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Comparative study of different types of shale

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ABSTRACT: Soil-water characteristic curve has considerable important parameter in unsaturated soil behavior. Undisturbed and disturbed soil samples were collected from different seven sites in Egypt to determine some of their physical and chemical characteristics of the soil sites. Data indicate that soil texture classes of the different experimental sites are silt clay, clay loam, sand clay loam, and clay. Results indicted that the dominant fractions of the all sites were very fine fractions such as silt and clay. The volumetric water contents at different applied pressures of all sites except for Gardenia site and New Cairo were very high as a result of increasing clay and silt fractions and for all shale samples show smooth curves with regular and gradual decrease in moisture released under different applied pressures close up to the predicted data with van Genuchten model. All sites have highly available water compared with loamy and sandy soil. All samples have high total porosity with range near to 70% except for Gardenia and New Cairo samples which their values of total porosity about 60%, these may be results from increasing of sand fractions in these sites. Data also show that, water holding pores (WHP) are the dominant soil pores.

Keywords: shale, water holding capacity, soil pores

INTRODUCTION

Shale is a fine-grained, clastic sedimentary rock composed of mud that is a mix of flakes of clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite. The ratio of clay to other minerals is variable. Shale is characterized by breaks along thin laminae or parallel layering or bedding less than one centimeter in thickness, called fissility **(Blatt, *et.al.,* 1996)**. are typically composed of variable amounts of clay minerals and quartz grains and the typical color is gray. Addition of variable amounts of minor constituents alters the color of the rock. Black shale results from the presence of greater than one percent carbonaceous material and indicates a reducing environment **(Blatt *et.al.,* 1996)**. Black shale can also be referred to as black metal, Red, brown and green colors are indicative of ferric oxide (hematite – reds), iron hydroxide (goethite – browns and limonite – yellow), or micaceous minerals (chlorite, biotite and illite – greens), **Blatt *et.al.*(1996).**

Clays are the major constituent of shales and other mud rocks. The clay minerals represented are largely kaolinite, montmorillonite and illite. Clay minerals of Late Tertiary mudstones are expandable smectites whereas in older rocks especially in mid to early Paleozoic shales illites predominate. The transformation of smectite to illite produces silica, sodium, calcium, magnesium, iron and water. These released elements form authigenic quartz, chert, calcite, dolomite, ankerite, hematite and albite, all trace to minor (except quartz) minerals found in shales and other mud rocks **(Blatt *et.al.,* 1996).**

Shales and mud rocks contain roughly 95 percent of the organic matter in all sedimentary rocks. However, this amounts to less than one percent by mass in an average shale. Black shales which form in anoxic conditions contain reduced free carbon along with ferrous iron (Fe^{2+}) and sulfur (S^{2-}). Pyrite and amorphous iron sulfide along with carbon produce the black coloration and purple **(Blatt *et.al.*, 1996).**

Soil-water characteristic curve has considerable important parameter in unsaturated soil behavior such as volume change, shear strength, diffusivity and absorption, as well as most soil properties such as specific heat, thermal conductivity and permeability which can be also related to the soil-water characteristic curve (Fredlund and Rahardio, 1993). This curve can be depicted as a continuous function describing the water storage capacity of a soil as it is subjected to various suctions. The SWCC contains significant information with respect to the amount of water contained in the pores at various suctions of soil and the pore size distribution corresponding to the stress state in the soil (Fredlund *et al*., 2002).

The present study aims to compare characteristics of some shale types such as soil particle size distribution, and soil water characteristic curve

MATERIALS AND METHODS

Soil sampling

Undisturbed and disturbed soil samples were collected from seven sites to determine some physical characteristics of each soil site.

Laboratory determinations

1- Particle size distribution, was carried out according to the International method (Klute, 1986) using NaOH as dispersing agent.

2- pF curves and soil moisture retention were determined using undisturbed soil samples. The completely saturated samples were exposed to constant levels of pressures 0.10, 0.33, 0.66, 1.00, 3.00, 5.00 and 15 bars using the pressure plate extractor and pressure cocker. The attained water percentage at each pressure was determined volumetrically **(Klute, 1986)**

Soil water characteristic curve was expressed by van Genuchten water retention model as defined by the following equation (van Genuchten, 1980):

$$S_e = \left[\frac{1}{1+(\alpha h)^n} \right]^m \qquad h < he$$

$$Se = 1 \qquad h >= he \qquad \text{Equation (1)}$$

$$S_e = \left(\frac{\theta(h) - \theta_r}{\theta_s - \theta_r} \right)$$

Where:

θ(h) is the soil water content at suction (h), L^3L^{-3}

θr is the residual soil water content, L^3L^{-3}

θs is the soil water content at saturation, L^3L^{-3}

α (L^{-1}) is related to the inverse suction of air entry

S_e is the relative water content

The fitting parameters were derived by fitting Equation 1 to the soil water retention data using the RETC program (van Genuchten *et al*., 1991).

The root-mean-squared (RMS) is calculated in order to determine the quality of the fit of the estimators to the data. The RMS is defined by the following equation"

$$\text{RMS} = \sqrt{\frac{\sum_{i=1}^{n} \left(\frac{y_i - Y_i}{Y_i} \right)^2}{n}}$$

Where y_i represents the predicted value, Y_i represents the observed field value, and n is the number of data points.

RESULTS AND DISCUSSION

Particle size distribution

Data of soil physical characteristics of the investigated sites are presented in Table (1). Data indicate that soil texture classes of the different experimental sites are silty clay, clay loam, sand clay loam, and clay. Results indicted that the dominant fractions of the all sites were very fine fractions such as silt and clay except for Gardenia site and New Cairo which contain much percentage of sand fractions. These results show that most of these sites consist of shale which their dominant fractions are clay and silt. Such kinds of samples possess the swelling by wetting and shrinkage by drying.

Table 1. Mechanical analysis of investigated soil samples.

Site	C. sand %	F. sand %	Silt %	Clay %	Textural class
Kafr Hameed -Brown	**1.2**	**1.2**	**45.2**	**52.5**	**Silty clay**
Kafr Hameed -Black	**0.9**	**2.5**	**46.8**	**49.8**	**Silty clay**
Gardenia -6 October (2)	**20.6**	**33.0**	**17.7**	**28.7**	**Sandy clay loam**
Gardenia -6 October (3)	**26.5**	**11.2**	**32.5**	**29.8**	**Clay loam**
Badr city	**0.3**	**3.0**	**47.7**	**49.1**	**Silty clay**
New Cairo	**0.6**	**31.0**	**29.6**	**38.8**	**Clay loam**
New Bani sewif	**2.5**	**2.0**	**35.3**	**60.2**	**clay**

Soil moisture characteristics curves

The shape of soil moisture characteristic curves mainly depends on some soil properties such as texture, structure, organic matter, soluble salts content and exchangeable cations. The effect of soil texture is related to the specific surfaces of different particles which affect the adhesion force between the particles surfaces and water molecules. Therefore, this effect appears within tensions higher than 1.0 bar. On the other hand, the amounts of water retained in the soil at low tensions, below 1.0 bar, are mainly depend on the structure patterns of soil particles and consequently, on the pore size distribution (**Hillel 1980**).

Data obtained for the retained soil moisture content under different applied pressures are reported in Table (2) and illustrated in Figs. (1 to 7). These data indicate that, all soil samples show smooth curves with regular and gradual decrease in moisture released under different applied pressures, except for at 15 atm, whereas, soil moisture content are sharply decreased. The volumetric water contents at different applied pressures of all sites except for Gardenia site and New Cairo were very high as a result of increasing clay and silt fractions. Also, Table (3) illustrates the parameters of van Genuchten model.

Table 2. Soil moisture content (m^3 m^{-3}) under different applied pressures of investigated soil samples

Location	Soil suction (bars)							Available soil moisture
	0.001	0.1	0.33	1.0	3.0	5.0	15	

Kafr Hameed -Brown	**0.691**	**0.630**	**0.599**	**0.572**	**0.564**	**0.558**	**0.265**	**0.334**
Kafr Hameed -Black	**0.702**	**0.641**	**0.628**	**0.610**	**0.603**	**0.598**	**0.282**	**0.346**
Gardenia -6 October (2)	**0.602**	**0.509**	**0.462**	**0.431**	**0.420**	**0.398**	**0.188**	**0.274**
Gardenia -6 October (3)	**0.585**	**0.497**	**0.474**	**0.447**	**0.427**	**0.396**	**0.173**	**0.301**
Badr city	**0.693**	**0.613**	**0.575**	**0.541**	**0.522**	**0.501**	**0.239**	**0.336**
New Cairo	**0.604**	**0.583**	**0.553**	**0.525**	**0.516**	**0.495**	**0.297**	**0.256**
New Bani sewif	**0.723**	**0.632**	**0.588**	**0.562**	**0.548**	**0.525**	**0.242**	**0.346**

*Each value of suction is the average of three locations for each site

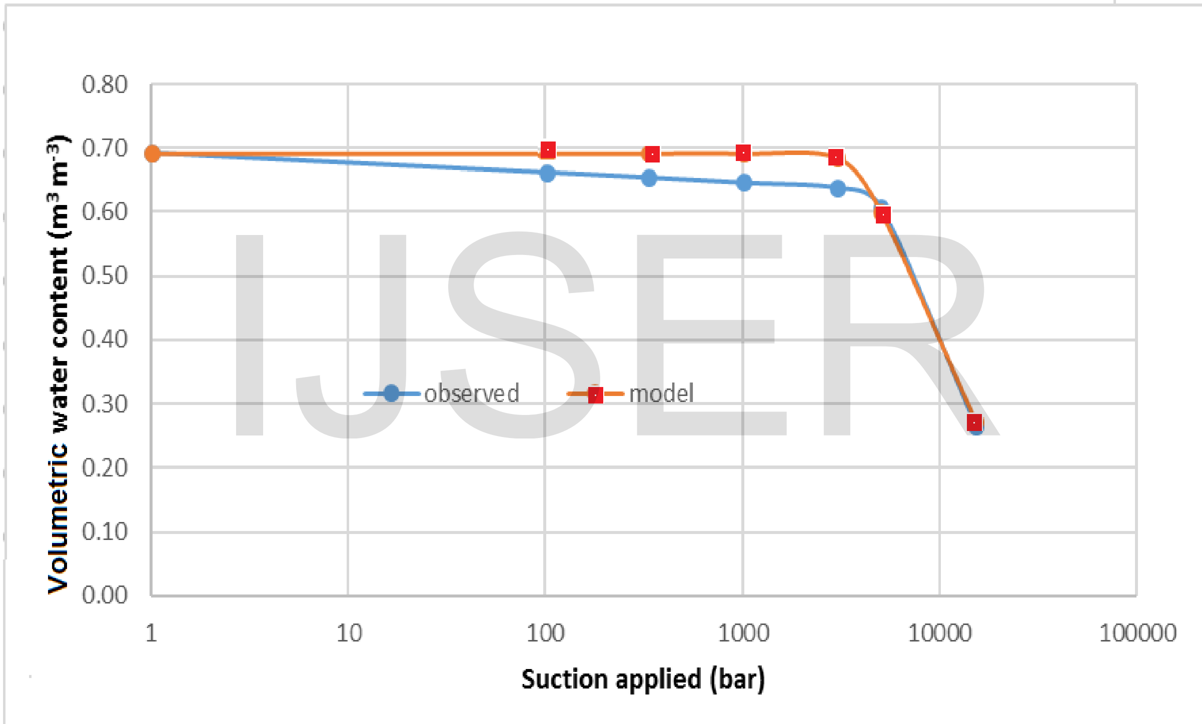

Figure 1. Soil moisture characteristic curve of Kafr Hameed –Brown shale

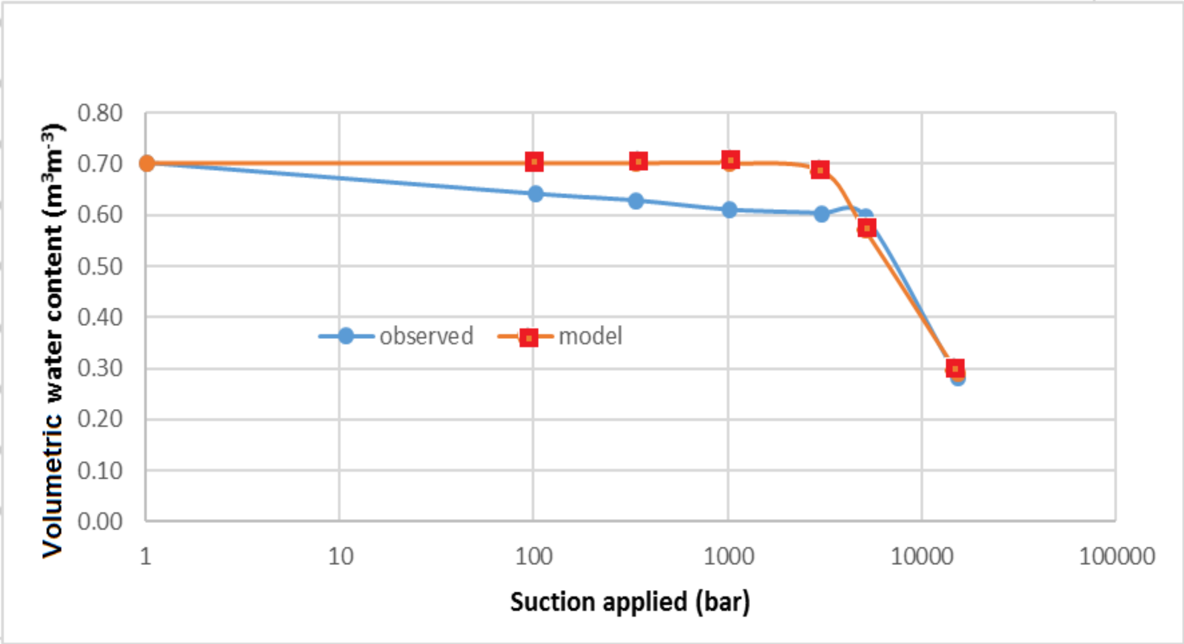

Figure 2. Soil moisture characteristic curve of Kafr Hameed -Black shale

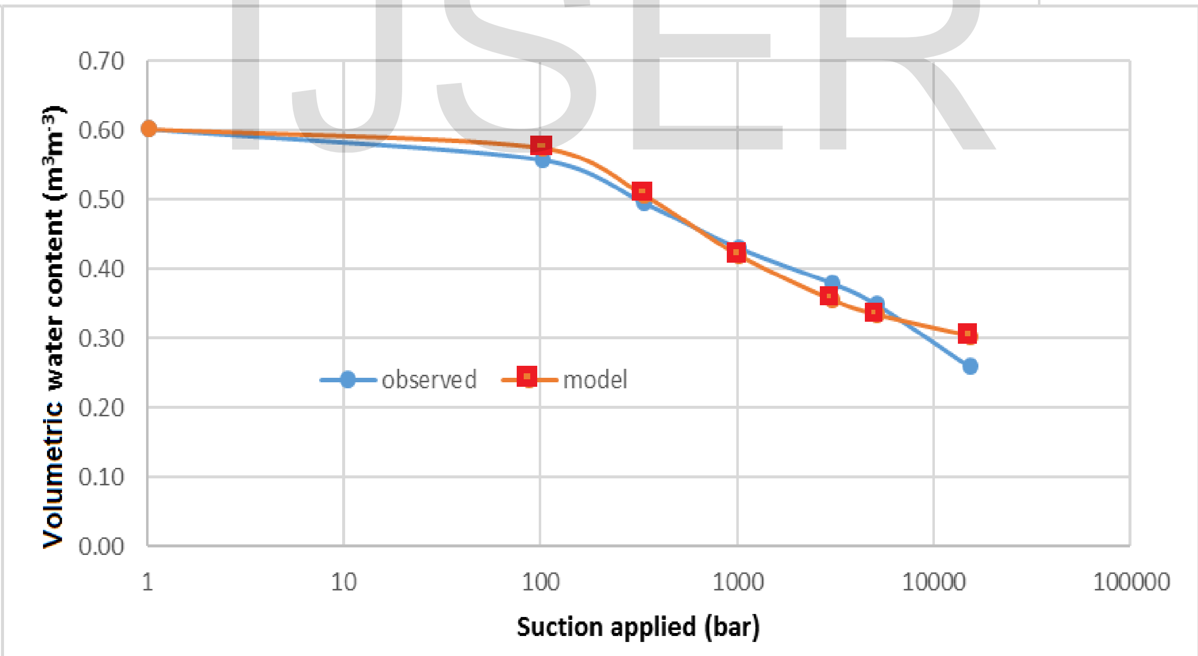

Figure 3. Soil moisture characteristic curve of Gardenia 6 October (2) shale

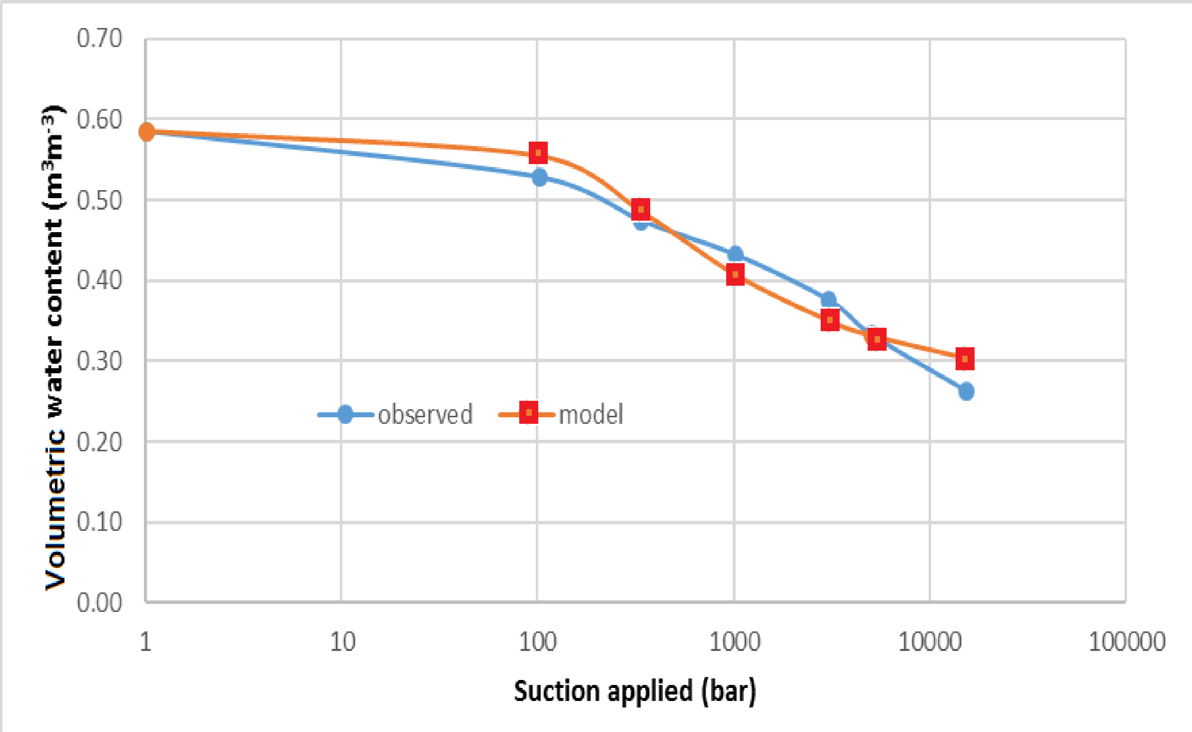

Figure 4. Soil moisture characteristic curve of Gardenia 6 October (3) shale

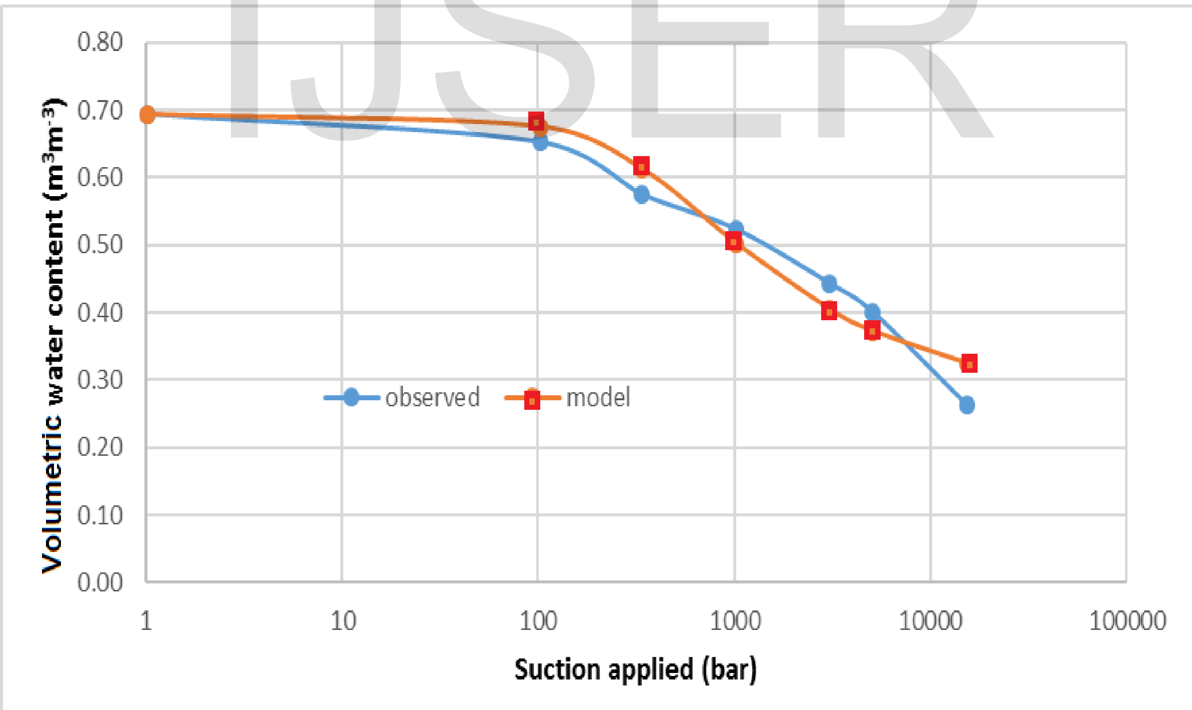

Figure 5. Soil moisture characteristic curve of Badr city shale

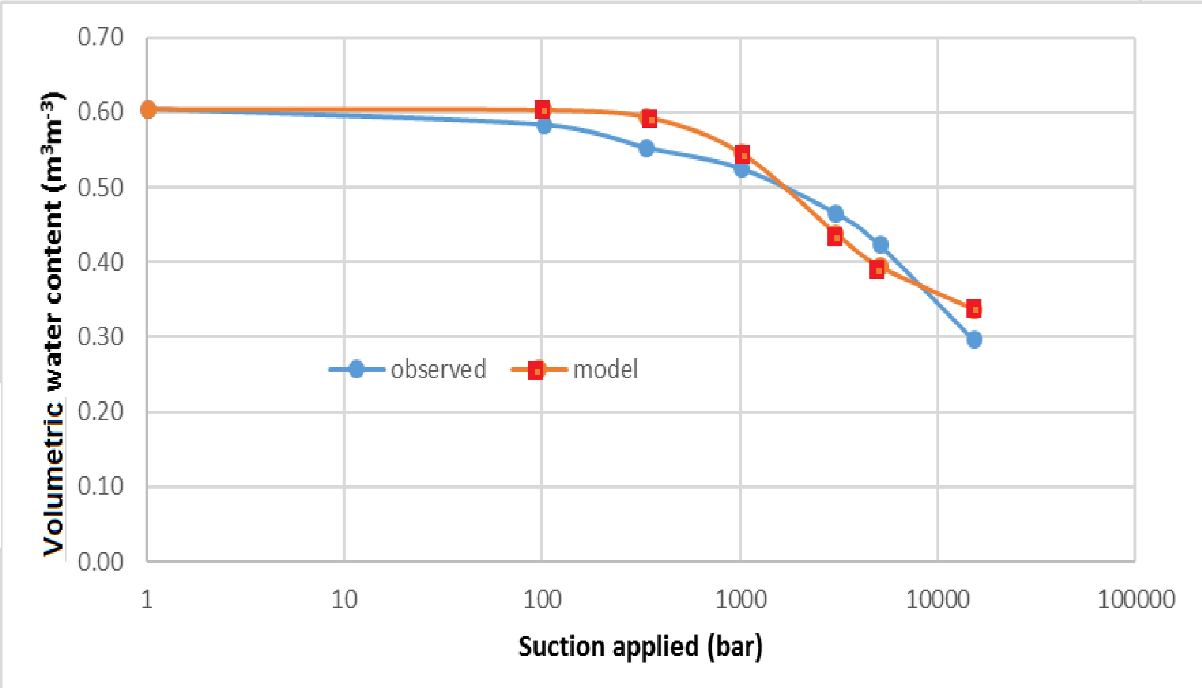

Figure 6. Soil moisture characteristic curve of New Cairo shale

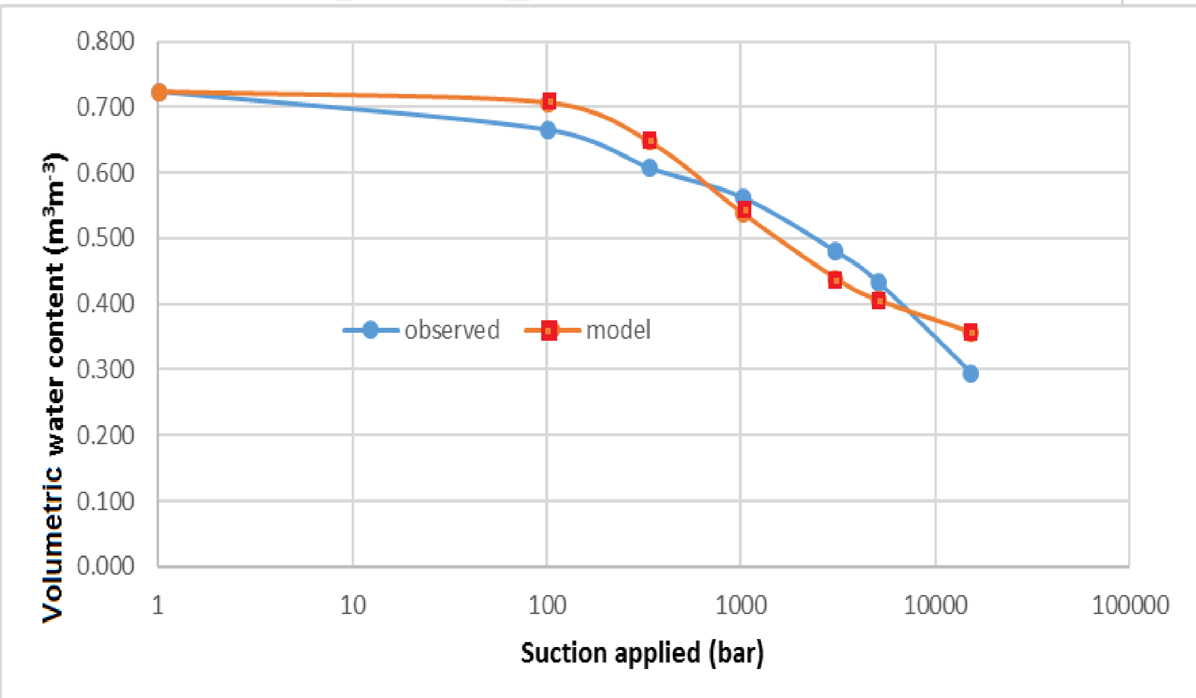

Figure 7. Soil moisture characteristic curve of New Bani sewif shale

Available soil moisture

The available soil moisture is defined as the difference between soil moisture content at the two limits of field capacity (0.33 bar) and permanent wilting point (15 bar). Data in Table (2) show that there are very small differences between available soil moisture values of the investigated soil samples except for Gardenia site and New Cairo. All sites have highly available water compared with loamy and sandy soil, this is mainly attributed to the increase in fine fractions silt and clay compared to sand fraction.

Total porosity and pore size distribution

Data presented in Table (4) indicate that slight variations in the values of total soil porosity (volumetric soil moisture contents at 0.001 bar) are obtained. These values are increased as the fine soil fractions (silt and clay) increase, and decrease as the sand fraction increases. Therefore, all samples have high total porosity with range near to 70% except for Gardenia and New Cairo samples which their values of total porosity about 60%. These may be resulted from increasing of sand fractions in these sites. Data also show that, water holding pores (WHP) are the dominant soil pores followed by non-useful pores, meanwhile the Quickly drainable pores (QDP) and Slow drainable pores (SDP) recorded the lowest values. This may be due to the high percents of clay and silt fractions in the studied soil sites compared to sand fractions. This behavior is expected for shale which can retain much of water and have highly percentage of micro pores compared to macro pores.

Table 4. Total porosity and pore size distribution of different sites

Location	**Total porosity %**	Quickly drainable pores, **QDP %**	Slow drainable pores, **SDP %**	water holding pores, **WHP %**	**UN-USEFUL %**
Kafr Hameed -Brown	**69.1**	**8.8**	**4.5**	**48.3**	**38.4**
Kafr Hameed -Black	**70.2**	**8.6**	**1.9**	**49.3**	**40.2**
Gardenia -6 October (2)	**60.2**	**15.5**	**7.7**	**45.5**	**31.3**
Gardenia -6 October (3)	**58.5**	**15.1**	**3.9**	**51.5**	**29.5**
Badr city	**69.3**	**11.6**	**5.5**	**48.4**	**34.5**
New Cairo	**60.4**	**3.5**	**5.0**	**42.4**	**49.1**
New Bani sewif	**72.3**	**12.6**	**6.0**	**47.9**	**33.5**

CONCLUSIONS

Studying the physical characteristics of soil is important for foundation damage because expansive soil pose significant hazards to foundations for buildings. Expansive soils owe their characteristics to the presence of swelling clay minerals. As they get wet, the clay minerals absorb water molecules and expand; conversely, as they dry they shrink, leaving large voids in the soil. Soils with smectite clay minerals, such as montmorillonite, exhibit the most profound swelling properties. Therefore, more studies are required to study the most soil characteristics affected the stability of foundation in different soil types and recognizing the type of clay minerals such as the expanding that have tendency to absorb more water. Clay content about 10-15% is classified as normal soil for foundations.

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الملخص العربى

دراسة مقارنة لبعض انواع الطفلة بمصر

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باحث بالمركز القومي لبحوث الاسكان والبناء – القاهرة – مصر

منحنيات الامتصاص للتربة لها اهمية كبيرة في دراسة سلوك التربة غير المشبعة. تم جمع عينات من التربة من مختلف سبعة مواقع في مصر لتحديد بعض الخصائص الفيزيائية والكيميائية ومنحنيات الامتصاص لها. وتشير البيانات إلى أن طبقات التربة تتكون من نسب مختلفة من الطمى والطين والرمل. اوضحت النتائج ان محتويات المياه الحجمية في الضغوط المختلفة من جميع المواقع باستثناء موقع جاردينيا والقاهرة الجديدة عالية جدا نتيجة و يظهر انخفاض منتظم وتدريجي في الرطوبة مع تغير الضغوط المختلفة و اوضحت النتائج ايضا ان جميع المواقع اظهرت توافق عالى لمنحنيات الشد الرطوبي مع البيانات المحسوبة من نموذج فان جينوختن وانها تحتوى على مسامية كلية عالية تقترب من 70% فيما عدا موقع جاردينيا والقاهرة الجديدة بلغت المسامية الكلية حوالى 60% ويرجع ذلك الى زيادة مكون الرمل فى هذه المواقع. كما اظهرت النتائج ان المسام الحافظة للماء كانت هى السائدة يتبعها المسام غير المفيدة بينما مسام الصرف السريع والبطيئ كانت الاقل فى القيمة.