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# Design Values of Resilient Modulus for Stabilized and Non-Stabilized Bases

## INTRODUCTION

The American Association of State Highway Transportation Officials' (AASHTO) new AASHTOWare pavement design software, Pavement ME Design, has recommended the use of laboratory determined resilient modulus of base, subbase, and subgrade soils in characterizing pavements for their structural analysis and design. The Louisiana Department of Transportation and Development (DOTD) currently utilizes the 1993 Pavement Design Guide, which requires structural coefficient input parameters. The new Pavement ME Design software requires the base course resilient modulus as an input parameter for pavement design. These resilient modulus design values for stabilized and non-stabilized base materials are not well established for Louisiana. Typical base course resilient modulus values need to be established for DOTD to begin implementing Pavement ME Design in the design of pavements in Louisiana. Laboratory testing is therefore required to establish resilient modulus values.

Current DOTD specifications allow both bound (soil-cement, cement-stabilized, and cement-treated base courses) and unbound materials to be utilized as base course materials. Bound materials are controlled by moisture content and dry density to obtain design strengths and utilize moisture content and dry density (e.g., ± 2% of optimum moisture content, and ≥ 95% of maximum dry density) as a quality control and acceptance criteria in the field. Unbound materials are controlled by moisture content and dry density (e.g., ± 2% optimum moisture content, and ≥ 98% of maximum dry density), which are used as a quality control and acceptance criteria in the field. Resilient modulus testing is not currently a design method or quality control parameter. There is a need to determine the design resilient modulus for the different materials at their in-situ acceptable values of moisture content and dry density (including field variation that may occur). These values can then be included in the design of pavement structures.

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## OBJECTIVE

The primary objective of this research study was to determine resilient modulus design values for typical base course materials, as allowed by DOTD specifications.

## SCOPE

The bound (stabilized) and unbound (non-stabilized) base course materials evaluated in this research study are typical base course materials specified and constructed as part of Louisiana roadways. Three stabilized soil types (classified as A-2-4, A-4, and A-6, according to the AASHTO soil classification) were evaluated as bound base materials. In-place cement stabilized (A-4) and in-place cement-treated (A-4) field base courses were also evaluated as bound base materials. Two aggregate types [Mexican Limestone and Recycled Crushed Portland Cement Concrete (PCC)] were evaluated as unbound base materials. The basic material properties of the bound and unbound base materials were characterized through laboratory tests, and then repeated load triaxial tests were also conducted to evaluate their resilient modulus.

## METHODOLOGY

Laboratory testing was performed on the typical base course materials allowed by DOTD specifications. The laboratory testing program consisted of physical properties tests (Atterberg limits, sieve/hydrometer analysis, and moisture-density relationship) and repeated loading triaxial (RLT) resilient modulus tests. The materials were evaluated at three moisture contents, which represent the range variation allowed during construction: 2% below optimum, optimum moisture content, and 2% above optimum.

## CONCLUSIONS

Based on the results of this study, the following conclusions can be drawn:

- For soil cement at 7-day curing, moisture content has an effect on resilient moduli as an increase (2% above optimum) or a decrease (2% below optimum) in molded moisture content caused a decrease in resilient moduli, which can be attributed to the fact that a material will have higher resilient modulus at its maximum dry density.

- For soil cement at 28-day curing, there was a significant increase in resilient moduli as compared to samples at 7-day curing. Resilient moduli design values ranged from 100,000-180,000 psi for the soil cement materials tested in this study. Resilient moduli values varied with molding moisture content for each material and the minimum value was selected.

- For soil cement, the cement content of a base course will enhance its strength characteristics and thus affect its response to loading as observed below:
    1. Cement stabilized base course (low cement content) generally behaved as a stress-softening material (i.e., an increase in deviator stress caused a decrease in resilient moduli).
    2. Cement stabilized base course (high cement content) generally behaved as a stress-hardening material (i.e., an increase in deviator stress caused an increase in resilient moduli).

- For unbound materials such as Mexican Limestone and Recycled PCC (crushed), moisture content has an effect on resilient moduli as an increase (2% above optimum) or a decrease (2% below optimum) in testing moisture content caused a decrease in resilient moduli, which can be attributed to the fact that a material will have higher resilient modulus at its maximum dry density. Resilient moduli design values ranged from 15,000-25,000 psi for the Mexican Limestone and Recycled PCC (crushed) tested in this study. Resilient moduli values varied with testing moisture content for each material and the minimum value was selected.

## RECOMMENDATIONS

Based on the conclusions drawn from this study, the following initiatives are recommended in order to facilitate the implementation of this study:

- For cement-stabilized base course (300 psi design strength), as specified by Sections 302 and 303 of the Louisiana Standard Specifications for Roads and Bridges (2006 edition), the following resilient modulus design values are recommended for use as design inputs:
    - a. A-2-4 (Cement Stabilized): 140,000 psi
    - b. A-4 (Cement Stabilized): 120,000 psi
    - c. A-6 (Cement Stabilized): 100,000 psi
    - d. A-6 (In-Place Cement Stabilized): 130,000 psi

- For cement-treated base course (150 psi design strength), as specified by Section 308 of the Louisiana Standard Specifications for Roads and Bridges (2006 edition), the following resilient modulus design value is recommended for use as a design input:
    - a. A-6 (In-Place Cement Treated): 110,000 psi

- For cement-treated base courses (150 psi design strength), which are typically constructed for low volume roads, design personnel may consider utilizing a cement stabilized base course (300 psi design strength) when the low volume roads are subject to overweight vehicles since cement-treated base courses generally behave as a stress-softening material.

- For Mexican Limestone and Recycled PCC (crushed), as specified by Section 302 of the Louisiana Standard Specifications for Roads and Bridges (2006 edition), the following resilient modulus design values are recommended for use as design inputs:
    - a. Mexican Limestone: 15,000 psi
    - b. Recycled PCC (Crushed): 20,000 psi