Deformation Behavior of Crushed Rock with two Different Maximum Grain Sizes in 1g Shaking Table Test

Kyushu Institute of Technology Student Member ○ Lei ZHANG Zhongyuan HUANG
Kyushu Institute of Technology Fellow Member Hideo NAGASE Akihiko HIROOKA
Kyushu Institute of Technology Nonmember Daishi FURUIE

1 Introduction

Crushed rock as a good prospective replacement material of the open cut replacement method is often used in ground improvement engineering, especially, in ports and airport construction. However, crushed rock might be directly dropped into water in practical engineering, so that the new constructed ground would be very loose. Therefore, it is very important to understand the deformation behavior of it. In this study, two modeling techniques which are parallel gradation technique and cut gradation technique, both them with two different maximum grain sizes (53mm and 26.5mm) are used to reduce the size of the crushed rock. All experimental results in 1g shaking table test of four cases are summarized in the paper.

2 Test Material and Experimental Program

The crushed rock used for this test was produced in Moji district of Fukuoka Prefecture in Japan, with an original grain size from 0 mm to 300 mm. Due to restrictions on the size of test apparatus, the crushed rock of original grain size is adjusted by two methods, and adjusted crushed rocks are called the parallel grain size and the cut grain size, respectively. The grain size distribution curves of each case are shown in Fig.1. As shown in the figure, the maximum permissible grain size of Case A and Case B are 53 mm and 26.5mm, respectively.

Fig.2 shows a cross-section of the ground model. As shown in the figure, the ground model with a thickness of 500 mm was made in the container with 700 mm high, 1400 mm long and 450 mm wide. The ground model was made by the water dropping method to simulate site construction, constructed ground is the loosest. All test materials reached an oven-dried state before being dropped into the water. Ground Models are divided into 10 layers, the weight of each layer is approximately 6.1 N. Moreover, a total of 13 sensors,

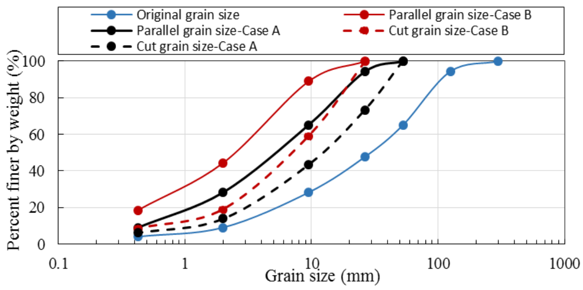

Fig.1 Grain size distribution curve

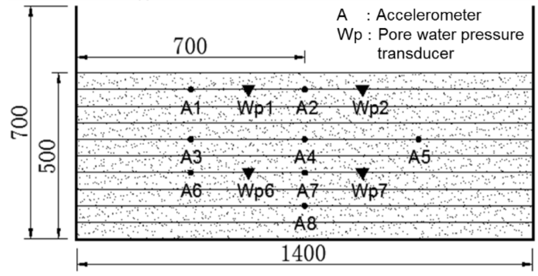

Fig.2 Cross-section of ground mode

including 9 accelerometers and 4 pore water pressure transducers were used for the test.

In this study, the input waveform is sinusoidal, assuming a level 2 earthquake, with wave number 30, input frequency 5.6 Hz, vibration time 5.33 s and the amplitude of input acceleration is 300 gal. The natural frequency of reclaimed land and alluvium is about 1 Hz. So, reclaimed land comprised of crushed rock is believed to be the most likely to liquefy in the earthquake motion with 1 Hz frequency. According to the conversion, input frequency is 5.6 Hz, in this test. And each ground model is vibrated three times, consecutively.

3 Experimental Results

Fig.3 shows time histories of acceleration response in Case B for two types grain size, all recorded by the No.4 accelerometer, which is placed at the middle of ground model. As shown in the left side of the figure, three times acceleration responses are almost same. Moreover, acceleration responses are all great at the beginning and suddenly become smaller until the vibration is over. It can be judged that liquefaction occur in the ground model with each vibration. The same result was proved right by the pore water pressure response. The time histories of excess pore water pressure ratio for the parallel grain size in Case A and Case B are summarized in Fig. 4 and both of them are recorded by the No 2 pore water pressure transducer. As shown in this figure, both excess pore water pressure ratios of Wp2 were more than 1.0.

The acceleration responses of the cut grain size are summarized in the right side of the figure. Different with parallel grain size, all acceleration responses have not suddenly changed. Although the figure of the time histories of excess pore water pressure ratio for the cut grain size was not listed at here, no excess pore water pressure ratio is more than 1.0. So, it can be considered that no liquefaction occur in the cut grain size. Moreover, acceleration responses of second vibration and third vibration are almost same. It is considered that the ground is even stronger because of vibration. Only results of Case B are listed in the figure, however, the same conclusion could also be obtained in Case A. Because the acceleration responses of both Cases in same grain size are almost same.

One of the main reasons of the different response at here is considered that there is the difference of percentage of less than 0.425 mm grain size. As shown in Fig.1, the parallel grain size has more percentage of less than 0.425 mm grain size. In particular, the parallel grain size in Case B has the most percentage of less than 0.425 mm grain size. The more percentage of less than 0.425mm grain size crushed rock have, the more likely to occur liquefaction.

The dry density of ground model in each phase in every case is summarized in Fig.5. Here, the dry density of ground model was estimated from the settlement of the ground surface. Both in Case A and Case B, the dry density of the parallel grain size is greater than the value of the cut grain size. So that it can be judged that the void ratio of crushed rock in the cut grain size is relatively greater. Apart from the parallel grain size in Case B, slopes of the other three lines are smaller and smaller after first vibration, in other word, the increase of the settlement response of the other three cases is smaller from the second vibration. It can be seen that the ground is consolidated with vibration. Moreover, slopes of the second and third part are almost zero for the two lines of the cut gain

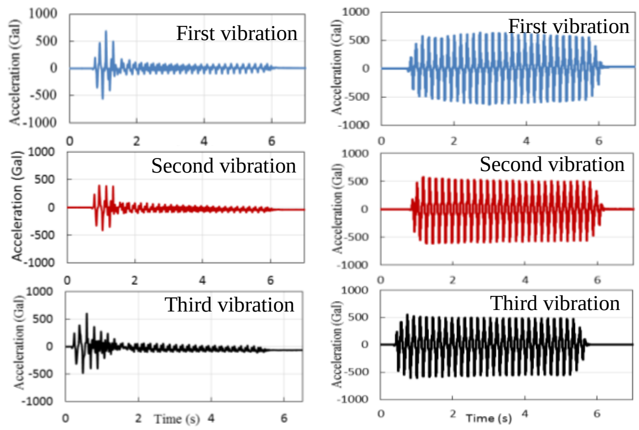

Fig.3 Time histories of acceleration response in Case B for the parallel grain size (left) and the cut grain size (right), all recorded by the No.4 accelerometer (A4).

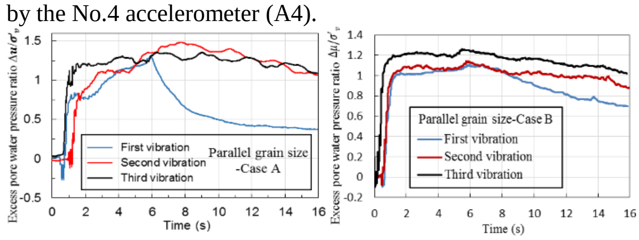

Fig.4 Time histories of excess pore water pressure ratio for the parallel grain size in Case A and Case B, both of them are recorded by the No. 2 pore water pressure transducer (Wp2).

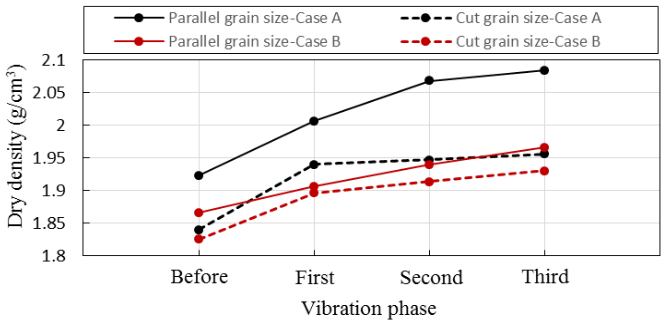

Fig.5 Dry density of ground model in each phase

size, so all the settlement response in the cut grain size from the second vibration are almost zero. Analyzing the acceleration response and pore water pressure response, it can be seen that liquefaction occurred in the parallel grain size in both Cases. It is considered to be the main reason for the difference between settlement responses of each case.

4 Conclusions

(1) The percentage of less than 0.425 mm grain size and grain size distribution is a substantial factor of deformation behavior of crushed rock, although, it is also impacted by grain size distribution.

(2) The response of deformation behavior of the parallel grain size is greater than that of the cut grain size. Therefore, in the design of crushed rock foundation on liquefaction prevention, the use of the parallel grain size can be more secure.