ARTICLE IN PRESS

HBRC Journal (2015) xxx, xxx–xxx

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

On the evaluation of pre-consolidation pressure of undisturbed saturated clays

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Received 27 October 2014; revised 6 February 2015; accepted 12 February 2015

KEYWORDS

Pre-consolidation pressure;
Sample disturbance;
Pocket penetrometer;
Sample quality

Abstract The objective of this research was to show the effect of sample disturbance on the values of pre-consolidation pressure σ_c by using Schmertmann method. A prediction of σ_c form pocket penetrometer is also achieved. This was carried out by comparing the values of σ_c that were estimated from the results of consolidation tests, with the readings of pocket penetrometer for same samples. Pocket penetrometer is a simple tool that can be easily used in field and laboratory to initially predict unconfined compressive strength for clayey soils. Before carrying out the consolidation tests on undisturbed samples, pocket penetrometer readings were recorded. The correlation obtained between pocket reading and σ_c values that resulted from consolidation tests was found to be valid for a wide range of clay stiffness, ranging between medium stiff to very stiff clay. As for soft clay, this correlation was found not to be applicable where its behavior is believed to be greatly affected by the degree of disturbance occurring to samples during drilling.

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Introduction

Pre-consolidation pressure σ_c is an important parameter, which expresses the stress history of soil especially for the behavior of cohesive soil. It is well known that accurate estimation of settlement of cohesive soil depends to large extent on the accurate value of σ_c. Many researchers did their best for how one can estimate σ_c from the results of consolidation tests. Moreover several researchers tried to predict σ_c from empirical correlations depending on soil properties such as moisture content, Atterberg limits, void ratio, shear strength and overburden pressure. Cone penetration test was widely used to estimate σ_c to overcome the disadvantages of disturbances, which occurred during drilling and when carrying out laboratory tests. The concept of pre-consolidation pressure and its importance is well defined in geotechnical engineering for calculating settlement. Pre-consolidation pressure, σ_c is commonly defined as the highest pressure to which the soil had been exposed in the past. Consolidation test results are considered the main laboratory test that can be used for determining the value of σ_c. Several researchers established different methods for obtaining σ_c from the consolidation tests. Casagrande [1]

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Peer review under responsibility of Housing and Building National Research Center.

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http://dx.doi.org/10.1016/j.hbrcj.2015.02.003
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Please cite this article in press as: A.H. Hammam et al., On the evaluation of pre-consolidation pressure of undisturbed saturated clays, HBRC Journal (2015), http://dx.doi.org/10.1016/j.hbrcj.2015.02.003

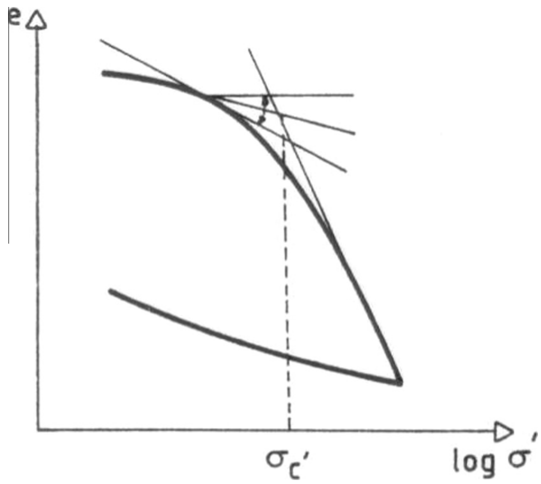

Fig. 1 Casagrande method for estimating pre-consolidation pressure.

is the oldest and most commonly used method based on the relation $e - \log \sigma'$, as shown in Fig. 1. This relation shows that the soil is under elastic behavior up to a certain pressure then it starts plastic behavior. According to the break point between the two behaviors, one can estimate σ_c graphically. Good results can be obtained if the break point is well defined on the curve $e - \log \sigma'$. In general, this curve is affected by the degree of sample disturbance, as shown in Fig. 2. Many researchers developed other methods depending on Casagrande method or new ones to define σ_c [2,3], as shown in Table 1.

Schmertmann method, $e - \log \sigma'$ [4] was an attempt to compensate the effect of sample disturbance by adjusting the results of consolidation test, as shown in Fig. 2.

Butterfield method [5] is based on plotting the variation between effective stress and volume change of specimen, $\log(1+e) - \log \sigma'$ or $\ln(1+e) - \ln \sigma'$. The pre-consolidation pressure is defined as the intersection point of the two straight lines.

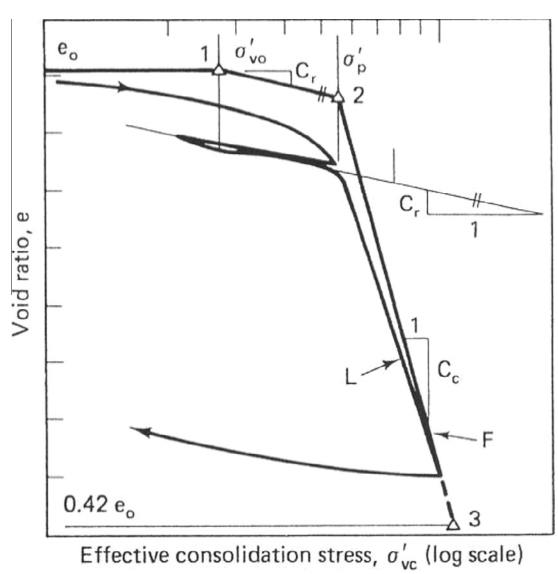

Fig. 2 Schmertmann method for predicting sample disturbance.

Pre-consolidation pressure is affected not only by sample disturbance, but also by load durations and load increment ratios during testing [10,11]. Al-Zairjawi [2] carried out experimental study and he concluded that the values of σ_c decreased as load durations and load increment ratios increased.

Correlations of pre-consolidation pressure

"Settlement analysis – the backbone of Foundation Research", said Terzaghi in 1929 [12]. It is well known that the accuracy of determining the consolidation settlement is considered the corner stone of estimating the total settlement of cohesive soil. Therefore, over past decades researchers developed several approaches to define the factors included in the consolidation equations. The amount of settlement depends mainly on three unknown factors that are included in the settlement equation, among them are compression index C_c or re-compression index C_r, void ratio e and pre-consolidation pressure σ_c. For saturated soil, void ratio can be estimated from moisture content W_c and specific gravity G_s. Moreover, Bowles [13] reported several correlations for estimating C_c (accordingly C_r) from simple soil properties such as moisture content and Atterberg limits. Hammam and Abdul-fadiel [14] have established a new correlation to estimate C_c from moisture content ($C_c = 1.38\ W_c - 15$). On the other hand, to overcome the complicated defects related to estimating σ_c from consolidation test researchers tried to develop empirical correlations between σ_c and some of soil properties. There are few correlations in the literatures among them are as follows:

– Nagaraj and Srinivasa [15] established the following correlation:

$$\log \sigma_c = 5.97 - 5.32\ (W_c/W_L) - 0.25 \log \sigma'_{vo} \quad \text{[kPa]} \quad (1)$$

– Solanki and Desai [16] developed new correlation as follows:

$$\sigma_c = 137.924 - 0.179\ \sigma'_{vo} - 30.48\ (e/e_L) \quad \text{[kPa]} \quad (2)$$

where e = void ratio, e_L = void ratio at liquid limit (W_L), σ'_{vo} = effective over burden pressure.

By examining the above correlations, it can be noticed that the first one depends mainly on the ratio (W_c/W_L) which can be considered as an indication of soil stiffness and hence it can be valid for certain soil conditions. While the second correlation assumed that value of σ_c should be less than certain value (137.924 kPa). Moreover, the authors themselves reported that this correlation depended on data of alluvial deposits of south Gujarat region.

Several researchers considered that the best estimation can be developed from the field tests especially cone penetration tests, *CPT*. Therefore, pre-consolidation pressure σ_c could be expressed by the following simple formula (after Mayne et al.) [17]:

$$\sigma_c = 0.33(q_t - \sigma_{vo}) \quad \text{[kPa]} \quad (3)$$

where q_t = total cone tip resistance, σ_{vo} = total overburden pressure.

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