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EXPERIMENTAL STUDY ON THE EFFECT OF LATERAL SWELLING PRESSURE OF EXPANSIVE SOIL ON RETAINING STRUCTURE

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Received 12 September 2013; accepted 13 November 2013

ABSTRACT

The lateral swelling of expansive soil on retaining structures investigation is very important for civil engineer .The used soil in this research is obtained from Assiut el gadida city projects; Assiut, Egypt .It contains SiO2, AL2O3 and Fe2O3 as main oxides.

For this research the physical and mechanical properties of soil are obtained, the purpose of the present paper is examining the phenomenon of lateral swelling pressure developed in clay soils after adding water to it. Also suggest useful means to predict the magnitude and distribution of those pressures for use in retaining structure design.

The behaviour of soil is swelling after adding water then affects on retaining structure. The effect of soil is depending on many factors as water content, depth, the type and quantity of mineral in soil composition, the time… etc.

The results showed that the swelling pressure on retaining structure increases by increasing the depth at soil up to depth equals 60cm and decreases beyond that. Also, the maximum swelling pressure occurred after 48 hours measured from adding water to expansive soil.

Keywords: Lateral swelling, expansive soil**,** Assiut el gadida city

1. Introduction

The swelling of highly plastic clays has resulted in severe damage to lightly loaded structures, such as houses, warehouses, small industrial buildings, and pavements in several areas of the world as shown in Photo 1.They exist in the United States, Australia, Africa, the Middle East area, and India.

Photo 1. Some Problems due to expansive soils (Mark G. Thomas 2008)

Although many researches and studies have been directed to expansive soil, the basic problem is how to deal with highly loaded structures on swelling soil remains unsolved. A practical method is how to design a structure that will be safe against heave within economical reach has yet to be found (Chen 1975).Distribution of expansive soil is generally a result of geological history, sedimentation and local climatic conditions. Arid climatic conditions and severe weathering environment prevailing in north eastern part of Africa promote the widespread occurrence of expansive soils in this region.

The expansive soil applies to soils, which have the tendency to swell when their moisture content is allowed to increase (El-Sohby and Rabba, 1981; Wayne et al. 1984; Chen et al. 1985; Mowafy et al. 1985; Popescu, 1986; Gens and Alonso, 1992; Sivapullaiah, 1996). The moisture may come from rain flooding, leaking water or sewer lines. Soils containing the clay mineral montmorillonite (a smectite) generally exhibit these properties (Wayne, 1984; Komine and Ogata, 1996). It cause cracking and break-up of pavements, railways, highway embankments, roadways, building foundations, slab-on-grade members and, channel and reservoir linings, water lines, sewer lines (Gromko, 1974; Wayne et al. 1984; Mowafy et al. 1985; Kehew, 1995).

Expansive soils swell laterally as well as vertically. Lateral volume changes will be accommodated by the cracks and fissures if there are cracks and fissures in the soil mass. However, when there are no cracks or when the cracks are very small and close up without accommodating all of the volume increase that is required by the expansive soil, the swelling soil becomes restrained in the lateral directions Aytekin, M.,(1992).

The result of this restrained case is the development of a lateral swelling pressure. The magnitude of this swelling pressure could be very high; Chen (1975) reported that lateral swelling pressure as high as 21.53kg / cm^2 could be obtained. The study of lateral swelling pressure might be twice that of the vertical swelling pressure (Andy, 1989), and another showed that the lateral swelling pressure was ten times larger than the vertical proposed by Coulomb (1776).

A number of subsequent prediction methods have been proposed, Coulomb's (1776) and Rankine's (1857) methods are more swelling pressure at a depth of 11in. (0.28m.) has been reported (Joshi and Katti, 1980).Prediction of lateral earth pressures has been a problem to civil engineers for a long time. The first rational approach by which lateral earth pressures could be estimated was simple and practical, and they have come to be known as the classical methods of prediction of lateral earth pressure.

Types of wall failure and wall distress can be seen in Photo 2. Some of these failures can be attributed to construction outside of the original design criteria (Marsh and Walsh, 1996), particularly the use of cohesive backfill as a substitute for granular backfill materials. The main reasons that cohesive materials are ever considered for use in these situations are always economic.

Photo 2. Wall Failure along Dam Spillway (Mark G. Thomas 2008)

Therefore, classical methods cannot be used to estimate the lateral pressure of expansive soils behind a retaining structure. There is no reliable method presently available that allows for the designer to predict the lateral pressures on retaining structures or basement walls due to swelling soils. While, for non expansive soils there are many methods available to design professionals by which they can predict the lateral earth pressures expected to be acting on retaining structures. When geotechnical engineers are faced with swelling type soils, the engineering properties of this problematic soil may be improved to make them suitable for construction.

2. The Model, Cells For Measuring and Properties of Tested Soil

The present investigation was conducted using laboratory model. The size of model was designed to minimize the errors in the reading of lateral expansive earth pressure on retaining structure. Pressure cells were designed to measure the lateral expansive earth pressure on retaining structure which created from the swelling soil pressure.

In this investigation, water content and soil density were approximately maintained constant for all tested samples. The main purpose of this research is to study the effect of lateral expansive pressure of retaining structures. To fillful this purpose, three variables were considered. The depth of soil, time and surcharge.

2.1. The model and cells for measuring

The tank used for model tests was constructed of two parts; the first part has dimensions of 130cm length x 40cm width in plan and 140cm high as shown in Photo 3. The tank is manufactured of sheets of wood plates stiffened with rods of steel by riveted connections from its two sides. The bottom and the back side are consisted of sheet of wood, the front of tank is consisted of a sheet of Perspex and its top is opened. The Perspex sheet has 130cm length, 30cm width and the thickness is 2cm. Six holes 20cm distance from center to center are obtained, the hole has 4cm diameter.


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Photo 3. The tank

Pressure cells were constructed to measure low stresses. It was made of Perspex diaphragm 0.3cm thick, 5cm external diameter. The strain gauge was of nominal resistance of 120 ohms. It was covered with a strip of steel has 0.10mm thick. The cells were calibrated under air pressure in a calibration chamber specially constructed for this purpose. The corresponding strain was measured by strain recording device P-3500. The cells were utilized to measure the lateral expansive earth pressure on retaining structure due to swelling soil with respect to depth, time, and surcharge.

2.2 Properties of tested soil

The soil used in this investigation was clayey silt; it's carried out from Assiut el gadeda city projects - Assiut. The soil was sieved by using sieve No. 200 which has an equivalent opening equal to 0.002mm. The portion passed from sieve No 200 was used by the hydrometer analysis test. Classification of soil according MIT system, this soil will be classified as silt, some clay and fine sand.

Table 1.
The values of (Dmm) and (N%)

Dmm	0.13	0.09	0.06	0.04	0.03	0.02	0.01	0.005	0.003	0.002	0.002	0.0006
N%	100	98.4	94	92.1	90	80.4	51.2	20.1	12.7	9.6	8.1	6.5

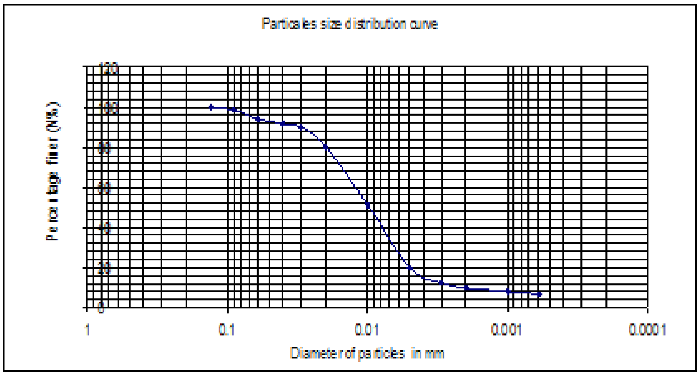

Fig. 1. Shows the relation between diameter of particles (mm) and percentage finer (N %).

Figure (1) shows that the soil consists of (9.6 %) clay, (84.4 %) silt and (6 %) fine soil

The main test results of the used soil were:

a- the free swell of clay equals 165 %

b- The vertical swelling pressure of soil equals 4.00 kg/cm^2

c- The lateral swelling pressure of soil equals 3.20 kg/cm^2

The vertical and lateral swelling pressure values of soil are measured According to "Different pressure Method".

The chemicals results of soil passed from sieve No 200 was obtained from X-rays fraction (XRF) as illustrated in figure (2). This test was carried out according to ASTM C114-00 and ASTM C114-10.

The chemicals results can be summarized as follows:

Oxides	SiO2	AL2O3	Fe2O3	CaO	MgO	SO3	Na2O	K2O	TiO2	P2o3	LOI**	TOTAL
Contents*	51.87	16.62	11, 45	1.50	2.37	0.02	3.33	0.57	1.62	0.50	9.97	99.82

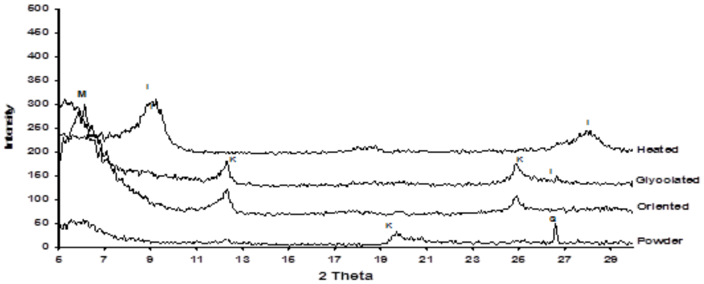

Fig. 2. The chemicals results for soil passing sieve No200 by using X-rays fraction XRF

3. Experimental Results and Discussions

The results of the laboratory tests were obtained from Figures3, 4,5and 6. It represents the variation of lateral stress distribution (σlat) with the depth and time at constant water content and density without surcharge at surface of soil.

3.1 Lateral swell stress and depth at constant water content, density and without surcharge.

Figure (3) shows the relationship between swell stress and depth at constant water content, density and without surcharge.

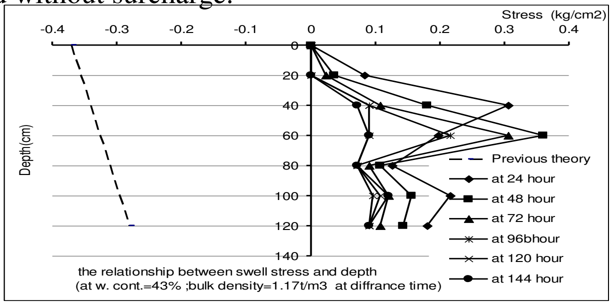

Fig. 3. Shows the relationship between swell stress and depth at constant water content, density and without surcharge.

By studying Figure (4), it can be noticed that the distribution of stresses within soil on retaining structure from tests is varied according to depth. It was shown that the stress (σlat.) increases with the increasing of the depth and its value is the biggest at depth equals 60.0cm from the surface of the soil.

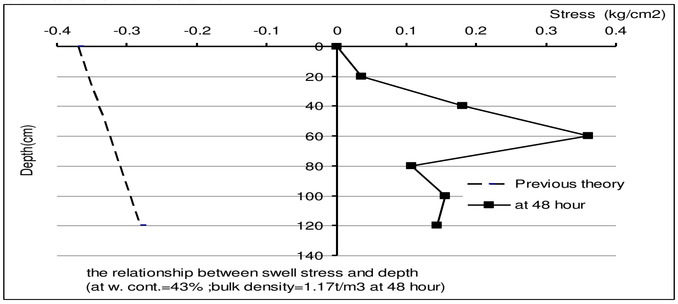

Fig. 4. shows the relationship between swell stress and depth at constant water content, density and without surcharge. (at time = two days)

Figure (5) shows that the stress increased with the time, from the interval of adding water to the soil. When the time equals 48 hours (two days), the stress(σlat.) reaches its maximum value. Then, it decreases to the smallest value after 144 hour(six days).

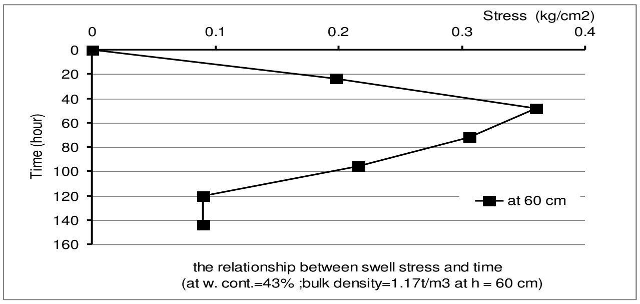

Fig. 5. Shows the relationship between swell stress and time at constant water content, density and without surcharge. (at h = 60.0cm)

Figure (6) shows that the values of stress (σlat.) decrease, the biggest values of stress are different according to type and quantity of the mineral of soil and the water content. This means that the mineral dissolves in the water and has the tendency to swell and expand, the stress develops, increases and exerts on retaining structure. The quantity and time of swelling depend on the quantity percent of minerals in soil, the time, the quantity of water, the depth... etc.

Also, it is noticed that, the measured values of stress (σlat.) recorded from laboratory tests don't agree with the predicted values from previous theories because the laboratory results depend on the chemical components of soil.

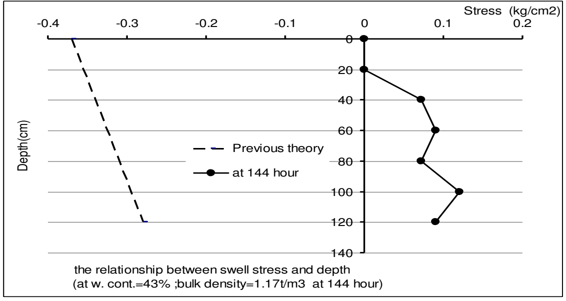

Fig. 6. shows the relationship between swell stress and depth at constant water content, density and without surcharge. (At time = six days)

3.2. Swell stress and time at constant water cont., density and Surcharge (at surface of soil) = 0.0 and 1.0 kg/cm^2

Figures (7),(8),(9) and (10) show the relationship between swell stress (σlat.) and time at constant water content, density and surcharge = 0,1.0 kg/cm^2 . Also, these figures show the values of active earth pressure on retaining walls according to:

$\sigma a = \sigma v Ka - 2c\sqrt{} Ka = \gamma H Ka - 2c\sqrt{} Ka$ Rankine (1857) (1)

where: $\gamma = 1.74 \ t / m^3, c = 2.00 \ t / m^2, \varphi = 6^o$, $Ka = 0.81$, $\sqrt{} Ka = 0.90$, applying in (1), at H = 60.0cm after passing 24,48,72 and 96 hours from adding water to the soil .

Figure (7) shows that the values of stress (σlat.) decrease when surcharge at surface increases from Q = 0.0, to 1.0kg /cm^2. At h is more than 60.0cm; (σlat.) is decreased due to the effect of surcharge at surface of soil.

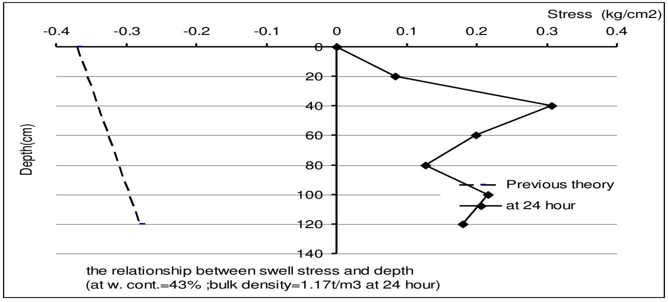

Fig. 7. Shows the relationship between swell stress and time at constant water content, density and surcharge = 0, 1.0 kg/cm^2 at h = 60.0cm after passing 24 hour

Also, figures (8), (9) and (10) show similar trend in which the values of stress (σlat.) decreased when surcharge at surface increased from 0.0,to 1.0kg /cm^2. The value of (σlat.) without surcharge is near the value of (σlat.) when applying a surcharge equals 1.0kg / cm^2 by passing the time from 24 hour to 96 hour.

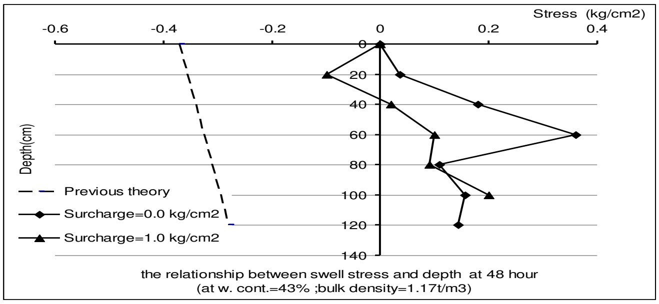

Fig. 8. Shows the relationship between swell stress and time at constant water content, density and surcharge = 0, 1.0 kg/cm^2 at h = 60.0cm after passing 48 hour

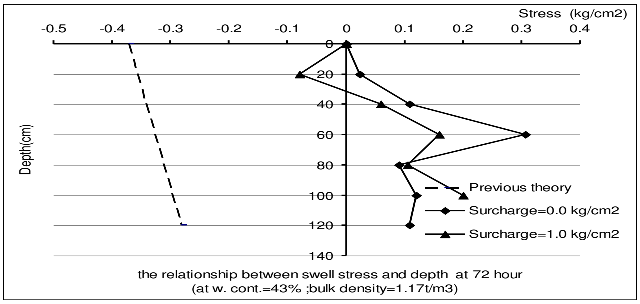

Fig. 9. Shows the relationship between swell stress and time at constant water content, density and surcharge = 0, 1.0 kg/cm^2 at h = 60.0cm after passing 72hours

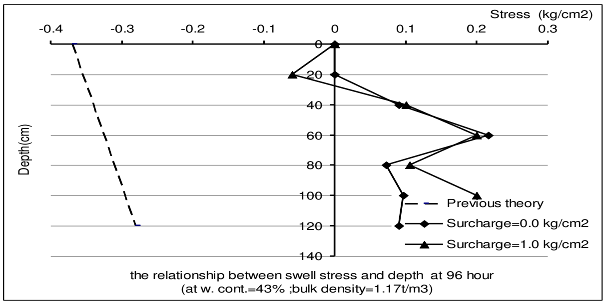

Fig. 10. Shows the relationship between swell stress and time at constant water content, density and surcharge = 0, 1.0 kg/cm^2 at h = 60.0cm after passing 96 hours

It's noticed that, (σlat.) differs according to the value of surcharge at surface of soil, the time and the depth.

From h= 0.0cm to h = 60.0cm the values of (σlat.) due to the presence of expansive soil is resisted by the stress due to the compression of surcharge. After that, the values of lateral earth pressure increase because the depth increases and the values of (σlat.) are resisted by the effect of Surcharge at surface. The effect of surcharge at surface on (σlat.) decreases after adding the water to the expansive soil. After four days, the effect of surcharge at surface = 1.0 k/cm^2 and zero are typically.

5. Conclusions

Conclusions of the experimental study can be summarized as following:

1-The lateral swelling stress (σ_{lat}) on retaining structures distribution of expansive soil depends on the depth of soil from the ground surface, the time after adding water, the water content is kept constant, density of soil (γ =1.74 t / m^3), minerals of soil.

2- Lateral swelling on retaining walls increases with the depth up to 60.0 cm deep.

3- Maximum lateral swelling on retaining walls equals 3.2kg / cm^2 and it occurs at 60.0cm from the ground surface after two days at (W= 0.43 , γ = 1.74 t/m^3).

4- The lateral swelling stress values (σlat) from experimental results don't agree with the stress values from previous theory ($\sigma_a = \gamma H K_a - 2c\sqrt{K_a}$), this is due to the deference between the chemicals component of soil, type of soil minerals and its quantities in soil, condition of experiments , type of taking measurements,…,etc.

5- The lateral swelling stress values within soil from previous theories are less than those of experimental values under constant conditions.

6- Lateral swelling pressure on retaining walls affecting is measured without the normal earth pressure

7- The design of retaining walls must take in our consideration the normal earth pressure and the Lateral swelling pressure

6. List of Symbols

h = the distance from surface of soil to any depth of soil (cm)
T = time (hour)
Q = surcharge at surface of soil (kg / cm^2)
W % = water content percentage
(σlat.) = lateral swelling pressure (kg / cm^2)

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دراسة معملية لتأثير الضغط الأنتفاشى الجانبي للتربة المنتفشة على الحائط الساند

ملخص عربى

- تعتبر دراسة الضغوط الجانبية للتربة الانتفاشيه على المنشات الساندة من الدراسات الهامة في مجال التربة و الأساسات و التي تخدم المهندس المدني في مجال التصميم ولهذه الدراسة تم تصميم نموذج معملي لدراسة تأثير الضغوط الجانبية الناشئة من انتفاخ التربة القابلة للانتفاش على المنشات الملاصقة والساندة لها ولهذه الدراسة قمنا بإحضار عينات التربة المنتفخة اللازمة للدراسة من مدينه أسيوط الجديدة - أسيوط – مصر، ولقد اشتملت الدراسة على تأثير الماء المضاف على انتفاخ التربة و قياس الضغوط الجانبية المتولدة عن الانتفاش وذلك على أعماق مختلفة من السطح و بعد مرور فترات زمنيه مختلفة في وجود أحمال سطحيه موزعه ومن نتائج هذا البحث تبين أن الضغوط الجانبية للتربة الانتفاشيه على المنشات الساندة تزداد كلما زاد العمق حتى تصل إلى أقصاها على عمق يساوى60 سم من سطح التربة كما وجد أن الضغوط الجانبية الناتجة عن ضغط الانتفاخ تقل بزيادة الأحمال السطحية كما يحتوى البحث على عديد من النتائج الهامة.