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Research paper



Engineering Behavior of Swelling Soil Treated by Tyre Ash

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Abstract

Swelling soils in arid and semi-arid climates are well known to cause detrimental damages in the form of cracks and differential movements of the civil engineering structures. For efficient and economical methods to reduce mitigation of swelling soils, there is a growing interest in using waste materials with a recycling it and using for improving soil properties . This work focused on using (tyre ash) as a reinforced for improving the swelling soil. Using the tire ash in soil improvement can be a feasible target for recycling this waste material, hence decreasing the pollution problems. An experimental program was conducted to determine the geotechnical characteristics of the swelling soil, including Atterberger limits ,Compaction, California Bearing Ratio and strength characteristics. Different percentages of tyre ash (5%, 10%, and 15%) were mixed with original swelling soil to calculate its influence on geotechnical properties. The experimental results displayed that 15% tyre ash reduced the plasticity and density considerably. Finally, the results show that improvement of swelling soils using tyre ash properly be an efficient technique in improvement the soil characteristics against swelling-shrinking potential of ground soils on which pavements and light weight structures are constructed. Therefore, the scrap tire rubber waste has a potential for improving swelling soils, thus giving a two advantages in enhancing a problematic soil and also resolving the problem of disposal of waste by recycling it. On the other hand, the results of axial compressive strength and California Bearing Ratio tests demonstrated that the amounts of tyre ash could enhanced the shear strength properties of soil.

Keywords: *tyre ash, swelling soil, soil improvement*

1. Introduction

Problematic soils (swelling soils) shows low strength, volume sensitivity and high compressibility. Swelling soils have the capability to swell when they become in connect with wetness and to shrink if wetness is extracted from them. The failure in many structures related to swelling soils have been recorded in many regions of the world, but are commonly most effective in arid and semi -arid areas. As a result, extremely reactive soils subject essential volume change related with the swelling and shrinkage operations. Consequently, many structures suffer acute distress and damage. The swelling potential of a swelling soil is generally assessed in the laboratory by utilizing a classical oedometer a apparatus. There are various techniques including soil treatment in situ. These techniques consist density improvements by using embankments(preloading) and dynamic compaction techniques, to reduce pore water pressure using different methods such as water removing by sand wall, the packing of solid soil grains by freezing, nailing and chemical improvement, and employ of stabilizing factors for example geotaxtiles and gravel piles [1]. Vosteen [2] recorded examination and developing into construction ways, the employ of cement dust and lime for improvements. Improvement of soft soils consist a mechanical improvement such as preloading method and chemical improvement. Chemical soil improvement technique includes mixing stabilizers with original soil to reduce water content and treat soil resistance using binding its particles or filling spaces among them. Swell reaction of problematic soils has been reported by many researchers since the 1950"s depended on plasticity properties and other tests executed in the laboratory [3 - 5].

The improved geotechnical characteristics of different soils, according to the employment of recycling materials productions, get about economic advantages and environmental [6]. Increment of such stabilizers decreased the liquid and plastic limits, excess water content, reduced dry unit weight and enhanced mechanical properties of soils [7]. This study concentrated on examining the improvement of swelling soils treated with tyre ash powder .Finally ,the research will investigate the improvement of properties in elements of bearing , Atterberger limits and index properties.

2. The Swelling Soil

This type of soils which exhibits a significant quantity changes of volume when subjected to wetting and drying conditions and its classified as problematic soil by many specifications. The value of plasticity index can be indicator for the swelling. In generally, the value of swell increase with the plasticity index [8]. The identification of the swelling soil can be done by different methods first by the mineralogical identification which investigates the existence of the expansive minerals like montmorillonite, the indirect methods by the soil properties as the plasticity and the direct method to find the swell pressure of the soil and its free swell index. The swelling pressure may be defined as the pressure required for getting the swollen soil back to its original volume. The swelling usually occurs in the unsaturated expansive soil subjected to wetting due to raining seasons, leakage from pipes and rising of the water table. The free swell may be indicated as the excess in the original volume to the original volume of the expansive dry soil when subjected to wetting.

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There are different ways to recognize the expansive soils in the field before construction of a foundation [9]:

• Stick when wet.
• Polished glaze on cut dry surfaces.
• Dry lump dropped in water expands so fast that it breaks up explosively.
• Deep cracks with polygonal pattern about 1 inch in the top width at the ground surface in the dry sea-sons.

In this work the soil used was brought from AL Anbar governorate southern of Baghdad city. Table 1 showed the geotechnical characteristics of the used soil . Based on the Unified Soil Classification System (USCS), the used soil has symbol (CH).The percentages of gravel, sand, silt and clay as shown in Figure 1.

Table 1. Physical properties, shear strength parameters of soil

property	value	Type of test	standard
L.L %	112	Atterberge limits	*ASTM 4318*
P.L%	44		
P.I	68		
G.S	2.89	Specific gravity of solids	*ASTM D854*
Sand content %	4	grain size distribution test	*ASTM D422- ASTM D421*
Clay and silt %	96		
γd max(gm/cm^3)	1.512	Standard Procter test	*ASTM D698*
Optimum moisture content %	28		
Cu at *opt*. kPa	75	Unconfined compression test	*ASTM 2166*
φu	0		

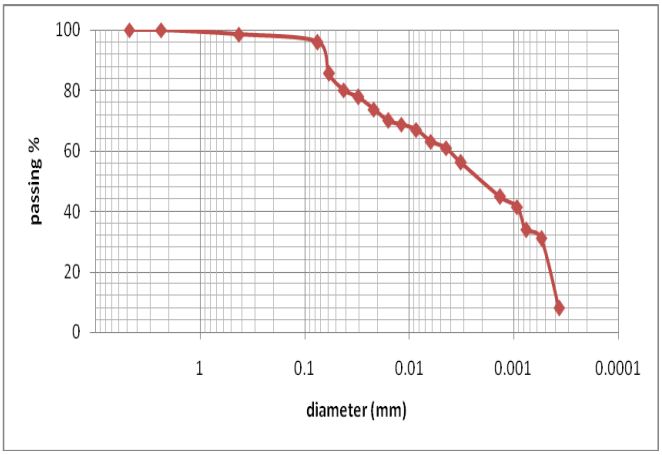


Fig 1: grain size distribution curve.

3. Tyre ash

This material used was obtained by burning the tires used and damaged. They were burnt under natural atmospheric pressure and temperature to get the powder . Tyre ash has a specific gravity 1.83.The ash was passed through sieve opening 0.075mm. The passed ash amount was kept in plastic bags to protect prehydration process through storage. The chemical properties of the tyre ash are shown in table 2.

Table2: 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
T.S.S	1.02
Na2O	1.23
CL	2.5

4. Practical Part

The experimental works were carried out at the University of Baghdad/ soil mechanic laboratory. The plasticity characteristics of the original and improved soil samples were measured by ASTM D 4318 . The Standard Proctor tests of samples were evaluated based on standard procedure ASTM D 698for measuring the maximum dry density(MDD) and the optimum moisture content(OMC) .The samples of modified original soil were all initially compacted at their optimum moisture content in a Standard Proctor mould by standard procedure ASTM D 1557, the strength tests were done to calculate a compression values by standard procedure ASTM D 2166. For finding the specific gravity value of tyre ash powder and the Soil solids, the standard method could not be employed, as the tyre ash floated on the surface of the water. So for calculating the specific gravity of mixtures, an analytical part was employed by considering each component's dry mass and the values of specific gravity based on ASTMD 854 and [10] . All treated soils were tested subjected to Standard conditions. The treated soil was saved in standard conditions for two days to permit wetting. After two days, wetted samples were extruded from the moulds employing a extruder device. The original swelling soil was treated with various tyre ash percentages which consist 5%, 10%, and 15% of dry weight soil. Both improved and unimproved soil samples were tested to investigate the changes in the geotechnical characteristic of the soil after treating with various percentages of improving additive. The practical side includes of evaluation of physical, mechanical properties of swelling soil at 0%, 5%, 10% and 15% tyre ash inclusions.

5. Results and Discussion

5.1 Physical Properties of Soil

The summary of physical characteristics of soil samples tested in this research is given in Table 3. Depended on these results, increasing the percentage of tyre ash causes a significant decrease in the specific gravity value (Gs20c̊) because the low unit weight of tyre ash, otherwise the tyre ash indicate to decrease in the value of liquid limit (LL) ,but it's causes slight increase in the plastic limit (PL) with a resulting decrease in plasticity index . These variations related to the mixing process between the plastic soil particles (plastic materials) and additive powder, which is a hard material, hence the amount of fine grain size decreases. Reduction in plasticity index of a swelling soil leads to a stabilization in the geotechnical properties. These are in apposite with these works [11,12].

Based on the results of compaction tests are reported in Table 4 and showed it in Figure 2, it was explained a significant decreasing in the maximum dry densities of swelling soil treated with tyre ash(MDD) and increased the optimum moisture content (OMC) relative to increasing of tyre ash percentages. The treatment by tyre ash has Similar behavior with other treatments such as liame, volcanic ash, riace husk ash, sugarcane straw ash and lime-natural pozzolanaic mixture [13, 14]. Tyre ash powder has large surface area and porous property lead to increase in the water content value (OMC) for wetting it . In other wise, the decrease unit

weight of swelling soil can also generate from the process rearranging the structure of clay particles, occurred by the chemical processes between two materials(soil and stabilizer) , resulting to increase in volume and decrease in weight as advanced by [15]. however, the addition of tyre ash decreased the maximum dry density(MDD).Basha et al. [16] found that the different in dry unit weight resulting of both the grain size and specific gravity of the stabilizer and soil.

Table 3. Index Properties of Soil Samples

TYRE ASH (%)	L.L (%)	P.L (%)	P.I (%)	GS
0	112	40	68	2.89
5	90	43	47	2.82
10	82	45	37	2.74
15	58	46	12	2.7

Table 4. Compaction characteristic

Tyre ash %	MDD(g/cm^3)	OMC %
0	1.512	28
5	1.419	31
10	1.38	35
15	1.36	36.5

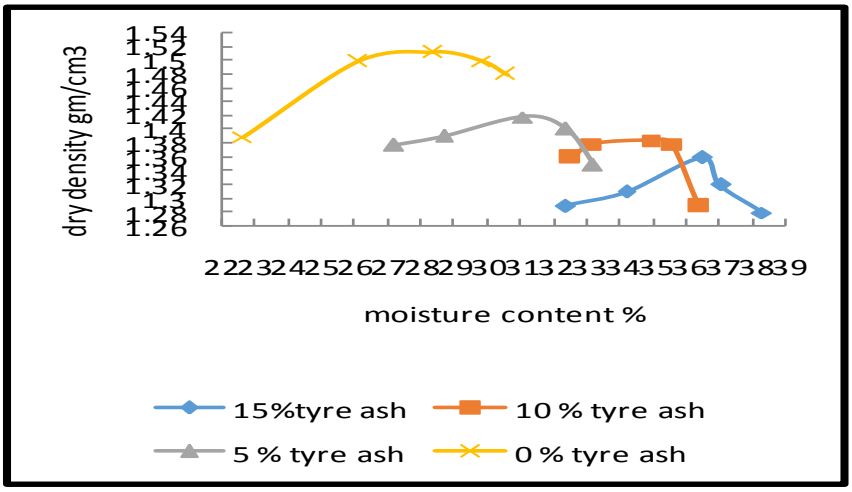


Fig 2: Relationship among dry density, moisture content and tyre ash .

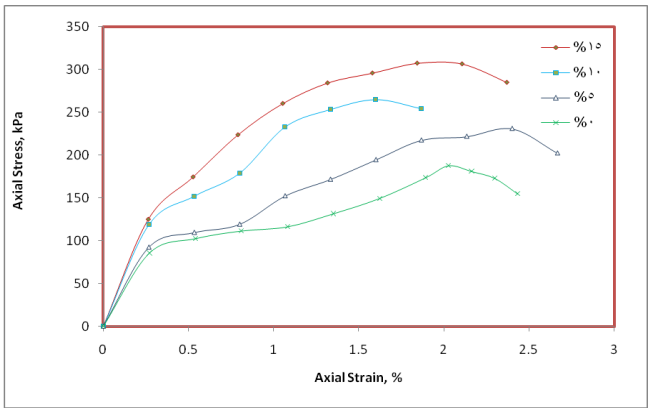


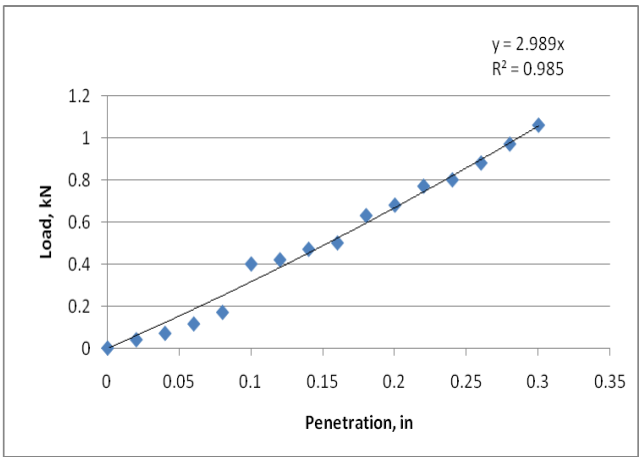
Fig 3: Variation of unconfined compressive strength with tyre ash content.

5.2 Axial Compression Strength

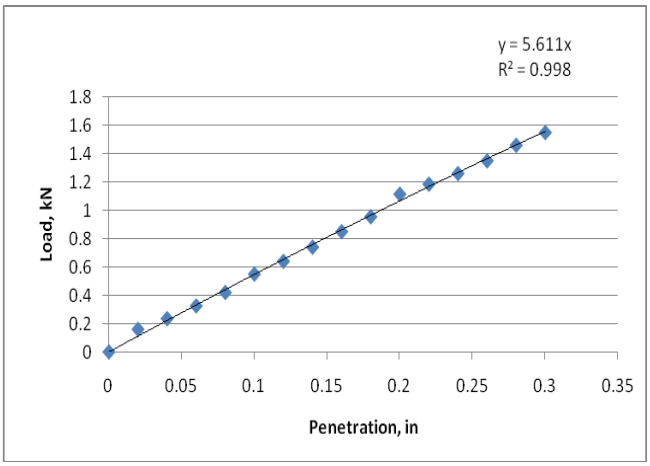
The Axial compression Strength results of the improved soils are reported in this section. To investigate the effect of the tyre ash materials on the shear strength properties of various percentages of its, this materials have the properties defined in table 2.The results of axial compression strength are presented in fig.3.Increasing of stabilizer increased the axial compression strength of the treated swelling soil for the different percentage treated. Increasing in soil strength caused by reaction of pozzalanic that a result from increasing in tyre ash addition that leads to changes in formation of silicate and fabric [17]. The following materials have a similar behaviors to tyre ash powder material for soil improvement lime, volcanic ash, rice husk ash, sugarcane straw ash, lime-natural pozzolanca mixture and Lime- rice husk mixture improved soils [18, 19].

5.3. California Bearing Ratio

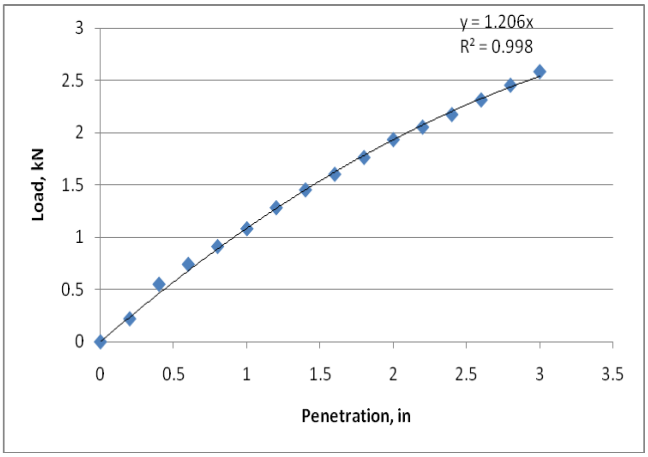
The California Bearing Ratio (CBR) test is a comparatively simple test that is widely employed to determine an explanation of bearing capacity for a sub-grade, sub base and the base layer materials for employ in road and airfield layers construction. The California Bearing Ratio test results are shown in table 5 and figures 4-7. All samples (CBR) increased considerably on improvement with stabilizer. There are many reasons for increase sing in the CBR values result from the amount of calcium from the stabilizer for the cementations reaction with the siliaca and iron oxiade from the swelling soil. The CBR results of the treated swelling soil show that unsuitable materials for base or sub-base layers of roads according to its values of CBR 60% and 30% respectively recorded by Iraqi specifications, but it's suitable materials for subgrade layers according to its values of CBR with the range (4-11%) reported by Iraqi specifications. Based on [20], a great reduction in soaked CBR values indicates that the soil is very sensitive to variations in the water amount.



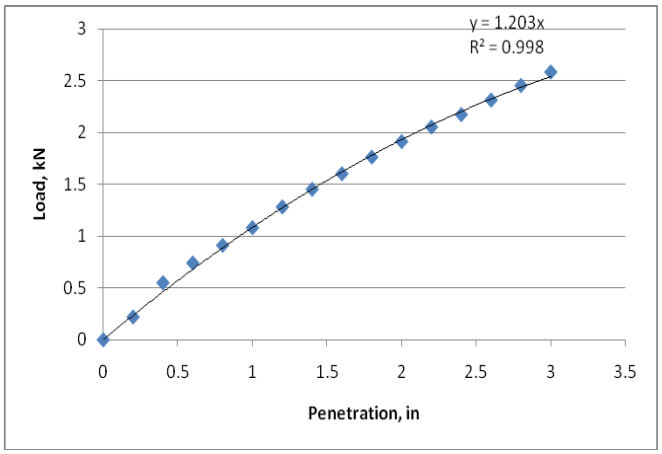
a).0%



b).5%



d).15%



c).10%

Fig4: Variation of California Bearing Ratio value with different tyre ash percentage(a0%, b5%, c and d).

6. Conclusions

In this research, a series of experiments were done on samples of swelling soil treated with several of tyre ash percentages to evaluate the geotechnical properties of soil improved with mixture. Depended on the results, CBR values on swelling soil improved with tyre ash(stabilizer) showed greater CBR values than unimproved soil opposite that undraind shear strength on swelling soil improved with tyre ash (stabilizer) showed greater Cu values than compacted unimproved soil. In standard compaction test the optimum moisture content increased with the increase of stabilizer addition but, decreased in specific gravity (Gs) value with the excess of tyre ash. In Atterbeger Limits (decreased the L.L, increased the P.L and decreased the P.I.) with the excess quantity of stabilizer addition.

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