Joint Transportation Research Program

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SPR-3408 2015

Assessment of Site Variability from Analysis of Cone Penetration Test Data

Introduction

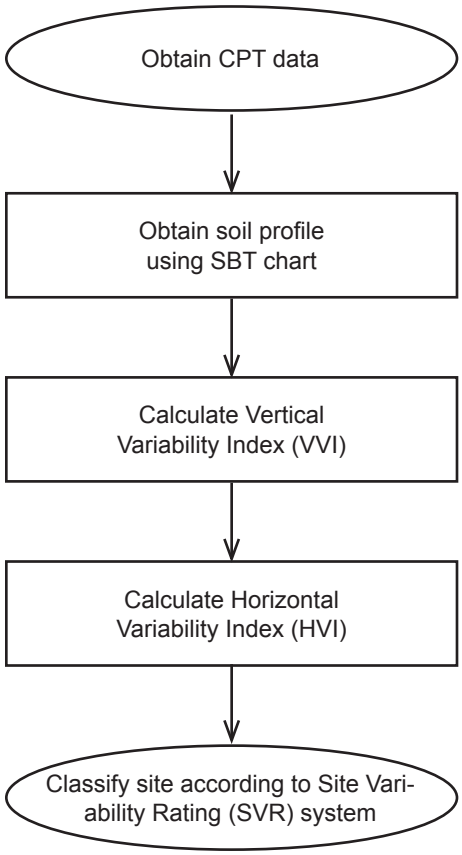
Site investigation is an important component of every construction project. The main goals of a geotechnical site investigation are (1) to define the soil profile and (2) to estimate the geotechnical properties of the different soils of the soil profile. The soil properties are derived from either *in situ* tests or laboratory tests. However, in both cases the number of *in situ* or laboratory tests is constrained by project budget and time. Since often a limited number of tests are performed, there is uncertainty associated with the soil properties estimated for a site for use in design. This uncertainty is an inevitable part of every geotechnical site investigation, raising the question as to how accurately soil properties derived from laboratory tests or *in situ* tests represent the soil properties of an entire site. Although this uncertainty cannot be eliminated, a site variability assessment may lead to lower or higher resistance factors for use in Load and Resistance Factor Design (LRFD).

In comparison with other *in situ* tests, the Cone Penetration Test (CPT) is considered a reliable tool. The result of the variability study of CPT parameters is helpful during the site investigation and design phases of a project. During the *in situ* investigation phase, the variability of the measured CPT parameters can be assessed in real time. If this variability is deemed high, based on a given number of CPT soundings, additional soundings can be performed to increase the reliability of the estimated soil properties to be used in design, and vice versa. In addition, safety factors or resistance factors to be used in design could be adjusted to reflect the outcome of the variability assessment of the CPT parameters measured for the project site. Therefore, an assessment of site variability can directly benefit a project by optimizing the site investigation cost and increasing the reliability of the foundation design.

Findings

In this report, knowledge of spatial statistics was applied to develop a rational methodology to assess site variability using CPT data. The subsurface soil profiles were estimated based on soil behavior type (SBT) charts using a soil profile generation algorithm developed in this research. Then, the vertical variability of each CPT sounding was quantified by a vertical variability index *(VVI).* The average of the *VVIs* for all soundings performed at a site was the site *VVI.* The horizontal variability of the site (site *HVI*) was assessed by considering the cross-correlation between cone resistances, the cone resistance trend differences, and the spacing between every pair of CPTs.

A site variability rating (SVR) system, integrating the vertical and horizontal site variability, was established to assess the overall site variability. An optimal sounding spacing calculation methodology was also developed to make the site



Soil variability analysis

investigation process more efficient, cost-effective, and reliable.

This report includes the following findings:

- The choice of SBT chart influences the soil profile generated using the soil profile generation algorithm; however, its effect on the variability indices that compose the SVR system is small.
- Close agreement was found between the SVRs obtained using the two SBT charts (Robertson, 1990; Tumay, 1985) selected for this research.
- •The site variability assessment depends on the soil profile length of the CPT soundings considered in the analyses (the depth of interest will be shallower for shallow foundations than for deep foundations). *VVI* and *HVI* calculations were performed for CPTs available from across the state of Indiana. These calculations, over the long run, can lead to reliable maps of site variability for the state, which would lead to better planning of site investigations and more economical design.

Implementation

Site variability rating maps (SVR maps) for various depths of interest were constructed for the state of Indiana, illustrating the potential use of the site variability assessment methodology proposed in this research. SVR maps provide easy visualization of regional site variability.

The following recommendations for implementation are made:

1. continue to develop a comprehensive geotechnical variability database for the state;
2. use CPT instead of SPT whenever possible because of its much greater reliability;
3. measure SPT energy ratio regularly;
4. increase data sampling rate of CPTs;
5. use real-time site variability assessment to establish spacing between CPT soundings;
6. develop a strategy to link LRFD of foundations to site variability assessment;
7. develop site variability iPad® applications to be used in the field by INDOT engineers;
8. update SVR maps for different soil profile lengths regularly to reflect additional CPT data collected in the context of new INDOT projects.

References

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Recommended Citation for Report

Salgado, R., Prezzi, M., & Ganju, E. (2015). *Assessment of site variability from analysis of cone penetration test data* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2015/04). West Lafayette, IN: Purdue University. http://dx.doi.org/10.5703/1288284315523

View the full text of this publication here:
http://dx.doi.org/10.5703/1288284315523

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