Influence of drain diameter on gravel drains performance as liquefaction countermeasures

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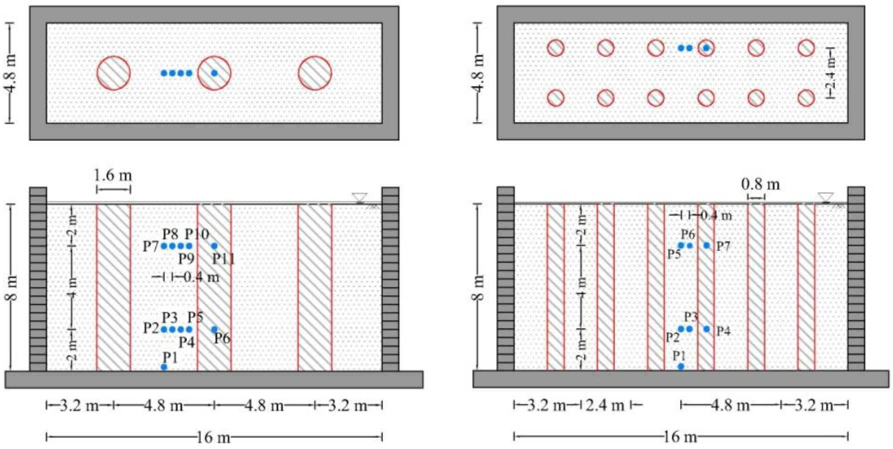
1. Introduction

The installation of gravel drain in a non cohesive soil is a commonly ground-improvement method used to prevent damage of liquefaction occurrence (Seed and Booker, 1977). Based on Seed and Booker's design procedure, the dissipation time of pore pressure depends on the consolidation properties of the sand itself, which is commonly described as time factor that inversely proportional to the square radius of the drain. A series of centrifuge tests for a uniform 8m-thick sand layer improved with gravel drains were conducted to observe the influence of drain diameter on the drainage performance. Numerical simulations were performed to simulate gravel drain behavior closely and compared it with the test result.

2. Methodology

Two centrifuge tests were carried out with two times different of drain diameter. The model was built by air-pluviating Ube Keisha #7 sand with index physical properties are e_{max} = 1.138 and e_{min} = 0.657 to a relative density of 60% in a laminar box. Keisha #1 was used as gravel drains material, wrapped with a mesh filter 0.05 mm opening to prevent clogging.



(a) Case 1 (b) Case 2

Figure 1. Schematic picture of centrifuge test

Permeability of the sand and the drain are $k = 2.4\times10^{-2}$ cm/s and $k = 3.2$ cm/s, respectively. For Case 1, 1.6 m diameter gravel drains were set at improvement ratios of 12%. Case 2 consists of 0.8 m diameter drain by keeping the improvement ratio constant. The base acceleration of 100 gal with 0.7 Hz frequency at centrifugal accelerations of 40g applied to the models.

Numerical simulation was conducted to simulate pore pressure behavior on granular soil considering purely radial drainage based on the equation expressed by Seed and Booker (1977), as follows:

$$\frac{k}{m_v\gamma_w}\left(\frac{\partial^2 u}{\partial r^2}+\frac{1}{r}\frac{\partial u}{\partial r}\right)=\frac{\partial u}{\partial t}-\frac{\partial u_g}{\partial N}\frac{\partial N}{\partial t} \quad (1)$$

where k is soil permeability, m_v is the coefficient of volume compressibility, and γ_w is the unit weight of water. In the calculation, m_v =0.00005 m^2/kN was chosen based on the recommendation value from JGS (1998) for medium dense sand. The boundary condition for drain was using the excess pore pressure in the drain observed from centrifuge test results.

3. Results and Discussions

Figure 2 showed excess pore pressure ratio for Case 1 and Case 2 increased significantly after t=15 s and reached the initial effective stress after t=20 s, at depth 2 m. P7 in Case 1 exceeded r_u =1 due to the subsidence of the sensor after the soil layer liquefied. Pore pressure in Case 1 started to dissipate at t=40 s meanwhile in Case 2 it starts earlier at around t=35 and almost fully dissipate at t=60 s. The sand layer did liquefy for both cases at a shallower depth, however for Case

2 can be observed that the effect of smaller diameter drain in accelerating the dissipation time. Further, at greater depth, excess pore pressure ratio is lower than 1 for Case 1 and 2 which shows no liquefaction occurred. The behavior of pore pressure ratio observed at 6 m depth are somewhat similar, in Case 2 with smaller diameter drain installed, the dissipation started earlier just right after its reached the maximum value at t=21 s. For both cases at the greater depth, pore pressures are fully dissipated after the time reach 50 s.

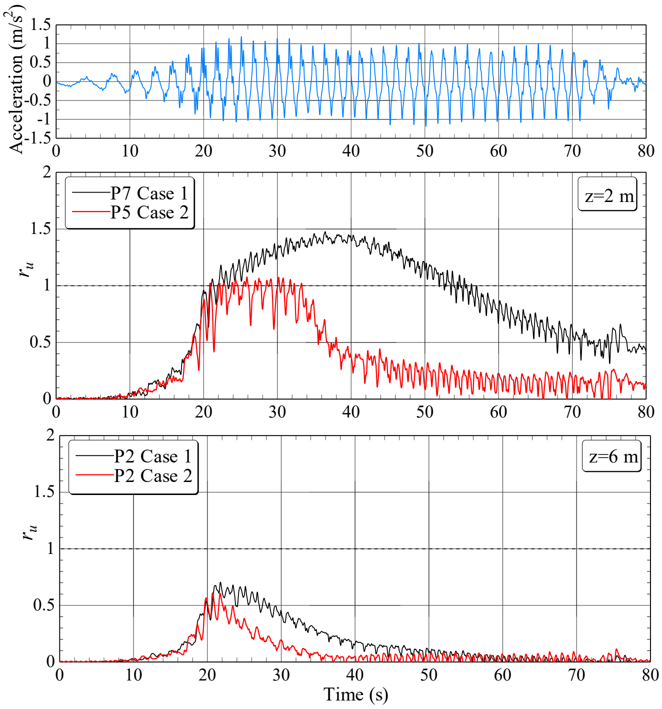


Figure 2. Input acceleration and excess pore pressure ratio for Case 1 and Case 2

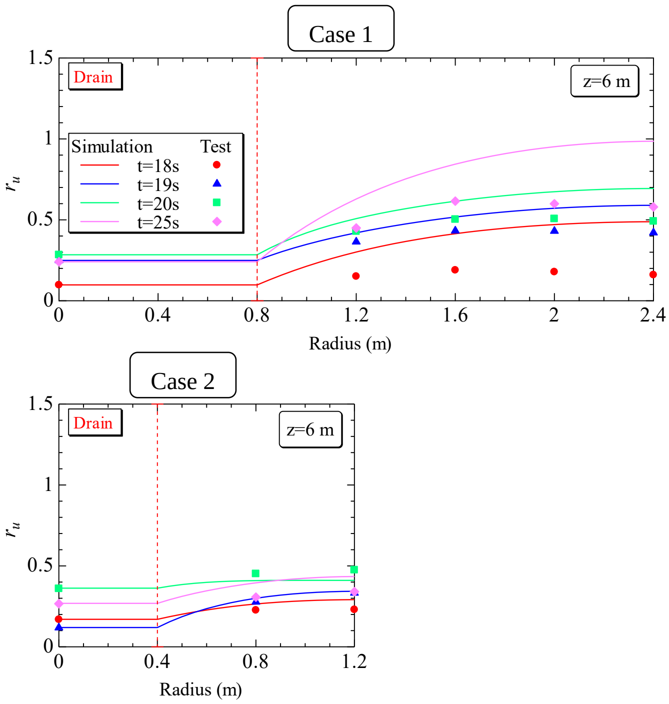


Figure 3. Radial distribution of excess pore pressure ratio Case 1 and Case 2 at 6 m depth

Numerical simulation results combine with the test results at the selected time for 6 m depth are presented in Figure 3. The simulation demonstrates the trend of radial distribution of pore pressure ratio relatively well alongside with the test results. In Case 1, the generation rate of pore pressure is faster and the zone of influence reached until the midpoint of the sand layer. For Case 2, r_u is maintained lower at everywhere in the sand and the zone of influence is wider than Case 1. It showed at the farthest point from the drain, excess pore pressure ratio almost at the same level with the pore pressure in the drain. r_u is still increasing for Case 1 at t=25 s, meanwhile at the same time in Case 2 it already dissipated. It is showed that a smaller diameter of the drain shortened the time needed to dissipate the excess pore pressure.

4. Conclusions

A series of dynamic centrifuge tests were performed to evaluate the effectiveness of gravel drain applied to uniform sand deposits, as liquefaction countermeasure. The effect of varying drain diameter was observed with a constant improvement ratio. The test result presented that excess pore pressure ratio on the smaller drain diameter is lower as compared to a larger drain diameter at the corresponding point. As the spacing ratio remained constant, the smaller diameter drain elevated the effectiveness of the drainage works.

References

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