Experimental study in soil reliquefaction under embankment due to aftershocks

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1. Introduction

The 2011 Tohoku earthquake occurred on 11th March 2011 led to catastrophic devastations including liquefactions underneath embankments which was located on the impermeable ground. Before occurrence of Tohoku earthquake, researchers focused on the occurrence of liquefaction under the embankment, that is, inside foundation ground. On the other hand, this huge earthquake led to the occurrence of liquefaction inside embankment, therefore the research focusing on the liquefaction inside embankment would be important for preparedness of the subsequent huge earthquakes. In terms of strength against liquefaction, many researchers, for instance, Tobita et al.(2005), have investigated the behaviors of embankments over liquefiable ground and also related to liquefaction resistance by considering loading history, ground water level, soil arching formation, and other factors. However, few researches which focus on the liquefaction inside embankment have been conducted. In this study, in order to study the change of strength against liquefaction due to the history of earthquake, centrifuge model tests subjected to some excitation patterns was conducted (Murai, 2019).

2. Outline of centrifuge test

In this study, centrifuge apparatus at Kyoto University, Uji campus was utilized for centrifuge test. In the centrifuge test, in general, two scales are considered, model scale and prototype, in addition, according to scaling law, the data which is obtained in model scale is converted to that in prototype. In this research, the centrifugal force which was added to the model was 50G for all cases. After 50G consolidation finished, the viscous water, which was adjusted to maintain consistency with scaling law, was supplied into embankment, and excitation wave was added to the model. As original sine wave, ‘Wave 1’ which has 1Hz frequency, 30 seconds as vibration time in terms of real scale was considered in this research, and n times 'Wave1' was added to the model as excitation wave. Table1 show each condition of experiment. In Case3, 3rd excitation was added to the model immediately after 2nd excitation. This meant that dissipation of pore water pressure due to 2nd excitation did not finish before adding 3rd excitation. In these experiments, earth pressure gauges (EP), pore water pressure gauges (PP), and acceleration gauges were set in embankment model as shown on Figure1,2. When the value of pore water pressure overcome that of earth pressure at the same point inside embankment, it is proper to determine liquefaction occur.

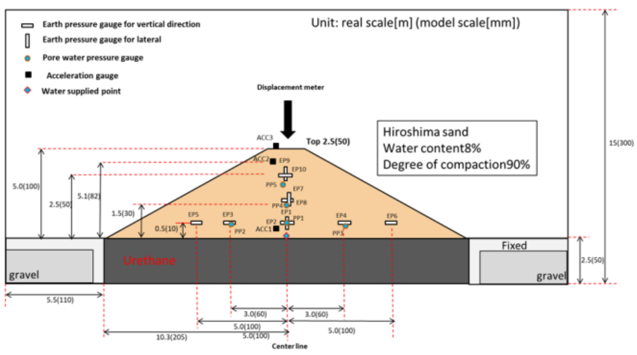

Figure 1. Layout and instrumentation for Case 1 & 2

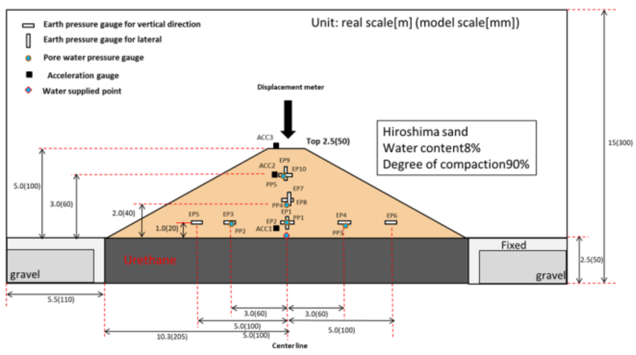

Figure 2. Layout and instrumentation for Case 3

Table 1. Condition of each test

	Amount of excitation	Magnification and order of excitation wave
Case1	2	1_1
Case2	3	1_1_1
Case3	3	1_1_1

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3. Result of experiment and consideration

As a result, the occurrences of liquefaction were observed at Case1, and Case2 for each 1st and 2nd excitation, in addition, formations of soil arching at Case1, 2 were also observed as shown on Figure3, 4. In order to evaluate the change of strength for liquefaction for each test, we focused on the change of effective stress during adding excitation. According to each result, each excitation finally led to the increase of effective stress except for 1st excitation of Case2 as shown in Figures 5 and 6. According to these figures, effective stress was smaller than 15kPa before 2nd excitation, and this was smaller compared with that before 1st excitation. As one cause, in Case2, the phenomenon which imitated liquefaction during consolidating process with 50G was observed, that is, the condition of core part of embankment was already too weak. This may be because we used Urethane as ground model, and it was too flexible for deformation, as a result, led to the formation of strong soil arching with much lower earth pressure at core part. However, after 2nd excitation and 3rd excitation, effective stress also increased in this case. Figures 3 and 4 show that accumulation of excitation could not lead to the collapse of soil arching in these cases, also in Case1, soil arching seemed to be stronger with the accumulation of excitation, on the other hand, each earth pressure at bottom increased with excitation history. This tendency was also observed in case soil arching was not formed, Case3. In terms of pore water pressure change due to each excitation, little differences were observed, almost same change for each case. Therefore, increase of effective stress seemed to depend on the increase of earth pressure. As one cause of increase of earth pressure, focusing on the amount of subsidence due to excitation, larger change of subsidence seemed to lead to the larger change of earth pressure at bottom. From this tendency, the change of density inside soil was considered to have the relationship with the change of strength for liquefaction, finally the accumulation of earthquake seems to lead to the difficulty of occurrence of liquefaction inside embankment

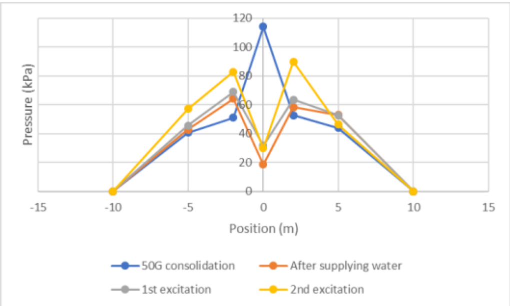

Figure 3 Earth pressure change at bottom, Case 1

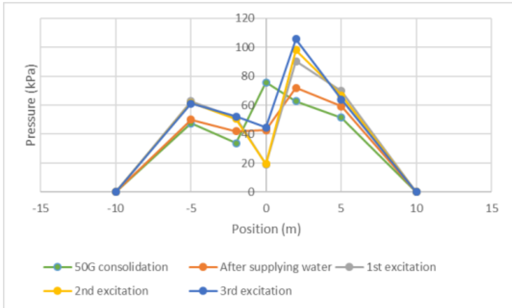

Figure 4 Earth pressure change at bottom, Case 2

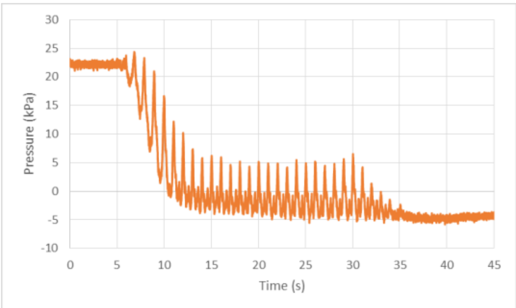

Figure 5 Effective stress change, Case 2: 1st excitation

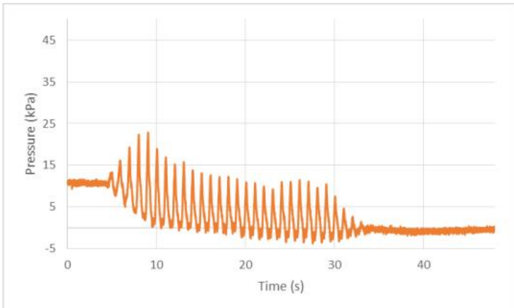

Figure 6 Effective stress change, Case 2: 2nd excitation

4. Summary

In this research, centrifuge tests were conducted in order to evaluate the behavior of embankment under earthquake. As a result, under soil arching condition, liquefaction was easily occurred, and soil arching was hard to collapse. Moreover, the accumulation of earthquake seems to lead to the increase of strength for liquefaction regardless of existence of soil arching. In addition, change of density inside embankment may have the relationship with the change of strength against liquefaction. As Urethane was utilized to model a flexible ground, the experiments might not able to realize the actual ground condition.

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