# Joint Transportation Research Program

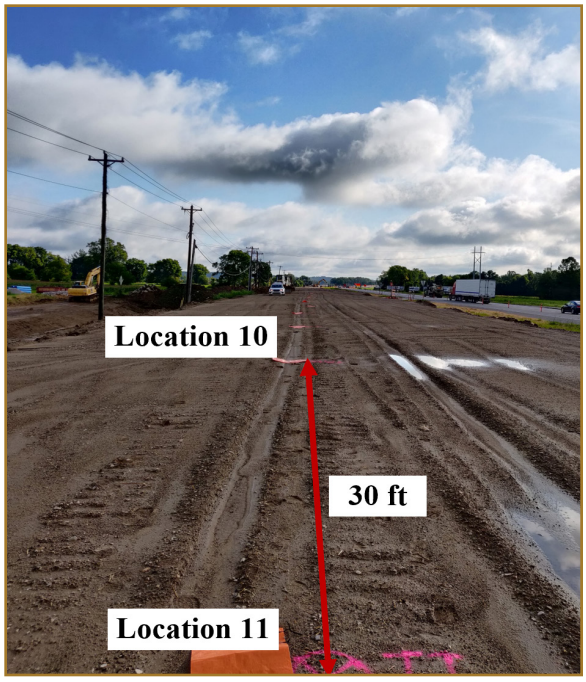

**Principal Investigator:** Antonio Bobet, Purdue University, bobet@ecn.purdue.edu, 765.494.5033
Boonam Shin, Purdue University, bshin@indot.in.gov, 765.463.1521 x281
Peter J. Becker, Purdue University, pbecker1@indot.in.gov, 765.463.1521 x249
**Program Office:** jtrp@purdue.edu, 765.494.6508, www.purdue.edu/jtrp
**Sponsor:** Indiana Department of Transportation, 765.463.1521


SPR-4420 2022


# Estimating Strength from Stiffness for Chemically Treated Soils

## Introduction

The quality of any pavement structure and its performance capabilities depend on the strength and stiffness properties of the subgrade soil; thus, the performance of a pavement can be improved by stabilization of available subgrade material. Cement stabilization is one of the most effective subgrade improvement methods because it increases the thermal, chemical, and mechanical resistance of the soil. Subgrade stabilization with cement-treated subgrades for INDOT projects is based on compressive strength. While Unconfined Compressive Strength (UCS) is a simple and commonly used laboratory test to measure the strength of treated soils, the in-situ strength determination of subgrade soils is a rather cumbersome process. However, the Falling Weight Deflectometer (FWD) Test is a non-destructive test used widely by INDOT to determine the stiffness of subgrades and the quality of the pavement structure. The laboratory determination of subgrade stiffness however is carried out by a Resilient Modulus Test ($M_R$). The current project aims to develop correlations between the compressive strength (e.g., UCS) and the stiffness (e.g., MR) of cement-treated subgrades. Three Indiana road project sites with access to untreated subgrade (US-31, SR-37, and I-65) were selected for this project. Cement-treated soil specimens were then used to perform UCS and $M_R$ tests. The specimens were prepared based on the cement percentages used for the design of the roads. Linear regression analyses were carried out to correlate soil properties (plasticity index, OMC and MDD) and resilient modulus with UCS results.




*SR-37 site locations for subgrade soil collection.*

## Findings

Based on the results of the tests and analyses performed, no direct statistically significant correlation was found between resilient modulus and UCS. The absence of good correlations between the two tests was consistent with the findings reported in the technical literature. However, it was observed that resilient modulus values depend on the type of soil. The range of resilient modulus values for cement-treated A-2-4 soils in this study ranged from 210 MPa to 275 MPa (30,000

psi to 40,000 psi), while cement-treated A-4 and A-6 soils fell in the range of 135 MPa to 240 MPa (20,000 psi to 35,000 psi). Linear regression analyses using normalized resilient modulus and normalized UCS showed a good correlation; However, this finding requires prior knowledge of the resilient modulus and unconfined compression strength of the soil, and the observation is based on limited data. More high quality laboratory data is needed to increase confidence in the results.

## Implementation

The results of the tests showed that the resilient modulus of A-2-4, A-4, and A-6 soils treated with cement fall within a fairly narrow range of values. These results could then be used as preliminary estimates of the expected values of the stiffness of the soil in the field, as well as the UCS values. Also, the correlation found between normalized $M_R$ and UCS can be used; however, it requires prior knowledge of the $M_R$ and UCS values of the soil.

## Recommended Citation for Report

Shivakumar, P., Gupta, K., Bobet, A., Shin, B., & Becker, P. J. (2022). *Estimating strength from stiffness for chemically treated soils* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2022/20). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317383

View the full text of this technical report here: https://doi.org/10.5703/1288284317383

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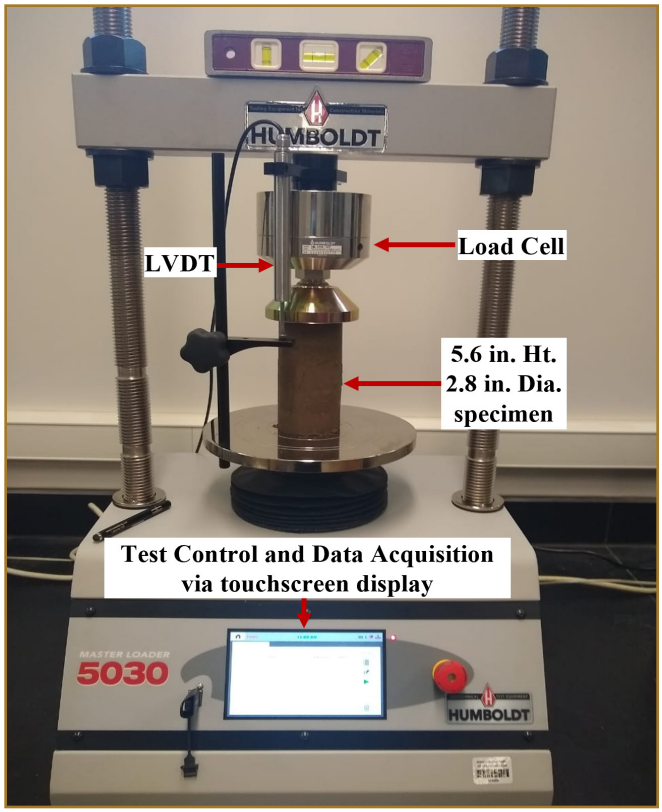


*Humboldt load frame used for unconfined compression tests.*

*Cement treated specimen post Unconfined Compression Test*