A Comparison between Static Load Test and Rapid Load Test for a Steel Pipe Pile Installed by Water Jet Vibratory Technique

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ABSTRACT: Ohashi River Bridge was constructed as a part of Matsue No.5 Road bridge with the length of 5.2km in Japan. Steel pipe pile sheet pile foundation was adopted for the foundation of the main pier. The bearing layer consisted of sand rock with N value larger than 50. Steel pipe piles were installed by water jet vibratory technique. After installation the inside soil of piles was dug up and concrete was stuffed inside for increasing the toe resistance of the piles. Static pile load test and rapid load test were conducted on the same test pile. The rapid load test was intended to be performed on other piers piles after comparison with static load test. The load tests were carried out on test piles with diameter of 1000mm. The test load was about 9000kN. The result of the comparison showed that the ultimate capacity of the rapid load test was equivalent to the static load test, and the stiffness of the load – displacement relation of the rapid load test increased resulted from load history by the static load test. The rapid load test was judged to be useful for indicating bearing capacities of other piers piles.

1 INTRODUCTION

Ohashi River Bridge was constructed as a part of Matsue No.5 Road at Matsue city in Japan. Steel pipe pile sheet pile foundation was adopted for the foundation of the main pier. Steel pipe piles were installed by water jet vibratory technique. After installation the inside soil of a pile was dug up and concrete was stuffed for increasing the toe resistance of the pile. However since the effect of the stuffing concrete was not clear, it needed to be confirmed. Then vertical pile load tests were conducted. A static load test and a rapid load test were carried out for the same test pile. The rapid load test was intended to be performed on other pier's piles after comparison with the static load test.

2 SOIL PROPERTY AND A TEST PILE

The bearing layer exists at the depth from GL-10m which is sand stone with N value of from 50 to 125. The sand stone stratum mainly consists of sand and silt and low cemented, high weathered.
The test pile was a steel pipe pile with the diameter of 1000mm and the length of 15.5m. The specification of the test pile is shown in Table 1.

Table 1. Specification of the test pile

Diameter (mm)	Length (m)	Material	Wall thickness (mm)	Position of stuffing concrete
1000	15.5	Steel pipe	14	From pile head -7.1m to -13.0m

Table 2. Measurement specification for the test pile

Item	Number	Sensor
Pile head displacement	4	Displacement strain transducer
Pile toe displacement	2	Displacement strain transducer and Steel rod
Strains of pile body	2 x 11 sections	Stain gage

The test pile was embedded into the bearing layer with the length of 4.2m. Figure 1 shows the soil boring log and the test pile position. The test pile was instrumented with the strain gages and the displacement transducers. The strain gages were attached at 11 sections along pile axis. The displacement transducers were attached at the pile head and the pile toe. The specification of the measurement is shown in Table 2.
The test pile was installed by water jet vibratory technique. After installation the inside soil of piles was dug up and concrete was stuffed.

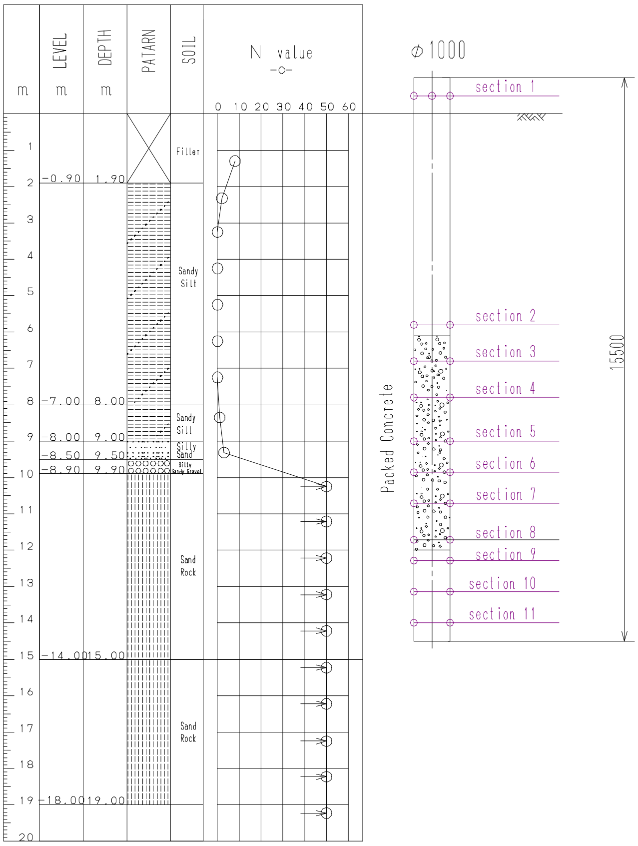


Figure 1. Soil property and test pile position

3 STATIC PILE LOAD TEST

3.1 Test method

The static pile load test was conducted according to Japanese Geotechnical Society standard, (2002). The planned maximum load was 9000kN. Figure 2 shows the load step sequence. The load test was due to be finished when displacement at the pile toe amounted to 10% of the pile diameter.

The equipment of the static load test is shown in Figure 3.

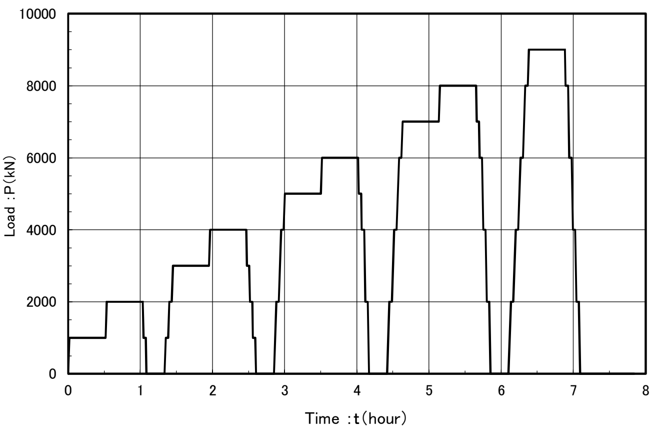


Figure 2. Load step sequence of the static load test

Figure 3. Photograph of the Static load test equipment

3.2 Test Results

The pile head load vs. pile head displacement curve and the pile head load vs. pile toe displacement curve are shown in Figure 4. The pile head displacement vs. log t curve is shown in Figure 5. In the figure "t" is holding time at each load step. The first limit resistance equivalent to yield resistance was determined to be 6000kN by the pile head displacement vs. log t curve. The pile toe displacement did not achieve to 10% of the pile diameter at maximum load step of 9000kN. The second limit resistance equivalent to ultimate resistance was estimated to be 9365kN by the Weibull distribution approximation method as shown in Figure 6.

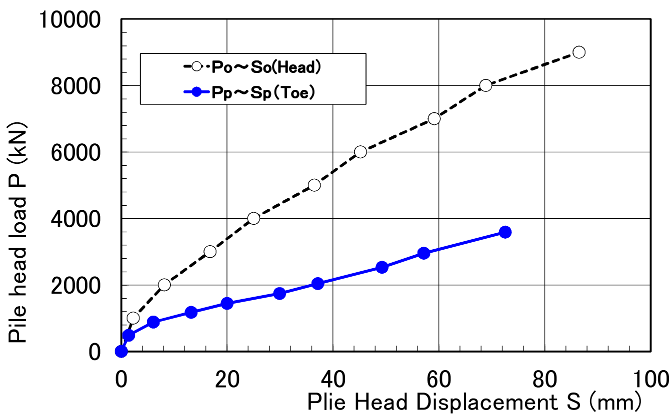


Figure 4. Pile head load vs. displacement curves

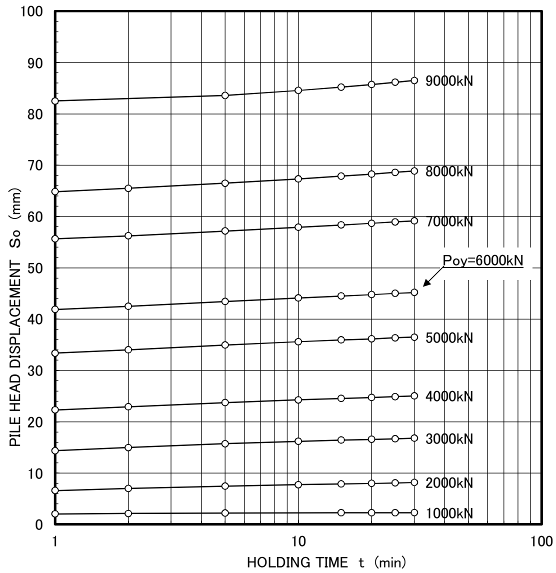
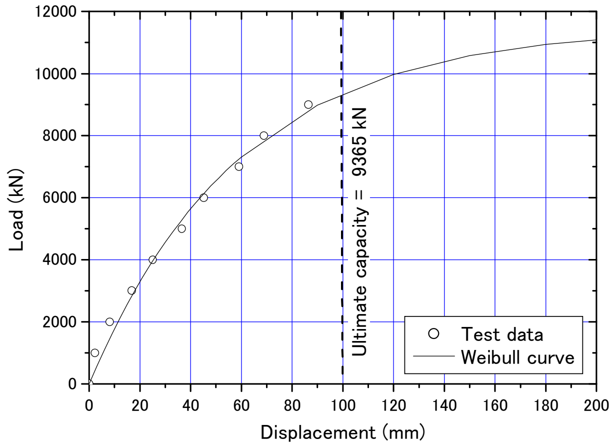


Figure 5. Pile head displacement vs. log t



Figre 6. Estimation of the second limit resistance by Weibull distribution

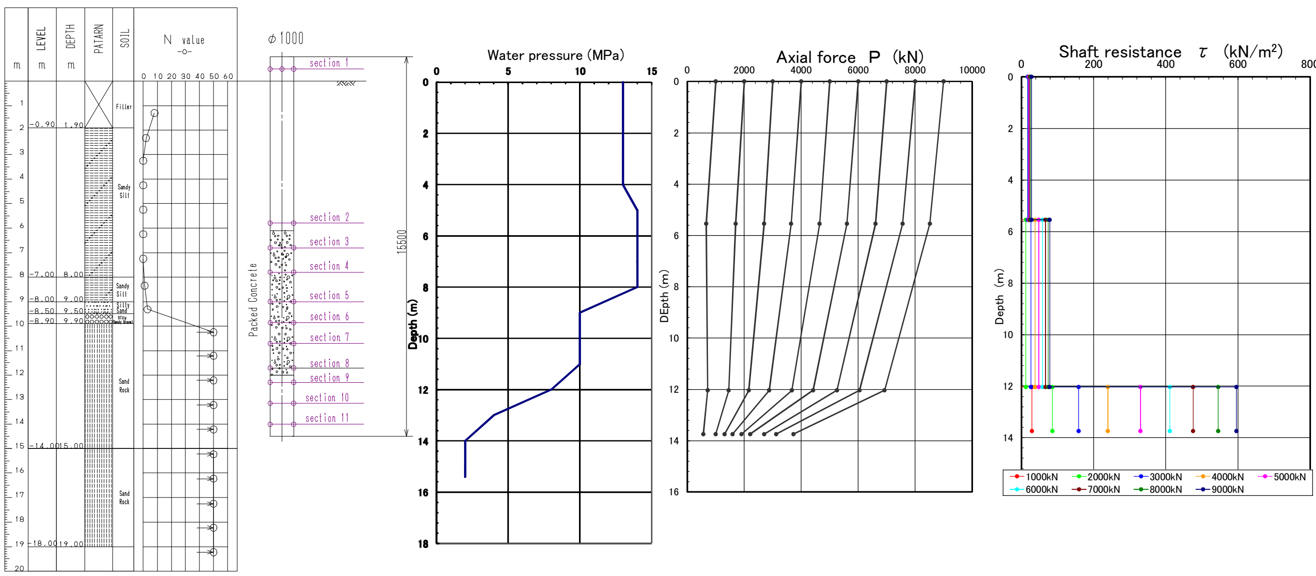


Figure 7. Axial force and shaft resistance distribution from the results of the static load test

The axial force of the test pile and the shaft resistance calculated by the axial force are shown in Figure 7. This figure also shows the record of the water pressure during installation by water jet vibratory technique. Shaft resistance at the depth from -5.5m to -12m was 78kN/m^2 which is only 78% of design value for a driven pile. The reason of the low resistance is considered with since water pressure was high there. The other hand shaft resistance at the depth from -12m to toe level was large to be 596kN/m^2 since water pressure was low there. The axial force at the depth of -12m was 6924kN which is 90% of the total load.
The axial force at section 11 with the depth of -13.8m considered to be toe resistance was 3725kN. This shows that stuffing concrete contributed to increase the toe resistance.

4 RAPID PILE LOAD TEST

4.1 Test method

Hybridnamic rapid load test (Miyasaka et al. , 2008) was carried out for the test pile five weeks after the static load test. Hybridnamic test is one of a vertical pile load test methods which excites rapid load by falling a heavy weight to a pile head. Hybridnamic cushion which is an elastomer sheet stuck on a steel plate was innovated for the Hybridnamic test. The Hybridnamic cushions on a pile head are able to translate impact force by falling a weight to desirable loose rapid force. An equipment of Hybridnamic test with a falling weight of 22ton is shown in Figure 8. The specification of the test equipment for this project is shown in Table 3. The maximum planned load was 9000kN and planned relative loading duration, T_r was 7.0.

Figure 8. Photograph of the Hybridnamic load test equipment

Table 3. Specification of the Hybridnamic load test

Pile length	(m)	15.5
Stress wave velocity	(m/s)	5,120
Relative loading duration	(ms)	7.0
Loading duration		60
Mass of weight	(ton)	22
Spring constant of cushion	(kN/mm)	120
Planned maximum rapid load	(kN)	9,000

3.2 Test results

The static soil resistance vs. pile head displacement curve resulted from Unloading point method (Kusakabe & Matsumoto, 1995) is shown in Figure 9. The maximum load was 7,611 kN at the maximum falling height of 2.2m. The maximum static soil resistance was 9,143 kN with the maximum displacement of 31.7mm resulted from Unloading point method. The behavior of the static resistance curve had become a yield situation since the remained displacement was relatively large 19.0mm. The time histories of the axial forces measured by strain gages are shown in Figure 10. Table 4 shows the result of the Hybridnamic test.

Table 4. Result of the Hybridnamic load test

Maximum load	(kN)	7,611
Maximum displacement	(mm)	37.1
Remained displacement	(mm)	19.0
Maximum static soil resistance	(kN)	9,143

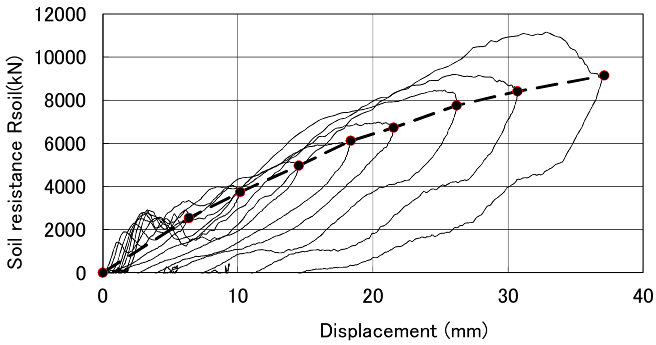


Figure 9. Rapid load vs. displacement relationship with Static soil resistance

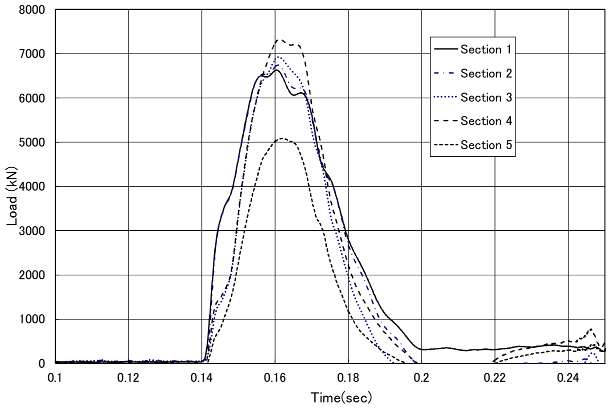


Figure 10. Time histories of axial forces from Hybridnamic test

5 COMPARISON BETWEEN STATIC AND RAPID PILE LOAD TEST

The rapid pile load test result was compared with the static result in order to evaluate the applicability to other bridge piers. The rapid load test was carried out to the same test pile after the static test. The static soil resistance vs. pile head displacement curve of the rapid pile load test was added to the continuation of the static load test curve in Figure 11. Although the curve shape of the rapid load test was larger than the initial stiffness of a static curve. It is almost equal to the shape of the last load cycle of the static load test. In Figure 12 the curve of the rapid load test is drawn on the curve of the last cycle of the static load test. The figure expresses coincidence of the two curves well.

The axial force distribution and the shaft resistance distributions are shown in Figure 13. The static curve is calculated from the final load cycle data and the rapid load is from final falling with the height of 2.2m. It is shown that these curves of Figure 13 also correspond well.

Comparing two test results showed that the rapid pile load test could apply to the check of the bearing capacity of other bridge piers.

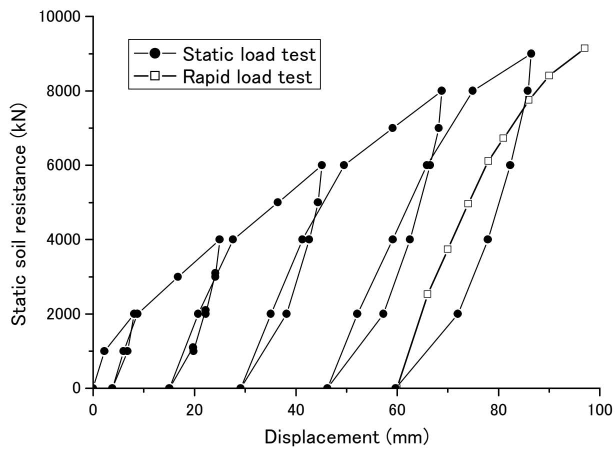


Figure 11. Comparison between the static and the rapid resistance curve

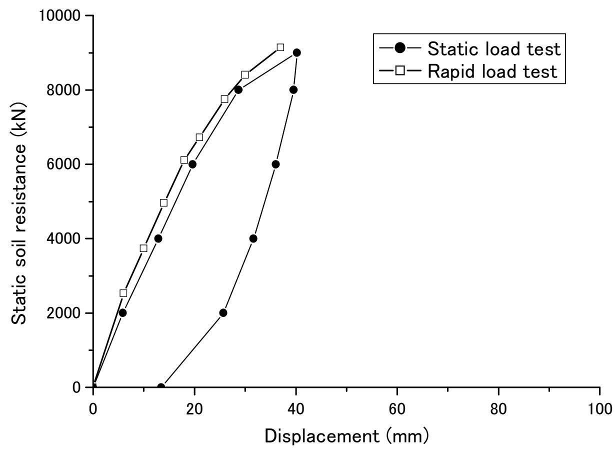


Figure 12. Comparison between the static and the rapid resistance curve at the static final load cycle

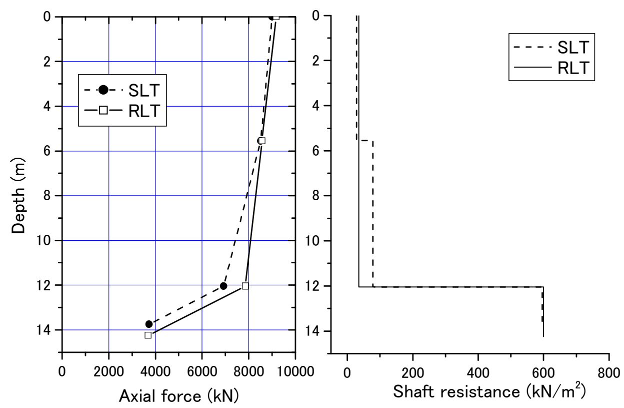


Figure 13. Distributions of the axial forces and the shaft resistance

6 CONCRUSIONS

A static and a rapid pile load tests were carried out on the same test pile with diameter of 1000mm.
It was shown as a result of the examination that the test pile has sufficient bearing capacity. Moreover, it also turned out that inside stuffing concrete contributed to increase of the toe resistance.

The rapid pile load test was compared with the static pile load test. The static resistance vs. displacement curves of the two load tests were well close. The rapid load test was judged to be useful for indicating bearing capacities of other piers piles.

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