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# MEASUREMENTS OF SUCTION AND WATER CONTENT DURING SATURATION OF COMPACTED EXPANSIVE SOIL

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**ABSTRACT:** The change of climate gives fluctuation of water content in its result rain, evaporation, rising water ground level and evapotranspiration. The expansive soil will volume change and suction. This behavior can damage on construction structures especially, roads and light building. The phenomenon is very interesting to be researched, how far the effect of water content change and variation suction toward the behavior volumetric swelling expansive soil. This paper presents results of measurement of swell percent, water content and total and matric suction under gradual and controlled moisture intake using dial gages and filter paper .It was found that the suction decreases with increase water content. The results showed that the greater swelling the smaller total and matric suction. The study showed that approximately a linear relationship between the suction with water content.
**Key words**: Expansive Soil, Suction, swelling.

## 1. INTRODUCTION

The process swelling of expansive clay influenced by environmental factors, including factors climate, rainfall, drainage systems and ground water level fluctuation. The changes in water content of clay soil would cause in volume changes. On the contrary, reduction of water content causes clay to shrink and when the water content increases the clay swell. The process of swelling more complex than the process shrinkage. The behavior swelling on expansive soils is a reversal of capillary events. When the water content increased and the soil becomes saturated, the capillary pressure will decrease and pore water pressure decrease and can be equal to hydrostatic stress. With the decrease of pore pressure tends to inflate the expansive soil back to swelling on the original position (1).

The phenomenon of swelling on expansive soil occurs in conditions of wetting with the degree of saturation (Sr<1), meaning the soil is in unsaturated condition. In this unsaturated condition of the expansive clay experienced three element: grain, water and air, resulting namely in negative pore water pressure or suction. As a result of this suction causes the soil properties to be changed especially on the degree of saturation and void ratio .So that the suction that occurred on expansive soil will affect the behavior swelling-shrinkage expansive clay (2).To understand the behavior of expansive soil, it is necessary to determine SWCC curve for this soil.

## MATERIAL PROPERTIES:
## A-EXPANSIVE SOIL:

The expansive soil used in this study was artificially prepared by mixing Iraqi bentonite from Al-Anbar city / Bushayrah Valley, 35 kilometers southern Al-Waleed Military Base from a depth of three and a half meters from natural ground level, with sandy soil . In order to increase the permeability of the prepared soil and to facilitate and accelerate saturation process, several trial mixes of bentonite-sand were performed. A ratio of expansive soil to sand of (8/2) was selected. At this ratio, the soil remains highly expansive and its permeability is increased.

## B-SOIL CONTAINER:

Soil steel container was made using a 4mm thickness plate with internal diameter 40cm and height 60cm.The base of container is supported by four steel rigid legs and contains in the center whole with diameter 2.5 cm with connected valve. This valve is connected to tank to perform the saturation process of soil from bottom to top of soil. The water level in the tank must be usually kept10cm more than the surface of soil. The containers were painted with two coats of anti-rust paint and two layers leady base to resist corrosion during test period. Figure (1) shows the container of the soil.

## TESTING PROCEDURE:

Seven containers are used to measure water content, heavy surface, total and matric suction changes during 45 days. Each container was prepared in the initial water content 18.62% and dry density 13.1 kN/m$^3$ which is compacted by hammer weight 5.5 kg and falling height 1.15m into six layers. The final thickness of soil bed was 30cm .Four sand drains were formed to reduce soil saturation period. The samples are extracting from the container each 7days by using cylindrical tube 50mm in diameter and 100mm in height .The samples are extracted from regions (parts) upper, medium and lower from expansive bed soil layer. These samples were used to measure water content and the soil suction (total and matric) by the filter paper method according to the ASTM D 5298-03.The soil samples were remolded in two odometer rings 50 mm in diameter and 19 mm in height, three filter papers (Whatman 42) were sandwiched between these two soil samples and two filter papers were separated from the soil sample by a pvc ring of 2.5 cm in thickness as followed by Fattah et al. (2012 and 2013 b). This group of soil samples and filter papers were placed in glass cylinder where the samples filled about two third of the cylinder space as recommended by Bulut et al. (2001) to reduce the equilibrium time. The samples were left to get the equilibrium condition for about ten days. Then the wet filter papers were weighed to the nearest 0.0001gm as quickly as possible, the filter papers were placed in jarred tins and inserted in the oven at 105 $^0$C for six hours and weighed again as recommended by Chao (2007) and Fattah et. al. (2012).

## RESULTS AND DISCUSSION:

Figures(2)and (3) show the results of change water content of expansive soil with depth and time during period of saturation for three parts of container. It is clear that the upper part of container reaches firstly saturation after ten days and it is wetted faster than medium and lower parts. This is attributed to flow of water upward through sand drains and the surface of expansive soil will be swelling and void ratio increases. Medium and lower parts need long period to reach this state of saturation. The lower part reaches the full saturation after 45 days.

The results shown in figures (4)to (7) showed that both total and matric suction reduced with time for three parts of container. The upper part reaches firstly lower values of total and matric suction because it is wetted and saturated faster than medium and lower parts as mentioned above. The effect of total and matric suction on behavior of expansive soil has contrary to the effect of water content and degree of saturation. The changes of total and matric suction in medium and lower parts are slow and need long time to reach state of saturation.

Figures (8)and (9) show the results of suction(total and matric) measured by filter paper method on expansive soil with respect to the soil water content for three parts of container. The figures show approximately a linear relationship between the suction with water content for all three parts of container. The results showed that the suction decreases with increase water content.

The inverse relationship between the water content and the soil degree of saturation with suction could be explained by the fundamental meniscus theory as follows, when the water content increases, the radius (Rs) of the meniscus will also increase. When (Rs) increases, the pressure difference between the pore air pressures and the pore water pressure (matric suction) will decrease as illustrated in equation (1) (Ravichandran and Krishnapillai, 2011).

$$u_a - u_w = 2T_s/R_s \quad \text{.......................................................(1)}$$

Where: $T_s$is the surface tension.

Figures (10) and (11) showed the changes between variation suction with swelling of expansive soil for three parts of container. The results showed that the greater swelling the smaller total and matric suction. This showed that the effect of suction to behavior swelling expansive soil is the opposite of the effect of water content and degree of saturation.
When the soil is subjected to wetting, this leads to decrease the interparticle contact forces due to the decrease in soil suction, the soil particle will move away from each other which lead to increase the volume and decrease the soil dry unit weight.

## CONCLUSIONS:

1. The suction within the soil tends to decrease with the increase in the soil water content due to the wetting process. On the other hand, the suction decreases with the increase in soil swelling under wetting due to decrease in the inter-particle contact forces causing the particles to move away from each other.
2. The effect of total and matrix suction on behavior of expansive soil has contrary to the effect of water content and degree of saturation.
3. Upper part of soil is more heave than medium and lower part of soil.
4. Although water seep through expansive soil from downward to upward, upper part is saturated before other parts due to increase in void ratio and decrease in overburden pressure of this part.

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**Table (1):** Physical Properties of Expansive Soil.

| Test Name | Standard | Soil Property | Value |
|---|---|---|---|
| Specific Gravity | (ASTM D-854) | Specific Gravity (Gs) | 2.78 |
| Atterbeg Limits | (ASTM D-4318) | Liquid limit(L.L)% | 102 |
| | | Plastic Limit(P.L)% | 43 |
| | | Plasticity Index(P.I)% | 59 |
| Grain size analysis | (ASTM D-422) | (Clay +Silt) % | 79.9 |
| | | Sand% | 20.1 |
| | | Gravel% | 0 |
| | | Unified Soil Classification System(USCS) | CH |
| Standard Compaction and (3/4) Energy of Standard | ASTM D-(1557) | Maximum Unit Weight(kN/m$^3$) | 13.4-13.1 |
| | | Optimum Moisture Content(O.M.C)% | 18-19 |
| | | Initial void ratio(e0) | 1.08 |
| Swelling Pressure | (ASTM D-3084) | Swelling Pressure | 260 |

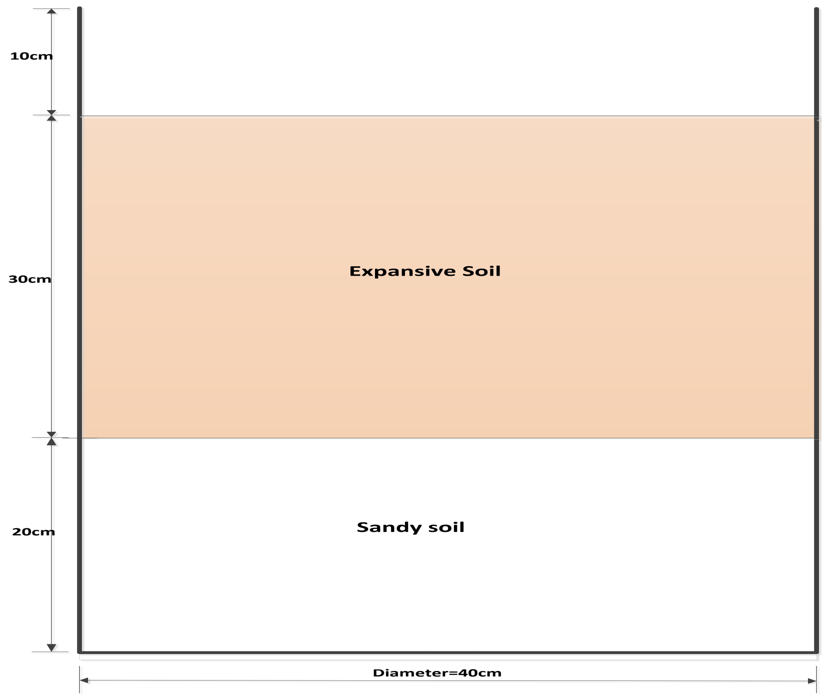
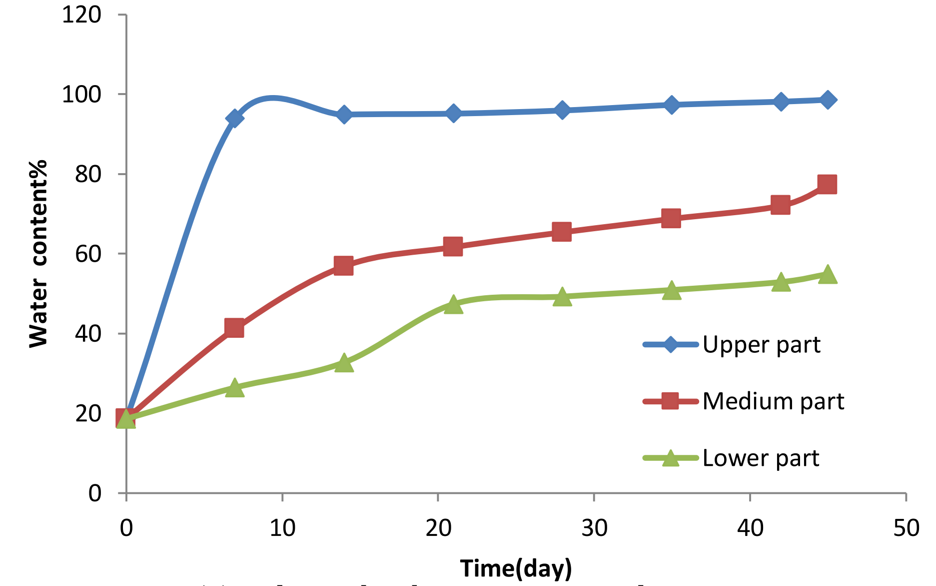
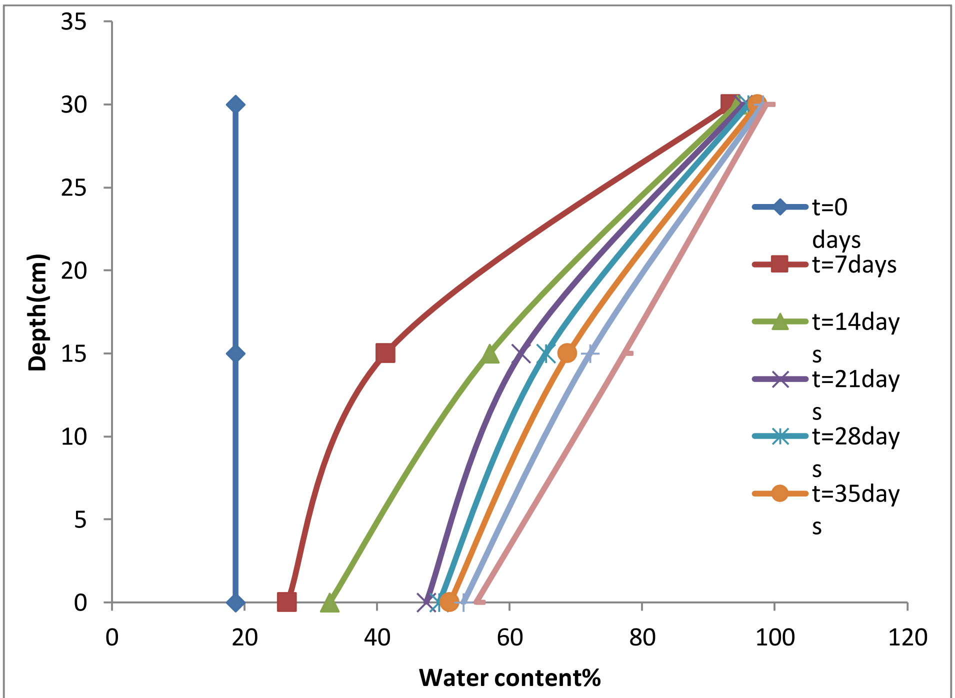


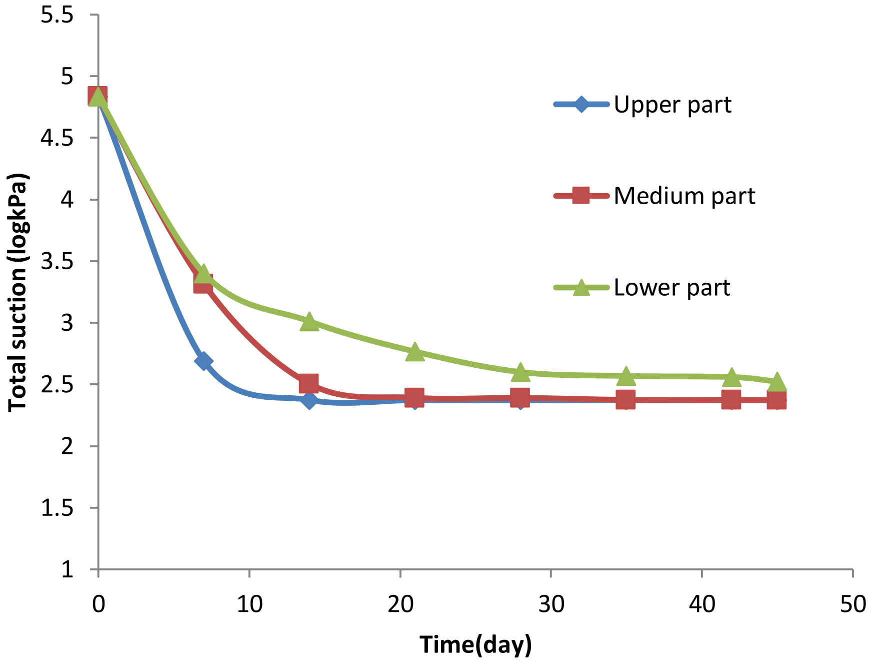

**Figure (1):** Soil Container Used in this Study.



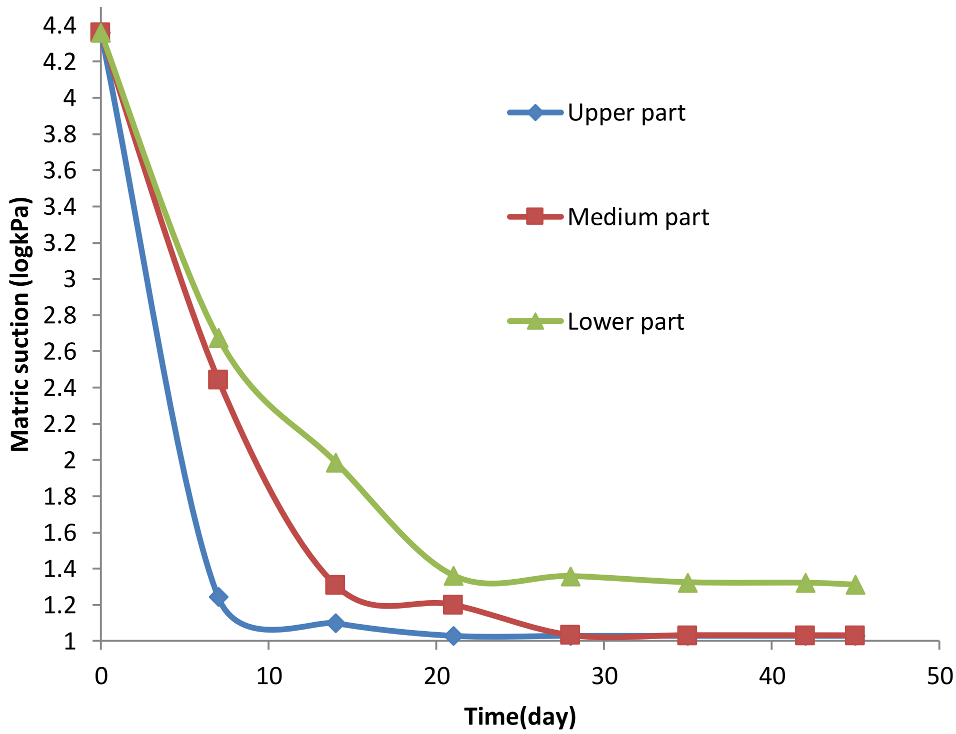

Figure(2):Relationship between Time and Water Content of Expansive Soil for Three Parts of Container.



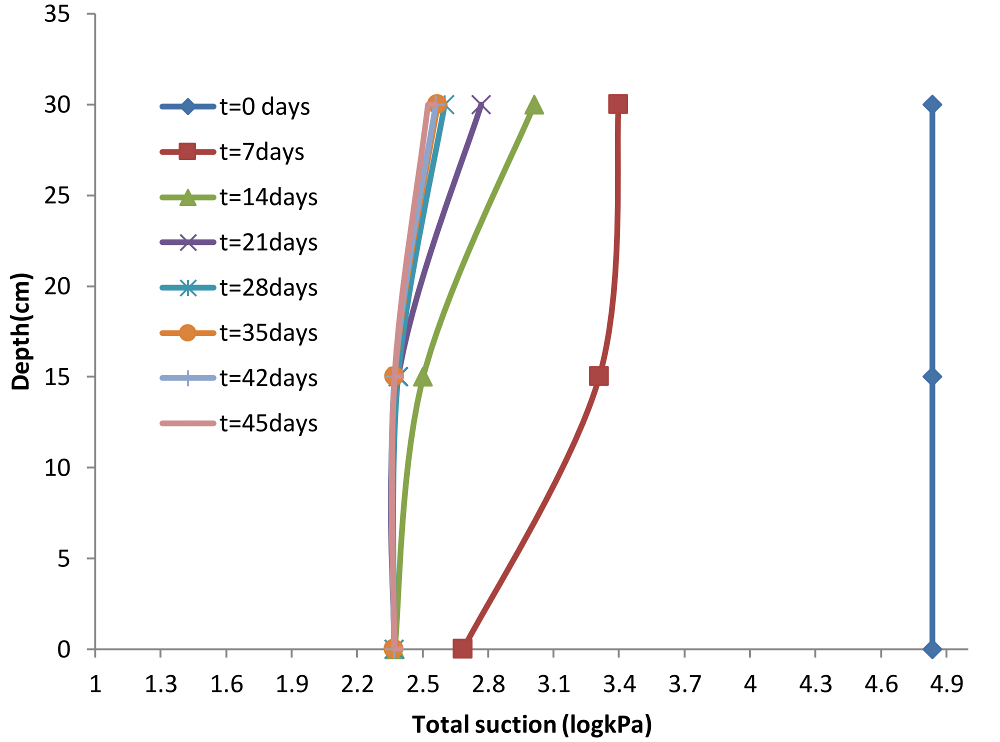

Figure(3):Variation of Water Content of Expansive Soil with Depth of Container at Different Times.



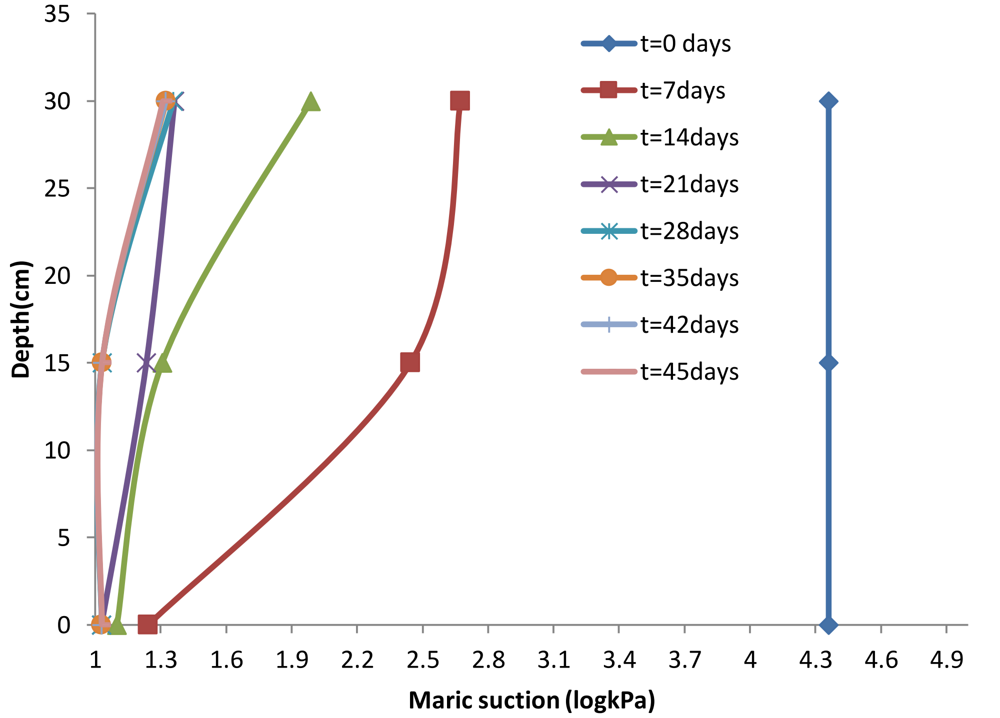

Figure(4):Relationship between Time and Total Suction of Expansive Soil for Three Parts of Container.



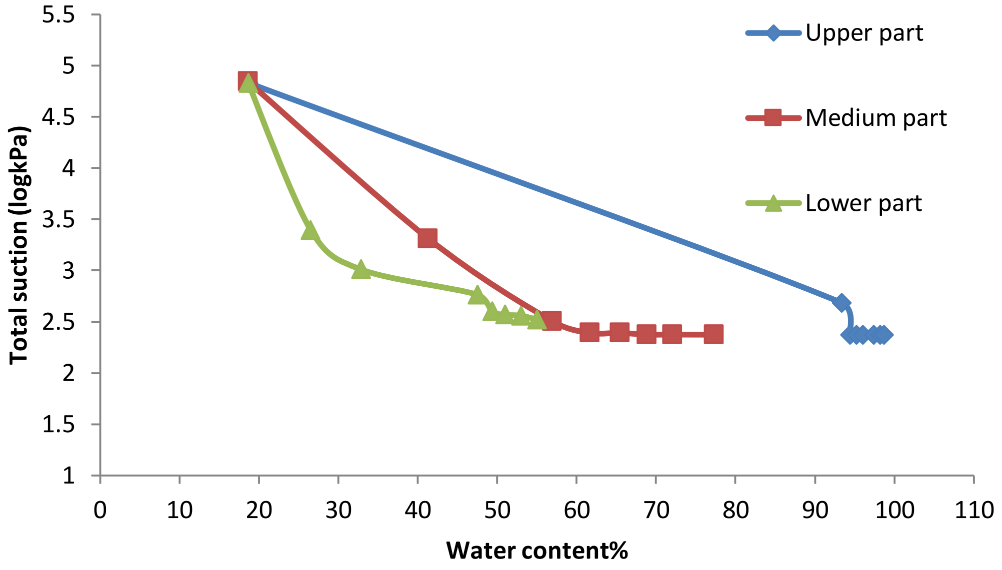

**Figure(5):Relationship between Time and Matric Suction of Expansive Soil for Three Parts of Container.**



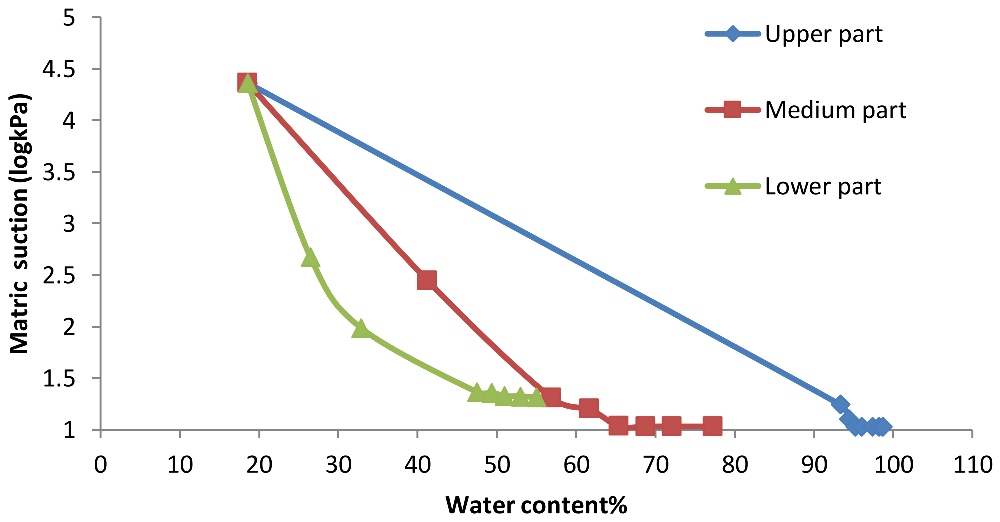

**Figure(6):Variation of Total Suction of Expansive Soil with Depth of Container at Different Times.**



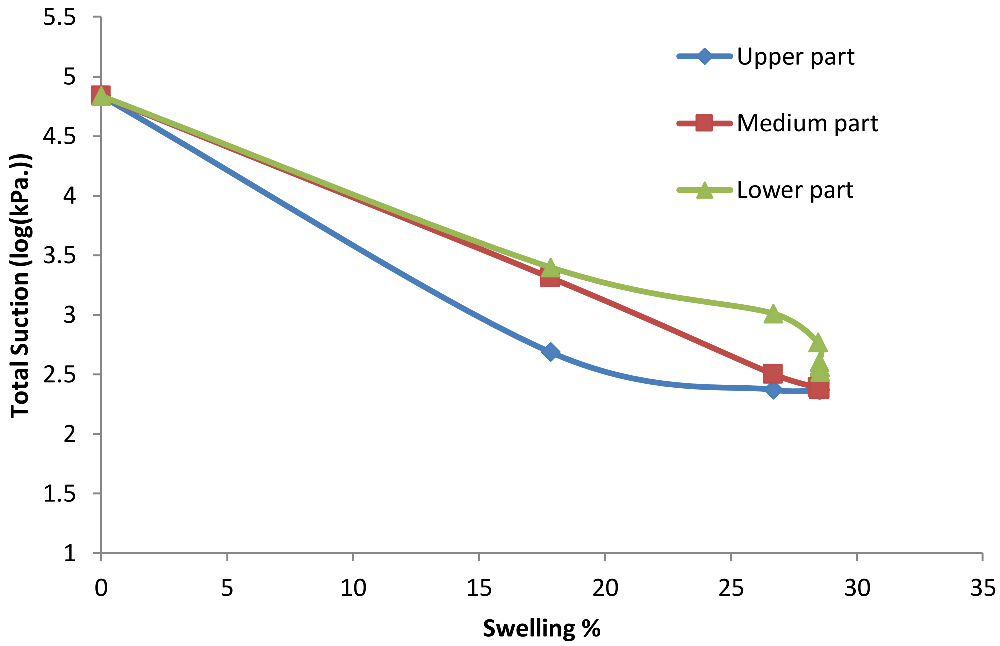

**Figure(7):Variation of Matric Suction of Expansive Soil with Depth of Container at Different Times.**



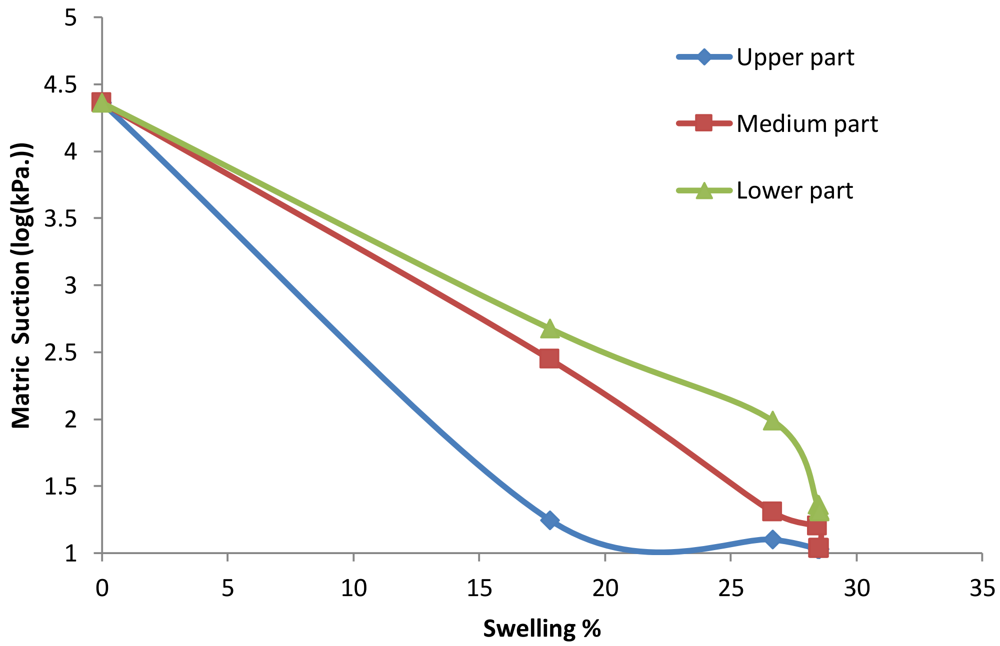

**Figure(8):Relationship between Water Content and Total Suction of Expansive Soil for Three Parts of Container.**




Figure(9):Relationship between Water Content and Matric Suction of Expansive Soil for Three Parts of Container.




Figure(10):Relationship between Swelling with Total Suction of Expansive Soil.




Figure(11):Relationship between Swelling with Matric Suction of Expansive Soil.

**الخلاصة:**

ان تغير الطقس يؤثر على محتوى الماء نتيجة المطر وارتفاع الماء الجوفي والتبخر.نتيجة لهذه العوامل فان التربة الانتفاخية يتغير حجمها وامتصاصها للماء.هذا السلوك يحطم الابنية وخصوصا الطرق والابنية الخفيفة الوزن.من المفيد البحث بهذه المشكلة ومعرفة تاثير تغير المحتوى المائي والامتصاص على التغير الحجمي للتربة الانتفاخية.هذا البحث يقدم نتائج قياسات نسبة الانتفاخ والمحتوى المائي والامتصاص الكلي والجزئي تحت تسليط ماء باستخدام مقياس التشوه وورقة الترشيح .وجد ان مقدار المص يقل بازدياد المحتوى المائي وكذلك انه كلما كان الانتفاخ اكبر كلما مقدارالامتصاصالكلي والجزئي اقل.هذه الدراسة وجدت ان العلاقة خطية تقريبا بين الامتصاص والمحتوى المائي.