Case Studies in Construction Materials 7 (2017) 138–143

Contents lists available at ScienceDirect

Case Studies in Construction Materials

journal homepage: www.elsevier.com/locate/cscm

Case study

Improvement of poor subgrade soils using cement kiln dust

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A R T I C L E I N F O

Keywords:
Subgrade properties
Cement kiln dust
By-product
CBR
Highway construction
Cost reduction

A B S T R A C T

Construction of pavements layers on subgrade with excellent to good properties reduces the thickness of the layers and consequently reduces the initial and maintenance cost of highways and vice versa. However, construction of pavements on poor subgrade is unavoidable due to several constrains. Improvement of subgrade properties using traditional additives such as lime and Portland cement adds supplementary costs. Therefore, using by-products in this domain involves technical, economic, and environmental advantages. Cement kiln dust (CKD) is generated in huge quantities as a by-product material in Portland cement plants. Therefore, it can be considered as an excellent alternative in this domain. In Iraq, Portland cement plants generate about 350000 tons of CKD annually which is available for free. Therefore, Iraq can be adopted as a case study. This paper covers using CKD to improve the properties of poor subgrade soils based on series of California Bearing Ration (CBR) tests on sets of untreated samples and samples treated with different doses of CKD in combination with different curing periods to investigate their effects on soil properties. The results exhibited that adding 20% of CKD with curing for 14 days increases the CBR value from 3.4% for untreated soil to 48% for treated soil; it, also, decreases the swelling ratio. To determine the effects of using this dose under the mentioned curing period on the designed thicknesses of pavements layers, a case study was adopted. The case study results exhibited that treatment of the subgrade soil by 20% of CKD with curing for 14 days reduces the cost of the pavements by $25.875 per square meter.

1. Introduction

Subgrade properties control the structural design of highway pavements system [1]. In subgrade construction of highway works, utilizing all types of natural materials is, mostly, unavoidable due technical, economic and environmental considerations [2]. Therefore, identifying and treatment of poor subgrade soils is an essential objective. Replacement is one of the common solutions. However, it is very costly and impractical in highways projects due to the huge volume of these projects. Improvement of poor soils using lime, Portland cement and other chemicals is an effective solution [3–5]. However, using these admixtures adds supplementary cost. In recent years, utilizing of industrial by-products in treatment of problematic soils is in high demand as it promotes more sustainable construction [6,7] and decreases the cost. Cement kiln dust (CKD) is an industrial by-product from manufacturing of Portland cement [8,9]. Mostly, disposal of CKD represents a considerable economic and environmental problem. Huge quantities of CKD accumulate annually over the world [9]. In Iraq, there are more than fifteen cement Plants which produce about two million tons of Portland cement and generates about 350000 ton of CKD annually. Therefore, employment of CKD as an admixture to improve the properties of poor subgrade involves economic and environmental advantages. This paper presents a laboratory oriented

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http://dx.doi.org/10.1016/j.cscm.2017.06.005
Received 4 April 2017; Received in revised form 11 June 2017; Accepted 20 June 2017
Available online 23 June 2017

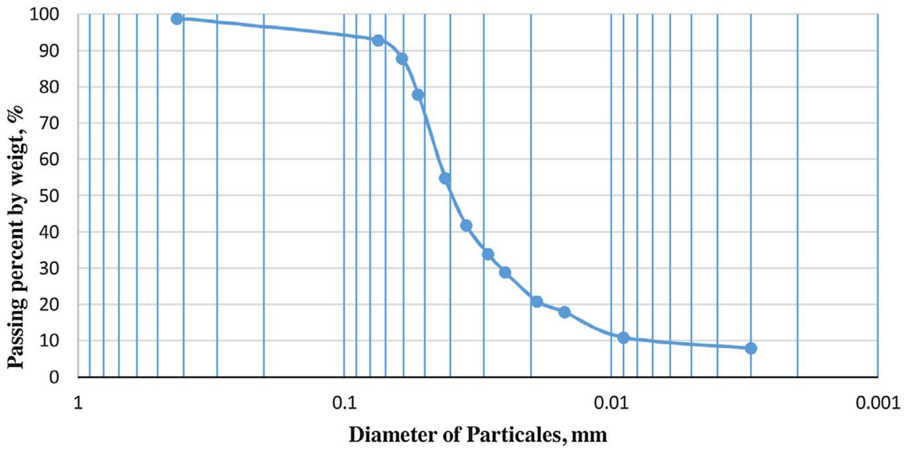

Fig. 1. The grain size distribution of control soil.

study to investigate the effects of CKD on the properties of the poor subgrade soils using CBR testing method. A series of CBR tests were performed on number of untreated samples and samples treated with different doses of CKD (5%, 10%, 15%, 20%, 25%, and 30% by the dry weight of the selected soil) in combination with different curing periods (1 day, 3 days, 7 days, 14 days, and 28 days). The results exhibited significant increase in CBR values and significant decrease in swelling ratios for treated samples. The optimum dose and optimum curing period were determined based on results obtained. To determine the effects of using the optimum dose under the optimum curing period on the designed thicknesses of pavements layers, a case study was adopted. The case study based on design data obtained from Iraqi ministry of construction and housing for a proposed highway. The pavement design of this highway was repeated using the CBR value attained under optimum conditions proposed by this study. The comparison between the original design and the modified design exhibited substantial reduction in the thickness of pavements layers which indicates considerable reduction in costs.

2. Properties of materials used

The soil used in this study was obtained from Baghdad, central region of Iraq. Generally, it is brown soft silty clay. The properties of the soil were studied by a series of tests. The grain size distribution of the soil used is illustrated in Fig. 1. Soil properties are presented in Table 1. Cement kiln dust was, freely, obtained from Kuffa cement plant in Najaf Governorate, Iraq. A number of tests were performed to determine its physical and chemical properties; the tests' results are shown in Table 2.

Literatures [9–11] demonstrated four points to describe the effects of CKD chemical composition on the properties of soil. First, CKD contains high content of free lime (about 15%) and low alkalies content (less than 4% water soluble K2O or less than 3% Na2O equivalent) increases the compressive strengths of clayey soils. Second, CKD contains low content of free lime (less than 8%) and high content of alkalies (more than 7% water soluble K2O or more than 3% Na2O equivalent) reduces the unconfined compressive strength of the clayey soil. Third, CKD contains moderate free lime content (8–15%) and low alkalies content decreases the plastic index value, reduces swelling, and increases strength and durability of the soil. Fourth, CKD with low LOI (less than 9%) and moderate alkalies (more than 3% Na2O) reduces the PI and improved the unconfined compressive strength. CKD used in this study contain moderate free lime and low alkalies contents (Table 2) which make it suitable for the domain of the study.

3. Testing program

In addition to the tests performed to determine the properties of materials used (control soil and CKD), a series of tests were performed using CBR method (AASHTO T 193) on a number of samples prepared at the optimum moisture contents and maximum dry density. To prepare the samples for testing, six different doses of CKD (5%, 10%, 15%, 20%, 25%, and 30% by the dry weight of

Table 1
The properties of control soil.

Property	Value	Type of test	Standard
LL	41%	Liquid Limit	
PL	25%	Plastic Limit	ASTM D 4318/AASHTO T 90
PI	16%	Plasticity Index	
Specific Gravity (Gs)	2.76	Specific Gravity of Solids	ASTM D 854/AASHTO T 100
Maximum Dry density (γdmax)	1887 kg/m3	Modified Compaction	ASTM D1557/AASHTO T 180
Optimum Moisture Content (OMC)	14%		
CBR Value	3%	California Bearing Ratio	ASTM D1883/AASHTO T 193