvement construction methods.

3. The Model Experiment Apparatus for the Centrifugal Model Experiments of Micropile Foundations.

(1) Outline of the Experiment Apparatus

Figure 2 is a schematic diagram of the loading apparatus used for the experiment. A loading plate (approx. 100 kg) is lowered inside a loading frame as the loading arm attached to the loading plate is loaded vertically downward on the MP foundation. The loading capacity depends on the weight of the loading plate, and is 981 N (100 kgf) in a gravitational field.

In a centrifugal force field on the other hand, it is the (centrifugal acceleration × weight of loading plate), and because the centrifugal acceleration for the experiment was set at 89 G, the loading capacity was 87.31 kN (8.9 tf). The loading plate descends under its own weight with the support of a hydraulic cylinder as its loading speed is maintained at a constant rate by using an adjustable value to regulate the quantity of oil discharged from the hydraulic cylinder during the descent. The basic specifications of the loading apparatus are a loading stroke of 50 mm, loading speed adjustable between 0.5 mm and 60 mm/min., loading capacity that is 981 N (100 kgf) in a gravitational field and is dependent on the centrifugal acceleration in a centrifugal force field. During this experiment, the loading involved a maximum drop of 15 mm, loading speed of 1 mm/min., and centrifugal acceleration of 89 G.

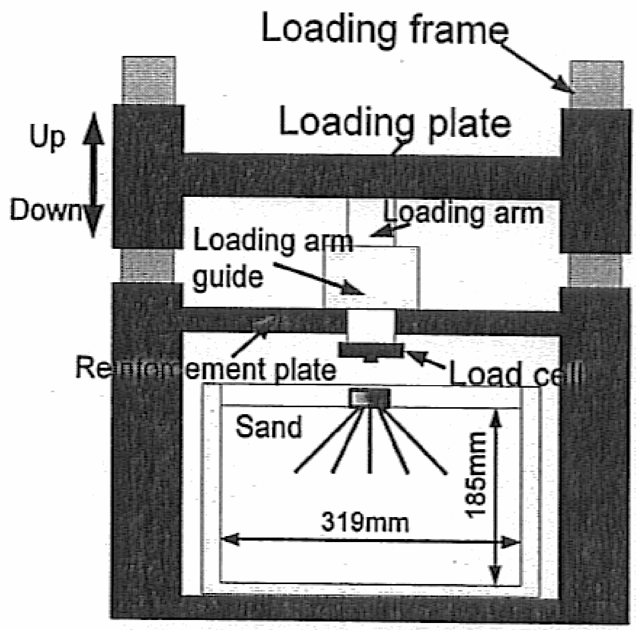

Fig.2 Schematic Diagram of Model Experiment

(2) Model ground construction method

The experiment was performed using air dried No. 7 silica sand and the cylindrical soil tank with an internal diameter of 319 mm shown in Figure 2.

The sand was inserted by dividing the entire amount inserted into 14 equal layers. It was dropped freely onto each layer from a height 465 mm above the bottom surface of the model ground through a discharge outlet with constant dimensions. The compaction was performed after every two layers up to the 8th layer from the bottom and once for every layer from the 9th layer up. Each compaction was done by striking the surface horizontally 100 times with a plastic hammer. This process formed dense ground with a relative density of sand greater than 95%.

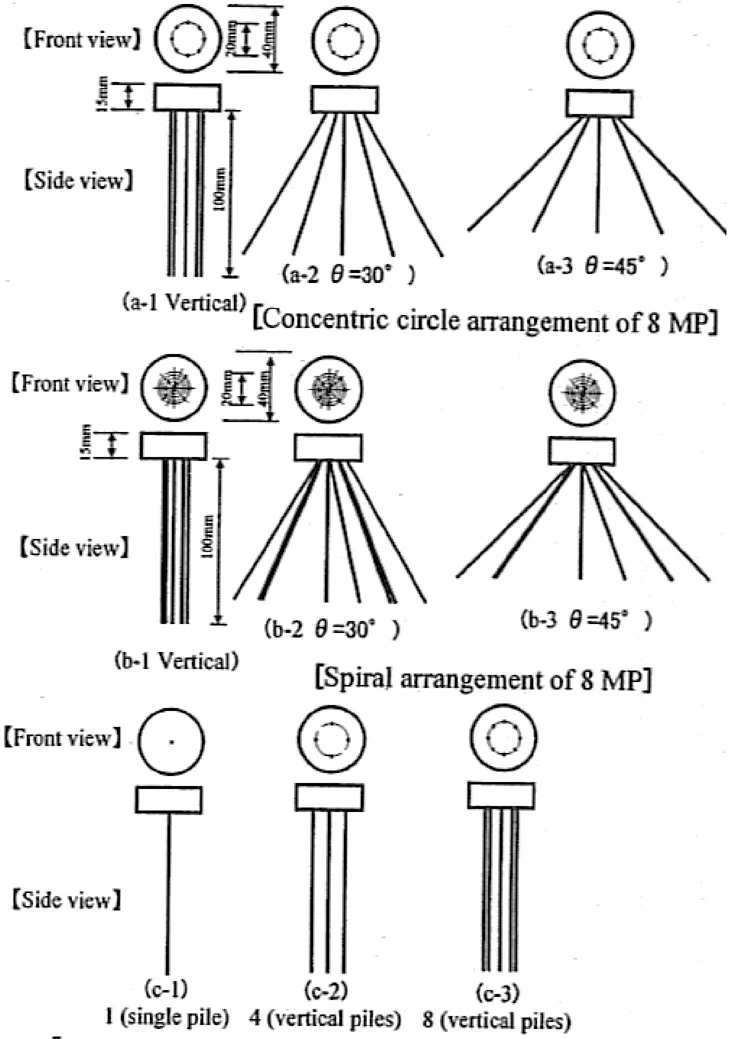

Fig.3 Models of the Micropile Foundations

(3) Models of the MP and the foundation

The MP were modeled by stainless steel rods with diameters of 2 mm and lengths of 100 mm. Sand was applied to their outer skins with bond to account for their friction with the ground. Because the steel pipes used to make MP in actual ground is 178 mm, the centrifugal acceleration for this experiment was set at 89 G. The foundation model was a stainless steel cylinder with a diameter of 40 mm and a height of 15 mm. Figure 3 shows the method used to install the MP under the cylindrical foundation. With 8 as the standard number of MP in all cases, 1 MP and 4 MP models were also prepared for comparison purposes. The piles were laid out at equal intervals in concentric circles and spiral patterns and the pile were installed vertically (0°) and at angles of 30° and 45° with the vertical direction as the axis.

REFERENCES

1) Matsuo et al.: The large centrifugal force loading test apparatus, From Public Works Research Institute Technical Memorandum 39-6 (1997).

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