Research on cavity formation below Ohkozu old movable weir in the Shinano River

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ABSTRACT

Ohkozu old movable weir of the Shinano River at Nagaoka city in Niigata Prefecture was demolished due to antiquated equipment in accordance with the construction of a new movable weir. Based on the results of boring exploration conducted during the construction, continuous cavity below the old movable weir was observed. Its continuous cavity is present over the entire area of the movable weir. The cavity of up to 16 cm has been confirmed. The following reason have been considered as the cause; 1) erosion by river water seepage flow due to big water head difference, 2) settlement of the surrounding ground due to liquefaction. Even if the pile foundation supporting the weir is robust after an earthquake, the bearing capacity of pile foundation is reduced by the liquefaction-induced ground settlement and the weir structure becomes unstable. Accordingly, risk of accelerating the erosion by the river water seepage flow is also increased. In this research, the cavity generating mechanism due to the liquefaction-induced ground settlement is focused on. 1-G shaking table model tests are conducted to clarify the influence of the presence of pile and weir pillar, number of piles to deformation and liquefaction of the surrounding ground.

Keywords: liquefaction, cavity, foundation, pile, shaking table model test

1. INTRODUCTION

Ohkozu old movable weir of the Shinano River at Nagaoka city in Niigata Prefecture was demolished due to antiquated equipment in accordance with the construction of a new movable weir (Ohtsuka, et. al, 2015). Based on the results of boring exploration conducted during the construction, continuous cavity below the old movable weir was observed. Its continuous cavity is present over the entire area of the movable weir. The cavity of up to 16 cm has been confirmed as show in Fig.1. The following reason have been considered as the cause; 1) erosion by river water seepage flow due to big water head difference, 2) settlement of the surrounding ground due to liquefaction. Even if the pile foundation supporting the weir is robust after an earthquake, the bearing capacity of pile foundation is reduced by the liquefaction-induced ground settlement and the weir structure becomes unstable. Accordingly, risk of
accelerating the erosion by the river water seepage flow is also increased. In this research, the cavity generating mechanism due to the liquefaction-induced ground settlement is focused on. As the first step, 1-G shaking table model tests are conducted to clarify the influence of the presence of pile and weir pillar, number of piles to deformation and liquefaction of the ground.

2 OVerview of Shaking Table Model Tests

1-G shaking table model tests are conducted to investigate the cavity generating mechanism due to the liquefaction-induced ground settlement. In the tests, the influence of the presence of piles and a weir pillar, number of piles to deformation and liquefaction of the surrounding ground is clarified.

Fig. 2 shows the schematic view of the shaking table model tests. The soil chamber, which measured 300 mm in length, 1100 mm in width and 400 mm in depth, has water tanks on its left and right sides to supply the model ground with water. Cushioning material which is made of foam rubber was attached to the sidewall surface in order to reduce the influence of reflected wave during shaking.

One span of the old moveable weir is modeled on a scale of 1 to 50. The size and material of a model weir pillar and a model weir pillar foundation is determined considering similarity rule. The detail of models is shown in Fig. 3. An aluminum pile with diameter of 5 mm and length of 180 mm is used considering similarity rule regarding bending rigidity and section stiffness.

The liquefiable ground is modeled with wet pluviation method by using Tohoku silica sand #6 with a relative density of 40%. The model piles are installed before ground preparation as shown in Fig. 4(Left). The weir pillar model is placed on the model ground surface after the ground preparation as shown in Fig. 4(Right). Here, in these tests the pile heads are covered by the sand with a thickness of 10 mm and not directly touched on the weir pillar foundation underside in order to model spreading gravel under the foundation in the actual situation. The layout of measuring instruments such as displacement gauges, accelerometers and pore water pressure gauges is shown in Fig. 2. Ground water level in all test cases is set up to the ground surface.

Table 1 shows the test cases. In the series of Case A, the weir pillar model is used in order to investigate the influence of the presence of weir and the dynamic interaction between a superstructure and a pile foundation in the liquefiable ground. In the series of Case B, the weir pillar model is not used in order to remove the other effects from the effect of the presence of piles in the liquefiable ground. In both series the number of piles in the ground is varied to confirm the influence of number of piles. As input, 40 cycles of an 8 Hz sinusoidal wave with a slope is used. The target acceleration (60, 150 and 230 gal) is gradated in stages. In each case, 3 times of shaking are conducted. Fig. 5 shows the input wave observed at the shaking table in the series of Case A. The input wave is approximately the same waveform in each case from Fig. 5, hence each of the experimental results is fully comparable.
of input acceleration because of the presence of the piles. On the other hand, Figs. 10 and 11 show the cavity under the weir pillar foundation and the total settlement distribution of the ground under the weir pillar foundation after the final shaking. Here, the settlement of the ground surface was measured by removing the foundation after the final shaking. From the both figures, the gap of average 9 mm between the ground surface and the foundation underside (the cavity) was observed.

Figs. 12 and 13 show the time history of the excess pore water pressure observed at the ground between piles of G.L. -25 mm and the total settlement of the ground surface in the series of Case B. Comparing with the results of Case A, it is found that the excess pore water pressure for Case B is less than that for Case A and the difference on the excess pore water pressure by
the number of piles for Case B is less than that for Case A. Further, the excess pore water pressure is constant after it reached the peak in the series of Case B although the excess pore water pressure is gradually increasing during shaking in the series of Case A. The reason seems to be caused by the settlement of the weir pillar foundation.

4 CONCLUSIONS

Based on the above results, there is possibility that the cavity is generated by the settlement of the surrounding ground due to liquefaction. In case that the liquefaction occurs, risk of accelerating the erosion by the river water seepage flow is also increased. The region is suffering from multiple large earthquakes, it is not possible to deny the possibility of liquefaction occurrence. Therefore, it is necessary to verify the possibility of complex mechanisms of the settlement of the surrounding ground due to liquefaction and the ground erosion due to seepage flow.

Fig. 8. Response acceleration ratio at (a) the weir top and (b) the ground between piles (G.L. -25 mm) in the series of Case A.

Fig. 9. Total settlement of the weir pillar in the series of Case A.

Fig. 10. Cavity under the weir pillar foundation caused by liquefaction in Case A-3.

Fig. 11. Total settlement distribution of the ground under the weir pillar foundation caused by liquefaction in Case A-3.

Fig. 12. Time history of the pore water pressure at the ground between piles of (a) G.L. -25 mm in the series of Case B.

Fig. 13. Total settlement of the ground surface in the series of Case B.

REFERENCES

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