Stabilization of Clay Soil Using Tyre Ash

Mahmood Dheyab Ahmed
Assistant Professor
Engineering College-Baghdad University
Email: mahmoud_baghdad@yahoo.com

Ahmed Mohamed. Adkel
Engineering College-Baghdad University
Email:Ahmed87_ce@yahoo.com

ABSTRACT

The planning, designing, construction of excavations and foundations in soft to very soft clay soils are always difficult. They are problematic soil that caused trouble for the structures built on them because of the low shear strength, high water content, and high compressibility. This work investigates the geotechnical behavior of soft clay by using tyre ash material burnt in air. The investigation contains the following tests: physical tests, chemical tests, consolidation test, Compaction tests, shear test, California Bearing Ratio test CBR, and model tests. These tests were done on soil samples prepared from soft clay soil; tyre ash was used in four percentages (2, 4, 6, and 8%). The results of the tests were; The soil samples which gave the value of plasticity test were 2% (25), 4% (25.18), 6% (25.3), and 8% (26.7).The soil samples which gave the value of specific gravity were 2% (2.65), 4% (2.61), 6% (2.5), and 8% (2.36).The value of maximum dry density in a compaction test observed with 2% percentage gave the value 15.8 kN/m3, the 4% gave the value 15.4 kN/m^3, 6% gave 15.3 kN/m^3 and 8%with 15.2 kN/m^3.Samples that gave the values of undrained shear strength test were 2% (55 kN/m^2), 4% (76 kN/m^2), 6% (109 kN/m^2), and 8% (122 kN/m^2). The best of them is 8%.

The sample that gave the best value for swelling test was 8%.The best value for compression index Cc was in 8%.The results of CBR test, were improved in all soil samples. The soil samples which gave the value for CBR were 2% (3.507%), 4% (4.308%), 6% (5.586%), and 8% (9.569%). The best value was obtained from 8%.

Keywords: soft soil, stabilization, shallow foundation**,** tyre Ash

تثبيت الترب الطينية الضعيفة باستخدام رماد الإطارات

محمود ذياب احمد
أستاذ مساعد
كلية الهندسة- جامعة بغداد

احمد محمد ادخيل
باحث
كلية الهندسة- جامعة بغداد

الخلاصة

التخطيط والتصميم وأنشاء الحفريات ووالأسس في الترب الطينية الضعيفة والضعيفة جدا تكون دائما صعبة للمهندسين وتمثل تحديا صعبا لهم التي تكون ذات مشاكل مسببة أضرارا في أعمال الإنشاء عليها بسبب ضعف مقاومة القص ومحتوى الماء العالي ووالانضغاطية العالية لها. هذا العمل تحرى في سلوك خواص الرص للترب الطينية الضعيفة باستخدام رماد الإطارات المحروقة في الهواء. أعمال التحريات تحتوي على الفحوصات التالية: الفحوصات الفيزيائية ,الفحوصات الكيميائية , فحص الانضمام وفحوصات الحدل و فحص القص و فحص ونسبه التحمل لكاليفورنيا وفحوصات الموديل. تلك الفحوصات أجريت على نماذج من التربة الطينية الضعيفة ,واستعمل رماد الإطارات بأربع نسب من رماد الإطارات (2 , 4 , 6 , و

8%) . وكانت نتائج الفحوصات لنماذج التربة التي تعطي قيم فحص اللدونة للنسب2%(25) , 4%(25.18) , 6%(25.3) , و8%(26.7). ونماذج التربة التي تعطي قيم الوزن النوعي للنسب 2%(2.65) , 4%(2.61) , 6%(2.5) , و8%(2.36) .وقيم فحص الحدل عند إضافة 2% تعطي قيمه $(15.8)kN/m^3$, 4% تعطي قيمه $(15.4)kN/m^3$, 6% أعطت $(15.3)kN/m^3$,و8% أعطت$(15.2)kN/m^3$. والنماذج التي أعطت قيم مقاومة القص الغير مبزولة كانت 2%kN/m^2 (55) , 4%kN/m^2 (76) , 6%kN/m^2 (109) , و8%kN/m^2 (122), حيث كانت أفضل قيمه بينهما هي 8% .والنموذج الذي أعطى أفضل قيمة لفحص الانتفاخ هو 8%.وكذلك أفضل قيمة لدليل الانضغاط هي 8%.ونتائج فحص CBR لكل نماذج التربة المحسنة, هذه النماذج أعطت 2%(3.507%) , 4%(4.308%) , 6%(5.586%) , و8%(9.569%) . وأفضل قيمة أعطتها نسبة 8% .

كلمات مفتاح: تربة ضعيفة، التثبيت ، الأسس الضحلة، رماد الإطارات.

1. INTRODUCTION

The engineering properties of the soil are important not only in foundation materials for the projects, but also in the materials for construction in embankments, dams, and other works. The improvement of soil properties is necessary to solve many engineering problems. An improvement is needed in the locations where the soils cannot support loads, for example the necessity for such improvement arises in the airfield runways and sub grade soil of roads, **Atkins, 1980**. One of the fundamental techniques by which the properties of natural materials can be improved is stabilization. In the middle and southern parts of Iraq, soft soils are encountered in many places low shear strengths and high settlements. Random data collected from several sites demonstrated values of undrained shear strength less than 30kPa in Basra governorate and less than 40kPa in Missan and Nasiriya governorates **Rahil, 2007**. In order to improve the behavior of such soils, attempts are made to utilize low cost local materials including waste products materials. Those studies consider stabilizing agents such as (cement-fly ash and lime-fly ash) as in the ground modification of soft compressible clays. Ali- AL Garbi clay belongs to such type of soil; it has greater softness and high compressibility. The suitable use of tyre ash can reduce the cost of stabilization of soft soil, as tyre ash is a waste material. **Afolagboye, and Talabi, 2013**.The choice of method depends on many factors that depend mainly on soil characteristics, type of equipment available, the economy, the type of structure and the time available.

Chemical stabilization includes mixing chemical additives (binding agents) with natural soils by removing moisture and improving strength properties of the soil. Commonly, the role of the stabilizing (binding) agent in the treatment process is either to reinforce the bounds between the particles or fill the pore spaces. Chemical stabilization can be classified into two types depending on the depth of the problematic soil and the type of geotechnical application. The traditional surface stabilization begins by excavating and breaking up the clods of the soil followed by the addition of the stabilization agent. Soil and additives are mixed together with known amounts of water and compacted.

The soil classification and the degree of improvement in the required quality of the soil, its relationship to choose the type determine the percentage added **Misra, and Biswas, 2005**.

As environmental protection is a major concern in the modern world, effective use of tyre ash for large-scale stabilization works can be regarded as economically fruitful and environmentally beneficial. Soil stabilization is used to achieve one or more of the following five items; Increasing the strength of the soil, improving the stability of the soil to withstand the small deformations produced by loading under any weather condition, controlling soil permeability to prevent surface water from entering the soil, and reducing compressibility.

2. BACKGROUND FOR SOFT CLAYS IN IRAQ

Soft clays are recent alluvial deposits probably formed within the last 10,000 years characterized by their flat and featureless ground surface. **Brand,** and **Bernner, 1981** are identified by their low undrained shear strength (Cu < 40 kPa (B.S,C.p.8004:1986)) and high compressibility (Cc between 0.19 to 0.44). They found that high natural moisture content, typically ranging from 40-60% with plasticity index ranging from 45-65% **Broms, 1987**. Soils with such characteristics create serious problems to geotechnical engineering associated with stability and settlements problems. The Tigris and Euphrates meet at Qurnah to form the Shatt AL-Arab which flows southward entering the Arabian Gulf at the city of Fao. The scanning of a number of site investigation reports led to some regions of soft clays in Iraq. Most of those locations are concentrated in the middle and southern parts of Iraq. Random data collected from several site investigation reports demonstrated values of undrained shear strength less than 30 kPa in Basrah governorate and less than 40 kPa in Missan and Nasirya governorates; also compression indices as high as 0.3 were also reported. The textures of those soils consist of fine silty clay loams, silty clay and clay fraction with up to 50-70% **Buringh, 1960**.These constituents with high water table throughout most of the southerly of the basins revealed a fair to poor soft deposit. **Al-Qayssi, 2001** studied 41 site investigation reports carried out by the Central Laboratory of Directorate of Military Work in the southern part of Iraq, from the early 1970 up to 200. Most of locations exhibit average undrained shear strength of less than 50 kPa and S.P.T. values less than 5 blows. In At 3000 B.C, the shoreline of the Arabian Gulf was located farther north near Basrah, where the rivers emerged part of the old river trance in the present inlet between Khor AL-Zubair and Umqaser. This wide triangle area is composed mainly of clayey soil and may be classified in the following two types according to **Rahil, 2007:-**

1. Normally consolidated young clay.
2. Normally consolidated aged clay.

The former is the clay distributed along the present river (Abu-Flus, Fao area) and the latter is the clay found distributed along the old river trace (Umqasr, Khor AL-Zubair).

2.1 Scrap Tyre

Waste tyres generated every day in Diobu part of Port Harcourt, Nigeria, can be used as light weight material either in the form of whole tyres, shredded or chips, or in mix with soil. Many studies regarding the use of scrap tyres in geotechnical applications have been done **Ghani, et al., 2002.**The re-use applications for tyres depends on how the tyres are processed. Processing basically includes shredding, removing of metal reinforcement and further shredding until the desired material is achieved **Carreon, 2006**.

Bernal, et al., 1996 reported the technical, economic and environmental benefits of using tyre shreds and rubber-sand, which include reduced weight of fill, adequate stability, low settlements, good drainage and use of large quantities of local waste tyres, which would have a positive impact on the environment. **Akbulut, et al., 2007** studied the modification of clayey soils

using scrap tyre rubber and synthetic fibers and concluded that they improved the strength properties and dynamic behavior of clayey soils.
Afolagboye, and **Talabi, 2013** assessed the consolidation properties of compacted lateritic soils stabilized with up to 8% tyre ash. This was carried out using time dependent one dimensional consolidation test to enhance the usage of the material in geotechnical engineering.
Afolagboye, and **Talabi,2014** assessed the effect of tyre ash on the geotechnical characteristics of compacted lateritic soils derived from migmatite gneiss in order to discover a conventional and cheaper stabilizer for pavement construction. The effects of engineering properties of clayey soil when blended with tyre ash are the main focus of this research. The enhanced engineering properties of various soils, resulting from the utilization of industrial byproducts or agricultural wastes bring about environmental and economic benefits **Walid,** and **Harichane**, **2010**. Addition of such additives reduced the plasticity index, increased optimum moisture content, decreased maximum dry density and improved both the compressive strength and California Bearing Ratio of soils **Rahman, 1986, Ferguson, 1993; Zia,** and **Fox, 2000, Parsons** and **Basha, et al., 2005; Senol et al., 2006 and Amu et al.,2011**.

3. EXPERIMENTAL WORK

3.1 Material Used

3.1.1 Soft soil

Soil used in this study was obtained from Ali-AL Girbi city south east of Baghdad city. The physical and chemical properties of the soil are summarized in Table 1. According to the Unified Soil Classification System (USCS), the soil is classified as (CL).The soil consists of 7.54% sand, 52.46% silt and 40% clay as shown in the grain size distribution curve in **Fig. 1**.

3.1.2 The tyre ash material

The tyre ash used was obtained from the burning of used and neglected tyres. They were burnt under normal atmospheric temperature and pressure (Burning air) to obtain the ash. The tyre ash was sieved through sieve No. 200. The sieved ash was immediately kept in air tight containers to prevent pre-hydration during storage or when left in open air. The major oxide compositions of tyre ash were determined in the Department of Chemistry-Science Laboratory, University of Baghdad. The chemical composition of the tyre ash is shown in Table 2.

3.2 Experimental Program

Soil sample was collected from one site with in Missan city ALi- AL-Gharbi region from depth of (1-1.5m). This sample was subjected to testing program, then the all samples were tested at different ratios of tyre ash (2%, 4%, 6%and 8%).

3.2.1. Specific gravity

Specific gravity for the soil studied was determined according to ASTMD-854-00. The results are summarized in the Table 1.

3.2.2. Atterbeger limits

Determination of the liquid limit, plastic limit, and the plasticity index of soil was performed according to test methods given in ASTM D 4318-00. The liquid limit, plastic limit and plasticity index value are summarized in the Table 1.

3.2.3. Grain size distribution

Wet sieving (by water) and hydrometer tests were carried out in accordance with ASTM-D-422-00.The grain size distribution of the sample is shown in **Fig**. **1**. The figure shows that the soil is classified as silty clay according to "ASTM" classification, designated as (CL) according to the Unified soil Classification System, and the percentage of clay is summarized in Table 1.

3.2.4. Moisture content

The moisture content of soil was carried out using ASTM D 2216-05. The sample was kept in the oven at a constant temperature of 100-110°C for a period of 24 hours. Water content of soil value is summarized in Table 1.

3.2.5. Consolidation test

One-dimensional consolidation test was carried out by using the standard odometer to determine the soil compressibility characteristics in accordance with ASTM –D2435-00.

3.2.6. Unconfined compression test

At first, unconfined compression test was carried out on disturbed samples in accordance with ASTM-D-2166-00. Unconfined Compression strength (q_u), undrained shear strength of cohesive soil (Cu), and the relationship between the soil consistency and its unconfined compression strength are according to DAS (2002).

3.2.7. Compaction test

The optimum water content and the maximum dry density of the sample were obtained using the Proctor standard compaction test carried out according to ASTM D698. **Fig. 2** shows the compaction curve obtained and shows optimum water content close to 22% and a maximum dry density of about 1.63kg/m^3.

3.2.8. California bearing ratio test

The California Bearing Ratio (CBR) test is a relatively simple test that is commonly used to obtain an indication of strength of a subgrade soil, sub-base and the base course materials for use in road and airfield pavement design **Liu,** and **Evett, 2003**. The results of the California Bearing Ratio test are summarized later in Table 2. This test is carried out according to ASTM D1883.

4. RESULTS AND DISCUSSION

4.1 Compaction Characteristics

The compaction test was used to determine the influence of stabilizers on maximum dry density (MDD) and optimum moisture content (OMC). The results of the MDD and OMC of soil samples mixed with tyre ash are reported in Table 3. And they are further illustrated in **Fig. 2**. The results show that adding tyre ash increased the OMC and reduced the amount of MDD progressively with the increase of tyre ash addition. Similar behavior was observed by other researcher for lime, volcanic ash, rice husk ash, sugarcane straw ash, lime-natural pozzolana mixture and stabilized soils **Bell, 1996, Hossain, et al., 2007, Eberemu, 2011 and Amu, et al., 2011.** The increase in OMC was due to the additional water required for wetting the large surface area of the fine tyre ash particles. The increase in OMC is also probably due to the additional water held within the flocculent soil structure due to excess water absorbed as a result of the porous property of tyre ash. The decrease in MDD of all treated soft soil was due to the partial replacement of relatively heavy soils with light weight tyre ash (specific gravity 1.92). This decrease in density could also be influenced by increase in porosity of all compacted soil samples due to addition of tyre ash. In addition, the decrease can also result from the flocculation and agglomeration of clay particles, caused by the cation exchange reaction, leading to corresponding increase in volume and decrease in dry density as advanced by **Lees, et al., 1982.** The increase in dry density is an indicator of improvement of soil properties; however, the addition of tyre ash reduced the MDDs. Several researchers **Basha, et al., 2005 and Ola, 1977** found that the change in dry density occurs because of both the particles size and specific gravity of the soil and stabilizer.

4.2 California Bearing Ratio

The California Bearing Ratio (CBR) test is a relatively simple test that is commonly used to obtain an indication of strength of a subgrade soil, sub-base and the base course materials for use in road and airfield pavement design **Liu,** and **Evett, 2003**. The results of the California Bearing Ratio test are shown in Table 4. The CBR values of all the soil samples increased considerably on stabilization with tyre ash shown in **Fig. 3**. This shows that the load bearing capacity of the soil increased with the stabilization mix. The increase in the soaked CBR may be due to the availability of calcium from the ash for the cementations reaction with the silica and iron oxide from the soft soil. Despite the increase in soaked CBR with stabilization, the soaked CBR values of the soils indicate that none can be used for sub-base and base course of roads because the values fall below the 30% and 80% respectively stipulated by **FMWH**, **1997**. The CBR values make the stabilized materials suitable for use as sub grade in road pavement because the value falls within the range (5–11%) specified by **FMWH**, **1997** for sub grade soils. According to **Simon, et al., 1973**, a high reduction in CBR values after soaking indicates that the soil is very sensitive to changes in the moisture content.

4.3 Unconfined Compressive Strength

The results of the unconfined compressive strength (UCS) of the stabilized soils are presented in Table 5. The trends of changes in UCS with various percentages of stabilizers for the clay soil are presented in **Fig. 4**. It is pertinent to note that curing was not necessary for soil samples without tyre ash additive. It can be seen from **Fig. 4** that the addition of tyre ash increased the UCS of the stabilized soft soil samples for the various percentage treated. This could probably be as a result of the increased pozzolanic reaction with increased tyre ash treatment which results in the formation of calcium silicate hydrates and micro fabric changes which is responsible for increased strength **Kedzi, 1979**. Similar behaviors were also observed by other researcher for lime, volcanic ash, rice husk ash, sugarcane straw ash, lime-natural pozzolana mixture and Lime- rice husk mixture stabilized soils **Bell, 1996, Hossain, et al., 2007, Eberemu, 2011 and Amu, et al., 2011.** These tests presented the effect of tyre ash on the geotechnical characteristics of compacted soft soils derived from migmatite gneiss. On the basis of the tests results, the following conclusions can be drawn. Specific gravity revealed that the soils are inorganic soft soil. The soils are well graded and (CL) according to (UCS). The plasticity index and liquid limit of the soil samples show that the soils are not suitable as base/sub-base materials in road construction because they are above the maximum 12% and 30% values respectively recommended for sub base/base soils. Casagrande chart classification indicated that the soil is of low plasticity and hence compressibility. The compaction results revealed that addition of tyre ash increased the OMC and reduced the amount of MDD with the increase of tyre ash addition. The CBR values of all the soil samples increased considerably on stabilization with tyre ash. The results of the findings show that the geotechnical properties of the stabilized soft soils were significantly improved but still unsuitable for base/sub-base materials in road construction.

4.4 Index Properties

The liquid and plastic limits of tyre ash treated soil decreased and increased respectively with the increase in additive quantity as shown in Table 6, and **Fig. 5**. This shows that the Atterberg limits of the soft soil were improved with a decrease in liquid limit, an increase in plastic limits with a resulting decrease in plasticity index. The liquid limit decreased from38.5to 32.2% with an increase in the tyre ash content from 0 to 8%. This could be attributed to the addition of tyre ash, which has less affinity for water and yielded a decreased liquid limit. The plasticity index decreased from 14.2to 5.5% with increase in the tyre ash content. These effects may be due to the partial replacement of the plastic soil particles by tyre ash fines, which is an abrasive non-plastic material, with consequent reduction in clay content. The plasticity of a soil is controlled by the amount of clay fraction in it; it decreases as the amount of clay fractions decreases **Arora, 2008.** Decrease in plasticity index of a soil shows an improvement in the engineering properties of the soil. This is in agreement with the works of other researchers **Ferguson, 1993, Zia and Fox, 2000, Parsons, and Kneebone, 2005, Basha, et al., 2003.**

4.5 Compression Index

Compression index (Cc) is an important parameter used in geotechnical engineering as it relates to the amount of anticipated consolidation settlement that a soil stratum will experience when introduced to loads that are greater than experienced in the past. The slope of the linear portion of the e-log p curve is designated as the Cc. The variation of compression index with tyre ash content and moisture content relative to optimum moisture content is shown in Table 7, and **Fig. 6**. The Cc generally decreased with increasing tyre ash for up to 8% treatment. Cc ranged from 0.2108–0.0677, at optimum moisture with increasing stabilizer content. The decrease in compression index may be attributed to the formation of pozzolanic products within the pore spaces from physico-chemical changes **Osinubi,** and **Eberemu, 2006**. They may also be attributed to the formation of cementitious bonds between clay particles caused by the addition of tyre ash. Similar results were obtained by other researchers **Anagnostopoulos, and Stavridakis, 2003, Kazemian, and Huat, 2009**. The settlement of soils is directly related to the compression index which implies that tyre ash can be used to reduce the settlement of soils. Soil structure compacted at the OMC are always flocculated. This results show that the compression index is influenced by the particle state of the soil fabric which is controlled by the moulding water content. **Cássia de BritoGalvão, et al., 2004** observed that addition of lime is effective in improving the compressibility characteristics of tropical soils and also effective in decreasing the potential for collapse of the soils when compacted to densities lower than their maximum dry densities.

4.6 Swelling Index

Variation of swelling index (Cs) with increasing tyre ash content is similar to that of compression index. The variation is shown in Table 7 and **Fig. 7**. Cs ranged from 0.02802–0.01901at the optimum moisture with increasing stabilizer content. **Anagnostopoulos,** and **Stavridakis, 2003** showed that the swell index of soft was also reduced with increasing cement ratio. The variation of swell index with moulding water content relative to optimum moisture content exhibited in Table 7 show that samples compacted at the optimum moisture content have the highest swell index. This may be attributed to water deficiency and random orientation of particles which leads to imbibe of more water and therefore more swelling. This also implies that swell index is influenced by the particle state of the soil fabric which is controlled by the moulding water content. Consequently, the samples at optimum moisture contents will swell less when unloaded because a more compact state of soil is attained when soil is compacted at optimum moisture content.

4.7 Coefficient of Volume Compressibility

The coefficient of volume compressibility (mv) is defined as the volume change per unit increase in effective stress for a unit volume of soil **Craig, 1992**. The volume change expressed in parameter is very useful to estimate the primary consolidation settlement. The variation of coefficient of volume compressibility with tyre ash content is shown in Table 8. The mv generally decreased with increasing the consolidation pressure and tyre ash content in the moulding water contents. This could probably be due to increase in effective stress and pozzolanic reaction taking place within the soil which in turn changed the soil matrix. For instance, at OMC, the values of mv for sample ranged from 2.074– 4.450 m^2/MN, 2.940 – 1.792 m^2/MN, 1.953– 1.396 m^2/MN and 1.094– 1.194 m^2/MN at 10, 20, 40 and 80 N/m^2 loading respectively. **Kazemian,** and **Huat, 2009** also showed that the coefficient of volume compressibility decreased by increasing the consolidation pressure and cement ratio.

The variation of coefficient of mv with different moulding water content in Table 8, and **Fig.8** shows that samples compacted on the dry side OMC have the least mv for all the pressure increments. This can also be attributed to the fabric of the compacted soil **Holtz,** and **Kovacs, 1981**. At the same compacting effort, with increasing water content, the soil fabric becomes increasingly oriented; that is, at dry of optimum, the soils are always flocculated, whereas wet of optimum the fabric becomes more oriented or dispersed. **Arora, 2008** stated that soils with flocculated structure are light in weight, have high void ratio and can resist external forces because of the bond due to attraction between particles hence they have low compressibility and high permeability.

5. CONCLUSIONS

In the present study, a series of tests were performed on soft soil mixed with different percents of tyre ash to investigate the strength and compressibility characteristics of soils stabilized with tyre ash mix. A program of standard laboratory tests carried out on soft clay soil taken from Ali-AL Girbi area in Missan governorate–East of Iraq.

The following conclusions are limited to the material used and test conditions under which the tests were conducted. Based on the results obtained from:

1. The measurements made before and after testing showed that the undrain shear strength in models of footing on soft clay soil improved by tyre ash material, the undrain shear strength is increased by about (1.3 – 14) % due to the implementation of soil stabilization.
2. CBR on compacted soft clay treated with tyre exhibited higher CBR values than compacted untreated soft clay soil.
3. Increased the OMC with the increase of tyre ash addition in compaction test.
4. It was noticed that (the L.L and P.I decreased, while the P.L increased) with the increase of tyre ash addition.
5. The Cc decreased with increase in percentage tyre ash regardless of the moulding water content.
6. The Cc and Cs are increases with increase moulding water content.
7. The Cs decreased with increase in percentage tyre ash irrespective of the mould ing water content.
8. The mv and Cv decreases with increasing tyre ash content and consolidation pressure regardless of the moulding water content.
9. The Cv decreases with increase moulding water content.
10. The soft clay treated with tyre has undraind shear strength higher than untreated soft clay soil.

REFERENCES

- Afolagboye L. O., and Talabi, A. O., 2011, *Consolidation properties of compacted lateritic soil stabilized with tyre ash*. Department of Geology, Faculty of Science, Ekiti State University, Ado-Ekiti, Nigeria

- Afolagboye L. O., and Talabi, A. O., 2014, *Effect of Curing time on unconfined Compressive Strength of lateritic soil stabilized with tyre ash*. Department of Geology, Faculty of Science, Ekiti State University, Ado-Ekiti, Nigeria.

- Akbulut, S., Arasan S. and Kalkan E., 2007, *Modification of clayey soils using scrap tire rubber and synthetic fibers*, Applied Clay Science, 38: 23-32.

- Al-Qayssi, M.R., 2001, *Unreinforced and Reinforced Behavior of Single and Groups of Granular Piles, Ph.D.* Thesis Submitted to the Civil Engineering Department Faculty of the Military Collage of Engineering, Iraq.

- Amu O.O., Ogunniyi S.A., and Oladeji O.O., 2011, *Geotechnical properties of lateritic soil stabilized with sugarcane straw ash,* Am. J. Sci. Ind. Res., 2(2): 323-331.

- Anagnostopoulos A. C., and Stavridakis E. I., 2003, *Influence of sand content on cement and durability of cement-acrylic resin treated soil*. Electron. J. Geotech. Eng. 8: Bundle D.

- Arora K. R., 2008, *Soil mechanics and foundation engineering, standard. Publishers Distributors*, Delhi, pp.118.

- Atkins, H.N., 1980, *Highway Materials, Soil, and Concretes, Reston Publishing Company*, Inc. Reston, Virginia.

- Basha E. A., Hashim R., Mahmud H. B., and Muntohar A. S., 2005, *Stabilization of residual soil with rice husk ash and cement*. Construction and Building Materials. 19:448-453.

- Bell, F. G., 1996, *Lime Stabilization of Clay Minerals and Soils*, Engineering Geology, Vol.42, pp.223–237.

- Bernal, A., C.W., Lovell and R. Salgado, 1996, *Laboratory Study on the Use of tire Shreds and Rubber-Sand in Backfilled and Reinforced Soil Applications*. Publication FHWA/IN/JHRP-96/12. Joint Highway Research Project, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana. doi: 10.5703/1288284313259.

- Brand, E.W., and Brenner, R.P., 1981, *Soft Clay Engineering*, Elsevier Scientific Publishing Company, Amsterdam, pp. 778.

- Broms, B.B., 1987, *Stabilization of soft clay in Southeast Asia*, proceeding 5thInternational Geotechnical Seminar 2-4 Dec. 1987.

- Buringh, P., 1960, *Soils and Soil Conditions in Iraq*, Metherlands by H. Veenman and Zonen N.V., Wageningen.

- Carreon, G. D., 2006, *Stabilization of marginal soils using recycled materials*. These soils Dissertations. Paper 2473.

- Cássia de BritoGalvão T., Elsharief A. and Simões G. F., 2004, *Effects of lime on permeability and compressibility of two tropical residual soils*. J. Environ. Eng-ASCE Vol.130:8.

- Das, B.M., 2002, *Principles of Geotechnical Engineering, fifth edition*, wadsworth group, pp.340.

- Eberemu O. 2011, *Consolidation Properties of Compacted Lateritic Soil Treated with Rice Husk Ash*, Geomaterials, 1, 70-78.

- Ferguson G. 1993, *Use of self-cementing fly ashes as a soil stabilization agent*. ASCE Geotechnical Special Publication No. 36, ASCE, New York.

- FMWH (Federal Ministry of Works and Housing) 1997, *General specifications (roads and bridges)*, vol II, Federal Ministry of Works and Housing, Lagos, Nigeria.

- Ghani, A.N.A., F. Ahmad, R. Hamir and S. Mohd, 2002, *Scrap Tire Based Lightweight Geomaterial for Civil Engineering Works*. In Proceeding of Malaysian Science Technology Congress, Oct. 17-19, Genting Highlands, MALAYSIA.

- Holtz D. R. and Kovacs D. W., 1981, *an introduction to geotechnical engineering, Prentice-Hall*, Inc., Chapter 5, Compaction, pp. l09-165.

- Hossain K. M. A., Lachemi M. and Easa S., 2007, *Stabilized soils for construction applications incorporating.*

- Kazemian S. and Huat B. B. K., 2009, *Compressibility characteristics of fibrous tropical peat with reinforced with cement column*. Electron. J. Geotech. Eng. 14, Bundle C, pp 1-13.

- Kedzi, 1979, *Stabilized Earth Roads*. Elsevier, Amsterdam, pp. 327.

- Liu. and J, Evett. 2003, *Soils and Foundation*, 6th ed. USA: Prentice Hall.

- Misra.A.,Biswas and Upadhyaya,S., 2005, *Physico-mechanical behavior of self-cementing class C Fly ash-clay mixtures*. Fuel, 84(11), 1410-1422

- Ola. S.A., 1977, *Potential of lime stabilization of lateritic soils.* Engineering Geology vol. II, pp 305-317.C.

- Osinubi K. J., and Eberemu A. O., 2006, *Effect of bagasse ash on the strength of stabilized lateritic soil.* Proceedings of 5th Nigerian Material Congress, Abuja, 15-18 November 2006, pp. 214-220.

- Parsons R. L., and Kneebone E. 2005, *Field performance of fly ash stabilized subgrade*, Ground Improvement 9:33-38.

- Rahil F.H., 2007, *Improvement of Soft Clay underneath a Railway Track Model Using Stone Columns Technique*. Ph.D. Thesis, University of Technology, Iraq.

- Rahman M.D.A., 1986, *the potentials of some stabilizers for the use of lateritic soil in construction*, Building and Environment, Vol. 21, pp 57-61.
- Senol, T.B., Edil, M. d., Sazzad Bin-Shafique, H. A., Acosta. and C.H. Benson. 2006, *Soft Subgrades, Stabilization by Using Various Fly Ashes*, Resources Conservation and Recycling, 46, 365-376.
- Walid Z. and Harichane K. 2010, *Effect of Lime and Natural Pozzolana on Dredged Sludge Engineering Properties*, Geotechnical Engineering, vol. 18, pp 589-600.
- Zia N. and Fox P. J., 2000, *engineering properties of loess-fly ash mixtures for road bases*. Transportation Research Record 1717, Transportation Research Board, 49-56.

SYMBOLES

ASTM :	American Society for Testing and Materials.
CBR :	California Bearing Ratio
C_c :	compression index.
CL :	clay of Low plasticity
C_s :	swelling index.
C_u :	undrained shear strength of soil (kN/m^2).
Cv :	coefficient of consolidation (mm^2/sec).
FMWH :	federal Ministry of Works and Housing
G_S :	specific gravity.
L.L :	liquid limit
MDD :	maximum dry density (g/cm^3).
mv :	coefficient of volume change (m^2/MN).
O.M.C :	optimum moisture content.
P.I :	plasticity index.
P.L :	plastic limit
q_u :	bearing capacity of soil.
T.S.S :	total soluble solids(%).
UCS :	unconfined compressive strength
USCS :	unified soil classification system.

Table 1. Properties of used soil.

Index Property	Value
Liquid Limit (L.L) (%)	38.5
Plastic limit (P.L) (%)	23.3
Plasticity index (P.I) (%)	15.2
Shrinkage limit (S.L) (%)	14
Activity (At)	0.2
Specific gravity (Gs)	2.75
Gravel (%)(larger than 2mm)	0
Sand(%)(0.06 to 2mm)	7.54
Silt (%)(0.002 to 0.06mm)	52.46
Clay (%)(less than 0.002mm)	40
CBR	3.4
Coefficient of permeability, K(cm/sec)	1.293 *10-8
Unconfined compressive strength, Cu (KN/m2)	19
Natural water content ,W°	17.5
Calcium oxide (CaO) (%)	14.55
SO_3content (%)	0. 2
Total soluable salts % (TSS)	1.53
PH value (%)	7.53

Table 2. Chemical composition of the tyre ash

Oxide	Composition (%)
Silicon oxide (SiO2)	32.33
Aluminum oxide (Al2O3)	3.8
Iron oxide (Fe2O3)	5.878
Calcium oxide (CaO)	21.86
Magnesium (MgO)	1.977
Trioxosulphates (SO3)	1.252
Potassium oxide (K2O)	1.3913
Tin oxide (TiO2)	0.2032
Na2O	1.23
pH	7.41
cL(%)	250
T.S.S(%)	1.02
Gs	1.33
Loss on Ignition (L.O.I)	30.08%

Table 3. Compaction characteristic.

Stabilizer%	MDD(g/cm^3)	OMC %
0	1.63	22.00
2	1.58	23.40
4	1.54	24.50
6	1.53	27.40
8	1.52	27.80

Table 4. Variation of California Bearing Ratio with tyre ash.

Stabilizer %	CBR %
0	3.41
2	3.51
4	4.31
6	5.58
8	9.56
10	9.66

Table 5. Variation of undrained shear Strength with tyre ash.

Stabilizer %	undrained shear Strength(kN/m^2)
0	41
2	55
4	76
6	109
8	122

Table 6. Index properties of soft soils.

Stabilizer (%)	L.L (%)	P.L (%)	P.I (%)	Ac
0	38.5	24.3	14.2	0.2
2	37.6	25	12.6	0.18
4	34.2	25.18	9.02	0.13
6	33.4	25.3	8.1	0.12
8	32.2	26.7	5.5	0.08

Table 7. Compression index and Swelling index of the compacted soil treated with tyre

Stabilizer (%)	Cc	Cs
0	0.2108	0.02802
2	0.2067	0.02564
4	0.1108	0.0237
6	0.0771	0.02085
8	0.06771	0.01901

Table 8. Coefficient of volume compressibility of the compacted soil treated with tyre ash

Tyer Ash / Pressure N/m^2	**mv * 10 $^{-7}$m^2/MN**				
	0%	**2%**	**4%**	**6%**	**8%**
10	4.4503	3.902	3.367	2.502	2.074
20	2.940	2.2740	2.247	2.115	1.792
40	1.953	1. 910	1. 7036	1. 5011	1.396
80	1.194	1.1631	1.1464	1.1317	1.094

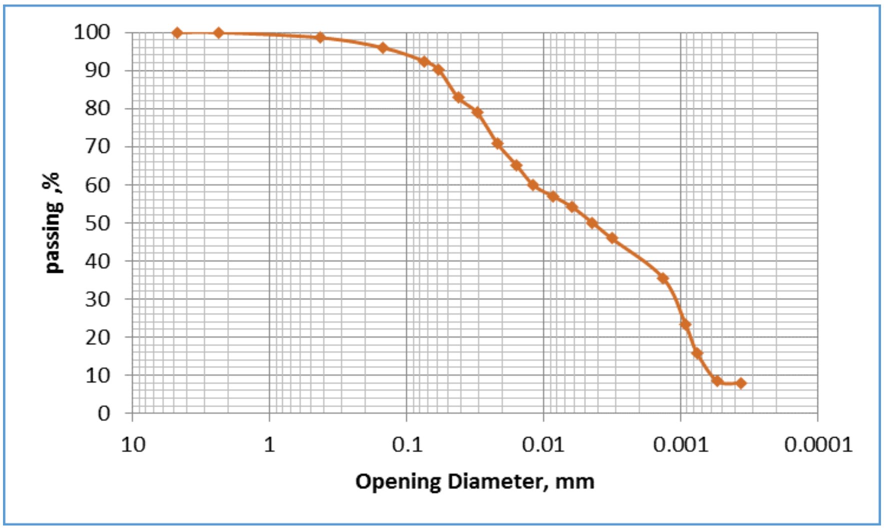

Figure 1 .Grain size distribution curve.

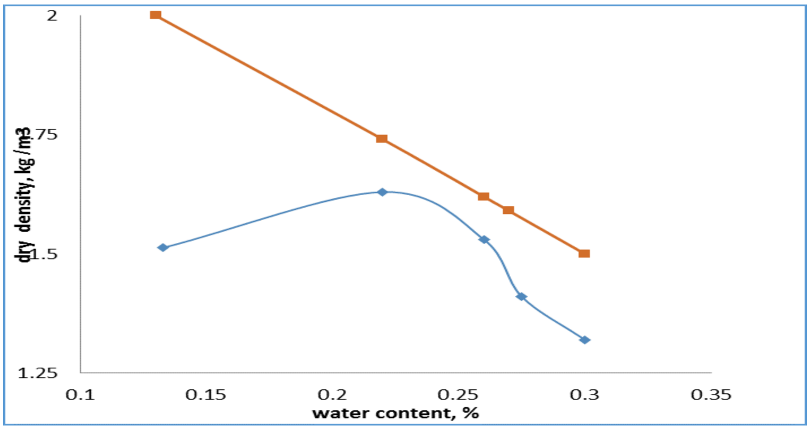

Figure 2. Compaction curve**.**

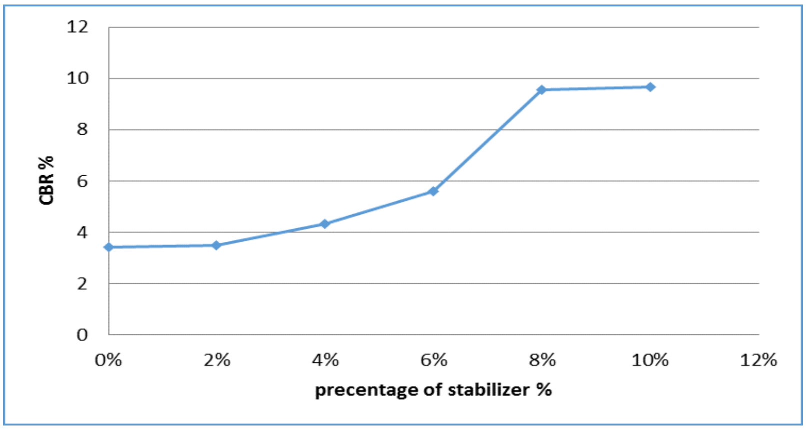

Figure 3. Influence of amount of stabilizer on california bearing ratio.

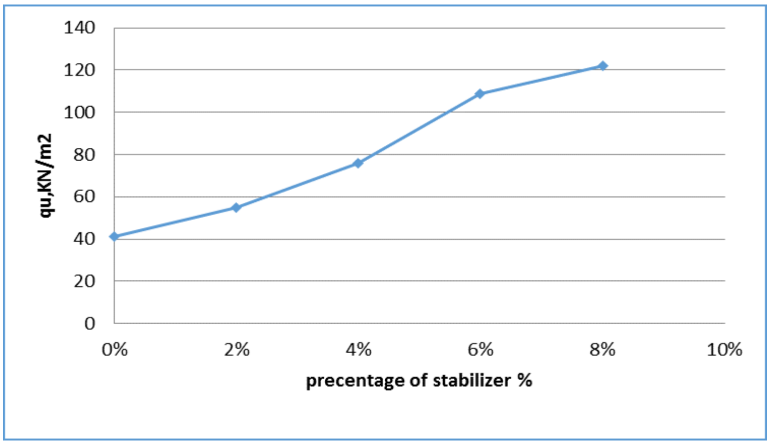

Figure 4. Variation of 2-day unconfined compressive strength with tyre ash content.

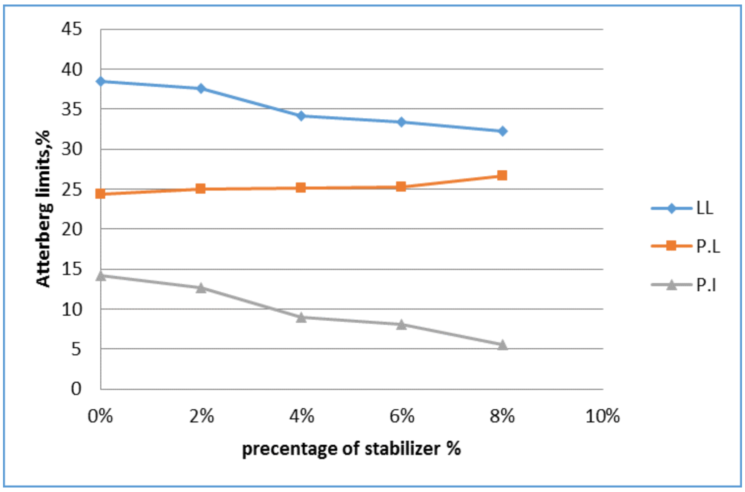

Figure 5. Variation of (L.L, P.L, P.I,) with amount of stabilize.

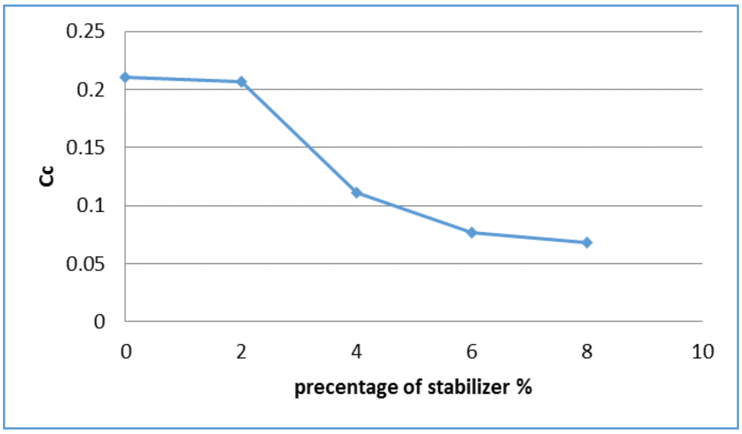

Figure 6. Variation of compression index with amount of stabilizer

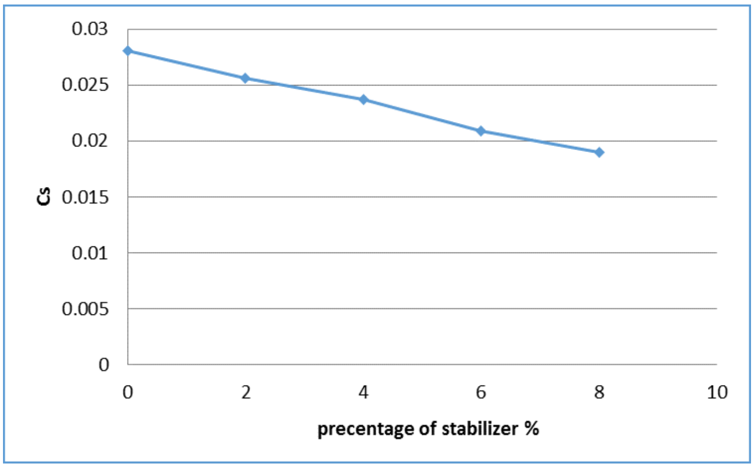

Figure 7. Variation of swelling index with amount of stabilize.

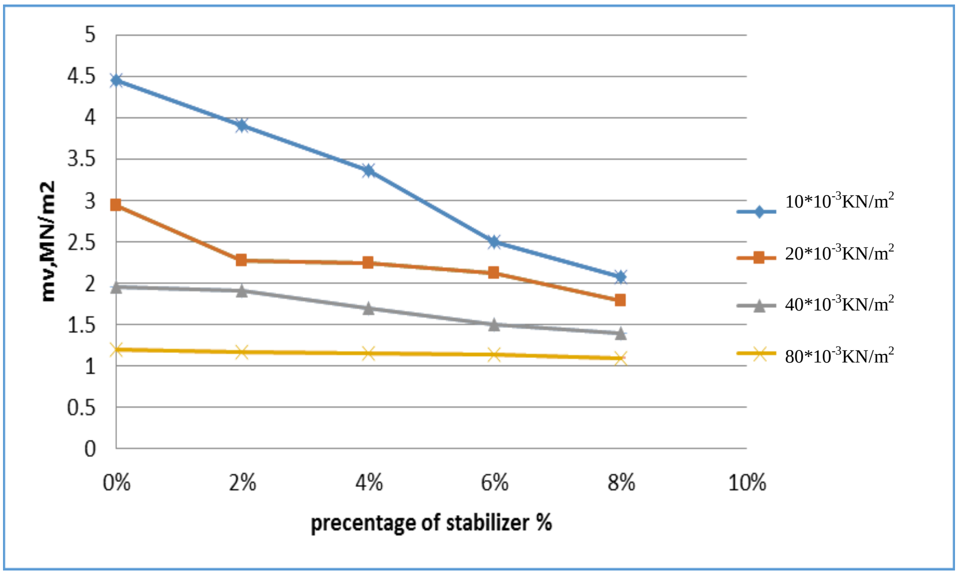

Figure 8. Variation of coefficient of volume compressibility with amount of stabilizer.