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# Simplified reliable prediction method for determining the volume change of expansive soils based on simply physical tests

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**KEYWORDS**

Expansive soils;
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**Abstract** Expansive soils widely exist at different locations in nearly all new construction sites in Egypt. This type of soil exhibits significant change in volume when subjected to water, leading to distortions in the structures and therefore huge monetary losses due to repair and in some cases to full removal of the structures.

An oedometer test is the widely used and most accurate apparatus that measures the volume change of the natural expansive soils. This traditional test needs high effort, high cost, and long time consuming to carry out causing true difficulties to execute a large number of swelling tests within the same time as essential requirements of the large projects. Thus, several researchers worldwide have made significant contributions through past long years to better obtain prediction of volume change behavior in natural expansive soils. Reliable and satisfied prediction occurs when its result is being so close to the results obtained by the oedometer apparatus.

The current study introduces a novel approach of considerable positive reliable prediction for volume change behavior in expansive soils by using only the results of some simply executed standard physical tests.

The approach philosophy is to significantly facilitate the efforts exerted by geotechnical engineers to determine reliable results of the mechanical properties for an enormous amount of expansive soil samples that suits the project needs which are hard to obtain by the ordinary experimental work by the oedometer apparatus only.


## Introduction

Practicing engineers rely on using a variety of design and stabilization techniques to reduce losses associated with construction over expansive soils [1]. The success of these recommendations depends on key information of the behavior of the volume change which has been created to the inundated

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expansive soils. Due to these reasons, the construction recommendations over these types of significantly problematic soils have been one of the greatest challenges to practicing engineers [2].

An oedometer test is a sort of geotechnical investigation performed by geotechnical engineers that measures most accurate results of mechanical properties of the soaked expansive soil samples. As a result, this traditional test takes into consideration all the essential factors which affect considerably the swelling of such type of soils. These factors are mainly concerned with the physical properties of the particles and the mass of the soil such as, initial moisture content, type of clay mineral, initial dry density, clay content, and types of non-clay minerals as lime, gypsum, silt, iron dioxide, and sand [3].

The oedometer test needs high effort, extreme care for proceeding its steps, long time consumption, and high cost especially when a large number of tests must be carried out within a limited time frame according to the construction project needs. Thus, in practice geotechnical engineers are occasionally challenged with establishing an effective method for reliable determination or estimation of the swelling pressure and the heave percentage of the expansive soils. However, it has proven to be difficult to date.

There have been lots of various empirical methods over the past long years that are available to predict the swelling behavior of the expansive soils. These methods are developed on limited data collected on local soils or soils from a certain region. Ignoring any item of the above mentioned factors has largely been unsuccessful in establishing criteria related to performance. Table 1 summarizes the list of the most common used methods which are concerned with the prediction of swell percent and swelling pressure of the expansive soils. Table 1 can be classified into two categories: the first one includes those methods which correlate the swell percent and swelling pressure to some of physical properties such as liquid limit, plasticity index, clay content, and type of clay minerals represented by clay activity; the second category includes these factors mentioned in the first category as well as the initial dry density [4].

Snethen [23] and Zein [24] confirmed that, it is difficult, if not impossible to express all the above mentioned factors affecting considerably the volume change behavior in expansive soils in one formula or a relationship. Thus, the agreement or discrepancy between the predicted results and the actual values was mostly unsuccessful. It is expected that the category (1) methods shown in Table 1 will predict deformations too far from the actual. The reason is that such methods ignore the soil structure which is the most considerably essential factor that governs the amount of deformation of the expansive soils. Prediction methods include the dry density as the parameter that will produce better results. The soil structure is expressed in Table 1 by the dry density ($\gamma_d$) or by the void ratio ($e$).

Elarabi [25] presented an approach that is concerned with the comparison of the most predicted equations which are established before that year shown in Table 1 and the experimental results by oedometer apparatus for three expansive soil samples. The percentage errors (discrepancies) between them vary from 14% to 91.6% for the swell percent and vary from 37.4% to 505.6% for swelling pressure. Therefore, he confirmed that the obtained results from the different predicted equations varied and also in many cases appeared to be so far than the measured values. He also confirmed that the most reliable approach for predicting the behavior of potentially expansive soils is the direct measurement of swelling.

As shown in Table 1, Zumarawi [22] developed two empirical equations for determining both swell percentage and swelling pressure depending upon the initial state factor ($F_i$) which is defined as follows:

$$F_i = [\gamma_d/\gamma_w] * [1/(w.e)]$$

where

$\gamma_d$: dry density.
$\gamma_w$: water density.
$e$: void ratio which can be calculated using the equation: $e = (G_s/\gamma_d) - 1$.
$G_s$: specific gravity of soil.

Based on Zumarawi approach, the percentage errors (discrepancies) between the measured and calculated values vary from 5% to 54% for the swell percent and vary from 10% to 67% for swelling pressure. These error values in this approach indicate that there is relatively good agreement than the previous approaches mentioned previously by Elarabi [25].

Hence, the main objective of the current study was to set tangible criteria for performance based on taking all main factors mentioned before by Sohby [3] for determining reliable results with significantly good agreement with that obtained by oedometer for the expansive clays. The obtained results are axial free swell (AFS) in percentage using vertical stress 1 psi (0.07 kg/cm$^2$) and also swelling pressure in kg/cm$^2$. Thus, this current approach is set to aid practicing geotechnical engineers for taking a reasonable decision to predict considerably reliable results of the volume change behavior of the expansive soils that suit the project needs without going through tedious efforts, time consuming and high cost accompanied by using the standard oedometer test especially when a large number of tests are required for the project needs.

## Experimental work

As discussed above, there is no simple and reliable correlation between swelling characteristics and the main factors mentioned before available to date. Based on that, a new method is established in this study to predict the percentage of axial free swell and swelling pressure by executing only some of the very simple physical tests. To achieve this objective, fifteen expansive soil samples were collected from different locations in Egypt which covers a wide range of the physical properties of that type of this problematic soil and consequently its mechanical properties.

The scope of the current study has been vigorously established by carrying out the two parallel procedures through the same time for each sample. The **first procedure** was executed for obtaining the AFS in percentage and SP in kg/cm$^2$ by using the oedometer apparatus in accordance with the standard test procedure using ASTM D-4546-03 for one dimensional swell. The tested sample was first allowed to its complete swell under the stress 1.0 psi (0.07 kg/cm$^2$) followed by consolidation under increasing loads until the sample reached its initial volume to obtain its corresponding value of swelling pressure. The **second procedure** incorporates some of the simplest physical tests as initial moisture content, initial dry density, and Atterberg' limits (liquid and plastic limits