International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 5 Issue 12, December-2016

Swelling Potential of AL-Ghat Compacted Soil

Abdulhafiz Alshenawy[1], Mohammed Almahbashi[2], Abdulmuhsin Dhowian[3]

[1,2,3]Civil, Department, King Saud University, Riyadh, Saudi Arabia

ABSTRACT

This paper presents a relationship between the swelling potential of compacted soil and the variation of dry density and water content of the soil. The swelling potential values measured by Odometer test for AL-GHAT compacted expansive soil in Saudi Arabia. Measuring free swelling considered as time consuming, so presenting strong expression to predict swelling potential is very important. The comparison of the results of presented relationship and the measured values proved the strength and reliability of the proposed expression.

Keywords: Expansive soil, compacted soil, swelling potential, Odometer.

1. INTRODUCTION

Expansive soils exists in several regions in the world. Saudi Arabia is one of the places where the most regions are semiarid. Expansive soils are soils that expand when water is added, and shrink when they dry out. This continuous change in soil volume can cause homes built on this soil to move unevenly and crack. These soils caused damage for infrastructure exceeds the natural disasters [1,2]. These types of soil are often cause problems of the buildings above such as cracking of pavements, ground heaving, differential settlement and canal linings [3]. In Saudi Arabia, expansive soils were responsible for millions of dollars worth of damage to man-made structures [4].

The swelling of soils generally is due to the presence of expansive clay minerals, hydration of cations on clay surfaces, and release of intrinsic stresses caused by over consolidation or desiccation of soils [5]. Many investigations were carried out to analyze the factors affecting the swelling of clayey soils [6-8]. The major factors affecting the swelling of such soils are mainly concerned with the physical properties of the particles and the mass of soil, such as initial dry density, initial water content, clay content, , type of coarse grained fraction and type of clay mineral [8].

When the water content of the clay changes the volume expansion occurs. Slight increase of water content, in the magnitude of only one to two percent, is sufficient to cause detrimental swelling. The initial water content of clay also controls the amount of swelling [9]. When natural water content is less than 15 %, dry clay with liquid limit more than 60 % and plasticity index more than 35 % usually indicates risk [2,10].

Soils which the plasticity low to medium were originally compacted at a higher density and lower water content, could swell appreciably and be applied high swelling pressure to the adjacent structures[11]. Swelling potential of clay decrease as the initial water content at the same dry unit weight increases. Also when dry unit weight increases, swelling increases. Soils with dry unit weights in excess of 17.62 kN/m3 generally exhibit high swelling potential [4,2]. Swelling potential can be reduced appreciably by increasing compaction water content by 2–3 % with respect to optimum water content and by decreasing soil density to 92–95%of maximum dry unit weight [11].

Swelling soils are described as soils which show considerable amount of volume increase when subjected to water. The conventional one-dimensional odometer swell tests are performed using three different procedures: free swell, swell under certain overburden pressure and constant volume swell [12]. Now, the most common method of swelling soil identification is the free swell procedure in a standard odometer by the ASTM D 4546 standard [11]. Swelling potential is known as an indicator of magnitude of the swelling. It can be defined as the equilibrium vertical volume change obtained from odometer-type test, expressed as a percent of the original height.

Many studies have worked to find the relationships between the swelling parameters and the initial condition of soils but each study has limits for application to certain soils.

Erguler and Ulusay [13] developed relationships for Ankara remolded samples:

$$Sp = -33.87 + 034LL + 3.3\ \gamma_d + 0.77w_c \qquad (1)$$

Çimen et al. 2012 [9] developed relations of swelling potential for compacted soils from Turkey region at dry side:

$$Sp = (0.3139\gamma_d^{0.3552} - 0.1177 w_c^{0.4470}) PI^{0.9626} \quad (2)$$

and at the wet side as:

$$sp = \left(0.4768\gamma_d^{0.3888} - 0.0033 w_c^{1.6045}\right) PI^{0.7224} \quad (3)$$

Sp: swelling potential (%)
PI: plasticity index (%)
w_c: initial water content (%).
γ_d: dry unit weight (kN/m3).

Vijayvergia and Ghazzaly [14] suggested a relationship of swelling percent with initial water content and liquid limit as in (4):

$$Log\ Sp = (0.44LL + -w_c + 5.5)/12 \quad (4)$$

Vijayvergia and Sullivan [15] developed a relationship with density and liquid limit with dry density as in (5):

$$LogSp = 0.0526\gamma_d + 0.033LL - 6.8 \quad (5)$$

γ_d: lb/ft3
LL: liquid limit

Seed [16] found the oldest relationship for swelling potential depend on plasticity index for undisturbed soils. The formula is:

$$Sp = 0.00216PI^{0.244} \quad (6)$$

For disturbed soils:

$$Sp = 0.0036PI^{0.244} \quad (7)$$

Nayak and Christensen [17] found relationships depend on the water content and the plasticity index as in (8):

$$Sp = (0.00229PI^{1.45} / w_c) + 6.38 \quad (8)$$

Schneider and Poor [18] linked the swelling by water content plasticity index as:

$$Log\ Sp = 0.9PI / w_c - 1.19 \quad (9)$$

Chen [2] proposed formula for compacted soil with range of density (15.7-17.3 KN/M^3) and water content (15 − 20%). The formula is:

$$Sp = 0.2558e^{0.0838PI} \quad (10)$$

Weston [19] found a formula depend on account the liquid limit in a corrected way. The formula is:

$$Sp = 0.000195\ LL^{4.17} w^{-2.33} \quad (11)$$

Another proposed formula taking account the clay content such as Basma equation [20]:

$$Sp = 0.00064PI^{1.37} C^{1.37} \quad (12)$$

Sabtan [21] proposed formula that take into account the water content, clay content and plasticity index as in (13):

$$Sp = 1.00 + 0.06(PI + C - w_c) \quad (13)$$

Komine and Ogata [3] suggested a formula for compacted bentonite as in (14):

$$Sp = (k\gamma_d - 1)*100 \qquad (14)$$

K: constant.

In this research attempt to find a relationship between swelling potential with change initial condition of AL-Ghat compacted soil by free swell odometer method.

2. EXPERIMENTAL STUDY

The soil taken from AL-Ghat city in Saudi Arabia is located about 270 km north of Riyadh Capital, which is known as expansive soil region as shown in Fig. 1. The physical properties of the soil as shown in the table (1). To determine swelling potentials of compacted clay, ASTMD4546 free swelling method was used as experimental procedures [12].

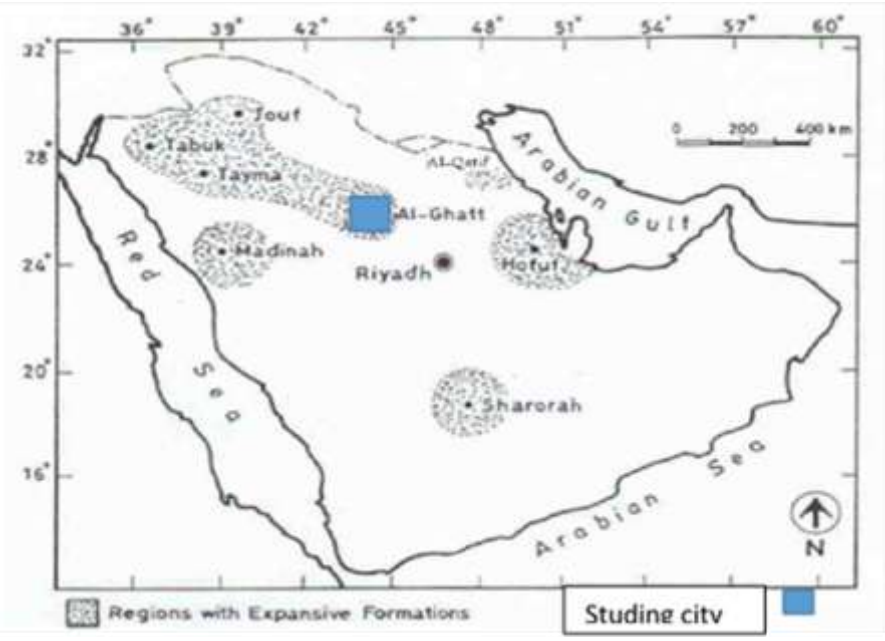


Figure 1. Map of distribution of the expansive soil in KSA

The samples were crushed and sieved through ASTM sieve No. 40 (0.425 mm). Then, they were oven dried, after that they were mixed with water to obtain the initial water contents (0, 8, 16, 20, 24 and 28%).

Samples were compacted by jack in conventional odometer cells with 2cm height and 7 cm diameter to obtain initial dry density 1.64,1.56 and 1.48 gm/cm3. Soil samples placed into odometer cell were allowed to swell freely during the inundation at seating pressure 7 kPa.

Table 1 Physical properties of the soil

Physical Property	values
Liquid Limit (%)	62
Plastic Limit (%)	30
Plasticity Index (%)	32
Finer than 200 µm(%)	78
Specific Gravity	2.83
USCS Classification	CH

The amount of swelling was measured from the vertical deformation dial gauge. The durations of completing swelling for 72 hours. At the end of this period, final swelling value did not changed and this value was used to determine the swelling potential. Curves of free swelling versus time at different water contents as shown in Fig.2-4.

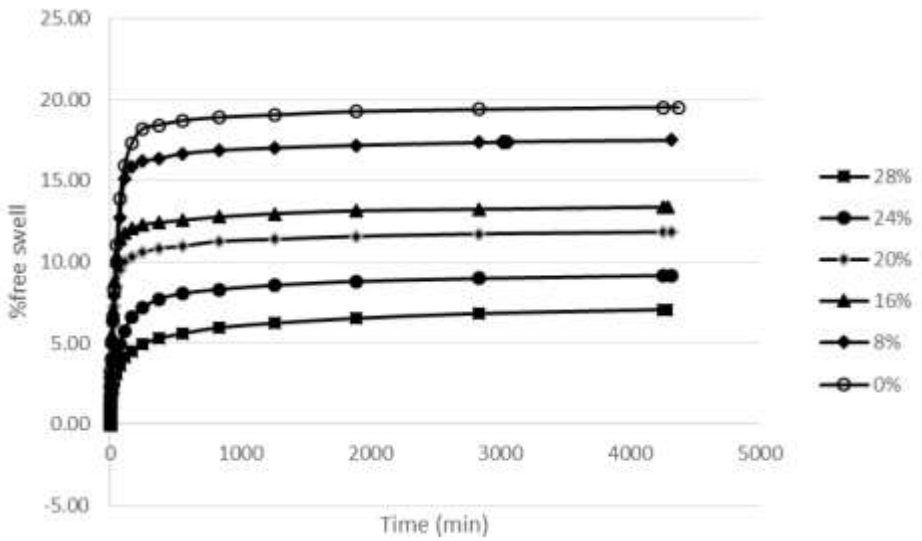


Figure 2 Swelling vs Time for γ_d=1.64gm/cm3 at different water content.

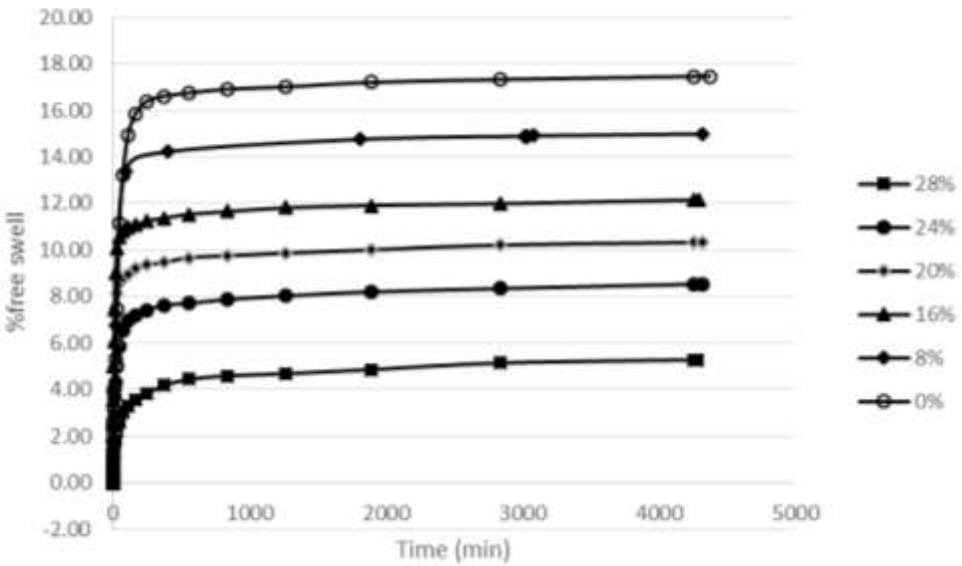
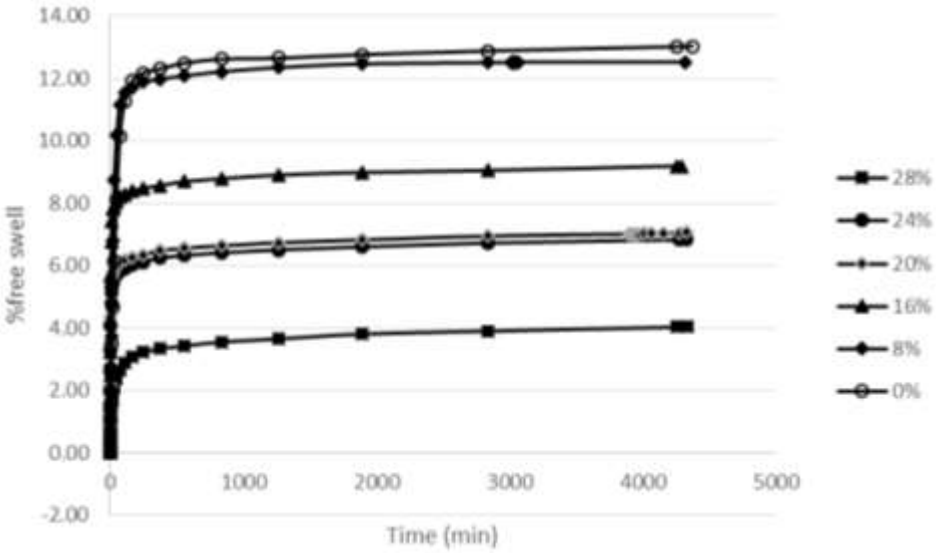


Figure 3. Swelling vs Time for γ_d=1.56 gm/cm3 at different water content.



b

Figure 4 Swelling vs Time for γ_d=1.48 gm/cm3 at different water content.

3. RESULTS AND DISCUSSION

The results of swelling tests obtained for samples given in Table (2). It is seen from this table that for any constant dry unit weight, potentials decrease when the initial water content increases; therefore, constant initial water swelling potential increases when the dry unit weight increases.

Table 2 Result of swelling potential

γ_d (G/CM3)	WC%					
	0	8	16	20	24	28
1.64	19.51	17.49	13.38	11.86	9.15	7.09
1.56	17.47	14.99	12.16	10.36	8.54	5.28
1.48	13.04	12.53	9.42	7.06	6.85	4.03

From the result found that the soils compacted at different water contents and dry densities produce different soil structures, which have different swelling. So using this parameters for prediction of swelling soil of this soil were considered.

Also the results of testing found the relation (R^2 =97.4%) between swell potential with dry density and water content as in (15) for change water content and optimum dry density until 90% dry density.

$$Sp = (5.552\gamma_d^{2.47} - 0.08729 w_c^{1.454}) \qquad (15)$$

Sp: swell potential %
γ_d: dry density (gm/cm^3)
w_c: water content %

The Comparison of measured and predicted swelling potentials of soil is shown in Fig. 5 for change water content and optimum dry density until 90% dry density.

Also from curve of swelling deformation found that the early swelling deformation rate increases as the dry density decreases but in the final swelling is opposite as stated in [3].

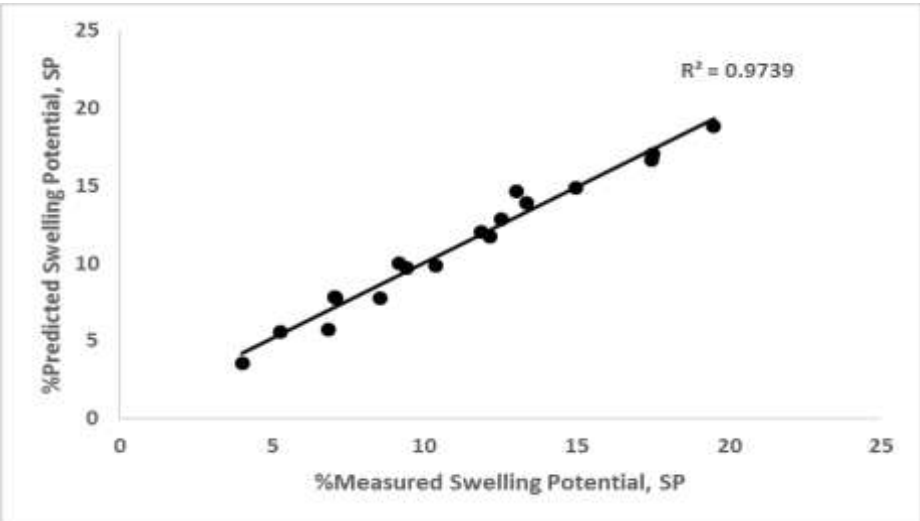


Figure 5. Comparison of measured and predicted swelling potentials (Equation 15)

CONCLUSION

A relationship to expect the swelling potential of AL-GHAT compacted soil is proposed by the free odometer test. The proposed expression were obtained by the regression technique from the experimental. For any increase in water content at the same density, swelling potential decreases. In addition, swelling potential increases with increasing dry density. The expression is valid for the dry density interval [1.64,1.48] g/cm3 and water content less than 28%.

REFERENCES

[1]. Jones, D.E.; Holtz, W.G.: Expansive soils–the hidden disaster. Civil Eng. 43(8), 49–51 (1973).

[2]. Chen, F.H.: Foundations on expansive soil. Elsevier, New York (1988).

[3]. Komine,H.; Ogata, N.: Experimental study on swelling characteristics of compacted bentonite. Can.Geotech. J. 31, 478–490 (1994).

[4]. Dhowian, A.W.; Erol, A.O.; Youssef, A.: Evaluation of Expansive Soils and Foundation Methodology in the Kingdom of Saudi Arabia. Saudi Arabia, Final Report: SANCST, AT-5–88 (1985)

[5]. Dhowian A., Orhan Erol, and Abdulfattah, Y., 1988. Evaluation of expansive soils and foundation methodology in the kingdom of Saudi Arabia, King Abdulaziz City for Science and Technology, Riyad.

[6]. Al-Mhaidip, A., 1999. Swelling behavior of expansive shales from the middle region of Saudi Arabia. Geotechnical and Geological Engineering, Vol. 16, pp. 291-307.

[7]. Azam, S. and S.N. Abduljauwad, 2000. Influence of gypsification on engineering behavior of expansive clay. Journal of Geotechnical and Geoenvironmental Engineering, Vol.126, No. 6, pp. 538-542.

[8]. El- Sohby, M.A. and A. R. El-Sayed, 1981. Some factors affecting swelling of clayey soils. Geotechnical Engineering, Vol. 12, pp. 19-39.

[9]. Çimen, Ömür, S. Nilay Keskin, and Hüseyin Yıldırım. "Prediction of swelling potential and pressure in compacted clay." Arabian Journal for Science and Engineering 37.6 (2012): 1535-1546.

[10]. Snethen, D.R.: Evaluation of expedient methods for identification and classification of potentially expansive soils. In: Proceedings of Fifth International Conference on Expansive Soils, Institution of Engineers, Adelaide, pp. 22–26 (1984).

[11]. Rahimi, H.; Baroothoob, S.H.: Concrete Canal Lining Cracking in Low to Medium Plastic Soils. Irrigat. Drainage 51,141–153 (2002).

[12]. ASTM.: Standard Test Method for One-Dimensional Swell or Settlement Potential of Cohesive Soils. Annual Book of ASTM Standards, D 4546-90, 04.08: 853–859 (1993).

[13]. Erguler, Zeynal Abiddin, and Resat Ulusay. "A simple test and predictive models for assessing swell potential of Ankara (Turkey) Clay." Engineering Geology 67.3 (2003): 331-352.

[14]. Vijayvergia, V.N.; Ghazzly, O.I.: Prediction of swelling potential for natural clays. In: Third International Conference on Expansive Soils, vol. 1, pp. 227–236 (1973).

[15]. Vijayvergia, V.N.; Sullivan, R.A.: Simple technique for identifying heave potential. In: Proceedings ofWorkshop on Expansive Clays and Shales, vol. 2, pp. 149–154 (1973)

[16]. Seed, H.B.;Woodward, R.J.; Lundgren, R.: Prediction of swelling potential for compacted clays. J. Soil Mech. Found. Div., ASCE 88(6), 107–131 (1962).

[17]. Nayak, N.V.; Christensen, R.W.: Swelling characteristics of compacted expansive soils. Clay Clay Miner. 19(6), 251–261 (1979).

[18]. Schneider, G.L.; Poor, A.R.: The Prediction of Soil Heave and Swell Pressures Developed by an Expansive Clay. Contraction Research Center, University of Texas, Research Report TR-9-74 (1974).

[19]. Weston, D. J., 1980. Expansive roadbed treatment for Southern Africa. Proceedings of the Fourth International Conference on Expansive Soils, Denver, Colorado.

[20]. Basma, A.A.: Prediction of expansion degree for natural compacted clays. Geotech. Test. J. 16(6), 542–549.

[21]. Sabtan, A.A.: Geotechnical properties of expansive clay shale in Tabuk, Saudia Arabia. J. Asian Earth Sci. 25, 747–757 (2005).