# Treatment of Expansive Clayey Soil with Crushed Limestone

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**ABSTRACT**
This paper aims at the improvement of expansive clays, by the addition of crushed limestone, obtained from the waste of masonry factories situated in the polluted industrial area, to the east side of Mosul city. This abandoned waste material creates serious environmental problems in the areas surrounding these factories requiring an urgent solution to dispose of the huge quantities heaped in there.
Different percentages of the crushed limestone by weight (passing sieve No.40) were added namely (2, 4, 6, 8, and 10%) to the clay obtained from "Al-Wahda district in Mosul" to reduce its expansiveness and improve its characteristics for many earth work construction. The test results showed pronounced reduction in the plasticity of the clay and significant decrease in the swelling properties, in the range of more than three and half times that of untreated one. These results represent very important factor for road embankment constructions.

## معالجة الترب الطينية الانتفاخية بمسحوق حجر الحلان

الخلاصة
حجر الحلان عادة مادة بنائية منتشرة الاستعمال في مدينة الموصل والتي هي في معظمها كربونات الكالسيوم . تقع معامل قطـع وصقل هذه المادة في المنطقة الصناعية الملوثة للجانب الشرقي للمدينة، مما خلف أكوام ضخمة من فضلات هذه المعامل والتـي تستدعي الضرورة الملحة إلى التخلص منها.
لغرض البحث، أضيفت كميات متباينة من مسحوق الحجر المار من منخل رقم (40) وفق النسب (6،4،2،8،10 %) وزنا، إلـى تربة طينية معروفة بانتفاخيتها، من اجل السيطرة على قابلية انتفاخها،وكذلك تحسين خصائصها الهندسية لغرض استخدامها فـي أعمال سداد الطرق .
بينت نتائج الفحوصات المختبرية انخفاض في لدونة التربة مع انخفاض كبير لخاصيتها الانتفاخية إلى حد يصل إلى ثلاث أضعاف ونصف قياسا لقيمتها قبل المعالجة.
تمثل هذه النتائج عاملاً مهما في تثبيت الترب الانتفاخية الطينية إلى الحد المقبول.

## Introduction

Soil stabilization is a vital task not only for weak soils, but also for expansive types as well. Expansive potential of highly plastic clays is a source of great damages and economical dispense (Gromko, 1974). The construction on sub grades requires sometimes to altered the engineering properties, of the, upper soil layers, using one of the soil stabilization methods (Ingles &Metcalf, 1972) or by replacement of the soil. The selection of the proper treatment method usually depends on of an economical study.

The changes of the engineering properties of soil by the addition of different compounds like KCL, Ca $(OH)_2$. bitumen or cement) have been studied thoroughly by several investigators (Ingles, 1972)(Al-Khashab, 2002)(Al-Ashou&Al-Khashab, 1993)(Sokolvich, 1973)Some of the compounds lead to soil improvement, while the other have harmful effect on the engineering soil properties, such as highly acidic chemicals(Ingles, 1972) (Sokolvich, 1973). The most common methods employed for the stabilization of clayey soils are cement and lime stabilization (Kezdi, 1979) (Sharma, 1985). These methods produce a stabilized layer of significant strength, which may not always be required in the subgrade of some structures. Besides, they are costly nowadays. Hence, this paper describes an investigation about the addition of a by product limestone which is abandoned in huge quantities, to expansive clay that have almost the same properties of the investigated soil, to improve their engineering properties. This waste material creates serious environmental problems nowadays in the masonry factories surrounding areas.

## Limestone

Limestone is the most widely rock in Iraq and particularly in Mosul area, where it can be extensively used in constructional activities, of this region many thousands years ago. Assyrian archeological sites are some of the famous examples in this respect. Limestones are sedimentary bedded rocks, often containing many fossils. They are classed as organically and chemically formed, but the most abundant is usually of organic origin (Blyth, 1963).Shelly limestone is an organically formed rock in which fossil shell form a large part of its bulk.

Limestone consists essentially of Calcium Carbonate, with which there is generally some magnesium carbonate and siliceous matter such as quartz grains.

The limestone may be composed of four minerals, Calcite (CaC03) Aragonite, Dolomite (CaMg (C03)2) and Magnetite (MgC03) (Boynton, 1980).

The chief constituent of limestone is that the Calcium Carbonate (CaC03) has cleavage faces, well developed in three planes of 75° with each other. The hardness is effervesces with cold dilute hydrochloric acid (HC1). It has variable colors but the color becomes white when it is pure (Field, 1955).

**Expansiveness Aspects of Mosul Clay Soils**

The clay in Mosul area generally found as moderately to high expansive. There swelling potentials varies between (4.7-15 %) for remolded samples and (2.4-9%) for undisturbed samples (Al-Layla and Al-Ashou, 1985).

The previous studies showed that the index properties can be used to estimate the expansiveness of these soils (Holts and Gibbs, 1956). However such estimation is more convenient for remolded rather than undisturbed soil. The swelling potential of the soil can also be estimated with the help of activity of the soil and the percentage of clay size particles, which can be used as measure for the amount of volume change (Seed et al, 1962).

**4-Tseted Materials and Discussion of Results**

The soil used in this investigation obtained from (1.5-2.0) m. deep test pits located at Al - Wahda district in Mosul. It is in general light brown colored clay with variable thickness covering almost horizontal rock strata. Geologically, the soil belongs to the Quatemary age, while the rocks (mainly gypsum with stiff clay beds) are referred to lower fars (Fat ' ha) formation (Al-Shaikh&Baker, 1973). The top clay soils have the following properties -L.L. (50-52) %, P.I (27-31) %. Thus the soil is classified as (CH) according to the Unified Classification System and described as "Inorganic clay of high plasticity ". The percentage of clay size particles (≤ 2m) is (40 - 42) % Fig (l).The specific gravity (Gs) is2.72. The activity of the soil is (0.64-0.77), the Linear shrinkage (13.8- 14.7) %. Hence, the swelling potential (S %) according to the formula presented by Seed et.al, 1962) is 5.61% and it can be classified as medium expansive soil following the classification suggested by Holtz(Holts&Gibbs, 1956).The clay minerals were identified by X- Ray Diffraction Analysis. The result shows that the clay minerals are: - Kaolinite, Chlorite, Illite and Montmorillonite, while the non - clay minerals are: Quartz Calcite and Gypsum(Al-Dabbagh, 2000). Cation Exchange Capacity (C.E.C) is 41 milliequivalent /100 gm of oven dry soil ,which confirmed that, this soil is of medium expansion as compared with value of Montmorillonite type(Grim, 1986).

The soil was mixed with different amounts of crushed limestone passing sieve No.40, namely (2, 4, 6, 8 and 10 %). The samples were kept in dishes with an excess of distilled water, inside an oven 50 °C, daily mixed till the dryness of all samples and become ready for engineering properties determination.

The test showed that significant changes in the engineering properties of the treated soil due to ($CaCO_3$) addition as will be discussed in the following paragraphs.

**4-1 Index Properties**

The consistency limits of the treated soil were determined. The results are presented in Table (1). It can be noticed that the liquid and plasticity' indices decreased with the increase of the added crushed stones. From Casagrande's plasticity chart (Sharma, 1985), it can be noticed that the classification of the soil has altered from (CH) to (CL) after treatment. Linear shrinkage, Table (2) shows that it was reduced from (13.38 to 10.3 %) by the addition of crushed stones. It is believed that these changes in the physical properties of the clay partly resemble the same effect of clay stabilization by sand addition as the increase of sand in certain amount of soil, the percentage of clay within this amount will be reduced, and consequently, the properties will be changed. (Al-Ashou et al, 1993).

The other cause of change in the properties is the effect of the presence of $Ca^{++}$ ions. These ions initially combined with, or absorbed by clay, creating an increase in the flocculation tendency of the soil fluid. This yields to decrement of the repulsive forces. These changes continue up to certain fixation point. This addition, contributes towards the improvement of soil workability, but not to an increase in strength (Bell, 1996). The addition in excess of the fixation point is utilized in the cementation process. As a result, the clay particles will readjust themselves into more stable configuration (Al-Khashab& Al-Hadedy, 2002), (Al-Ashou& Al-Khashab, 1994).

### 4-2 Grain Size Analysis

Table (3) and Fig (1) describe the test results. It can be shown that the clay size particles ($\leq 2\ \mu$) decreased with the increase of limestone addition, while the percentage of silt size particles ($2 - 7.4\ \mu$) increased. This phenomenon is due to the flocculation of clay particles to the silty size resulting from the presence of $Ca^{++}$ and consequently a decrease in the double water layer occurred, as described in sec. (4-1) above.

### 4 -3 Modified Compaction Test

The modified proctor test was conducted on soil samples treated with (0, 2,4,6,8 and 10%) of crushed limestone. The samples were compacted at different moisture contents, to obtain the moisture - density relationship. The results are plotted in Fig (2) and summarized in Table (4). To clarify the difference due to the treatment. It can be noticed that the dry density ($\gamma_d$) increases with the amount of crushed stone added up to 4%, and then it tends to decrease. So, it can be said that (4%) addition is the optimum, that gives the maximum density.

### 4-4 Unconfined Compressive Stress

For the comparison study of (U. C. S), the curves of Fig (2) were used to maintain the same dry unit weight of all soil samples, (equal to 1.67 gm/cc) with different moisture contents as indicated from the said Fig. Three soil samples for each percentage of the added crushed stone, were prepared using a compaction tool, Fig. (3) , Especially manufactured to resemble the Harvard Miniature tool. The compaction effort was done by using the same energy of the Modified Proctor Compaction Methods. The results were tabulated in Table (5) which shows that 4% addition gives maximum amount of the (U .C .S).

### 4-5 Swelling Properties

For the purpose of this study, swelling pressure and free swelling tests were conducted on samples treated with (2, 4, 6, 8 and 10%). of crushed stone addition.

All samples were prepared as indicated in sec. (4-3), i.e. having the same dry unit weight (1.67 gm/cc) with different moisture contents as indicated in Fig (2) , using the tool shown in Fig (4) .Three Samples were prepared for each test. The results are presented in Table (5). The tests results show that the swelling pressures and free swells decreased considerably with an increase of crushed stones addition.

## 5- CONCLUSIONS

The following points can be concluded from the results of this work:

1. The index properties of the clay were changed by the addition of the crushed stone towards silty characteristics.
2. The reduction of the index properties towards less plastic nature indicates that there will be pronounced redaction in the swelling potentials.
3. The maximum obtained Unconfined Compressive Stress was gained by 4% crushed stone addition.
4. The continues addition of crushed stone cause decreased the clay swelling pressure and to the amount of free swell.

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**Table (1) The Consistency Limits of Treated and Untreated Soil.**

| Crushed Limestone passing sieve No. 4 | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|
| Liquid Limits (L.L) % | 51 | 39 | 38.5 | 38 | 37 | 35 |
| Plastic Limits (P.L) % | 27 | 27.52 | 28 | 29 | 29 | 30 |
| Plasticity Index (P.I) % | 24 | 11.5 | 10.5 | 9 | 8 | 5 |

**Table (2) The Linear Shrinkage of Treated and Untreated Soil.**

| % Crushed Limestone Passing sieve No. 40 | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|
| Linear Shrinkage % | 13.38 | 12.93 | 12.6 | 12.2 | 11.9 | 10.3 |

**Table (3) Grain-Size Analysis Results.**

| % Crushed Limestone passing Sieve No. 40 | (%)Clay | (%) Silt | (%) Sand |
|---|---|---|---|
| 0 | 40 | 53 | 7 |
| 2 | 36 | 57 | 7 |
| 4 | 32 | 61 | 7 |
| 6 | 30 | 63 | 7 |
| 8 | 29 | 64 | 7 |
| 10 | 24 | 69 | 7 |

**Table (4) The Modified Compaction Test Results.**

| % Crushed Limestone passing sieve No. 40 | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|
| Max. Dry Density ($\gamma d$) kN/m$^2$ | 16.6 | 17.1 | 17.2 | 17.1 | 17.1 | 17.0 |
| Optimum Moisture Content (O.M.C) | 19.7 | 19.0 | 18.5 | 18.8 | 19.5 | 20 |

**Table (5) Unconfined Compressive Strength**

| % Crushed Limestone passing sieve No. 40 | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|
| Water Content (W/c)% | 19.7 | 17.0 | 16.0 | 17.0 | 17.2 | 16.5 |
| Unconfined Compressive Strength kN/m$^2$ | 20 | 30.4 | 50.9 | 41.9 | 34.6 | 22.5 |

**Table (6) Swelling Prosperities**

| % Crushed Limestone passing sieve No. 40 | 0 | 2 | 4 | 6 | 8 | 10 |
|---|---|---|---|---|---|---|
| Swell Pressure kN/m$^2$ | 19.5 | 14.0 | 8.6 | 6.9 | 5.9 | 5.5 |
| Free Swell (%) | 4.76 | 3.3 | 3.0 | 2.6 | 1.4 | 1.3 |

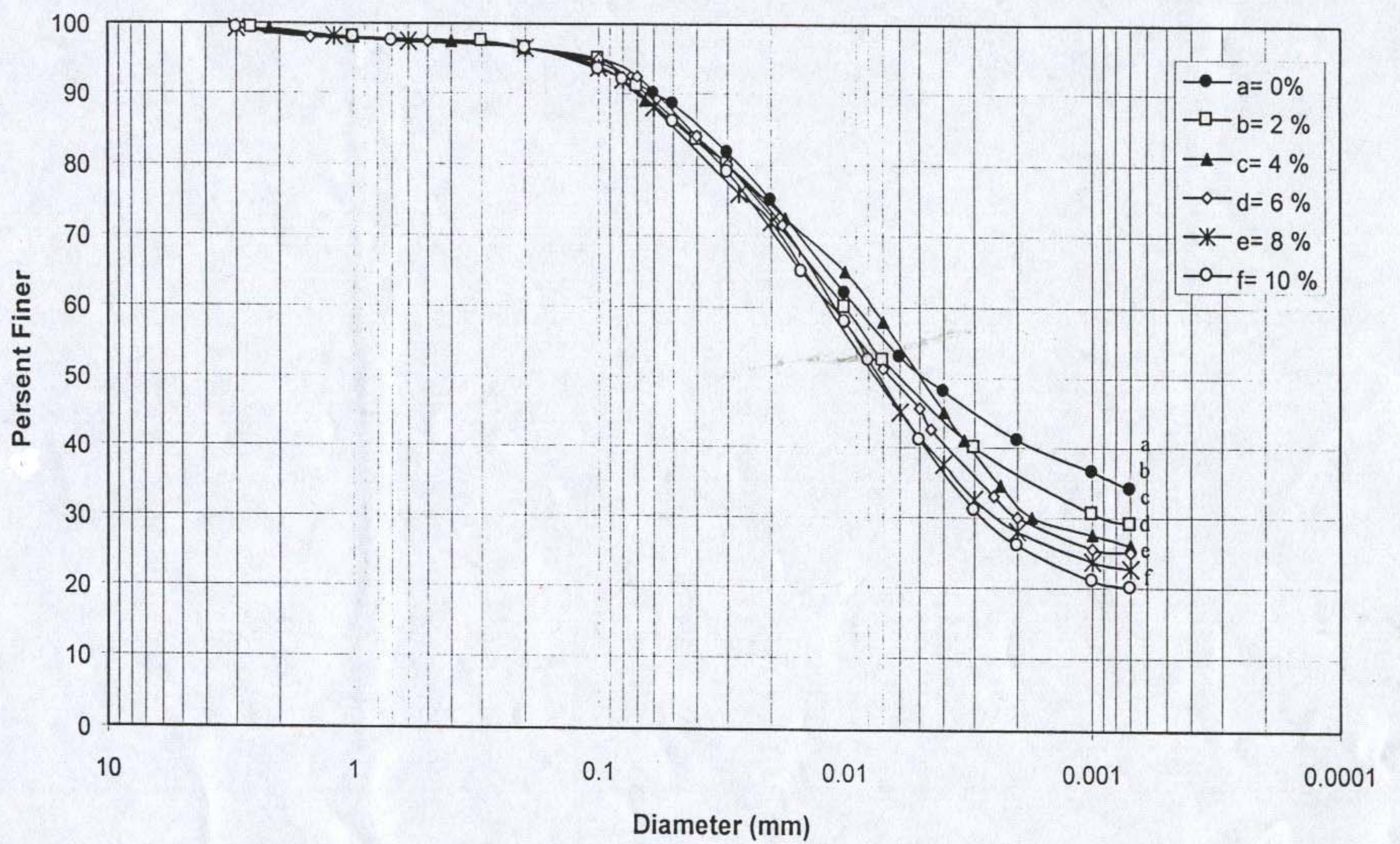


Fig (1) Grain Size Distribution Diagram

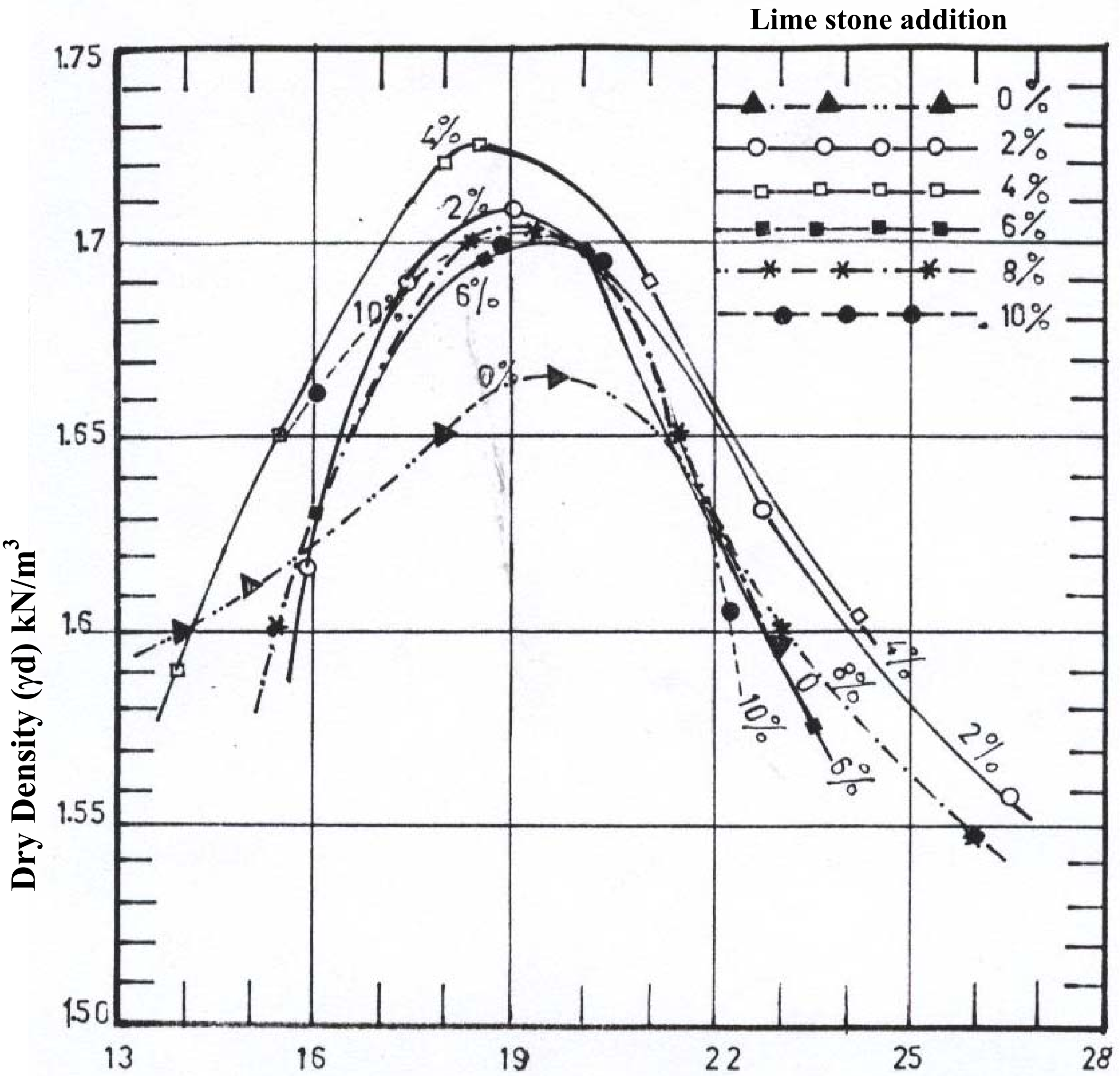


**Fig. 2 Modified Procter Compaction Test Results**

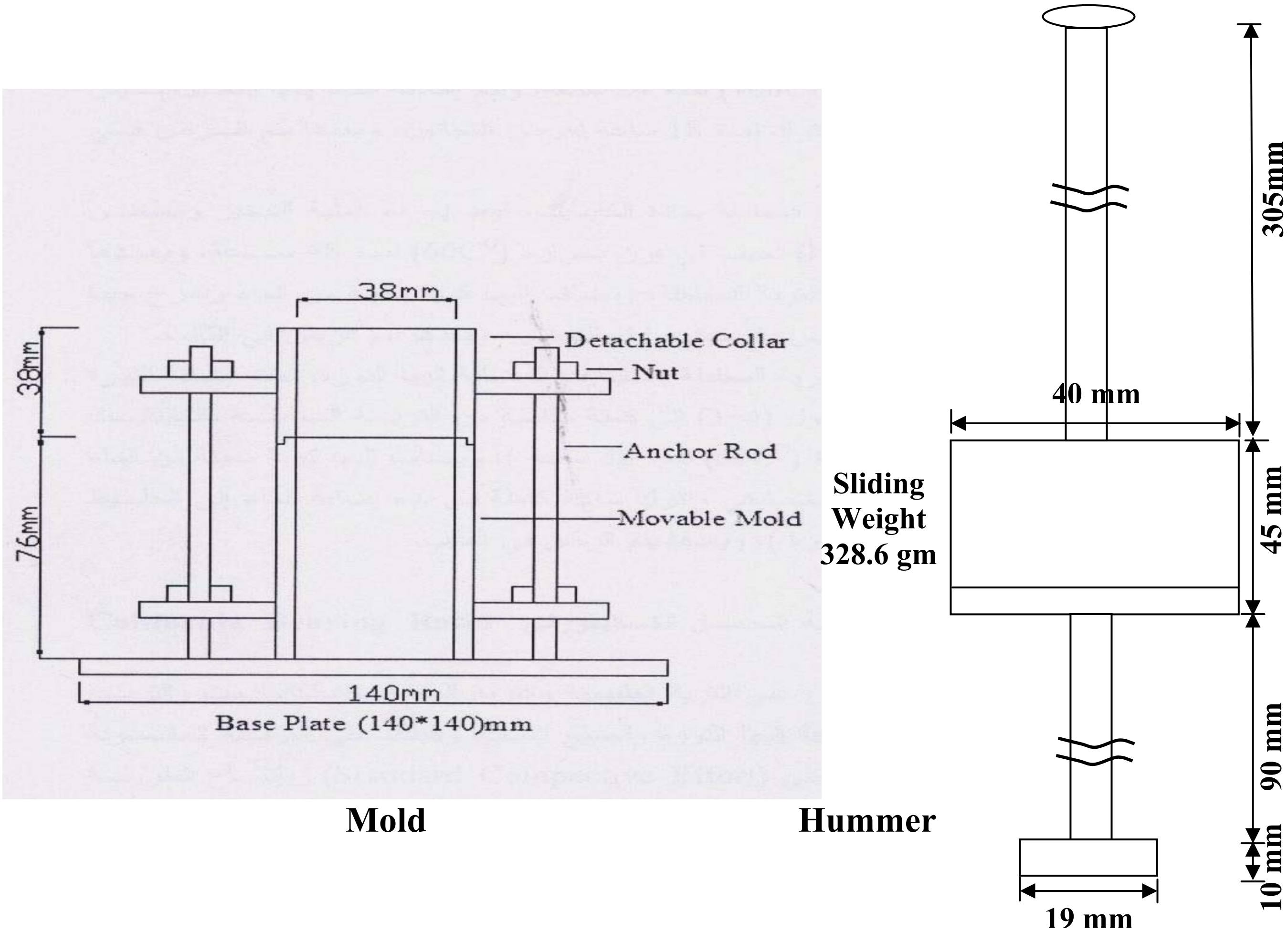


**Fig. 3 Compaction Tools**

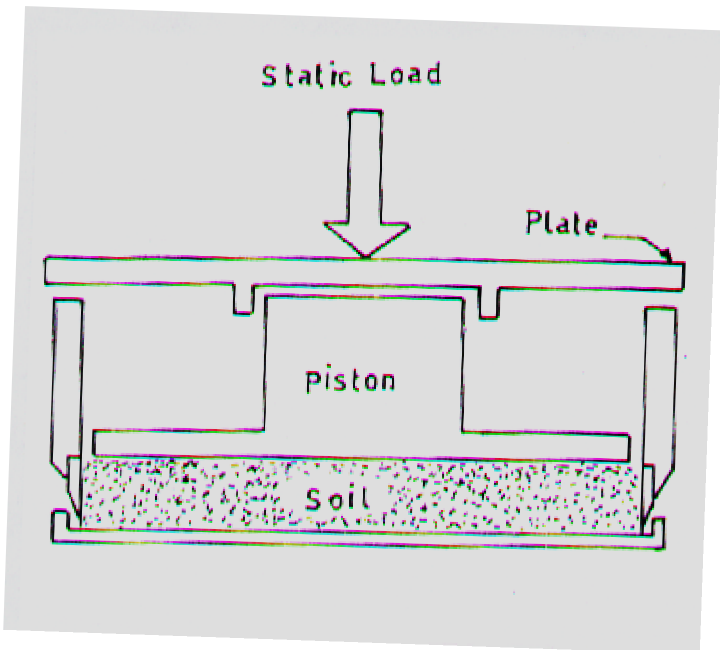


**Fig. 4 Soil Samples Preparation Tool for Swelling Tests**