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Instrumented Dynamic Cone Penetrometer: Development and Applications

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ABSTRACT: Dynamic cone penetration tests have been performed for the characterization of subgrade in the road and railway. This paper presents the application of an instrumented dynamic cone penetrometer (IDCP) to a field and a comparison with the result of standard dynamic cone penetration test. The IDCP consists of a cone tip, driving rods, and a falling weight with a guide. In the cone tip of the IDCP, strain gauges configured with full-bridges are installed to detect cone resistance during dynamic penetration. Two dynamic cone penetration tests using IDCP standard DCP are carried out at a site. The experimental results show that the cone resistance increases with increasing depth, while the dynamic cone penetration index decreases with increasing depth. The regression result between cone resistance and dynamic cone penetration index shows a strong power curve relationship. This study suggests that the IDCP can be effectively used for more accurate subsurface characterization in shallow depth.

1 INTRODUCTION

Shear strength of soils, which is one of most important parameters in geotechnical engineering, can be determined by laboratory tests and in situ tests. The shear strength can be obtained directly in the laboratory test using a sample, while that can be estimated indirectly from the in situ test. However, the in situ test is relatively rapid and economical to the laboratory tests. Furthermore, in case of loose sand and highly weathered rock, the shear strength can be determined more reliably by in situ test, because the strength obtained from the laboratory test can be significantly affected by sample disturbance.

A variety of in situ tests have been used to determine the subsurface strata and the geotechnical parameters. Cone penetration test (CPT), which is a most popular method of in situ tests, is widely used not only for subsurface characterization but also for direct geotechnical design. The CPT provides a continuous profile of the subsoil with a high reliability. However, in some of fields such as slope, railway, and cold region, there is a limitation to access, and thus, the CPT rig which is supposed to support the reaction force is limited.

Dynamic cone penetrometer (DCP) is also one of the useful in situ testing devices with an intension to evaluate the strength and variability of the subgrade. The DCP testing is relatively inexpensive, and its procedure is simple and straightforward. DCP Index (DCPI) obtained from the DCP test has been correlated with several engineering properties, such as California bearing ratio, resilient modulus, and dry density (Siekmeier et al. 1999, Salgado and Yoon 2003, Abu-Farsakh et al. 2004, Ampadu et al. 2006, Mohammadi et al. 2008). However, the DCP test has some limitations related to the effect of sleeve friction and the efficiency of transferred energy (Livneh 2008, Byun and Lee 2013).

This paper presents the use of instrumented dynamic cone penetrometer (IDCP) in a field. The cone resistance estimated from IDCP is compared with DCPI measured from the standard DCP.

2 EXPERIMENTAL STUDY

Standard dynamic cone penetrometer is composed of a hammer, upper and lower shafts, anvil, and cone. The diameter of standard cone is 20 mm, and that of lower shaft followed by the cone is 16 mm. The difference in diameter between the shaft and cone makes it possible to assume that the sleeve friction can be disregarded. In case of instrumented dynamic cone penetrometer (IDCP) used in this study, the components of IDCP are similar to those of standard DCP. Especially, the IDCP has a cone tip and driving rod with a consistent diameter of 24 mm. To measure the cone resistance during the dynamic cone penetration test, four strain gauges were mounted near the cone tip, configured with Wheatstone bridge. For the instrumentation, a hollow bar was selected as a driving rod.

Two dynamic cone penetration test were performed at a site. Two test positions were closed to each other within 1 m spacing. After sampling from three different depths and analyzing grain size distributions, the soils were classified as silty sand with mean diameter of 1 to 2.3 mm and uniformity coefficient of 46 to 99.

3 EXPERIMENTAL RESULTS

Figure 1 shows the variation in dynamic cone penetration index (DCPI) along the penetration depth. The DCPI is defined as a advanced depth per blow. The DCPI decreases with an increase in depth, ranging from 93 to 9 mm/blow.

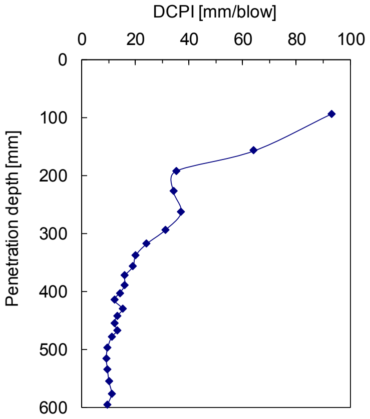

Figure 1. Profile of dynamic cone penetration index from a standard dynamic cone penetration test.

The force signals obtained from the strain gauges vary according to the time during the dynamic penetration. To determine a constant force at each blow, a cone resistance (CR) is calculated as follows.

$$CR = \int Fdt/(A\Delta t) \quad (1)$$

where F is the force varying according to the time; A is the cross-sectional area of the cone tip; Δt is the period from the initial rising time to the time to first zero force detected at the cone tip. Figure 2 shows the cone resistances estimated at each depth. The cone resistance increases with increasing depth.

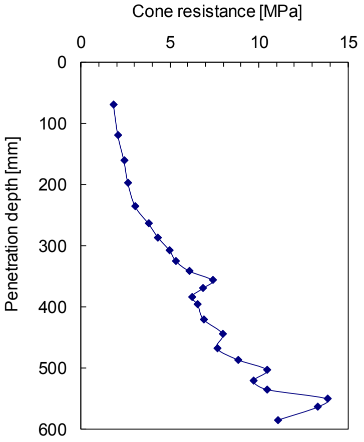

Figure 2. Profile of cone resistance obtained using instrumented dynamic cone penetrometer.

To establish a relation between the DCPI and the cone resistance, a regression analysis was conducted, and a power curve relationship is present as follows.

$$CR = \alpha \cdot (DCPI)^{\beta} \quad (2)$$

where α and β are coefficient and exponent, which were set to 60.46 and -0.79, respectively. Figure 3 shows a strong power curve relationship between the DCPI and the cone resistance with coefficient of determination of 0.91. The cone resistance increases with a decrease in the DCPI. The results demonstrate that the cone resistance will be more useful at the soils where the DCPI is less than 20 mm, because the variation in cone resistance is greater than that in DCPI.

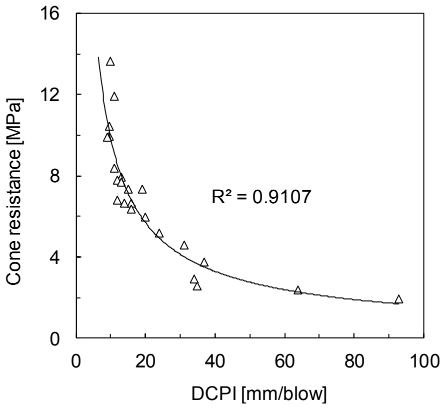

Figure 3. Correlation of cone resistance and dynamic cone penetration index.

4 CONCLUSION

In this study, an instrumented dynamic cone penetrometer including four strain gauges near the cone tip was applied to a fileld. Two dynamic cone penetration tests were performed using a standard DCP and IDCP to compare the results of IDCP with those of standard DCP. The dynamic cone penetration profiles showed that the cone resistance increases with increasing depth, while the dynamic cone penetration index decreases with increasing depth. In particular, a strong power curve relationship between cone resistance and DCPI was found. Thus, the IDCP may be effectively used as an alternative to DCPI for more accurate subsurface characterization in shallow depth.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

Abu-Farsakh, M Y., Alshibli, K., Nazzal, M., and Seyman, E. (2004). *Assessment of in-situ test technology for construction control of base courses and embankments*. Louisiana Transportation Research Center.

Ampadu, S. I. K., and Arthur, T. D. (2006). The dynamic cone penetrometer in compaction verification on a model road pavement. *Geotechnical Testing Journal*, 29(1), 70-79.

Byun, Y. H., and Lee, J. S. (2013). instrumented dynamic cone penetrometer corrected with transferred energy into a cone tip: a laboratory study. *Geotechnical Testing Journal*, 36 (4), 533-542.

Byun, Y. H., Yoon, H. K., Kim, Y. S., Hong, S. S., and Lee, J. S. (2014). Active layer characterization by instrumented dynamic cone penetrometer in ny-alesund, svalbard. *Cold Regions Science and Technology*, 104, 45-53.

Mohammadi, S. D., Nikoudel, M. R., Rahimi, H., and Khamehchiyan, M. (2008). Application of the dynamic cone penetrometer (dcp) for determination of the engineering parameters of sandy soils. *Engineering Geology*, 101, 195-203.

Salgado, R., and Yoon, S. (2003). *Dynamic cone penetration test (dcpt) for subgrade assessment*, INDOT Research FHWA/IN/JTRP-2002/30, SPR-2362.

Siekmeier, J. A., Young, D., and Beberg, D. (1999). Comparison of the dynamic cone penetrometer with other tests during subgrade and granular base characterization in Minnesota. *Nondestructive Testing of Pavements and Backcalculation of Moduli, 3*.