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Application of Mini Cone Associated with Screw Rod for Characterization of Railway Subgrade

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ABSTRACT

The condition of a railway subgrade should be investigated to evaluate the track quality. This paper presents the application of a mini cone associated with the screw rod, which can measure the cone tip resistance in the railway subgrade. In the railway field, the screw rod is penetrated by rotation into the ballast layer with a minimal disturbance. After the tip of screw rod reaches the top of subgrade, the mini cone is pushed into the subgrade. The field tests show high-resolution profiles of the cone tip resistance. This study demonstrates that the mini cone associated with the screw rod may be a useful device for the characterization of the subgrade.

1. INTRODUCTION

Railway substructure, which consists of the ballast and subgrade, plays an important role for providing resistance to the dynamic loading of traffic. In particular, the subgrade condition have a strong influence on the track quality, such as the change of track geometry. The change of track geometry may occur due to the settlement of the subgrade. Thus, the shear strength and stiffness of the subgrade are critical parameters to assess the railway substructure.

Trial pit excavation and automatic ballast sampler have been generally used to assess the railway substructure. Also, as a invasive method, dynamic cone penetrometer (DCP) has been widely applied to the subgrade of railway and road. As non-invasive methods, the portable falling weight deflectometer (PFWD) and ground penetrating radar (GPR) have been attempted to evaluate the subgrade of railway and road due to their quick measurement (Al-Qadi et al. 2010; Asli et al. 2012; Sussmann et al. 2003). However, the conventional methods for the characterization of the railway substructure are insufficient to obtain geotechnical engineering parameters from the railway subgrade.

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2. MINI CONE WITH SCREW ROD

2.1 Device Components

The new cone penetrometer described in this paper consists of a screw rod and a mini cone. Fig. 1 shows the shape of the screw rod and mini cone. The screw rod, which has a outer diameter of 60 mm, is used to penetrate through the ballast by rotation. In the screw rod, a cover cone is combined to substitute for the cone tip. Note that the cover cone should be extracted for the application of the mini cone.

The mini cone is used to evaluate the variation of soil strength in the subgrade. The mini cone has an tip angle of 60^o and a diameter of 15 mm. The mini cone can produce the profile of the cone tip resistance with high resolution due to the small diameter of the mini cone. In the mini cone, four strain gauges were attached to measure the mechanical resistance. The full-bridge circuit configured with four strain gauges is used to amplify the response of resistance and to compensate the effects of temperature and eccentric load. To measure the cone tip resistance, the input voltage of 1 V was constantly applied to the strain gauges. In addition, two guide columns and a guide plate can be applied for the verticality of the screw rod.

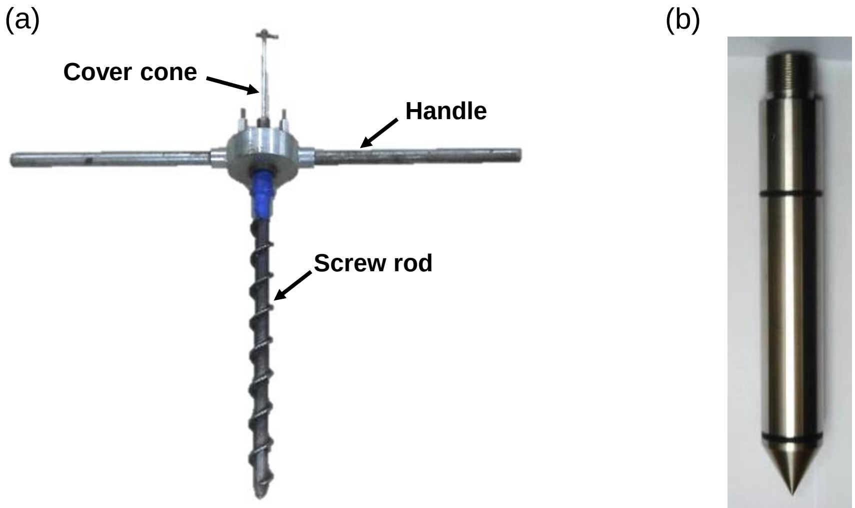

Fig. 1 Pictures: (a) screw rod; (b) mini cone.

2.2 Test Procedure

The application of the mini cone associated with the screw rod is schematically shown in Fig. 2. First, the screw rod is rotated for the penetration into the ballast, as shown in Fig. 2(a). After the screw rod is penetrated up to the top of the subgrade, the cover cone will be removed. For the static penetration, a electric motor is installed on the handle plate. Then, the mini cone is passed through the inner hole of the screw rod, as shown in Fig. 2(b). After that, the mini cone is pushed into the subgrade at the penetration rate of 1 mm/sec.

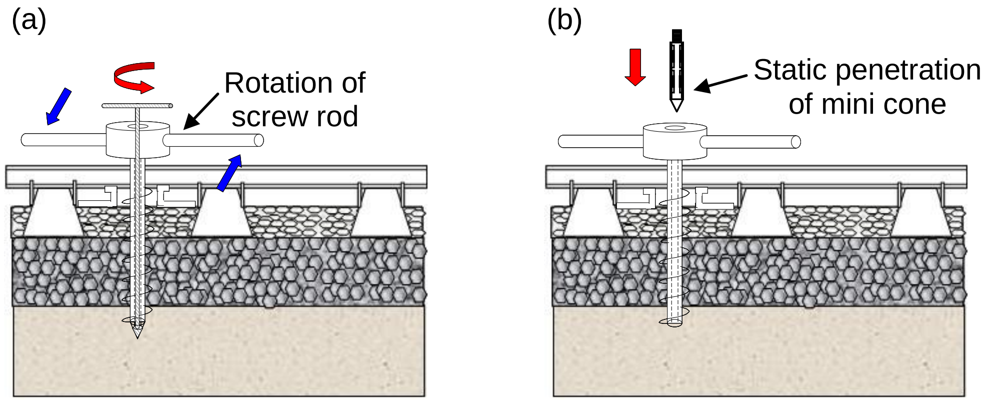

Fig. 2 Schematic drawing of application of the mini cone associated with the screw rod: (a) rotation of the screw rod; (b) static penetration of the mini cone.

3. EXPERIMENTAL PROGRAM

Field application tests were carried out near Korea University in Seoul. At two positions in the railway, the cone penetration tests using the mini cone were conducted for characterization of the railway substructure. Based on the results of the dynamic cone penetration tests reported by Byun et al. (2013), the thickness of the ballast including sub-ballast was estimated to be approximately 600 mm. Thus, the screw rod was penetrated by rotation up to the depth of 600 mm, and then the mini cone was pushed from the depth of 600 mm to 950 mm. Fig. 3 shows the profiles of the cone tip resistance at two position.

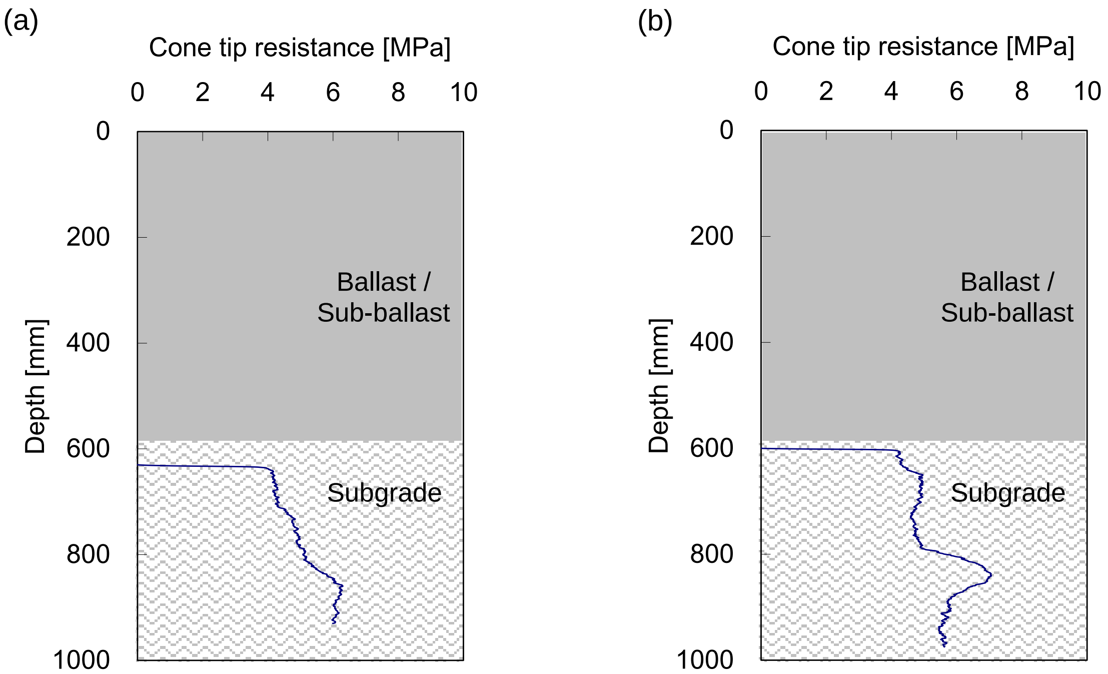

Fig. 3 Profiles of cone tip resistance obtained from the field: (a) first; (b) second.

The cone tip resistance gradually increases from the depth of 600 mm to 800 mm, and then dramatically increase up to the depth of 845 mm. Finally, the cone tip resistance remained constant to be approximately 5.6 MPa to 6.1 MPa.

4. CONCLUSIONS

The mini cone associated with the screw rod was applied for the evaluation of the in-situ soil strength in the subgrade of railway. The screw rod was designed to penetrate through the ballast by rotation. The mini cone with diameter of 15 mm can provide the high-resolution profile of soil strength for the subgrade. The field tests using the mini cone associated with the screw rod were performed at the railway site. The results of field tests showed that the cone tip resistance increases with an increase in the depth. Furthermore, the evolution and range of the cone tip resistance were consistent at two position. This paper represents that the mini cone associated with the screw rod may be effectively used for the characterization of the subgrade, providing the engineering parameters without the main disturbance of the substructure.

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