Importance of Permeability Effect on Liquefaction-induced Deformation of Sand

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1 Introduction

Due to previous earthquakes, the pore water pressure increases and settlements occur during and after an earthquake due to rearrangement of grains and redistribution of voids within the soils. Large deformation can occur when there is liquefaction in the sand deposit, which has a great damaging effect on lifeline facilities and foundations. Recently, several researchers have been studying the liquefaction-induced ground lateral flow by model tests in 1-g and centrifuge shaking table tests[1,2]. The effect of permeability can be very significant especially when considering earthquake-induced residual excess pore pressure. Researches that mentioned this issue seem to be quite few [3]. A series of 1-g shaking table tests were performed varying the permeability by using water and polymer fluid mixtures in order to model the varying permeabilities. This paper attempts to achieve a detailed discussion about this issue by reporting the results of those 1-g shaking table tests.

2 Outline of test

Fig. 1 shows a schematic rigid soil container which was employed in the 1-g shaking table test. The dimensions are 80cm×30cm×70cm. Toyoura sand used in this study, was rained down into the container filled with water or polymer fluid to a pre-calculated depth at the relative density Dr=40% with horizontal sand surface and 5%, 10%, 20% inclination. Sloped ground was underlain by a layer of compacted sand which was densified by lightly plunging and the surface soil was trimmed by removing the overlying loose sand. Consequently, the liquefiable sand layer with uniform slope angle and thickness were prepared. During sample preparation, a square grid of noodles and markers were installed along one of the transparent side walls so that the overall deformation of the sand layer during shaking table tests could be observed visually and recorded by a digital video camera. Acceleration and excess pore water pressure in soil layers of each shaking table test were measured at the positions shown in **Fig. 1**. Mixtures of polymer fluid of 0.05%, 0.01%, 0.005% and water were used in this study to model different permeabilities of the model sand deposits. Shaking was generated by two methods. One was an impulse in the transverse direction and the second was in the longitudinal direction. The acceleration of shaking was increased by step loading: 100

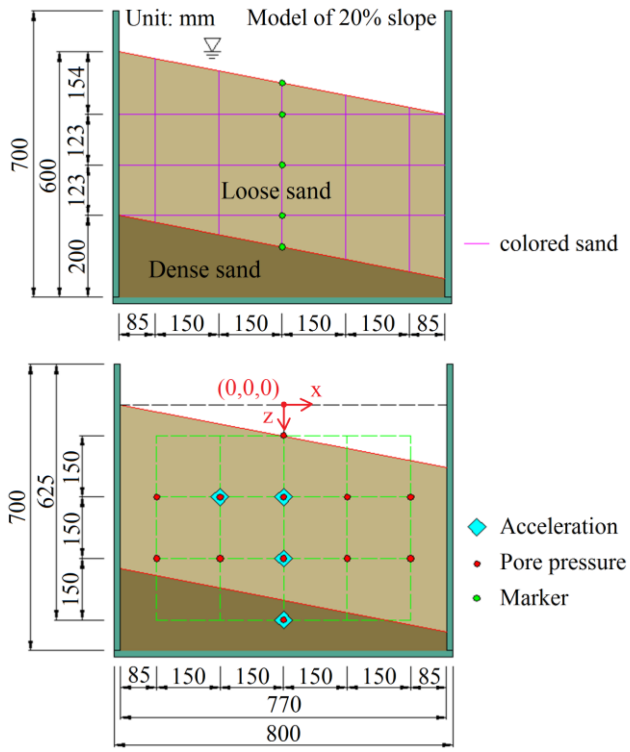

Fig. 1 Configuration and measurement of shaking table tests

Table 1 Tests condition

Sand	Toyoura sand	
Thickness	40 cm	
Inclination	0%, 5%, 10%, 20%	
Relative density	40%	
Pore fluid	Water	k=0.0091 cm/s
	polymer-0.005%	k=0.0044 cm/s
	polymer-0.01%	k=0.0027 cm/s
	polymer-0.05%	k=0.0013 cm/s
Shaking direction	Longitudinal/Transverse	
Duration time	3Hz, 6 circles	
Intensity	100Gal, 200Gal, 300Gal	

Gal, 200 Gal and 300 Gal of 3Hz under the test condition as shown in **Table 1**.

3 Test results and analysis

Fig. 2 compares the excess pore pressure ratios measured in cases using water and Polymer-0.05% as pore fluid, with both tests having an input peak acceleration of 300Gal for 2 seconds. It shows clearly the effect of soil permeability on pore pressure dissipation after or during shaking. Excess pore pressure stays at unity for a much longer time in which case uses polymer as pore fluid with low permeability. The liquefied condition could remain a longer time when the sand permeability decreases. It can be seen that the settlement continues for a longer time but much smaller than witch in higher permeability sand layer as shown in **Fig. 3**.

By comparison the lateral movement mostly stopped as soon as the shaking ended in both high and low permeability sand layers. However, as shown in **Fig. 4**, the lateral displacement is significantly affected by the permeability of liquefied layer when the gradient of ground surface is 20% in those model tests. Larger lateral displacement occurred in the higher permeability condition, despite the fact that the excess pore pressure did not dissipate until much later. However, this tendency was not clear when the gradient of ground surface is small.

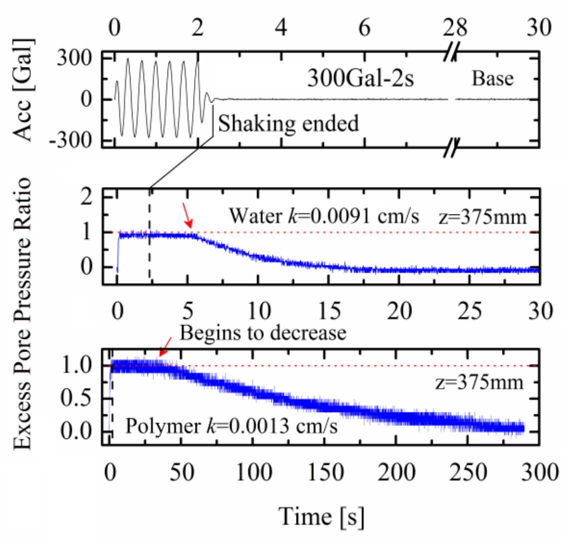

Fig. 2 Excess pore pressure response

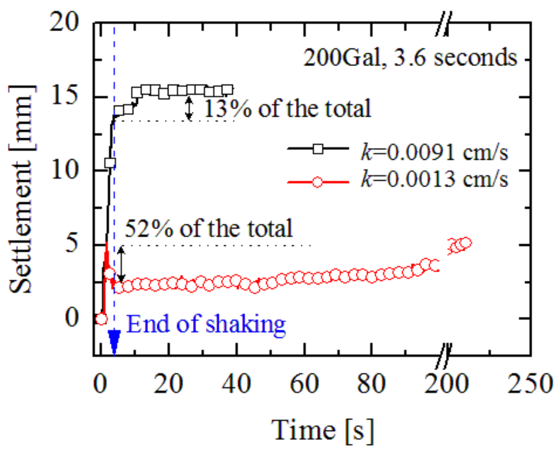

Fig. 3 Settlement of sand surface in shaking table tests

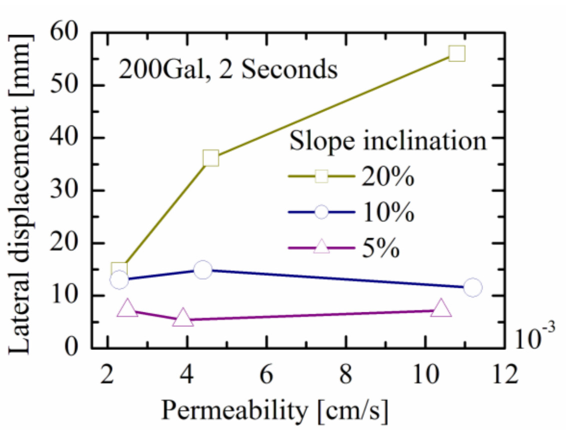

Fig. 4 Permeability effect on the lateral displacement

4. Conclusions

On the basis of test results, the following conclusions were drawn;

(1) The ground deformation occurs rapidly after the beginning of liquefaction and the rest as the pore pressure dissipated,

(2) The settlement continues for a longer time but much smaller than witch occurs in higher permeability sand layer,

(3) The lateral displacement of sand layer is mostly developed during shaking in both low and high permeability sand layers, but the permeability affect significantly on the lateral displacement in liquefied layer with large ground surface inclination

References

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