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Stabilization Clayey Subgrade Soil Using Waste Materials

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Abstract

In the traditional construction of roads, the source materials from borrow-pits are the very common for the roadbed-layers. The construction "total cost" of the roads is affected by important factors such as the source's materials. Enhancing the compaction properties of the local soils for roadbed application with the assistance of selected industry waste materials is found to help reduce the cost of the roads. This work shows the finding of the laboratory compaction study of the local clay subgrade. The compaction was conducted with standard and modified methods on soil mixed with two waste materials (fly ash and cement dust). The influence of waste materials on the clay subgrade compaction behavior was investigated to determine the optimum content of fly ash and cement dust. Finally, the result indicated that the studied parameters were highly influenced by the type of waste materials mixed with it.

Keywords: cement dust, fly ash, compaction properties, waste materials, clay subgrade.

تحسين التربة الطينية التحتية باستعمال مواد المخلفات

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الخلاصة

في الانشاء التقليدي للطرق، تعد المواد الاساسية من حفر الاقتراض هي الأكثر شيوعًا لطبقات الطريق. تتأثر التكلفة الإجمالية لبناء الطريق بعوامل مهمة مثل مواد الاساسية. ان تعزيز خصائص الرص للتربة الموقعية لغرض انشاء طبقات الطريق وبمساعدة مواد مختارة من النفايات الصناعية يساعد في تقليل تكلفة انشاء الطرق. يعرض هذا البحث نتائج دراسة الرص المختبري للتربة الطينية المحلية. تم إجراء الرص باستخدام الطريقة القياسية والطريقة المعدلة على نماذج التربة الطينية المخلوطة بمادتين من النفايات (الرماد المتطاير وغبار الأسمنت). تمت دراسة تأثير مواد النفايات على سلوك الرص للتربة الطينية لتحديد المحتوى الامثل لهذه المواد. اخيرا, أشارت النتائج إلى أن معاملات الرص للتربة الطينية تأثرت بشكل كبير بنوع مواد النفايات المخلوطة بها.

الكلمات المفتاحية : غبار السمنت, الماد المتطاير, خصائص الرص, مواد المخلفات, التربة الطينية التحتية.

1. Introduction

The development of the countries is mainly affected by their transportation (Senol, et al., 2012). The design and construction process of roads in Iraq should get more attention. The cost of these roads is affected by factors like the availability of material. Generally, the filling from borrow-pits are the common geomaterials for roadbed construction. The adoption of these geomaterials considers the highly economical compared to using other local fill materials such as what is locally called the "subbase soil". However, nearly the unfavourable engineering characteristics of the filling soils from borrow-pits necessities the application of suitable stabilization techniques to satisfy the engineering requirements of the roads design (Hazirbaba, 2017; Al-Taie, et al., 2020; Altameemi, et al., 2023).

Stabilization techniques in geotechnical engineering are various, they include mechanical, thermal, chemical, microbial, and electrical techniques (Al-Taie, et al., 2019; Ming-Juan, et al., 2024). However, in transportation engineering, techniques using chemical agents like asphalt, lime, cement, or salts are widely applied (Holtz, et al., 2010; Al-Kalili, et al., 2022). In recent years, chemical agents from the industrial wastes were utilized as an alternative additive for commonly use materials (Hussein, et al., 2019; Hussein, et al., 2020). The using of these materials as stabilization agent may assist in lowering the negative effects of industrial wastes , on the one hand, also enhance un-favoured properties of the soils, on other hand (Al-Baidhani, et al., 2020). However, according to scholars, materials (like fly ash, ground granulated, cement kiln dust, “rice husk ash”, blast slag, etc.) have been identified as sustainable stabilizers (Al-Naje, et al., 2020; Hassan, 2023). These wastes are called "possess pozzolanic" and "sustainability cementitious materials", as Rios, et al., 2016 mentioned.

Improvement of problematic geomaterials using sustainable materials can enhance their properties. In fact, the construction of layers of the roadbed itself is influenced by these materials, as the roadbed includes of mixing the soil with suitable additives. The needed enhancement in soils properties due to mixing with suitable sustainable agents can be ensured by investigating the required parameters of resulting mixture. The compaction in lab by hammers and falling masses is major way utilized to investigate the required parameters. Indications regarding minimizing the settlement and permeability, improving the soil’s strength and bearing value, and dominant volume-change in roadbeds can be gained from exploring the compaction parameters (Jacobson, 1938). The current paper aims to apply waste-sustainable materials, obtained from local Iraqi industry, in stabilization of local subgrade soil. The experimental work presents the findings of an investigation of utilizing fly ash and cement-dust, and materials used for enhancement of commonly obtainable cohesive subgrade in Baghdad Governorate. Fly ash from the by-product (from local electrical power-plant) and cement-dust (from domestic by-product Iraqi factories of cement) have been chosen as additives. Each year million-tons of domestic wastes are produced, accumulated, and unfortunately, rarely reutilized or recycled. Laboratory physical characteristics of clays subgrade, fly ash, and cement-dust were determined, and compaction characteristics of the mixes of the clay soil with various contents of fly ash and cement-dust were explored. The standard manual-compaction and modified one were conducted, and the findings of them were compared to explore the influence of chosen agents on the compaction characteristics and to get the best values of them.

2. Materials and Methods

Clay soil in current paper is the frequent available clay subgrade-soil of city of Baghdad Governorate. It was collected from a site located in Alsweeb, southern Baghdad. The additive materials utilized are flyash and cement dust. In the lab, the sample of soil was prepared for the testing program and subjected to a series of identification and classification tests by ASTM standards (D422, D854, D2487, D4318). Accordingly, it was found that the subgrade soil is a fine-grained lean clay or CL as shown in Table (1) and Figure (1).

Table 1: Physical- properties and classification of the subgrade soil.

Liquid Limit, LL,%	Plastic Limit, PL,%	Plasticity Index, PI, %	Specific Gravity,Gs	Type of soil according to ASTM D2487	Type of soil according to (AASHTO 1982)
33%	20%	13%	2.66	Lean clay or CL	clayey soil (A-6)

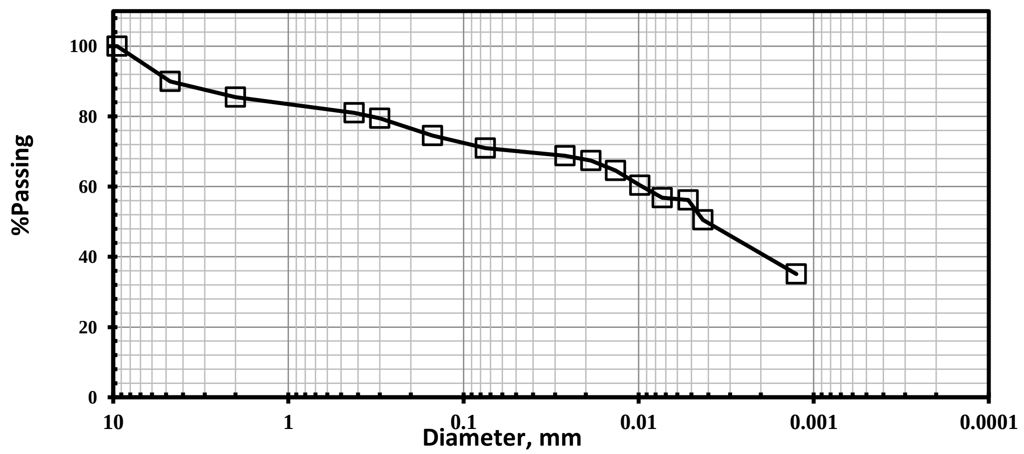

Figure (1): Particle-size distribution of the clay subgrade.

The additives utilized in current paper are flyash and cement-dust; they were collected from the local industry factories in Baghdad and Karbala. The samples of these additives were subjected to a series of laboratory tests to determine their physical properties. According to the test result, as shown in Table 2, these materials were non-plastic with fine-grained texture.

Table (2): Physical characteristics of materials used.

Additives	Liquid Limit, LL,%	Plastic Limit, PL,%	Plasticity Index, PI, %	Specific Gravity,Gs	Material Texture
Flyash	-	-	NP	2.1	Fine-grained (100 % pass sieve no.200).
Cement-Dust CKD)	-	-	NP	3.0	Silt sized (100 % pass sieve no.200)

All investigated materials were dried in an oven (105 to 110 °C as per ASTM standards, ASTM D2216) to prepare for utilization in laboratory. Soil mixes with fly ash and soil with cement-dust was conducted by mixing, in a dry state, to the ratios of the flyash and cement dust with the soil, the ratios used are 10.0 %, 15.0 %, 20.0 %, and 25.0 % by the soil. For each mix, the standard Procter-compaction, (according to ASTM D 698), and Modified Procter-compaction one, according to “ASTM D 1557”, were implemented. The cylindrical steel mold of a 944 cm^3 volume, 101.6 mm diameter, and height of 116.4mm was utilized. The prepared mixes were subjected to compaction, inside the steel mold (with cylindrical-shape), utilizing standard and modified manual hammer. In the standard-test, applied energy effort to compact the sample of soil-additive mixtures is 600 kN-m /m^3, whilst in modified test, the energy-effort utilized is 2700 kN-m / m^3.

Figure (2): Compaction test for stabilized subgrade soil

3. Results and Discussion

This research shows the influence of compaction on properties of natural clay-subgrade soil mixed with sustainable waste materials and to reach the optimal amounts of these agents. Figures (3) to (6) present the tests result.

The influence of various flyash amounts on compaction characteristics of clay-subgrade soil is as illustrated in Figure (3) and Figure (4). Clay soil was blended with 10.0 %, 15.0 %, 20.0 % , and 25.0 % flyash, then, the mixes was underwent to standard and modified-compaction efforts. Examination of Figure (3), reveals that utilizing the standard hammer cause a significant decreasing in the values of "maximum dry unit weight", where unit-weight values lessen when augmenting of flyash amount from (0.0 % to 25.0 %). Furthermore, values of the “optimum molding water content” found to exhibit unlike behaviour, they look to be greater as the amount of fly ash augmented, and they attain the maximum amount at 25.0 % fly ash. Accordingly, one can conclude the following: compaction of clay-subgrade with fly ash materials by adopting standard effort (600 kN m / m^3) causes a reduce in unit weight. This can be attributed to the low solid weight of fly ash solids where the Gs (i.e. specific gravity) is 2.10 Table (2), whilst its influence is well-pronounced in raising the "optimum water content" (Hussein, et al., 2020; Al-Naje, et al., 2020).

On the other hand, the modified compaction-test findings are shown in Figure (4). Analyses of the clay soil—fly-ash mixtures illustrated that the blending of the fly-ash waste with untreated subgrade produces a light decrease in “unit weight”, such reduction increases as the ratios of fly-ash material increases. Apposite behaviour can be distinguished in the amounts of optimum "water content”, for soil blended with 10.0 % fly-ash, the mixtures show a slight raising in water content, whilst for 15.0 % fly-ash and greater, a very clear raising in the amount of the “water content” can be observed.

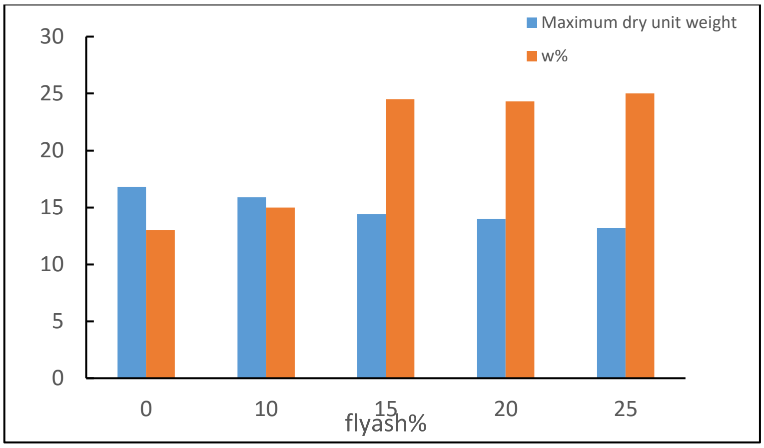

Figure (3): Effect of fly— ash on compaction-characteristics for soil.

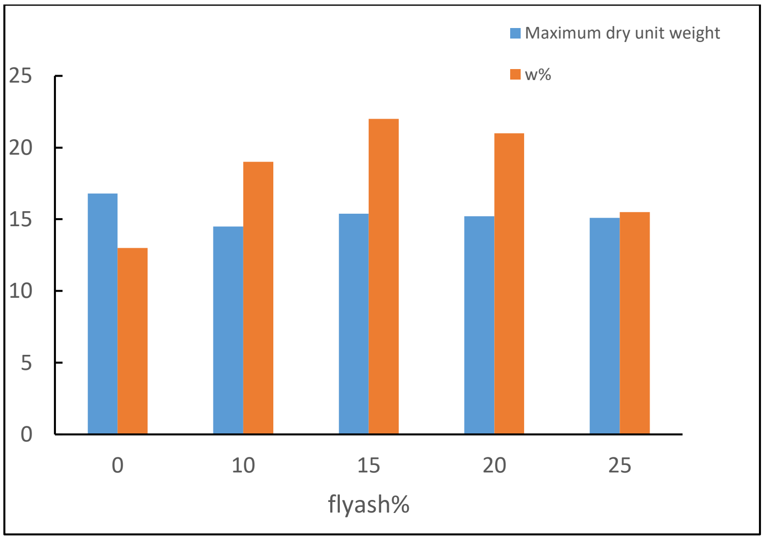

Figure (4): Effect of fly— ash on modified—compaction characteristics for soil.

It clear in Figure (5) that the influence of fly-ash content on compaction-properties of clay subgrade (modified test) is very confined for fly-ash content more than or equal 15.0 %. By examining Figure (5) illustrated that soil—cement dust mixes compacted utilizing the standard hammer shows a limited reduction in the “dry unit weight” with augmenting the amount of the cement— dust (CKD). While magnitude of optimal moisture “water-content” exhibited different behaviour, it looks to augments with augmenting waste content until the water content arrives maximum amount at 15.0 % cement—dust, then its value drops at 25 % cement dust content. One can conclude that compaction of mixtures of soil—cement-dust by enforcing standard effort, 600.0 kN.m / m3, slightly affects the “unit weight”, but its influence is obvious in the values of the content of water (Al-Naje, et al., 2020; Hussein, et al., 2020).

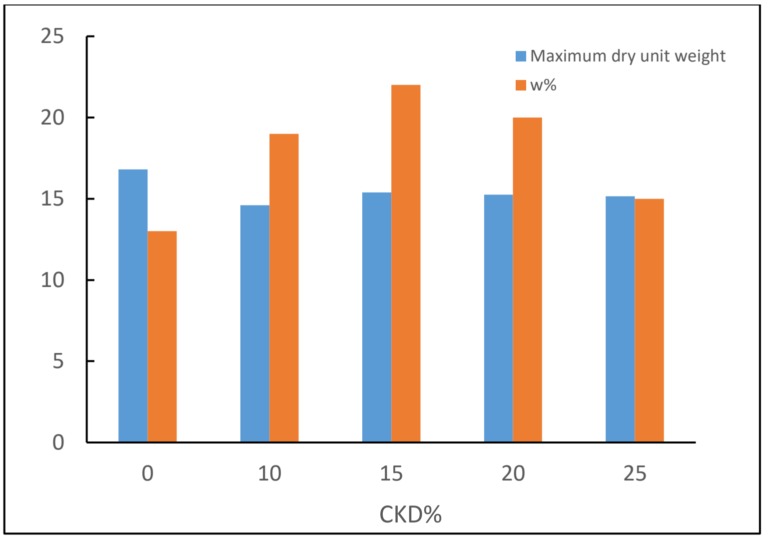

Figure (5): Effect of cement—dust on compaction characteristics for soil.

The influence of the compacted on mixtures of soil—cement-dust using modified-mass hammer, Figure (6), is differ comparing with that of standard-mass hammer Figure (5). The result presents a positive influence of using the cement-dust, generally, "dry unit weights" of mixtures were improved as compare to untreated subgrade soil. The "maximum dry unit weights" show their better values at 10.0 % cement-dust. In fact, at 10.0 % additive, the needed water contents to attain the optimal amount of the unit-weight are at their minimum amounts. As a result, compaction of mixers prepared from clay soil and cement dust by using modified effort, 2700.0 kN m / m3, shows good enhancement on the compaction properties (i.e. the molding water content and unit weight) in reference to the natural subgrade soil (Hussein, et al., 2020).

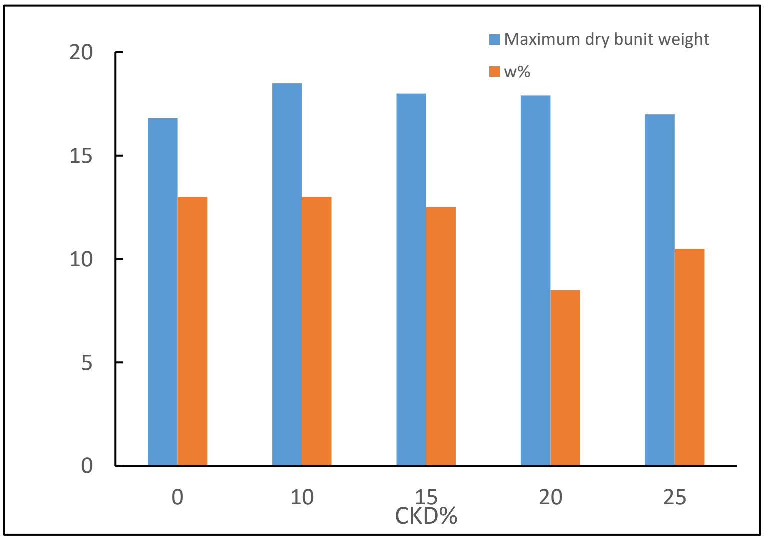

Figure (6): Effect of cement—dust on modified—compaction characteristics for soil.

4. Conclusion:

The present work illustrated the findings of the experimental compaction examination (utilizing standard and modified proctor tests) that utilizing various proportional (0.0 % , 10.0 % , 15.0 %, 20.0 % , 25.0 %) of fly ash and cement-dust materials for improvement of widely available clay subgrade fill material of regions of governorate Baghdad. The widely available fill from subgrade material usually classified as A—6 soil and evaluated as “Fair to Poor” subgrade. The chosen waste materials are non—plastic, fine—grained texture materials. These are the fly ash and cement dust. The findings of this examination showed that the compaction of soil-flyash mixtures (standard test) causes a reducing in “unit weight”, this may be due to the “ lightweight” of fly-ash (G s=2.10), whilst its influence is well-pronounced in raising the "optimum water content". Furthermore, the influence of fly-ash amount on compaction properties of the clay subgrade-soil (modified test) is decreased for fly-ash amount more than or equal 15.0 %. On the other hand, compaction of soil-cement dust mixtures (standard test) has a little influence on the “unit weight”, whilst its influence is well - pronounced on "optimum water content". Also, compaction of soil—cement-dust mixers (modified test) has a high enhancing influence on compaction properties (both the “unit weight” and “molding water content”) in comparison to the clay subgrade-soil. Nevertheless, the “maximum dry unit weight" closes to its optimum amount at 10.0 % cement-dust.

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