EVALUATION OF LIQUEFACTION POTENTIAL IN RELATION TO THE SHEARING HISTORY USING SHEAR WAVE VELOCITY

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論文題名：EVALUATION OF LIQUEFACTION POTENTIAL IN RELATION TO THE SHEARING HISTORY USING SHEAR WAVE VELOCITY
（せん断履歴に着目した、S 波速度による液状化ポテンシャルの評価）

区　　分　：甲

論　文　内　容　の　要　旨

The serious disasters caused by the recurrence of soil liquefaction during the 2016 Kumamoto Earthquakes, is the primary motivation in this study. The potential cause of these disasters was considered mainly with two directions by researchers. Most opinions supposed the foreshock as the pre-shearing impact on the ground greatly when mainshock came. In this concern, the changes of particle structure and excess pore water pressure, which were produced by the foreshock, influenced the liquefaction potential significantly. On the other side, some of researchers concerned from the special geological conditions in Kumamoto-Aso area. The volcanic grains may play an important role to affect the soil behaviors in liquefied sites. However, the mechanism is still not clear now. More importantly, the investigation method needs to be developed urgently for the future earthquakes, which could evaluate liquefaction potential and the changes quickly and reliably.

According to these concerns, Kuroboku, a typical volcanic soil distributed in Kumamoto-Aso, was selected as one of the test materials to detect the liquefaction behaviour. This is for discussing the potential influence from volcanic component in liquefied sites. Boiled sand was carried into the tests to represent the typical soil condition for the liquefied sites in the 2016 Kumamoto Earthquakes. Fine sand also was used to represent a sandy ground where is very prone to be liquefied generally. These samples tested by using cyclic tri-axial apparatus assembled with bender elements. The liquefaction and re-liquefaction behaviours were investigated by cyclic tests. Meanwhile, the velocity of shear wave in samples was measured by bender elements accompanied with the cyclic tests. The velocity was discussed on the correlation with the liquefaction potential, concerning the effects from shearing history particularly.

The contents of each chapter in this dissertation are arranged briefly as follows:

In Chapter 1, the research background and motivation were described. The damages induced by soil liquefaction were considered as one of the most destructive disasters in earthquakes. Meanwhile, the recurrence of liquefaction also was not uncommon. Two typical issues of the 2011 Earthquake off the Pacific coast of Tōhoku and the 2016 Kumamoto Earthquakes were introduced for the recurrences of liquefactions in Japan. The objectives and research flow of this study were also presented in this chapter.

In Chapter 2, the literatures were reviewed from the researches related to the changes of liquefaction behaviours by pre-shearing and the shear-wave-based evaluation on liquefaction potential.

Two dominant explanations were described briefly for the changes of liquefaction resistance effected by pre-shearing. Their considerations based on the views from the stress-strain relation and from the micro changes of particles structure respectively. Some previous studies related to the basic physical properties of Kuroboku and the boiled sand also were presented.

In Chapter 3, the setup of test equipment was introduced firstly. Secondly, several preparation methods for samples were discussed with the influences on saturation degrees. The general test conditions and test progresses were introduced finally.

In Chapter 4, liquefaction and re-liquefaction behaviours of the fine sand were investigated. The saturated sand was discussed primely. Some results from partially saturated sand were compared. The main results indicated the great reduction of liquefaction resistance in saturated sand if it was liquefied once. The excess pore water pressure *EPWP* and axial strain produced much faster in re-liquefaction stages. At the same time, the *EPWP* increased much faster than axial strain in re-liquefaction stage. The re-liquefaction behaviour of partially saturated sand was affected by cyclic load ratio *CSR* potentially.

In Chapter 5, Kuroboku and boiled sand were tested for detecting the liquefaction and re-liquefaction behaviours. The results indicated the Kuroboku owned a very high liquefaction resistance even if the fines were removed. The liquefaction resistance increased significantly after first liquefaction stage. The boiled sand owned the lowest liquefaction resistance in the three soils though it contained approximately 10% of fines.

In Chapter 6, the shear-wave-based evaluation on liquefaction potential was discussed with different soils and shearing histories. The effect of shearing history was concerned as two situations, that the excess pore water was completely discharged or remained in soil. The results expressed that this shear wave velocity cannot clearly indicate the change of liquefaction resistance between first and second liquefaction stages. However, the velocity performed a well relationship with the residual effective stress in soils. In a determined soil, this method could indicate the reduction of liquefaction resistance quantitatively when *EPWP* produced. Furthermore, in a simulated in-situ condition, the correlation became closer that the shear wave velocity increased with the increasing of liquefaction resistance generally. In previous researches, the method was very limited to identify a saturated ground, which could be liquefied or not by the proposed boundaries. Based on the laboratory results in this study, the scope of application was significantly extended to the grounds with the different saturation degrees, relative densities, and shearing histories.

In Chapter 7, the achievements and the discussion for the whole dissertation were presented. And some recommendations for further work were proposed.