RUTGERS
Center for Advanced Infrastructure and Transportation

Project Overview Report

1. UTC Identifying Number

   DTRT13-G-UTC28

2. Center Identifying Number

   CAIT-UTC-NC42

3. Project Title

   Experimental evaluation of the engineering behavior of soil-biochar mixture as a roadway construction material

4. Principal Investigator & Contact Information

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5. Rutgers/CAIT Project Manager

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6. Customer Principal

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   Delaware Department of Transportation

7. Project Description

   Reports indicate that humanity discharges 43 gigatonnes of carbon dioxide annually. This discharge is 25% greater than just a decade ago (Lehmann & Joseph 2015). Studies indicate that converting forestry and agricultural waste into biochar could remove 4 gigatonnes of carbon dioxide each year (Lehmann & Joseph 2015). Biochar soil amendment has gained strong research interest because of the significant benefits biochar might provide, including carbon dioxide sequestration, increased plant fertility, decreased nutrient leaching, and enhanced soil moisture retention capacity (reduced irrigation) (Schimidt 2012). The application of biochar in storm water management is also gaining attention by the state and federal transportation agencies (Wang et al. 2015; Abera et al. 2016). Even though biochar has been shown to provide these benefits in some soils, in others the benefits have been minimal and sometimes even detrimental. An example is soil hydrology, where biochar sometimes increases and sometimes decreases hydraulic conductivity, the maximum rate of water infiltration under a unit hydraulic gradient. Without models that predict biochar's influence on soil's engineering properties, its large-scale application is severely limited.

   There are a few current studies that are underway and try to reconcile contradicting results that were reported by past studies. The PI is currently collaborating in such a research and is investigating how the hydraulic conductivity of soils is affected by the presence of biochar. The PI has seen only one past study (Reddy et al. 2015) that examined the effect of biochar addition on the engineering properties of soil-biochar mixtures. Other than that most studies focused on the flow-related properties of soil-biochar mixtures (Fellet et al. 2011; Reddy et al. 2014; Lim et al. 2015; Tian et al. 2015; Abera et al. 2016). One shortcoming of past studies is that their approach towards investigating the effects of biochar addition is not robust. Apparently, the strength and volume change (deformation) behavior of soils are inherently coupled with their hydrological (flow-related) properties. Looking at the flow-related effects only, thus, would be a rather inconclusive approach. In this study it is proposed to

investigate the over-arching influence of biochar on the strength and volume change properties of soils in addition to its effects on flow-behaviors.

This study proposes an experimental approach in which multiple combinations of: biochar fraction (2%, 6%, 10% by mass); biochar type (plant-based, animal-based); biochar size (fine, coarse); soil type (clay, sand, clay+sand or commonly available soils in the Mid-Atlantic Region) will be prepared and the physicochemical (moisture and organic content, alkalinity, density, specific gravity etc) and geotechnical (flow-related, deformation-related, and strength related) properties of the resulting mixtures (clay-biochar, sand-biochar, clay+sand-biochar) will be investigated using standard testing procedures. Apparatuses such as the rigid-wall permeameter (ASTM D5856 2007), flexible-wall permeameter (ASTM D5084 2010), Oedometer (ASTM D2435 2011), direct shear test (ASTM D3080 2011) and triaxial shear test (ASTM D7181 2011) will be used. The effect of compaction (ASTM D698 2012; ASTM D1557 2012) on the relevant engineering properties of the mixtures will be investigated. Stress strain curves will be developed and material variables such as the angle of internal friction and coefficient of cohesion will be determined using existing failure criteria (e.g. Mohr-coulomb). The data obtained from a series of physical testing will play a pivotal role in assessing multiple unanswered and unasked questions of the future. Obtained results will be compared amongst each other and engineering discussion/interpretation of results will be made.

8. Implementation of Research Outcomes (or why not implemented)

   This study will involve the PI, one graduate, and two undergraduate students. The PI will assume mainly the role of supervising the overall progress of the study. In addition, the PI will guide and mentor the graduate student in what needs to be done at a given time. The Graduate student will execute most of the literature survey, experimental and analytical aspects of the research, and drafting the reports to be submitted for review. The undergraduate students, which will be selected from UD's pool of senior undergraduate students, will help the graduate student in performing the laboratory tests. Within the 18 month project performance time proposed, two undergraduate students (one at a time) will assist in executing the laboratory tests.

   Findings from this project will have significant implications, ranging from fundamental understanding of the physicochemical and geotechnical properties of soil-biochar mixture and identification of areas of application for soil-biochar mixture on a mid- to large-scales to the development of practical ways of implementation for soil-biochar mixture as an innovative engineered-geomaterial. In the long term, the successful completion of this research would also aid in developing and validating a new system of application in which new laboratory and field testing protocols, new behavior predicting models, and new quality check/control mechanisms are developed for the soil-biochar mixture, which the PI believes is a "new" construction geomaterial that is unique in many ways from its components. The long-term outcomes will impact some important policies and products that have practical significance to local and federal agencies that constantly deal with road-construction materials. The PI identifies Delaware Department of Transportation as the primary external client for this research. The research team plans to collaborate with Jennifer Pinkerton, P.E., Chief Material & Research Engineer at Delaware Department of Transportation, through periodically held meetings to go over plans, procedures of execution, and results obtained. Once the various application potentials of the soil-biochar mixture are identified and the concomitant science and engineering are well understood, throughout the meetings and interim reports that will be reviewed by the client, the research team will systematically introduce possible adoption mechanisms to the external client.

9. Impacts/Benefits of Implementation (actual, not anticipated)

   TBD

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10. Dates and Budget

    Start Date: 9/1/2016
    End Date: 3/1/2018
    UTC (CAIT) Dollars: $ 59,395
    Cost Sharing: $ 59,396
    Total Dollars: $ 118,791

11. Keywords

    Biochar, soil, shear strength, compressibility, hydrology, road construction material, state of good repair, economic competitiveness

12. Web Links (Reports and Project Website)

    https://cait.rutgers.edu/cait/research/experimental-evaluation-engineering-behavior-soil-biochar-mixture-roadway-construction