Chapter 6

Conclusions and recommendations

The following conclusions can be drawn from this research work aimed at investigating soil behavior under cyclic torsional shear loading in relation to traffic-induced phenomena.

1. Soil specimens under the cyclic torsional shear loading test can be characterized by torsional deformation accompanied by the development of pore water pressure. The rearrangement of soil particles occurred at the initial period of loading application in order to attain structural stability. The behavior of soil was affected by loading magnitude, number of cyclic loading, loading frequency, confining stress and bulk density. Higher loading magnitude together with higher Nc resulted in a higher amount of torsional shear strain. Although higher loading frequency seemed to produce a higher amount of torsional shear strain, the difficulty existed in explaining its effect in the lower $\tau_{z\theta}$ domain. Confining stress and bulk density showed the same effect tendency in which soil specimens under lower values of these parameters attained higher torsional shear strain. However, it was found that the effects of the above parameters no longer appeared when the term of effective stress ratio was taken into consideration.

2. From the viewpoint of trafficability and traffic efficiency, the failure point in this test was defined as the point where the stress started to decrease. The failure characteristics of soil specimens under this test can be described by the strain softening phenomena without the appearance of initial liquefaction but with the development of pore water pressure up to about 30% of the confining stress at failure.

3. Dynamic shear strength under this study was defined based on the maximum

shear stress criteria of the classical shear strength theory. The dynamic shear strength was affected by bulk density but no significant effect of the loading frequency was found. Higher bulk density resulted in higher dynamic shear strength. Besides, the soil specimen under cyclic torsional shear loading might have higher shear strength against the relevant external force than the one under a static loading condition. For critical state, the determination was carried out with the help of the relationship between torsional shear strain and effective stress ratio that was independent of the loading frequency. It is ascertained that significant failure of the soil specimen took place within a certain range of loading magnitude. Beyond this range, the soil specimen encountered failure state during the first loading cycle. On the other hand, below this range, soil specimen did not reach failure state even when using a higher Nc.

4. The loading-free process in the loading and loading-free processes of cyclic torsional shear test made the soil specimen behave differently from that of the normal cyclic torsional shear loading test. During the cyclic loading process, torsional shear strain and pore water pressure were developed while an increase of bulk density and axial strain occurred during the loading-free process. In addition, the amount of increase of bulk density depended on the development of pore water pressure during the preceding cyclic loading process. It is deduced that soil under this specific loading mode was stiffening while the loading set increased. Even though failure occurred in the first loading set, the soil specimen became stiffer when the loading set was continued. Moreover, loading magnitude, Nc in the loading set and bulk density affected the soil behavior.

From the viewpoint of this research work, the following recommendations are presented:

1. The results of interrelationships between parameters involved in the behavior of soil compaction suggest that there are some specific relationships and parameters that seem to be useful in predicting and determining field soil compaction induced by machinery traffic. These include the critical stress that can produce a large magnitude of soil deformation as presented in Fig. 3.8, the loading intensity in terms of $Nc \times \tau_{z\theta}$ that leads to soil failure and $Nl \times \tau_{z\theta}$ in relation to the increase of bulk density in the loading and loading-free test. Further study should be conducted to clarify the functions of these parameters and the capability of predicting field soil compaction. The significance of these parameters exists in selection of machinery size and the number of repetitive works in the field.

2. Since the effect of loading frequency remained ambiguous in this study and was also problematic when compared with previous research works, clarification of its effect is still needed to be undertaken. With the guidance of these test results and literature reviews, further studies on the effects of loading frequency may redirect the attention toward two major parameters: ranges of loading frequency and loading magnitude. The combinations of these parameters seem to bring about absolutely different scopes.

3. The loading and loading-free processes of the cyclic torsional shear test seem to be capable of predicting soil compaction for the whole period of crop production. However, the relationships between the parameters involved should be further investigated in a way that reflects the actual field phenomena.

4. To prove the usefulness of the indoor experimental approach using the cyclic torsional shear loading test for simulating traffic-induced soil compaction, a comparative study with actual field tests are essential.