EXCESS PORE PRESSURE DISSIPATION IN NON-HOMOGENEOUS SOIL DEPOSITS SUPPORTING EARTHEN EMBANKMENTS

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1. INTRODUCTION

Extensive failures in soil embankments such as river dykes, road embankments and earth dams, supported on a cohesionless foundation soil, have occurred during the past major earthquakes. Failures were destructive when the underlying saturated soils liquefied, resulting in cracking, settlement, lateral spreading, and slumping of the embankment(Koga and Matsuo 1990; Adalier 1998). Various experimental studies(Koga and Matsuo 1990; Adalier 1998; Kano et al. 2007) and numerical analyses (Aydingun and Adalier 2003) have been conducted to examine the behavior of embankments resting on uniform cohesionless soil during earthquakes. It is noted that the real soil profile is complex and a soil deposit is neither uniform nor consists of continuous layers. Natural sand deposit normally consists of many sublayers with different soil particles and properties, ranging from soft sand lenses to stiff cohesive clay and coarse sand layers, referred to as non-homogeneous soil deposits. Maharjan and Takahashi (2012, 2013) conducted centrifuge model tests followed by numerical analyses to investigate the liquefaction mechanism in non-homogeneous soil deposits and found that more excess pore water pressure remains for a longer period of time at discontinuous region in non-homogeneous soil deposits compared with the continuous layered and uniform soil deposits, manifesting a larger settlement at the corresponding part causing non-uniform settlements. Accordingly, the present study examines the dissipation of excess pore pressure in non-homogeneous soil deposits supporting an earthen embankment.

2. NUMERICAL ANALYSES

A numerical analysis has been conducted for an earthen embankment resting on a liquefiable non-homogeneous soil using finite element code based on extended subloading surface model (Hashiguchi and Chen 1998; Takahashi 2002). Dimensions and soils of the target deposits are determined so that they can be modeled in the geotechnical centrifuge. A soil structure with 8m wide and 2.4 m high embankment supported on 8.4 m of non-homogeneous liquefiable soil where the ground water table is 0.4 m below the ground surface was systematically studied. Non-homogeneous soil consists of two types of soils, i.e., Toyoura sand and Silica sand No. 8, both of relative density 50%. Silica sand No. 8, referred as silt, being ten times less permeable than Toyoura sand, was employed to create the non-homogeneity by introducing periodically distributed silt patches (Fig.1). Two cases were considered; in the first case, NH_case1, lower silt layer consists of two discontinuities of length 1.5 m, while upper part consists of one discontinuity of 3 m (Fig.1(a)). The arrangement of the discontinuities was reversed in the second case, NH_case2, as shown in Fig.1(b). An embankment resting on uniform Toyoura sand was also studied for comparison purpose. Earthquake ground motion recorded at the Hachinohe Port in 1968 Tokachi-Oki earthquake (NS component) was applied for the seismic excitation. During the numerical simulations, excess pore water pressure time histories were sampled at the locations indicated in Fig.1.

3. RESULTS

Figure 2 compares the time histories of excess pore water pressure ratios, r_u measured against depth in uniform sand and non-homogeneous soil deposits. The excess pore pressure ratios begin to build up from the onset of shaking at all the locations but the excess pore pressure ratios reach the value of 1.0, attaining the liquefaction only at the ground far from the embankment as stated by different previous researchers. In contrary, the excess pore water pressure ratios are the lowest just beneath the embankment centerline, indicating the state of liquefaction could not reach even during shaking, a significantly stiffer response. Vast differences are observed in the dissipation of excess pore water pressure ratios between uniform and non-homogeneous soil deposits. The total time taken for the dissipation of pore water pressure is about 1000 s for the uniform sand deposits, while the time taken for complete dissipation is about 2000 s for the non-homogeneous soil deposits. It is worth noting that the excess pore water pressure ratios remain around 1.0 for quite a longer period of time in free field zone atP2 and P7 of non-homogeneous soil deposits, in contrast to the uniform sand deposits. Despite the lower values of excess pore water pressure ratios below the embankment centerline and toe, the value is relatively larger for a longer period of time for non-homogeneous soil deposits. Moreover, a significant difference is seen in excess pore water pressure ratio atP5 and P12 for test NH_case2, being located above the discontinuous region, P5 and P12 attain larger excess pore water pressure ratio for longer period of time than that for test NH_case1. The dissipation of pore water pressure is generally followed by migration of the pore water from the underlying foundation soil toward the free field. The longer period of dissipation and redistribution of pore pressure after shaking might play a vital role in post-liquefaction delayed failures of embankments.

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4. SUMMARY AND CONCLUSIONS

This paper presents the preliminary analysis results for the comparison of excess pore water pressure responses in uniform and non-homogeneous soil deposits. Dissipation of pore water took a longer period of time for non-homogeneous soil deposits, which might be incorporated by migration of pore water from underlying foundation soil toward the free field; causing a larger settlement of embankment and larger heave at the free field ground surface and post-liquefaction delayed failures. More detail numerical analysis including the centrifuge tests will be further conducted for the better understanding of seismic response of earthen embankments resting on non-homogeneous soil deposits.

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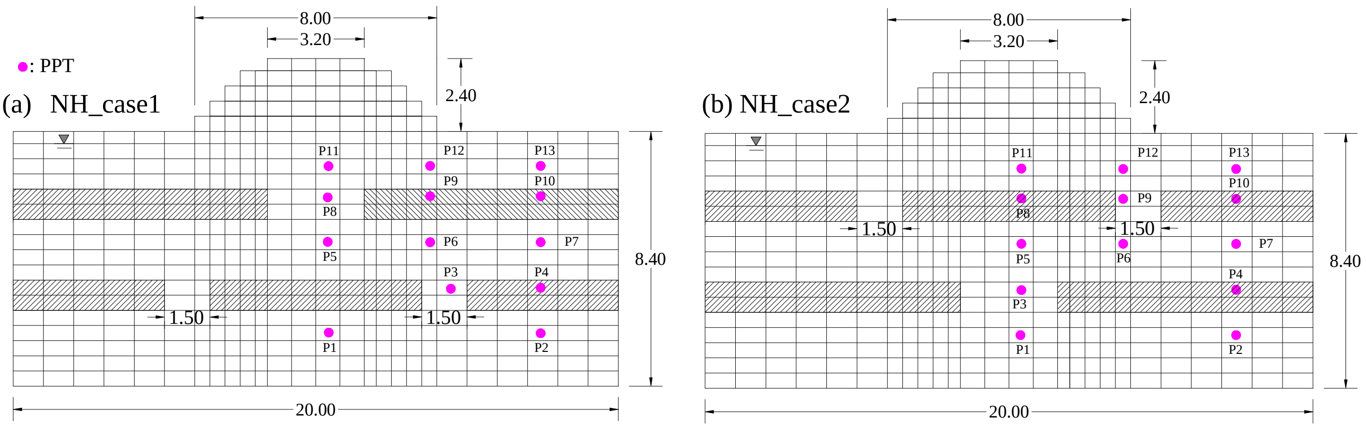

Fig.1:Model configuration for non-homogeneous soil deposits supporting an embankment

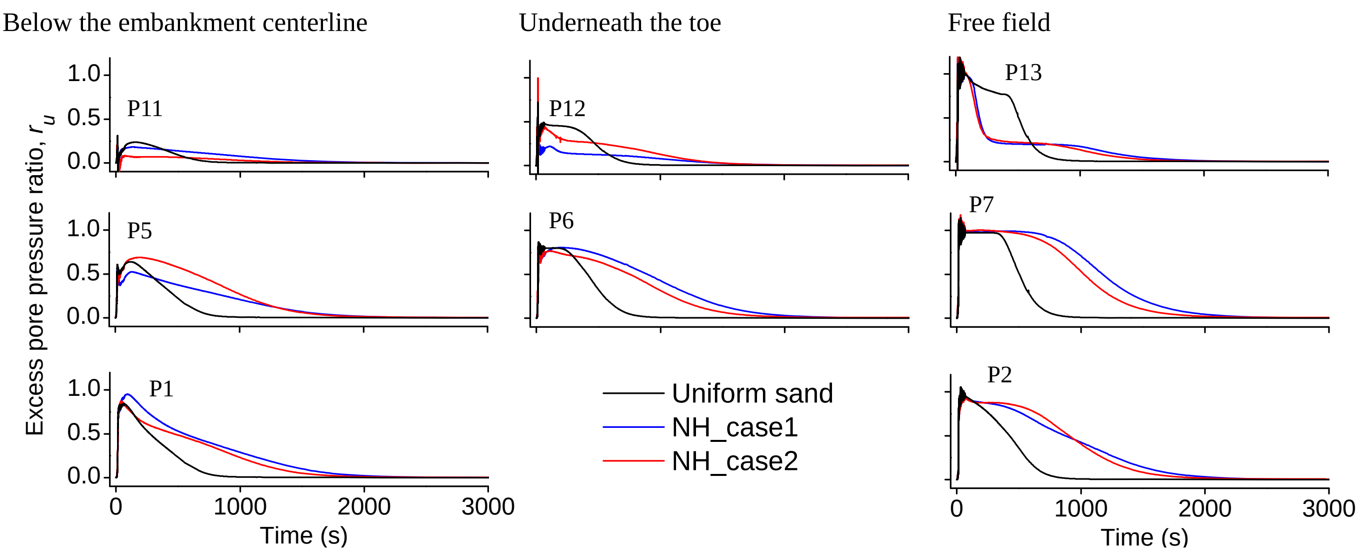

Fig.2: Comparison of excess pore pressure dissipation curve in uniform sand and non-homogeneous soil deposits