Ain Shams Engineering Journal (2013) 4, 423–433

Ain Shams University

Ain Shams Engineering Journal

www.elsevier.com/locate/asej
www.sciencedirect.com

CIVIL ENGINEERING

GIS and geotechnical mapping of expansive soil in Toshka region

Mary Labib [a], **Amani Nashed** [b,*]

[a] *National Water Research Center, Construction Research Institute, Cairo, Egypt*
[b] *National Water Research Center, Survey Research Institute, Cairo, Egypt*

Received 21 January 2012; revised 16 November 2012; accepted 22 November 2012
Available online 6 April 2013

KEYWORDS

Swelling pressure;
Atterberg limits;
Clay content;
Geographic Information System (GIS);
Spatial analysis

Abstract This paper presents the results of a subsurface site investigation that was performed to characterize different soil and rock formations along Sheikh Zayed canal with particular emphasis on the swelling characteristics of the clays in that area. Site-specific empirical correlations were developed to predict the clay swelling potential and pressure from simple and economic laboratory test results. The data were input into a Geographic Information System (GIS) framework to provide interactive maps that show the spatial distribution of the variables and identify their characteristics. These maps are then used to easily identify the values of swelling pressure/potential at various locations. This research provides a tool that is based on simple index tests that can be used to provide data that otherwise would require elaborate and costly investigations; the GIS framework allows storing, retrieving and updating these data easily to assist taking supported decisions dynamically.

1. Introduction

Expansive clay beds are widespread all over Egypt. They are considered problematic soils due to their volumetric changes upon moisture content fluctuations [7,13,34,4,23,43]. The main factors governing the swelling potential as well as the swelling pressure of expansive soil, are the mineralogical composition and clay size fraction [30,29,32,18].

Direct and indirect techniques have been developed for better classification of the degree of volume change. The parameters used to estimate the swelling potential and swelling pressure include Atterberg limits, colloidal content and clay activity [2].

The oedometer test is a successful tool to measure swell potential and swell pressure [11,14,22]. Other methods that successfully estimate the percent of swelling includes chemical [12,6] and mineralogical analyses.

Due to the difficulty of extracting "undisturbed" soil specimens for testing, great attention is given to empirical investigations of the swelling behavior of the natural soils that are based on testing "disturbed samples" [9,17,33,20,37]. As a result of

* Corresponding author. Tel.: +20 122 311 21 50.
E-mail addresses: mslabib@hotmail.com (M. Labib), nashedamani@yahoo.com (A. Nashed).

Peer review under responsibility of Ain Shams University.

Production and hosting by Elsevier

2090-4479 © 2012 Ain Shams University. Production and hosting by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.asej.2012.11.005

these investigations, several empirical correlations have been proposed [28] that relate the swelling behavior to certain physical properties of soils such as consistency limits and clay content; all of which are easily obtained from testing disturbed samples. These empirical equations are easy to apply and give satisfactory results [15].

This research was thus put onto track, in order to develop empirical relationships between swelling potential, swelling pressure, plasticity index and clay content for clay from Toshka region in Upper Egypt. The empirical relations are derived from experimental investigations carried out on a large number of soil samples representing a wide variation of clay contents and consistency limits, from El-Sheikh Zayed canal. The steps of the present investigation are presented in this paper.

The literature was first reviewed to be aware of the available formula in the field of interest. A study area was chosen and described. The study area was visited and field measurements so as sampling were undertaken. Laboratory examinations were carried out in order to analyze the obtained samples. Based on the examination results, empirical formulae were established.

These empirical relations are used as a tool for identifying the soil activity in the region and mapping the study area. The large volume of data concerning the bore holes properties needs to be stored, managed and visualized and this is best done by a Geographic Information System (GIS) in an integrated geographic framework.

Moreover, a customized GIS program can provide detailed maps for the different variables used in defining the swelling pressure as well as any other parameters of choice.

A geo-database is designed to store the location, Atterberg limits, soil formation, free swelling and the calculated swelling pressure for each collected sample studied in this research. This analysis approach was adopted recently to the soil in Harran plain located in the South East of Turkey [40,41] where the swelling behavior of clayey soils was studied by using Geographical Information System (GIS) including liquid limit (LL) and plasticity index (PI) contour maps. Moreover, the values of swelling percentages determined for soil located in this area are used to obtain the swelling potential hazard map by means of a customized GIS program. It is expected that this map will be a useful tool for planners and engineers in their efforts to achieve better land-use planning and decide necessary remedial measures. Similarly, this research introduces the most valuable property of GIS, ability to provide an interactive map, to the Toshka region. This map can be used in future work in the region and provide decision makers with a reliable and convenient tool to evaluate the soil properties and help them take decisions on the feasibility of executing new national projects in Toshka region, with due consideration to the actual soil properties; this also applies to any future modifications of existing structures or any possible future field variations.

2. Literature review

The literature was reviewed in order to perceive an insight about the available formulas that focused on predicting swelling potential or swelling pressure. Moreover the literature review demonstrated the capability of using GIS in addressing geotechnical problems.

From the reviewed literature it was found that:

Seed et al. [33], investigated, artificially prepared compacted soils, (i.e. clay mineral) and obtained the following equation:

$$S_p = K(A^{2.44})(C^{3.44}) \quad (1)$$

where S_p is the swelling potential in percentage; C the clay content in percentage; A the activity of soil = I_p %/C % and K the a constant for all types of clay minerals = 36×10^{-5}.Seed et al. [33] reported that plasticity index (I_p) is a suitable factor for predicting swelling potential. The study carried out by Seed et al. [33] gave reasonable results when compared with actual soil conditions. One criticism to this method is that the volume change was measured on samples prepared from commercial grade clay minerals and may not accurately represent in situ material behavior because of the variation in composition of most soils. They gave the following relationship:

$$S_p = (K)(M)(I_p^{2.44}) \quad (2)$$

where M is the 60 for natural soils 100 for artificial soil and I_p the plasticity index in.

Ranganatham and Satyanarayan [28] proposed the following equation:

$$S_p = m_1(S_I)^{2.57} \quad (3)$$

where S_p is the swelling potential in percentage; m_1 the constant = 41.13 and S_I the shrinkage index = (liquid limit − plastic limit)/liquid limit.

Sowers and Kennedy [37] carried out swelling pressure tests on undisturbed samples and gave the following relationship:

$$\text{Log}(P) = 2.132 + 0.208(\text{LL}) + 0.000665(\gamma_d) - 0.0269(w_o) \quad (4)$$

where P is the swelling pressure in kg/cm^2; LL the liquid limit in percentage; γ_d the natural dry density in kg/cm^3 and w_o the natural water content in percentage.

Pidgeon [24] predicted the swelling pressure (P) and developed a correlation for swelling and swelling pressure as follows:

$$P = 2.7 - (2.4e_o/I_p) \quad (5)$$

$$F = 1.38P - 1.8w_o \quad (6)$$

$$\text{Log}\,P = 3.45 - 63e_o/I_p \quad (7)$$

where P is the swelling pressure of clay in kPa; F the free swelling of the clay in percentage; e_o the clay initial void ratio and I_p the plasticity index.

Komornic and David [15] provided a statistical comparison with measured data and provided a relationship for predicting swelling pressure using liquid limit, natural dry density, and natural moisture content as follows:

$$\text{Log}\,P = -2.132 + 0.0208(\text{LL}) + 0.000665(\gamma_d) - 0.0269(w_o) \quad (8)$$

where P is the swelling pressure of clay in kg/cm^2 and γ_d the natural density in kg/cm^3.

Vijayvergiya and Ghazzaly [42] expressed the swelling potential as follows:

$$\text{Log}\,P = 1/12(0.44LL - w_o - 0.4) \quad (9)$$

The method is based on data collected from a wide variety of samples and is very simple to use, this means that all that is required is the natural water content and liquid limit. However, experience with regard to application of the method is relatively limited.