The Centrifugal Model Tests on Load Sharing between the Existing Pile and the Micropile

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ABSTRACT

After Hyogo-ken Nanbu Earthquake, there is the necessity of seismic retrofitting of the existing structure. The reinforcement of the foundation under the footing is indispensable to improvement of seismic resistance.□However, unlike the case in which foundation is newly constructed, the construction is difficult, since it becomes the work in bridge clearance, and the cost becomes also large amount of money. Therefore, the research is carried out for the purpose of the establishment of the seismic retrofitting of the existing foundation by micropiles (they are called the following, MP) with small effects of the approach structure and the bridge clearance space. This report describes the result of centrifugal model tests in order to clarify the sharing rate for horizontal load in reinforcing the existing pile by MP.

1.INTRODUCTION

Recently, large damage has been generated by the earthquake in the civil engineering structures in Turkey, Greece, Taiwan, etc. In Hyogo-ken Nanbu Earthquake 1995, the largest damage since Great Kanto Earthquake of collapse of the bridge pier and falling of the bridge girder, etc. was generated even in Japan. Therefore, the Ministry of Construction established the new specification for highway bridges in 1996. Under this specification, in addition to elastic design as in the past, highway design account for the non-linear properties of both foundation members and the ground around a foundation.

By comparing foundation with the bridge pier, the damage survey and the restoration after the earthquake are difficult. Therefore, it is not desirable to occur on the foundation of the large damage which becomes the restoration with the problem. The examination for the effect of strength degradation for the liquefaction shall be carried out under the soil condition which is wider than the convention, and the design for the fluidization with the liquefaction is also newly regulated. There is a case in which the reinforcement is required without satisfying earthquake resistance in existing foundations, when it is changed from such situation.

On the other hand, as seismic retrofitting of existing foundations, it has been the addition of piles, relatively large-diameter piles, and the expansion of a footing. In this case, the range which is larger than the footing must be excavated. Therefore, it is necessary to carry out the wide road passage regulation in order to ensure the working space. And construction cost is very high, since it becomes the construction in bridge clearance unlike the case of the new foundations. From such fact, the positive introduction of rational reinforcement work has been required in order to carry out efficient seismic retrofitting at limited budget. From them, it aims at the establishment of the seismic retrofitting of the existing foundations by micropiles with small effects of existing structures and the bridge clearance space.

2. TEST PURPOSE

The Ductility design method is possible to conveniently show the behavior at the accuracy in which it is sufficient practical use, when the behavior in the earthquake is not complicated. However, both pile diameters and rigidity are different, when existing foundation is reinforced in MP. Therefore, it seems to be able to not always apply the design method as well as the case in which foundation is newly constructed.

For example, the elastoplastic model is used as lateral resistance characteristics, and in the sand ground, upper limit of the lateral ground reaction of the pile except for front row is reduced in 1/2. It is anticipated to become not always such load sharing rate, when existing foundation is reinforced in MP. Therefore, the centrifugal load testing was carried out for the purpose of clarifying sharing rate of existing pile and MP for horizontal load.

3. TEST EQUIPMENT

The experiment used large centrifugal test equipment in Public Works Research Institute. Figure.1 shows the outline of loading equipment and the arrangement of model piles. In the experiment, 2 kinds of model pile of real 1/20 scales were used, as it was shown in Table.1. One is result of simulating the steel pipe pile as an existing pile, result of simulating MP as a reinforcing pile on the other hand. The strain gauges were affixed to the pile body in diagonal of 2 directions in order to require the flexural strain. And the rosette gages were affixed to the pile top under the footing in order to require the shear force. The head of each pile is being coupled by the footing.

It was made the model ground in order to the silica sand fall from the air in the mold, and in order to the

Table.1 Test pile specifications

Pile type		O.D. (mm)	Thickness (mm)	Length (m)	EI (kN·m2)
Steel pipe pile	Model	30	1,0	0,5	1,9273
	Full scale	600	20	10	308371
MP	Model	9	0,5	0,5	0,0243
	Full scale	180	10	10	3891

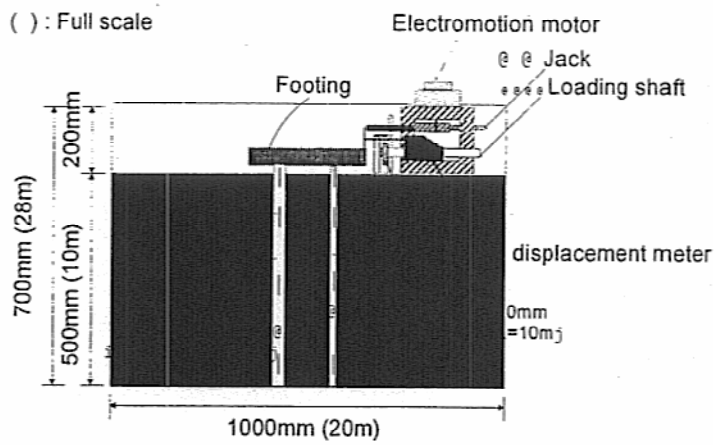

Fig.1 Test setup.

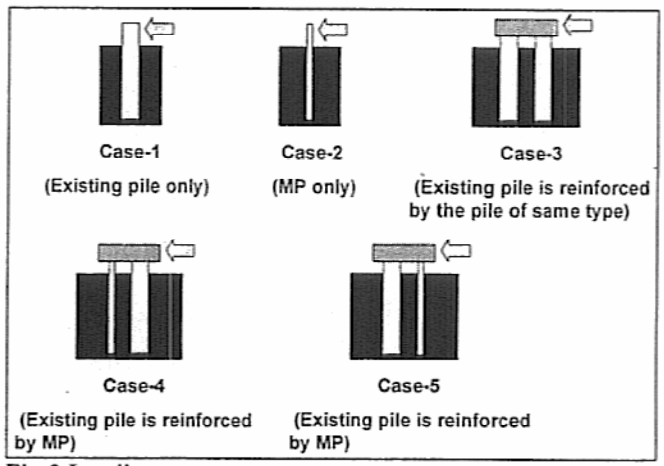

Fig.2 Loading test cases

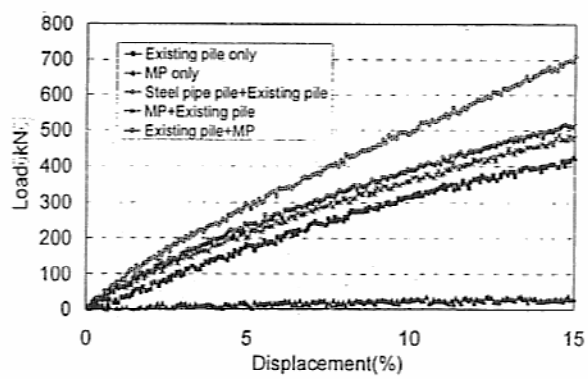

Fig.3 Load-displacement relationship

relative density become over 90%. Under centrifugal acceleration 20G, the footing center was loaded with the horizontal force, and it gave large displacement over 10% of the pile diameter by the displacement control, and load-displacement relation and strain of each pile body were measured.

4.TEST CASES

The test case was made to be 5 cases shown in Figure.2. Case-1 is the existing pile only, and Case-2 is the MP only. Case-3 assumed that the existing pile was reinforced by the pile of same kinds (steel pipe pile). In Case-4, the existing pile was reinforced by MP, and it loaded since the existing pile side so that MP may become the front row. In Case-5, the existing pile was reinforced by MP, and it loaded since the MP side. And the pile pitch of Case-3□5 was made to be 2.5D (D:existing pile diameter).

5.TEST RESULTS

5.1 Horizontal Load-Displacement relationship

Figure.3 shows the horizontal load-displacement relation of the footing in each case. The displacement was standardized at the pile diameter of the existing pile, and the load was converted in the full scale. Based on this result, in comparison with the load of each case in the identical displacement, Figure.4 and 5 show the pile group effect.

By removing the load of Case-3 in the result of making the load of Case-1 to be the double, pile group efficiency of Case-3 obtained it. By removing the load of Case-4 in the result of adding the load of Case-1 and Case-2, pile group efficiency of Case-4 obtained it.

As shown in Figure.4, the pile group effect has appeared in Case-3. The efficiency lowering has reached about 20%, when the displacement

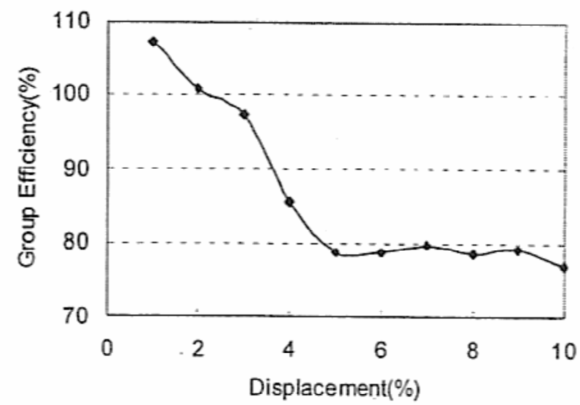

Fig.4 Group efficiency (Case-3)

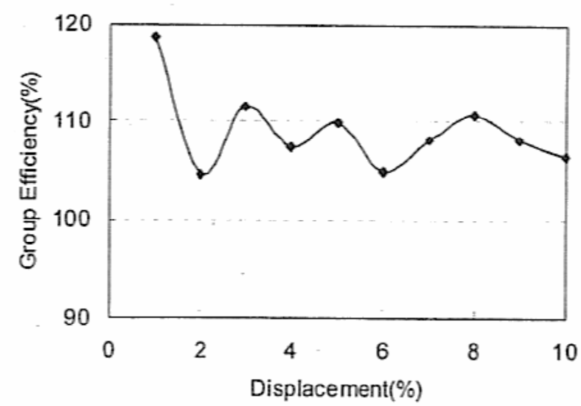

Fig.5 Group efficiency (Case-4)

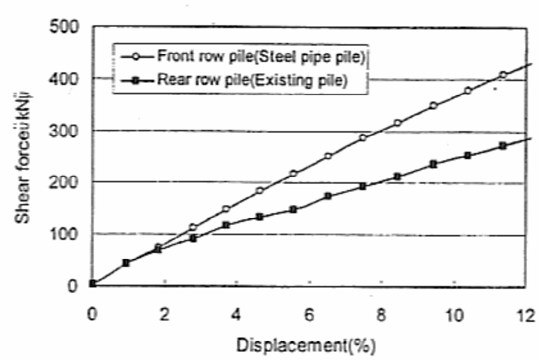

Fig.6 Shear force of pile top(Case-3)

exceeds 5% of the pile diameter. However, in Case-4 reinforced by MP shown in Figure.5, the efficiency tends to increase a little on usual negative pile group effect without appearing. Though it is not supposed that the actually positive pile group effect has appeared, the negative pile group effect is difficult to seem to occur in the large deviation, when it was reinforced by the small-diameter pile.

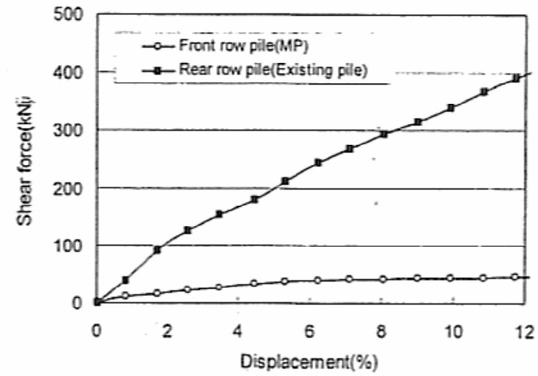

Fig.7 Shear force of pile top(Case-4)

5.2 Sharing rate of the shear force at pile top

Figure.6 and 7 show the shear force-displacement relation at pile top in Case-3 and 4, respectively. And, Figure.8 and 9 show sharing rate of the shear force between front row pile and rear row pile in Case-3 and 4, respectively. As shown in Figure.8, the sharing rate of the rear row pile lowers to 40% when the displacement exceeds 5% of the pile diameter, though the sharing rate of front row pile and rear row pile is almost equal when the displacement is small. This seems to originate for reducing the lateral ground reaction of the rear row pile in the large deviation.

On the other hand, as shown in Figure 9, the sharing rate of MP is low with the 20% weakness in the region with the small displacement since the flexural rigidity of MP is very small compares in the existing pile. In addition, the sharing rate of MP lowers in the large deviation to 10%, and it becomes a result which sharing rate of the rear row pile (existing pile) rises.

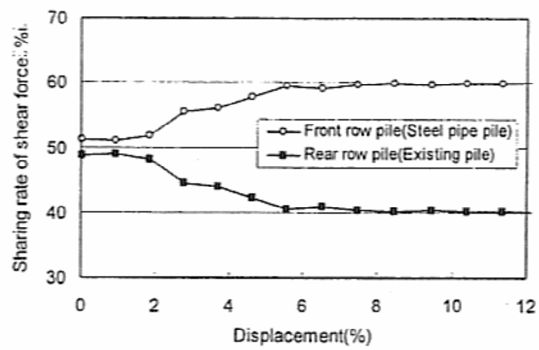

Fig.8 The sharing rate of shear force(Case-3)

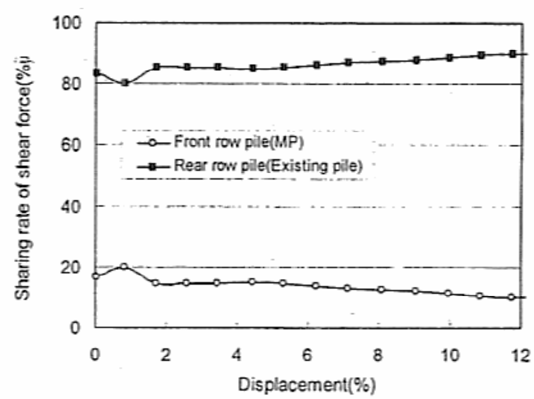

Fig.9 The sharing rate of shear force(Case-4)

5.3 Bending moment distribution

From the flexural strain measured in each pile body part, bending moment was calculated. Figure.10 is the result of Case-3, and it shows the value in displacement 2,6,10% of each pile of front row and rear row. Figure.11 is similarly results of Case-4. It is near 2.0m on the depth of the largest bending moment in the existing pile. And, it is near 1.0m in MP. These values agree almost with the theoretical value calculated using inversion k value estimated from the soil test result.

5.4 Distribution of the lateral ground reaction

The lateral ground reaction was obtained by differentiating bending moment to 2 times, and

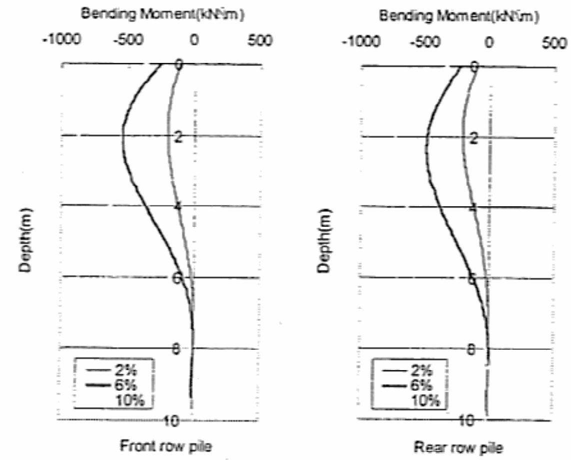

Fig.10 Bending moment (Case-3)

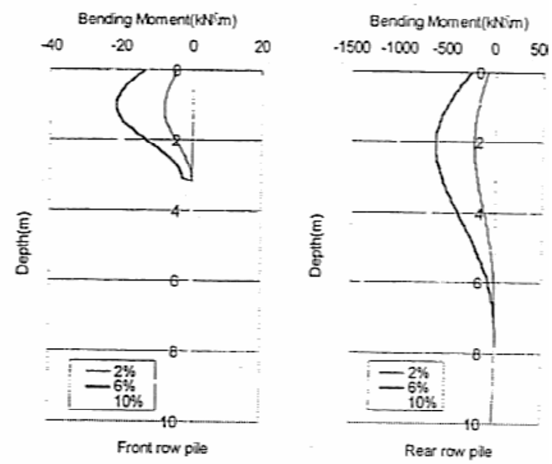

Fig.11 Bending moment (Case-4)

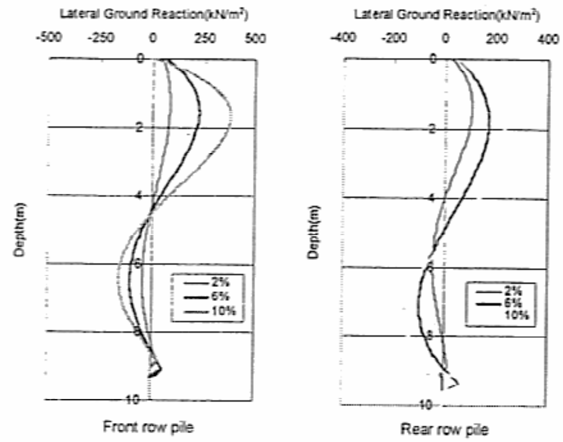

Fig.12 Lateral ground reaction (Case-3)

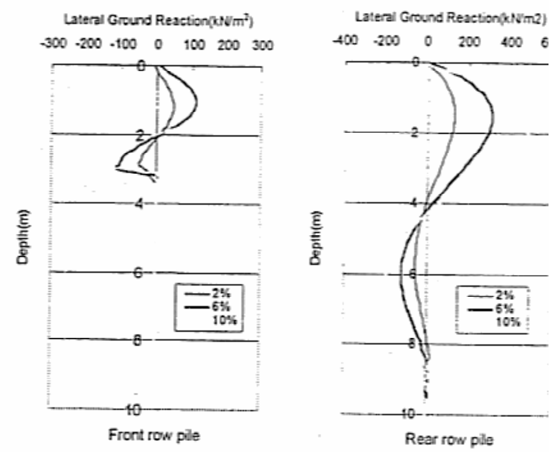

Fig.13 Lateral ground reaction (Case-4)

dividing by the pile diameter. The value of the flexural strain has been approximated here by the sixth polynomial, since the dispersion of measured value greatly influences the lateral ground reaction, when the value of measured flexural strain is used as it is. Figure.12 and 13 show results of Case-3 and 4, respectively.

5.5 Lateral ground reaction-displacement relationship

Figure.14 shows lateral ground reaction-displacement relationship in every depth of the front row pile and the rear row pile in Case-3. The initial gradient is almost equal for both front row pile and rear row piles. And, the lateral ground reaction of the rear row pile reaches the upper limit at displacement about 4%, and it is being reduced in the large deviation at about 1/2 of the front row pile. This agrees with a loading test result by the pile group in a past. Similarly, Figure.15 is results in Case -4, In the rear row pile (existing pile), the reduction in the lateral ground reaction is not observe, and the value becomes almost equivalent a case in which it was placed in the front row side. The lateral ground reaction of front row pile (MP) becomes about 40% of the existing pile.

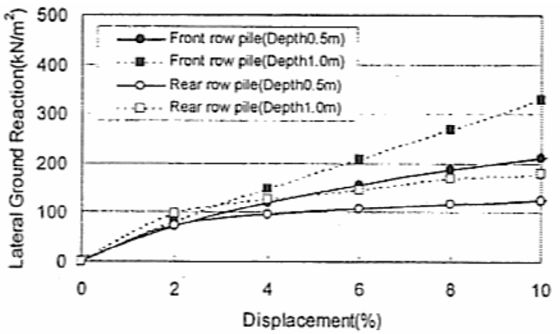

Fig.14 Ground reaction-displacement (Case-3)

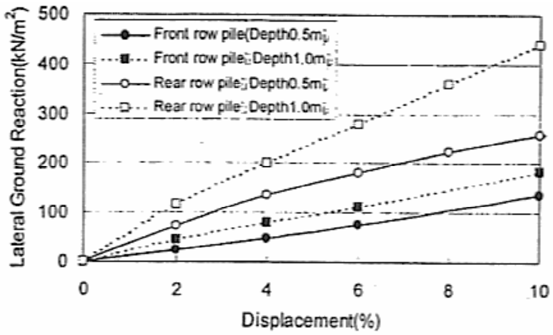

Fig.15 Ground reaction-displacement (Case-4)

6.CONCLUSIONS

It becomes following ways, when the result got by present centrifugal model testing is arranged.

(1)Efficiency lowering by the pile group is not generated, when the existing pile was reinforced by MP.

(2)Since the rigidity is smaller than the existing pile, sharing rate of the horizontal force is small, when MP was used by the vertical pile. And the sharing rate lowers with the increase in the displacement, and the burden of the existing pile increases.

What is used as an incline seems to be effective for MP with the small rigidity. It is necessary to experiment on group effect and network effect including the incline in future.

REFERENCES

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2)Sagara,M. et al.:Centrifugal Model Tests on a Micropile Foundation Pat 1,2nd International workshop on Micropiles,1999