Effect of Some Environmental Conditions on Durability of Clayey Soil Stabilized by Waste Lime

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ABSTRACT.

This investigation was conducted to assess the efficacy of some environmental conditions of soil specimens stabilized with optimum waste lime content 6%. These conditions are represented by cycles of (wetting-drying-freezing), (wetting-freezing-drying), (drying-wetting-freezing), (drying-freezing-wetting), (freezing-wetting-drying) and (freezing-drying-wetting). The soil specimens were subjected to these conditions, the durability of these specimens is study by knowledge the change in unconfined compressive strength, volume change and loss in weight. The results indicated that the unconfined compressive strength decreases with cycles for all conditions, but for different percentages according to the type condition. Where the condition more effect that starting freezing-drying-wetting. Also the results show that the specimens subjected to cycles of (freezing-drying-wetting) and (wetting-freezing-drying) destroyed at the end of eight cycle, but the specimens were subjected to other conditions destroyed at the end of tenth cycle. The results show that the maximum loss in weight for specimens subjected to cycles starting wetting-freezing-drying, and the maximum value of volume change for cycles starting freezing-drying-wetting. Finally these condition are regarded very severe conditions and effect on durability of soil stabilized.

Key words: Durability, Environmental conditions, Stabilization, Clayey soil, waste lime

1. INTRODUCTION.

Construction materials were used in different civil engineering applications should have sufficient durability against the different environmental conditions [1]. The soil in nature has different values of strength, these values of strength depend on the type of soil [2]. The natural soil was destroyed when its subjected to environmental conditions. To increase these values of strength and to make it more stable with long time, it has to improve the soil [3]. The durability is defined as the ability of material to retain ability and integrity over the years of exposure to the destructive forces of weathering [4]. To increase the strength and durability of , the soil must be improve by mechanical and chemical stabilization [5].Chemical stabilization of soils involved additives such as lime, waste lime and cement, these additives were very effective to increase the strength and durability of soil[6] However, recent studies related to understanding of the durability of natural or stabilized soils with respect to the influence of environmental factors such as wetting-drying, freezing-thawing cycles and immersion on some engineering properties have been carried out relating to the following tests, unconfined compressive stress, direct shear tests and flexural tensile tests [3,4,7,8,9,10,11].Many researchers studies the durability of soil stabilization by additives, the researchers were measuring the durability of soil by measuring the change in strength and change in volume and loss in weight, it was found that the additives used such as (lime, cement) increased the durability of soil.[3, 12].

In this research the study was showing the effect of some environmental conditions represented by triple cycle (W-D-F) on the durability of soil specimens stabilized by waste lime. The soil specimens cured at 25°C for 7 day, the durability is measured by change in strength, volume change and loss in weight.

2. MATERIALS AND TESTING PROCEDURES.

2.1 Materials.

2.1.1 Soil.

The soil used in this study is a clayey soil collected from Al-Hadbaa district, within Mosul city at depth (1.0 m) below the ground surface. The soil was oven dried for (2 days at 60^0 C), disaggregated gently using hammer to pass through as ASTM # 4 sieve (Annual 1993). The sieved soil was then homogenized thoroughly and kept in plastic bags until testing. Some of the index properties and chemical test results of soil are listed in **Table (1)**, using the relevant tests according to the ASTM standards [13].

2.1.2 Industrial Waste Lime.

Industrial waste lime as by-product production (500-1000 tons/year) was obtained from sugar factory in Mosul city. This waste material is a mixture of many impurities (with small pieces of limestone rocks) organic and inorganic, soluble and insoluble. The chemical properties of industrial waste lime are listed in **Table (2)**.

2.1.3 Water.

Tap water is used in the tests and distilled in some tests as required by the testing procedures.

2.2 Testing Procedures.

2.2.1 Compaction Test.

Sufficient amount of clayey soil was dried at 60°C for 2 days in the oven after that the required amount of water was added and thoroughly mixed by hand. Soil specimens have been prepared by varying waste lime percentage as 0, 2, 4, 6 and 8%.. The oven dry soil sample was mixed with waste lime to obtain a uniform color. A sufficient quantity of water was added to bring the moisture content of the mixture to the desired optimum moisture content after that the treated soil samples putting in plastic pages and left for one hour while the natural soil left for 24 hours. The mixture was remolded in to cylinder of diameter 5cm and height 10cm.) by dynamic method of compaction used modified compactive effort according to (ASTM, D: 1557). Mixture of untreated and treated soil was compacted in specific mold according to the required tests by modified proctor.

2.2.2 Unconfined Compression Test.

To find the unconfined compressive strength (U.C.S) of soil by the unconfined compression test, the specimens were prepared on natural and treated soil with (2, 4, 6, 8%) of waste lime. The treated samples were left one hours as mellong time after adding of water to soil –waste lime mixtures inside the plastic pages with out subjected to air to prevent loss of water from the soil samples. A Cylindrical mold of (D: 50mm and H: 100mm) was used to prepare specimens of the soil. All specimens were treated with waste lime were sealed with aluminum foil then , finally covered by paraffin wax to curing of this specimens for 7 day at temperature of 25°C.the unconfined compression was test conducted according to (A.S.T.M, D:2166).

2.2.3 Environmental Conditions.

To study the effect of environmental conditions on the unconfined compressive strength, volume change and loss in weight of stabilized soil with 6% waste lime , this percentage of waste lime represents the optimum waste lime content according to the illinois procedure, which depend on the unconfined compressive strength value [7]. After preparation, the specimens were cured for 7 days at 25°C then, subjected to the environmental conditions.

Some environmental conditions were represented in this study by the following tests procedure:

1.Wetting – Drying – Freezing test procedure designated by (W-D-F)
2. Wetting – Freezing – Drying test procedure designated by (W-F-D)
3. Drying – Wetting – freezing test procedure designated by (D-W-F)
4. Drying – Freezing – Wetting test procedure designated by (D-F-W)
5. Freezing – Wetting – Drying test procedure designated by (F-W-D)
6. Freezing – Drying – Wetting test procedure designated by (F-D-W)

These procedures was done to determine the soil strength of lime stabilized clayey soil subjected to these conditions. Six identical sets of specimens were prepared at maximum dry density and optimum moisture content of the modified compactive curve of 6% waste lime content.

The first set of specimens was subjected to 12 cycles of triple cycle (wetting– drying – freezing) were 2 days for wetting and 2 days for drying where the drying process at degree of temperature 60°C and 2 day for freezing at degree of temperature -5C. The unconfined compressive strength estimate at the end of 2^{nd} , 4^{th} ,6^{th} , 8^{th} , 10^{th}, 12^{th}) of wetting- drying - freezing cycle. At the end of each cycle of (W-D-F), the volume change was measured, also the loss in weight was taken at each of (W-D-F) cycle. The second to sixth sets of soil specimens were subjected to the same above environmental condition and the same test procedure, but , the starting condition is different, where,2^{nd} set was (W-F-D), the 3^{rd} set was (D-W-F), the 4^{th} was (D-F-W), 5^{th} was (F-W-D) and 6^{th} set was (F-D-W).

3. RESULT AND DISCUSSIONS.

3.1 Compaction Characteristics.

The compaction characteristics of untreated soil specimens and treated soil specimens with different percentages of waste lime (2 ,4 ,6. 8 %) are shown in **fig. (1)**. The maximum dry unit weight decreases with waste lime, while the optimum moisture content increase, this behavior is similar to that in lime, also the causes of this behavior, (decrease in density) may be due to immediate reaction between waste lime and soil, while the increase in optimum moisture content) may be due to increase of the fine material and hydration of waste lime.

3.2 Unconfined Compressive Strength.

The Unconfined compressive strength (U.C.S) of treated (natural) soil specimens and treated with waste lime are shown in **fig.(2)**, it is observed that the U.C.S. increased with waste lime, also noticed that the U.C.S. of soil increase up to 6% of waste lime then, decreases. The decrease in strength when the soil stabilized by 8% of waste lime was due to the extra waste lime, which act as a fill material due to uncompleted reaction with lower degree of curing temperature 25°C. The U.C.S. of untreated soil specimens was 900 kN/m^2 , while the U.C.S. of treated soil with percentages of waste lime (2, 4, 6, 8 %) attains after 7 days curing time at 25°C temperature of order (1060, 1219, 1760, 1500) respectively, that gave an improvement ratio (1.2, 1.4, 2.0, 1.7) times compare with control soil specimens (untreated specimens).

3.3 Effect of the Environmental Conditions on the Durability of Soil.

The environmental conditions regarded a severe conditions and effect on the durability of soil, to measure this effect three methods were taken:

1. Unconfined compressive strength.
2. Volume change.
3. Loss in weight.

3.3.1 Unconfined Compressive Strength.

The variations in unconfined compressive strength of waste lime stabilized soil specimens when subjected to the third cycle (W-D-F) condition were studied. The results shown in **fig.(3)** and **table (3)** the unconfined compressive strength was determined at the end of each two cycles of a test. From the results, it may be observed that the general trend given reduction in strength with cycles but in different percentage of reduction depends on the type of condition (starting condition). It was noticed that the maximum reduction percent in strength at the end of second cycle, if the cycle starting by freezing in (F-D-W) condition was 50% of original strength while, the minimum reduction in strength percent at the end of second cycle was 13% for the condition (F-W-D), the reduction in strength of the other conditions at the end of second cycle were (36, 29, 22 and 18%) for triple cycle conditions (D-W-F), (W-F-D), (W-D-F) and (D-F-W) respectively. At the end of the fourth cycle, the percent reduction in soil strength reached a maximum value 72% for (F-W-D), while the minimum percent was 28% for (F-W-D). The reduction in strength for other conditions between (28- 72%). At the end of sixth cycle the maximum reduction in strength was 93% for (F-W-D), while the minimum reduction was 45%. The reduction in strength for the other conditions between (45-93%). At the end of eight cycle the specimens subjected to (F-W-D) and (W-F-D) conditions were destroyed and the reduction in strength reached to 100%, while the specimens were subjected to other condition were destroyed at the end of tenth cycle.

3.3.2 Volume Change.

The volume change is also regarded method to know the durability of soil stabilization when subjected to environmental condition. The volume change in the soil specimen was measured at the end of each part condition of one cycle , which means at the end of wetting and end of drying and end of freezing for each cycle. **Fig. (4)** and **table (4)** show the variation in volume change through the 12 cycles of a test (third cycle). As can be observed from this figure, an initial increase in volume during the wetting part of the first cycle , if the test starting by wetting as (W-F-D) and (W-D-F), where the wetting part gave 8% increase in volume, also in freezing part the volume increase, but through drying part the volume decrease to reach the value less than 1% the original volume. The second cycle for the same type of condition the wetting part given the increase in volume but less than that in the first cycle were 5%.It is noticed, during freezing part the volume increase if the preceding part was wetting, because the water in the porous soil specimens increase in volume due to freezing condition part. While the volume sustain constant during freezing if, the preceding part was drying because, the soil particles were drying and the voids fill by water. This behavior continue through the following cycles but in difference value, but the specimens don't reach to the 12 cycle where the specimens were destroyed before that, If the cycles starting by drying as (D-W-F) and (D-F-W) in the first cycle the volume decrease through the drying part by (6-7%) compare with the original volume. The following part if wetting as (D-W-F), the value will increase to reached 5% compare with the original volume, but if the followed part was freezing the volume sustained. Through the third part of the first cycle, if freezing as (D-W-F) the volume increase while in wetting third part (D-F-W) the volume increase also increase but less volume this trend continue until the destroyed specimens before reached to 12 cycle. In triple cycle starting by freezing, the volume increase by (5 – 5.5%) after that, if the 2nd part of the first cycle was wetting the volume continue increase to reached 8.5%, while if the 2nd part of the first cycle was drying the volume will decrease to 2% less than the original volume. For the 3rd part of the first cycle if it was drying the volume will decrease but, if it is wetting the volume increase to 8%. This behavior will continue but in different values less than in the first cycle until the specimens are destroyed before 12 cycles because these conditions were regarded a severe conditions compare with wetting – drying or freezing – thawing cycles only.

3.3.3 Loss in Weight.

All test results for the percentage loss in weight in represent of durability (alternate triple cycle conditions) tests are shown in **fig. (5)**. As can be seen from this figure, the general trend is that of a steadily increasing cumulative loss in weight with cycles. It can also be observed from the curves that the maximum loss in weight occurs in soil specimens subjected to (W-F-D) about 43.3% at the end of seventh cycle after this cycle the specimens were destroyed. While the minimum less in weight was 6.0% in the soil specimens subjected to (F-W-D), were the specimens don't destroy until the end of the tenth cycle of this triple condition. The cumulative percent of loss I weight of other fourth environmental condition lies between the maximum and minimum values were (6.0 – 43.3%). At the end of these triple cycles, all soil specimens destroyed and don't arrive to 12 cycles because these conditions are regarded very severe conditions.

4.CONCLUSIONS.

1. The triple cycle (W.D.F) starting cycle by any condition wetting or drying or freezing is regarded a sever condition and the unconfined compressive strength reached zero (no strength in soil) before reached the specimens to 12 cycles.

2. The volume change occurs in soil specimens having different wetting or drying or freezing but in all conditions the volume will effective durability of soil specimens.

3. The soil specimens subjected to these conditions suffered loss in it is weight with different percent depend on the type of condition , If cycle condition starting by W then F then D, the cumulative maximum loss in weight was 43.3, while the minimum loss in weight was 6.5% from cycle starting F then, then W, then D. Other conditions gave values between them.

4. The waste lime is regarded not efficiency to stabilized soil, if the soil subjected to the triple cycle (W-D-F).

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Table (1): Physical and chemical properties of natural soil.

Properties	Values
Liquid Limit (%)	51
Plastic Limit (%)	24
Plasticity Index (%)	27
Linear shrinkage (%)	14
Total Soluble salts (%)	1.9
Organic matter (%)	1.3
Specific gravity	2.72
Sand (%)	14
Silt (%)	40
Clay (%)	46
Soil Classification (USCS)	CH

Table (2): Chemical composition of waste lime.

Composition	$Ca(OH)_2$	CaO	$CaCO_3$	AL_2O_3	Fe_2O_3	SiO_2	MgO	H_2O	**L.O.S**
Waste lime	43.6	8.19	12.74	14.9	0.42	16.9	3.13	0.1	0.02

- **L.O.S** = Loss of Ignition

Table (3): Effect of environmental conditions on U.C.S of waste lime stabilized soil.

No of cycle	W.D.F (kN/m^2)	R %	W.F.D (kN/m^2)	R %	D.W.F (kN/m^2)	R %	D.F.W (kN/m^2)	R %	F.W.D (kN/m^2)	R %	F.D.W (kN/m^2)	R %
0	1410	0	1410	0	1410	0	1410	0	1410	0	1410	0
2	1100	22	1000	29	900	36	1160	18	1230	13	700	50
4	890	37	750	47	700	50	930	34	1010	28	400	72
6	630	55	150	89	500	65	700	50	770	45	100	93
8	480	66	0	100	350	75	570	60	620	56	0	100
10	200	86			0	100	240	83	340	76		
12	0	100					0	100	0	100		

Table (4): Effect of environmental conditions on volume changes of waste lime stabilized soil.

No. of Cycles	W.D.F	W.F.D	D.W.F	D.F.W	F.W.D	F.D.W
0	0	0	0	0	0	0
0.33	8	8	-6	-7	5.5	5
0.66	-1.5	17	5	-3	8.5	-2
1	-2	-1	8.5	2	-0.5	8
1.33	5	5	-5	-5	-1.5	18
1.66	-4	15	5	-3	6	0
2	-5	-3	10	1.5	1	5
2.33	5	5	-4	-6	-1	19
2.66	-4	14	4	-3	7	1
3	-5	-3	12	1	2	6
3.33	6	4	-4	-7	0	18
3.66	-5	13	5	-2	9	-2
4	-3	-3	13	1	0.5	5
4.33	7	4	-6	-8	0	17
4.66	-5.5	11	4	-3	8	-3
5	-4	-4	12	0	1	4
5.33	6	1	-3	-10	-0.5	15
5.66	-7	8	4	-4	4.5	-5
6	-6.5	-4	9	-1	1.5	4
6.33	5.5	0	-9	-11	-1	14
6.66	-7.5	7	3	-5	5	-5
7	-7	-4	7	-2	1	3

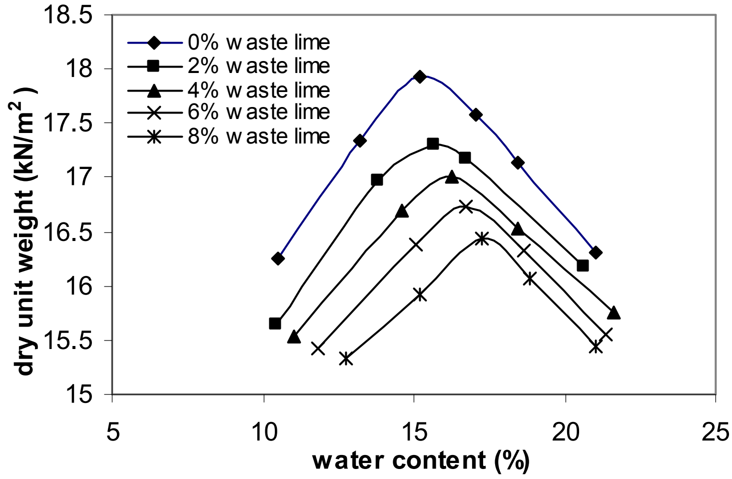

Figure (1): Dry unit weight and water content relation for natural and waste lime treated soil.

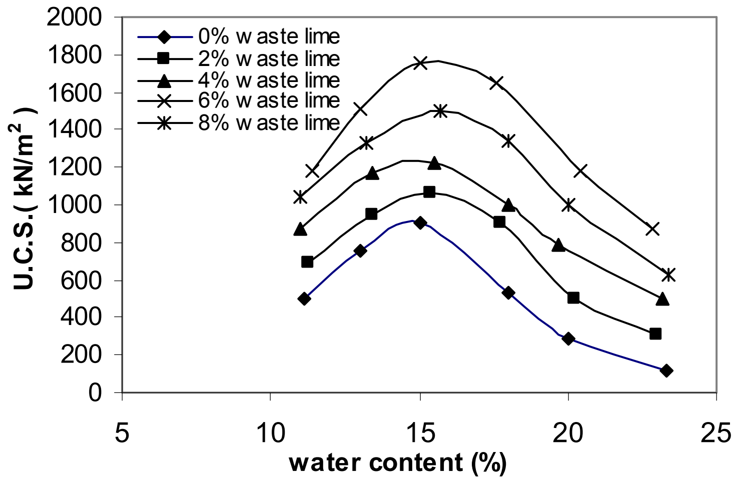

Figure (2): Unconfined Compressive Strength and water content relation of natural and waste lime. treated

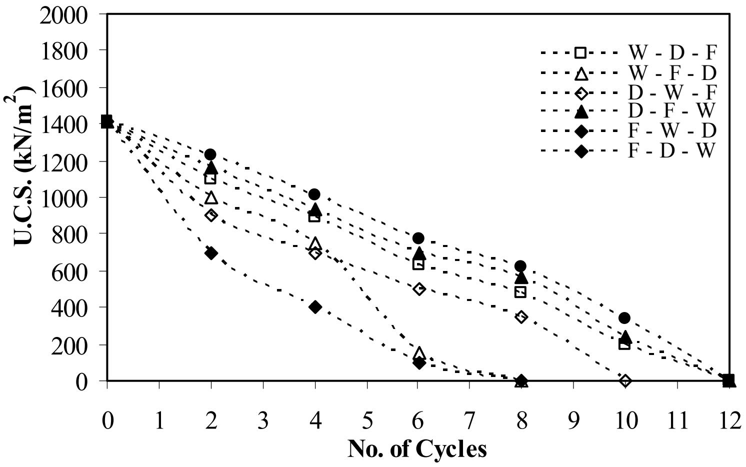

Figure (3): Effect of environmental condition on unconfined compressive strength of waste lime stabilized soil.

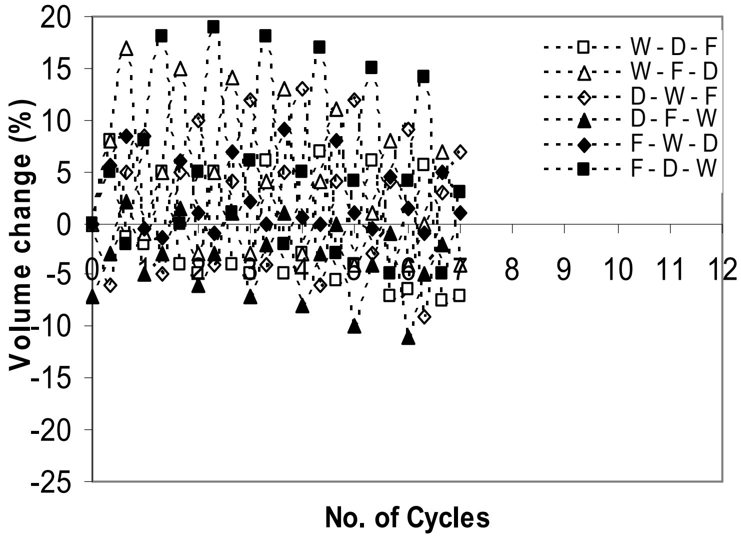

Figure (4): Effect of environmental conditions on volume changes of waste lime stabilized soil.

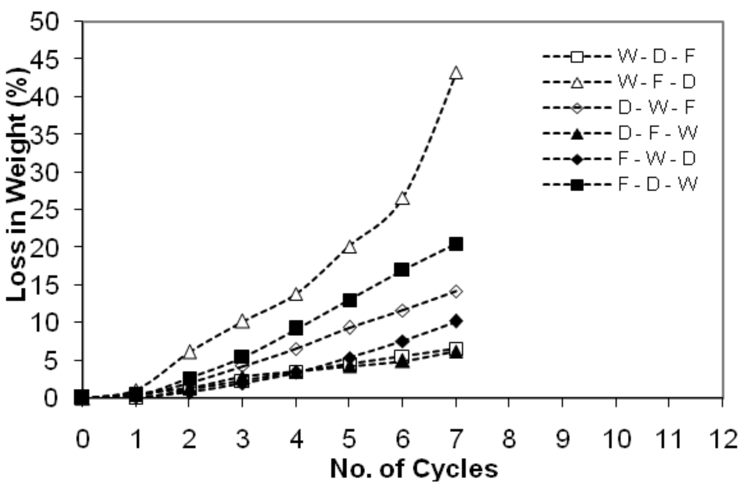

Figure (5): Effect of environmental conditions on the loss in weight of waste lime stabilized soil.

تأثير بعض الظروف البيئية على ديمومة الترب الطينية المثبتة بمخلفات النورة

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الخلاصـة

يهدف هذا البحث إلى دراسة تأثير بعض الظروف البيئية على نماذج التربة المثبتة بالنسبة المثلى من مخلفات النورة والتي هي 6%، وتتمثل هذه الظروف بدورات (ترطيب–تجفيف–انجماد) و (ترطيب– انجماد تجفيف) و (تجفيف–ترطيب–انجماد) و(تجفيف– انجماد–تجفيف) و (انجماد–ترطيب–تجفيف) و (انجماد–تجفيف–ترطيب). عند تعرض النماذج لهذه الظروف يتم دراسة ديمومة نماذج التربة المثبتة من دراسة تغير كل من قوة الانضغاط غير المحصور مع الدورات وكذلك تغير الحجم وفقدان الوزن. أظهرت النتائج ان قوة الانضغاط غير المحصور تقل مع الدورات وللظروف الثلاثة المذكورة ولكن بنسب مختلفة وفقا لطبيعة الظرف، إذ كان الظرف الأكثر تأثيرا هو بدء الدورات بالانجماد–تجفيف–ترطيب. كما أظهرت النتائج ان النماذج المعرضة لدورات (ترطيب–انجماد–تجفيف) و (الانجماد–التجفيف–الترطيب) انهارت النماذج في نهاية الدورة الثامنة.بينما النماذج المعرضة للظروف الأخرى انهارت في نهاية الدورة العاشرة.كما أظهرت النتائج ان اعلى نسبة للتربة المتساقطة (الفقدان في الوزن) كان في النماذج المعرضة للدورات المبتدئة بالترطيب–تجفيف وانجماد، وأعلى تغير في الحجم في النماذج المعرضة للدورات المبتدئة بالانجماد–تجفيف–ترطيب. تعد هذه الظروف قاسية جدا وتؤثر بشكل كبير على ديمومة التربة وكأنها تتحول إلى تربة غير مثبتة.

الكلمات الرئيسية:الديمومة،الظروف البيئية،الإستقرارية،التربةالطينية،الجير المفقود.