# EXPERIMENTAL STUDY
# FOR FLEXURAL BEHAVIOR OF MICROPILE BODY

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## ABSTRACT

JAMP (Japanese Association of Micropile) have conducted laboratory tests for Micropile system to confirm feasibility and efficiency of micropile system for seismic retrofit of foundations in Japan. This paper presents the results of this study. The pile body possesses sufficient bending deformation capacity and the specimens with a coupling joint yielded strength and stiffness values larger compared to those of composite members. Thus, the pile design was deemed structurally sound.

## 1. INTRODUCTION

After Kobe Earthquake, many seismic retrofit programs for bridge superstructures and substructures have been conducted in Japan. However, Very few foundations have been retrofitted for following reasons;

1) Construction space for pile driving machine is not enough in many cases
2) Seismic resistance of retrofitted foundations is not clear
3) Foundation retrofit is costly

Micropile is "drilled and grouted pile" with steel pipes which diameters is less than 300mm and driven by boring machine, featuring small diameter with thick wall and mechanical joints with couplers not welding (Fig.1). The advantages of this system are practicable with small space, cost effective and less construction noise and vibration. Laboratory tests and field tests were conducted for confirmation of feasibility and efficiency of Micropile system for seismic retrofit of structural foundation. This article presents the outline of the tests and discusses the test results.

Micropile system is widely used for structural foundation and soil reinforcement in Europe and for some bridge retrofit project in the USA.

## 2. OUTLINE OF TEST SETUP AND PROCEDURE

The tests were performed to clarify bending deformation characteristics of grouted steel pipes for oil wells with small diameters and thick walls, used as a part of high-capacity micropiles reinforced with steel pipes, and to obtain data used for analyses and design of high-capacity micropiles subjected to horizontal forces. The tests consisted of preliminary tests performed for confirmation of specimens and test apparatus, Series I focusing on the ultimate strength and stiffness of composite members consisting of seamless steel pipes used for oil wells, grout and thread-lugged bars, and Series II focusing on the ultimate strength and stiffness of composite members incorporating coupling joints for the steel pipes. Table 1 shows the types of specimens used for alternating horizontal loading tests, Table 2 shows the specifications for composite materials, and Fig.2 shows a schematic diagram of the specimen. Apparatus for the loading tests consists of actuators, a vertical jack and an abutment test wall. (See Fig.3) The maximum horizontal force for the loading test was 500 kN, and strokes for the jack were within ± 150 mm. The tests did not involve any axial loading. The alternating loads were determined assuming the yielding displacement of steel pipes as $1\delta$, and the loads resulting in displacements in the positive and negative directions that are integral multiples of it (i.e., 2 δ , 3 δ , 4 δ , and so on) were applied. The measured items for the loading tests included the load, horizontal displacement of the steel pipe, and strain (of the steel pipes, reinforcement and grout).

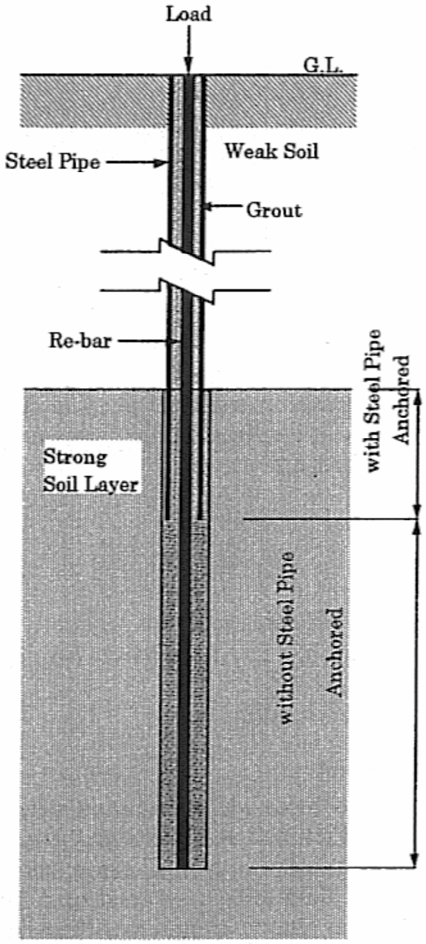

Fig. 1 Micropile system

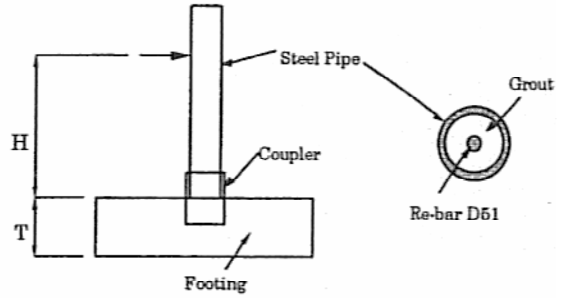

Fig. 2 Typical specimen

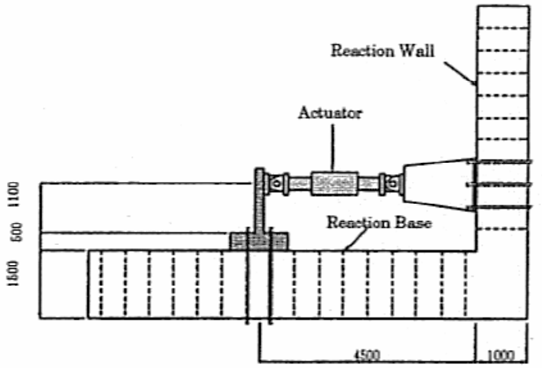

Fig. 3 Test setup

Table 1 Types of specimens

| Series | Specimen | Re-bar | Grout | Coupler |
|---|---|---|---|---|
| Pilot test | 1 | ○ | ○ | — |
| I | 2 | × | × | — |
|  | 3 | ○ | ○ | — |
|  | 4 | ○ | ○ | — |
|  | 5 | ○ | ○ | — |
| II | 6 | ○ | ○ | — |
|  | 7 | ○ | ○ | ○ |

Table 2 Material Properties

|  |  |
|---|---|
| Steel pipe | O.D. = 178 mm |
|  | Thickness = 12.6 mm |
|  | fpu = 759 N/mm$^2$ |
| Re-bar | SD490, D51 |
| Grout | f'c= 30 N/mm$^2$ |
| Footing | f'c = 40 N/mm$^2$ |

## 3. RESEARCH FINDINGS AND DISCUSSION

### (1) Series I

The loading point for the test series I was set at 1.0 m above the top surface of footings. Loading tests for the composite materials were performed for 3 specimens (the specimens Nos. 3 through 5). The loading test was performed for the specimen No. 2 provided only with a steel pipe, so as to allow comparison of results with the composite materials. Fig.4 shows the relationship between loads and horizontal displacement for the specimen No. 4, as an example of the load-horizontal displacement relationship for composite materials. Fig.5 shows the load-horizontal displacement relationship (envelopes) at loading points for the specimens used in the Series I tests. Alternating loads were applied to the maximum stroke of actuators (6 δ ), but the specimens withstood the loads as their ductility was large. Fig.6 shows the relationship between bending moment and curvature (the M- ϕ relationship) derived from their measurements. The results revealed approximately 20 % more bending stiffness for the composite members compared to the cases with plain steel pipes only. The increase is believed to be attributed to the effects of grout materials, thread-lugged bars, and reinforcing bars.

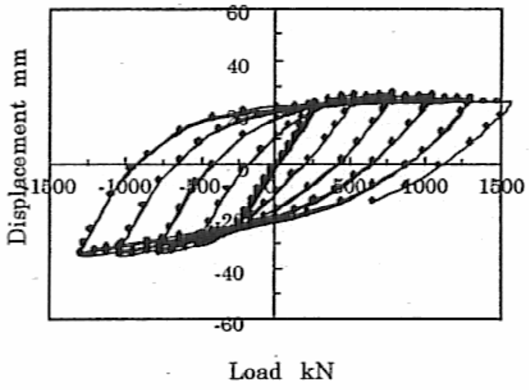

Fig.4 Load-displacement relationship (Specimen 4)

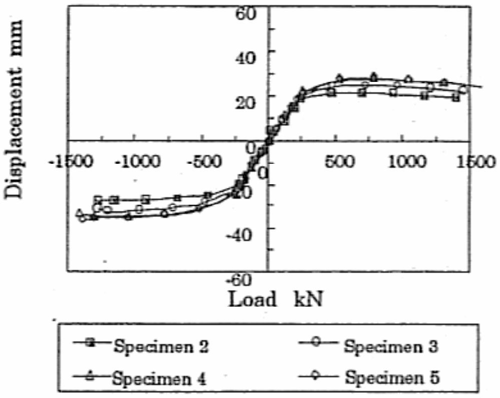

Fig. 5 Load-displacement relationship

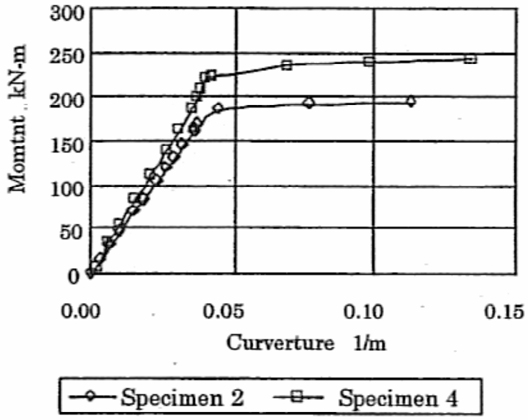

Fig. 6 M- ϕ relationship

### (2) Series II

The loading points for the Series II tests were shifted to 0.8 m from the top surface of footings, since the specimens did not rupture during the Series I tests. Loading tests were also performed for the specimen No. 6 which is a composite member, so as to enable comparison of results with specimens with a coupling joint. Fig.7 shows the load-horizontal displacement relationship for the specimen No. 7 having a coupling joint. The steel pipe of the specimen No. 6 failed at 7d, and the coupling joint of the specimen No. 7 at 4d. Fig.8 shows the load-horizontal displacement relationship (envelopes) at the loading points of specimens used in the Series II tests. As can be seen from Fig.11, the specimen No. 7 provided with a coupling joint had larger strength and stiffness compared to those of the composite members, although its deformation capacity was lower.

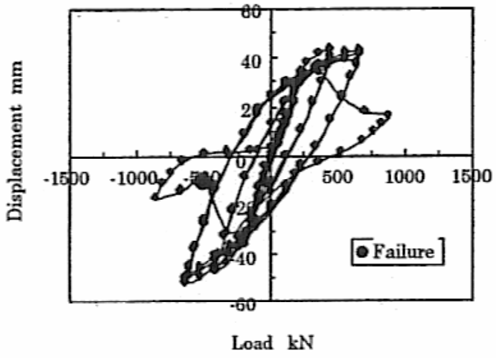

**Fig.7 Load-displacement relationship (Specimen 7)**

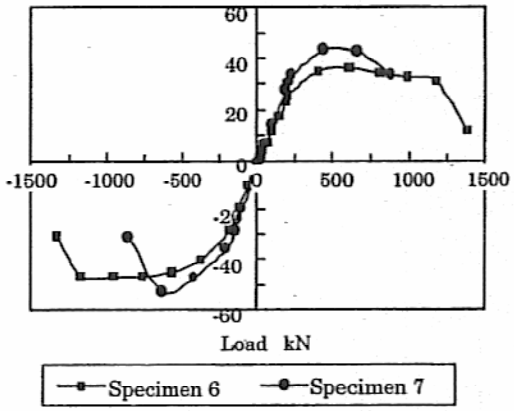

**Fig.8 Load-displacement relationship**

## 4. CONCLUSIONS

The following information was obtained through the tests conducted for the study.

1) The pile body possesses sufficient bending strength and deformation capacity

2) The specimens with a coupling joint yielded strength and stiffness values larger compared to those of composite members. Thus, the pile design was deemed structurally sound.

With respect to bending properties of buried micropiles, it is necessary to accumulate data obtained from field horizontal loading tests, etc., in order to clarify interactions between the modulus of subgrade reaction and bending stiffness of the pile body.