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A case study in evaluating the status of consolidation of a soft soil deposit by incomplete piezocone dissipation tests using laboratory and field data

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Abstract

By using the piezocone penetration test (PCPT or CPTu), one can develop not only a better understanding of the soil stratification, but also an understanding of soil behavior parameters related to soil compressibility, as well as soil strength. This paper describes a case study that utilizes incomplete piezocone dissipation test to estimate status of consolidation of a soil deposit. Incomplete pore pressure dissipation record of PCPT is extrapolated on an inverse time scale (1/*t* method) to estimate the "in situ" pore pressure and "residual excess" pore pressure. No case study has been reported in open literature where this methodology has been utilized to estimate the status of consolidation of the soil deposit. In this paper, the 1/*t* method was verified using dissipation data from rigorous calibration chamber tests and field test data.

Keywords: Piezocone; Dissipation; In situ pore pressure; Residual excess pore pressure; Extrapolation; 1/*t* Method; Status of consolidation; IGC: C3/C8

1. Introduction

The piezocone penetration test (PCPT or CPTu) is an in situ test that intrudes a cylindrical cone penetrometer with a pore pressure sensor into the ground to obtain soil parameters that lead to characterization and the evaluation of engineering design parameters of subsurface. This in situ device has been noted lately as a preferred mechanism for also determining the hydraulic conductivity (i.e. permeability and/or the flow characteristics) and consolidation of saturated fine-grained soils. The piezocone penetrometer can be stopped during penetration, and the excess pore pressures generated around the cone will start to dissipate. Using the "full" rate of dissipation to equilibrium pore water pressure, one can estimate the magnitude of the hydraulic conductivity (i.e. permeability) of the deposit and thereby determine its coefficient of consolidation. The status of the consolidation of the soil deposit can also be rated. If equilibrium pore water pressure is to be determined, the dissipation test should continue until no further dissipation is observed. However, full dissipation test is usually rather time consuming and is not performed to reach equilibrium pore water pressure unless it is being undertaken for research. In general practice, most dissipation tests are carried to 50–80% of

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completion and are thus "incomplete" – they end without achieving equilibrium pore water pressure.

Incomplete dissipation records for estimating the in situ hydrostatic pore pressure, u_0, have been used in open literature. Extrapolation of the piezocone dissipation data on an inverse time scale (1/*t* method) is the methodology of choice (Whittle et al., 2000). In this study, the extrapolation method is utilized to evaluate as to whether a soil deposit is underconsolidated or completely consolidated. To verify the effectiveness of the 1/t extrapolation method in estimating the status of consolidation, 12 dissipation test results were analyzed. Two of the dissipation tests were performed on soil samples under rigorously controlled conditions in a laboratory calibration chamber, and the rest of the dissipation data were obtained from field tests at the construction site of a soil improvement project being undertaken in the southwest coastal area of South Korea. The 1/*t* method analyses indicate that, even with incomplete piezocone dissipation tests, one can effectively use the extrapolation method to estimate the consolidation status of soil deposits.

2. Theoretical background

Piezocone penetration can generate the excess pore pressures around the cone and the status of consolidation can be estimated using excess pore pressure dissipation data.

2.1. Mechanism of excess pore pressure generated by piezocone penetration

The penetration of the piezocone produces a cavity expansion in the immediate vicinity of the penetration path, as shown in Fig. 1. Such expansion occurs around the tip and along the path of the shaft of penetration. This cavity expansion generates excess pore pressures around the tip (u_1) and along the path (u_2 or u_3) in the deposit being penetrated under undrained conditions. This means that cone penetration imposes very high strains in the soil in front of the tip and along the path of penetration (Likitlersuang et al., 2013). When the penetration process is arrested for the dissipation test, a highly disturbed zone of soil mass exists around the penetrometer. This is the cavity expansion zone. In this study, we considered excess pore water pressure behind cone tip (u_2). The remolding and compression of soils in this zone will result in changes of hydraulic conductivity (i.e., permeability) (Gupta and Davidson, 1986).

Once the penetration of the piezocone is stopped, the excess pore pressure gradually dissipates with time. This dissipating or decreasing excess pore pressure can be plotted with respect to change of time. This plot is called a dissipation curve. Using this plot, the value of the hydraulic conductivity and coefficient of consolidation for the soil deposit can be estimated (Arulrajah et al., 2007; Cai et al., 2012; Chu et al., 2002).

Fig. 2 shows a typical normalized dissipation curve for soft clay, plotted on a logarithmic time scale. In Fig. 2, u_T and u_i are the measured pore pressure at any time *t* after dissipation commenced, and the initial pore pressure at the beginning of the dissipation test (when penetration was arrested), respectively.

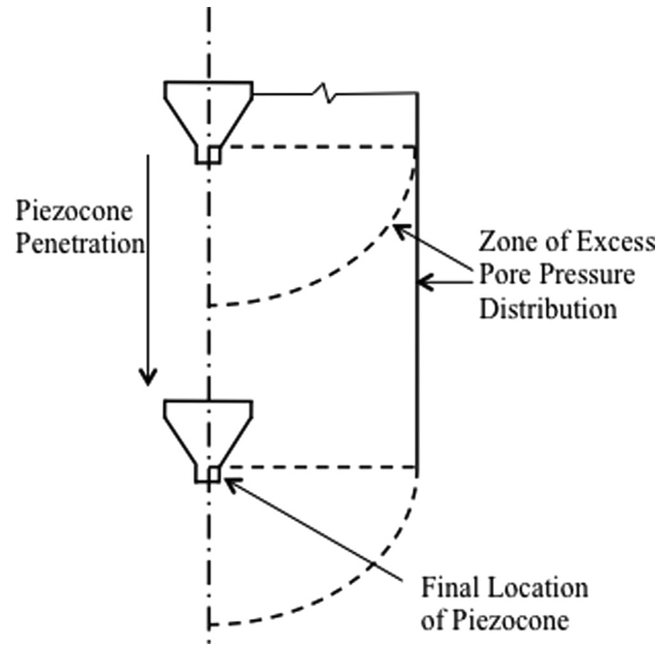

Fig. 1. Mechanism of cavity expansion (Gupta and Davidson, 1986).

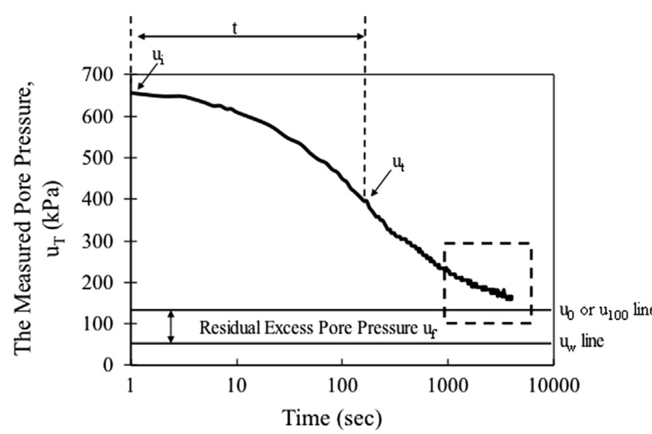

Fig. 2. Typical dissipation curve.

Obtaining the reliable in situ hydrostatic pore pressure, particularly in underconsolidated clays, is of the utmost importance. The pore pressure measured by the piezocone at time *t* after starting dissipation, $u_{T,}$ can be divided into two components: in situ hydrostatic pressure, u_0, and excess pore pressure generated by piezocone intrusion, Δu.

$$u_0 = \text{“original” in situ hydrostatic pressure } (u_w) + \text{residual excess pore pressure } (u_f) \quad (1)$$

$$u_w = \gamma_{water} \times \text{distance to groundwater level from dissipation depth}$$
u_f = residual excess pore pressure in the soil due to ongoing consolidation in the deposit (if underconsolidated)
γ_{water} = unit weight of groundwater (2)

$$\Delta u = u_T - u_0$$
u_T = the measured excess pore pressure at any time *t*. (3)