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Technical Paper

# Evaluation of CPT-based characterization methods for loose to medium-dense sands

Abouzar Sadrekarimi

*Assistant Professor, Department of Civil and Environmental Engineering, Western University, London, Ontario, Canada*

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**Abstract**

As a result of the difficulties related to obtaining undisturbed samples of cohesionless soils, CPT-based empirical correlations, often developed from calibration chamber experiments, are widely used for determining many soil parameters for geotechnical investigation. This paper describes the application of 19 reduced-scale calibration chamber cone penetration tests to evaluate empirical correlations for predicting the relative density, the unit weight, the constrained modulus, and the soil identification of loose to medium-dense sands. A subtraction cone, 6 mm in diameter with an apex angle of 60° and a net area ratio of 0.75, is used in the laboratory tests. Due to the fine gradation of the quartz sand used in the experiments, some of the CPT results are located within the silty sand range of the soil identification charts. An extensive evaluation is also presented for the stress normalization process of the CPT data. It is determined that a relative density-based overburden stress normalization method provided the best estimates for correcting the cone tip resistance for effective overburden stress.


*Keywords:* Cone penetration test; Calibration chamber test; Sand; Relative density; Modulus; Critical state; Stress normalization; Soil identification

## 1. Introduction

Geotechnical engineering analyses and designs require accurate identification and characterization of soil layers, as well as an assessment of soil stratigraphy at the site. However, due to the difficulties in obtaining undisturbed samples of cohesionless soils, geotechnical engineers often rely on field tests to obtain the in-situ soil characteristics. Owing to relatively lower costs, simplicity, continuous measurement with depth, and excellent repeatability and accuracy, the electronic cone penetration test (CPT) has emerged as one of the most popular tools for ground investigation in geotechnical engineering. CPTs are particularly instrumental for characterizing saturated loose to medium-dense cohesionless soils due to the susceptibility of these soils to static or cyclic liquefaction and their potential for liquefaction flow failure. As CPT does not directly measure any particular soil properties, extensive research has been conducted to develop empirical correlations of CPT measurements with soil type and engineering properties (including unit weight, relative density, and modulus) using laboratory calibration chamber experiments (Schmertmann, 1978; Villet and Mitchell, 1981; Baldi et al., 1986; Jamiolkowski et al., 1988, 2001; Huang and Hsu, 2005). These experiments can provide the most reliable and precise experimental data for developing CPT-based correlations and calibration as the entire procedure (including sample preparation, consolidation, and cone penetration) is conducted in the laboratory and can be readily monitored and controlled.

Carrying out controlled CPT calibration chamber tests with a standard cone (with a diameter of 35.7 mm) requires a large-diameter (typically more than 1.2 m) chamber. Such an experiment can be expensive and time-consuming, as sample preparation

*E-mail address:* asadrek@uwo.ca
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involves placing a large volume of sand in the testing chamber at a controlled density. The control of sample uniformity and external stress can also become difficult (Parkin and Lunne, 1982). Due to these challenges, several studies have employed miniature cones and reduced-scale calibration chamber devices (Abedin, 1995; Huang and Hsu, 2005; Kumar and Raju, 2009; Kokusho et al., 2012; Franzen, 2006; Pournaghiazar et al., 2011) frequently on dense sands, with little experimental data on medium-dense to loose sands. This is often because of the collapsible fabric of loose sands which results in initially loose calibration chamber samples collapsing into a denser state during sample saturation and flushing (Been et al., 1987b). This study presents the results of miniature CPT calibration chamber experiments (Damavandi and Sadrekarimi, 2015) carried out at Western University. The results are employed to evaluate a number of existing empirical correlations for determining some of the geotechnical properties of loose to medium-dense sands.

## 2. Experimental procedure

### 2.1. Miniature CPT system

The largest cell that could be accommodated in an existing uniaxial loading frame is manufactured as a CPT calibration chamber in this study. The large custom-made cell contains cylindrical specimens of 150 mm in diameter and 195 mm high. The major components of the CPT calibration chamber are schematically illustrated in Fig. 1. A stainless steel cone,

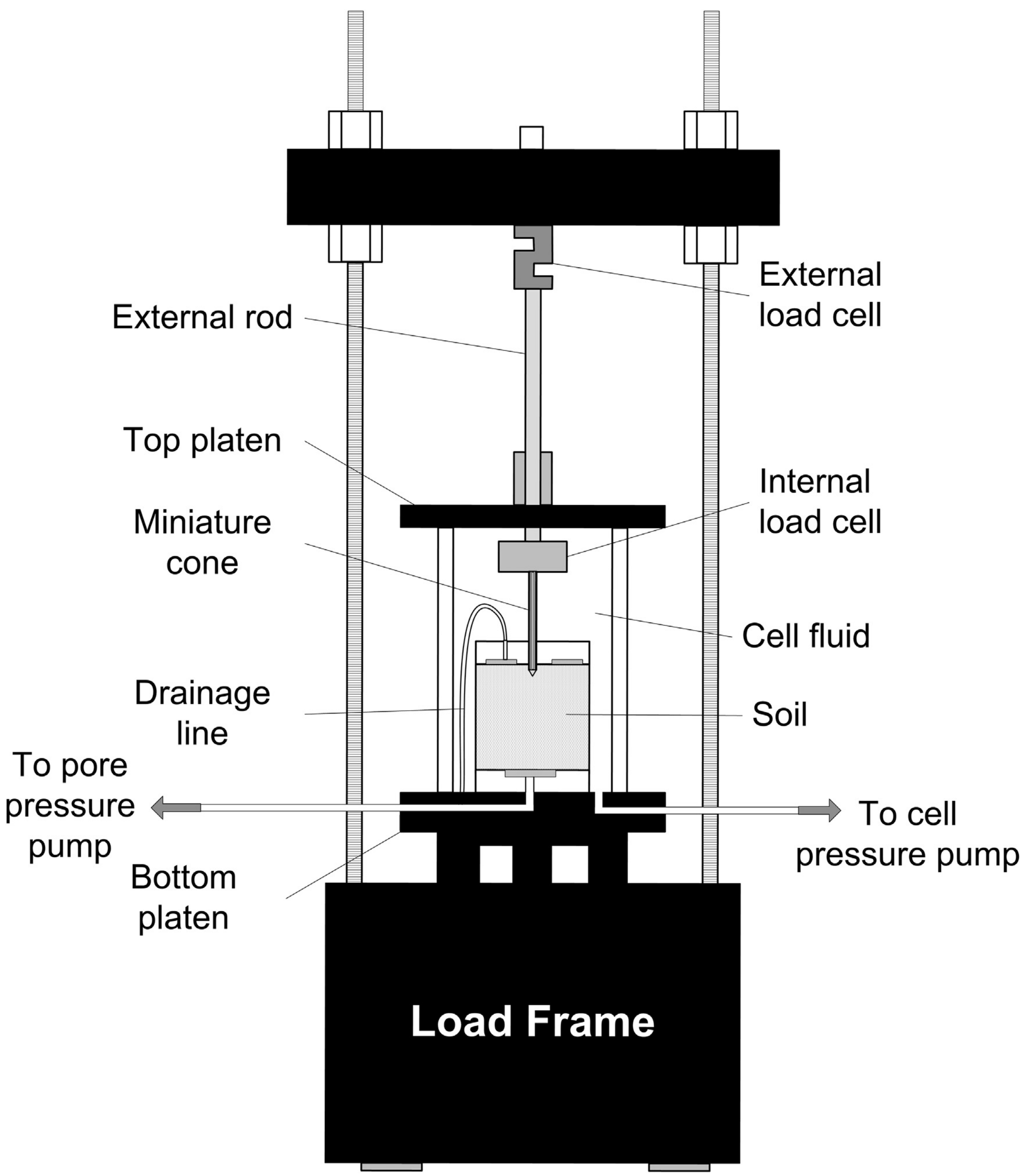


Fig. 1. Illustration of calibration chamber testing components.