Sustainable Civil Infrastructures

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New Approaches of Geotechnical Engineering: Soil Characterization, Sustainable Materials and Numerical Simulation

Proceedings of the 6th GeoChina International Conference on Civil & Transportation Infrastructures: From Engineering to Smart & Green Life Cycle Solutions – Nanchang, China, 2021

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Sustainable Civil Infrastructures

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Introduction

This volume contains eight papers that were accepted and presented at the GeoChina 2021 International Conference on Civil & Transportation Infrastructures: From Engineering to Smart & Green Life Cycle Solutions, held in Nanchang, China, during September 18–19, 2021. The articles presented in this volume cover new approaches of geotechnical engineering introduced by researchers, engineers and scientists to address contemporary issues in geotechnical engineering such as the usage of sustainable materials in soil, soil characterization with new methods and numerical simulations to predict material properties. This information should lead to smart and green life cycle solutions in engineering. Various types of research were used in the various studies, including field measurements, numerical analyses and laboratory measurements. It is anticipated that this volume will support decisions regarding the optimal management and maintenance of civil infrastructures to support a more sustainable environment for infrastructure users.

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About the Editors

Dr. Jinwoo An is an assistant professor of Civil and Mechanical Engineering in the School of Engineering at the University of Mount Union. He received his Ph.D. in Civil Engineering from the University of Central Florida in 2015 and his Master in Civil Engineering from the University of Texas at Austin in 2012. He is an experienced and energetic engineer, researcher and educator. He previously worked at a structural engineering company as an assistant engineer to finish a structural design of a multipurpose building with 29 floors (Macroscale). For his dissertation, he conducted a research on the mechanical and structural performance of cement composite materials, which incorporated sustainable materials (mesoscale). During his postdoctoral career, he deeply explored the effects of micro- and nanomaterials as additives in cement composite materials (micro- and nanoscale). He also authored, co-authored and edited more than 50 technical reports, journal and conference papers.

Dr. Jizhe Zhang is an associate professor of the School of Qilu Transportation, Shandong University. He is a professionally registered pavement engineer with a research interest in moisture damage of asphalt mixture, composite modification of bituminous materials, asphalt mixture recycling and solid waste utilization in asphalt pavement. He completed his graduate studies at the Wuhan University of Technology, China, and obtained his doctorate from the University of Nottingham, UK. He has published over 50 journal papers and ten conference papers. He is the young academic editor of the Journal of Traffic and Transportation Engineering (English Edition). He is a member of technical committee in the World Transportation Convention and a member of the expert committee of iFRAE 2021.

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Polymers, Materials, Frontiers in Materials and International Journal of Hydrogen Energy. Her research and practical interests include design and preparation of functional materials, new building materials, asphalt and modified asphalt technology and comprehensive utilization of material waste residue. She has completed a number of national, provincial and ministerial scientific research projects as the host. She has worked significantly on rubber powder modified asphalt and has been researching on molecular design and techniques to improve the performance of modified asphalt.

CBR Strength of Treated Subgrade Soils

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Abstract. Calcium-based stabilizing agents have been extensively used to improve the engineering properties of base and subgrade layers of pavement systems. Recently, polymers and chemical stabilizers have become popular due to cost efficiency, ease of application, and fast curing times. This study presents a comprehensive laboratory testing program quantifying the strengths of treated subgrade soils. Here, the strength is defined in terms of California Bearing Ratio (CBR) values. The results of the CBR tests showed that non-traditional stabilizing agents significantly increased the strength characteristics of subgrade soils.

1 Introduction

A typical pavement structure consists of three layers including asphalt, base, and subgrade layers. The subgrade layer is made up of native soil and it acts as the foundation that provides stability to the pavement structure. Effectively designed pavements are expected to last for long periods but throughout the service life pavements experience distresses in terms of fatigue cracking (alligator cracking), rutting, bleeding, and potholes. Distresses significantly reduce the overall strength and durability of a pavement system and put additional costs on the rehabilitation and maintenance budgets of state and federal transportation agencies. Numerous researches are actively working on developing methods and products to increase the pavement resistance over distresses. The stabilization of subgrade and base layers improves the strength, compressibility, and durability characteristics of pavements.

Calcium-based stabilizers including cement and lime have been effectively used by the U.S. transportation departments. Cement stabilization depends on hydration products immediately created by the calcium silicates and calcium aluminates present in the cement itself. Excess free lime produced during hydration also allows for long term pozzolanic reactions to occur. Since base courses typically have low plasticity, cement is often used to improve the strength characteristics of these materials. Research findings also reveal that cement treated soils show a brittle behavior which is often the reason for shrinkage cracks in the stabilized layer. Reflection cracks through the asphalt

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surfaces typically follow the same patterns as the cracks in a cement treated base [1]. Soluble sulfates present in soils can induce chemical reactions between cement/lime and residual soils resulting in significant loss of strength and heaving. Sulfates cannot be efficiently removed from the soil; therefore, non-traditional stabilizers have been recently recommended as alternative base stabilization products. Introduced as a non-traditional stabilizer for soil stabilization and erosion control, polymer and chemical stabilizers have become popular also due to cost efficiency, ease of application, and fast curing times. In this paper, an extensive laboratory testing program was executed to determine the CBR strength characteristics of subgrade soils after polymer and Claycrete (a chemical stabilizer) treatment. Parametric sensitivity analyses were carried out to evaluate the effects of subgrade soil type and stabilizing agent treatment levels.

2 Literature Review

In the literature, calcium-based stabilizers including cement and lime have been documented by numerous researchers. Kayak and Akyarli [2] studied the effects of lime on soil stabilization in clayey soil in the Ankara Province road in Turkey. In this study, %5 of lime by weight led to an increase in the CBR value by around 16 to 21 times for different type of clays. Similarly, Sariosseiri and Muhunthan [3] studied the use of cement to treat soils in the Washington state. Cement treatment showed significant improvement in the engineering properties. Particularly at 10% cement rate the soil samples showed relatively high unconfined compressive strength. Treated samples; however, showed more brittle response compared to untreated soils.

Non-traditional stabilizers including polymer and chemical admixtures have also been documented. For example, Hawakins et al. [4] proposed a method using chemical stabilizers named carboxylic acid and polyolefins for dust control and soil stabilization. A heterogeneous mixture was produced by blending the aliphatic or cyclic organic compounds with carboxylic acid. It was observed that polyolefins control the dust and improves the soil stiffness and modulus by more than 100%. It was reported that this chemical acts as a plasticizer and the penetration of this chemical helps for dust control.Recently, Srinath et al. [5] studied polymer binders to stabilize the subgrade soils. The primary objective of this study was to investigate the subgrade soils engineering properties in terms of physical, chemical, mechanical and microstructural properties and the results were utilized in the pavement design and analysis to determine their impact. The results showed a significant reduction in the subgrade rutting under high loading and different weather conditions. It was concluded that reduction in subgrade rutting helps for effective deformation transfer, subgrade to have longer bonding, and to reduce the rehabilitation costs. More recently, Hemant Gc et al. [6] investigated the significance of rubber and polymer in asphalt mix towards the pavement fatigue performance in terms of tensile strength and cost-effectiveness. In this study, three different mix designs such as conventional HMA mix, Asphalt Rubber (AR) and Polymer modified mix were adopted and these mixers were evaluated utilizing 3D move analysis software. It was observed that the utilization of modified mixtures significantly increases the service life of the pavements and more economical. From the results it was concluded that the AR mix has significantly increased the fatigue life and also it was cost effective (by 24 times compared to conventional HMA). It was observed that high speed and thick pavements show much more significant results as the asphalt is much stronger at high frequency loadings.

3 Objectives

Engineering properties of subgrade soils can be improved with the application of non-traditional stabilizing agents including polymer and chemical admixtures. The main objectives of this research are to compare the CBR strength properties of polymer and claycrete treated subgrade soils and to investigate the impact of different types of admixtures on the overall pavement performance.

4 Laboratory Testing Program

Laboratory investigations were based on two types of stabilizing agents including polymer and Claycrete. The polymer was in the form of aqueous dispersion. The pH value was around 4.5–5.5 and the density was around 0.9982 g/cm^3 (68 °F or 20 °C). The specific gravity (relative density) was around 0.95–1.10, Water = 1 (liquid). Claycrete was used as a chemical stabilizer in the laboratory testing program. It is an ionic soil stabilizer which is designed especially for clay soils. The pH value was around 2.0 to 2.5. The specific gravity of claycrete was around 1.1. The flash point of the claycrete was greater than 61 °C. The polymer was provided by Terra Pave International which is located at the University of Texas at Austin.

Two commonly observed soil types were used in this study. They were labelled as Clayey Soil (CS) and Sandy Soil (SS). The gradation of the CS soil was chosen to be as 40% of retained soil in between sieve no.4 (opening size 4.75 mm) and sieve no. 40 (opening size 0.425 mm) plus 40% of retained soil between sieve no.40 and sieve no. 200 (opening size 0.075 mm) plus 20% of clay. The gradation of SS soil was chosen to be as 45% of retained soil in between sieve no. 4 and sieve no. 40 plus 45% of retained soil between sieve no. 40 and sieve no. 200 plus 10% of clay. The particle size distribution curves of CS an SS soils are given in Fig. 1.

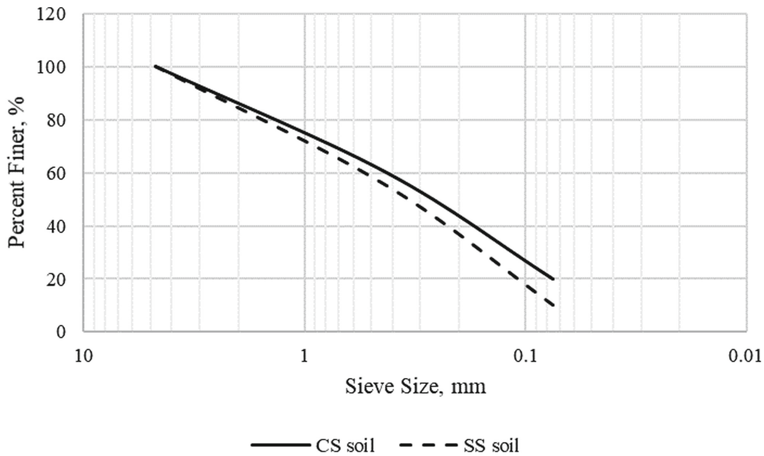

Fig. 1. Particle size distribution curves of CS and SS soils