IDAHO TRANSPORTATION DEPARTMENT

RESEARCH REPORT

Local Calibration of “C-Values” for Common Idaho Soil Types for Use in Mechanistic-Empirical Pavement Design

RP 289

By

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Shannon & Wilson

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16. Abstract

AASHTOWare Pavement ME software has been adopted by the Idaho Transportation Department (ITD) for Mechanic-Empirical analysis of pavement structures. AASHTOWare analyses are platformed on the laboratory resilient modulus test, AASHTO T 307. The test is appropriate for evaluating "undisturbed" subgrade samples and reconstituted materials. Laboratory tests are conducted to measure the response of materials under conditions simulating moving wheel loads. Falling Weight Deflectometer (FWD) tests also provide field measurements of pavement deflection or response under conditions simulating moving wheel loads. To correlate laboratory-established resilient moduli with moduli back-calculated from field tests, AASHTOWare utilizes a ratio called the "C-Value," or M_R/E_{FWD} Ratio. Global default values have been developed that may be overly conservative for Idaho roadways, resulting in thicker pavements The objective of this study was to develop a database of laboratory resilient moduli together with appurtenant FWD data, such that local Idaho C-Values could be determined. This study used design-funded projects to collect C-Value data during the duration of the research project and leverage it into a state-wide calibration of the important and analysis-sensitive C-Value. The results of this work suggest that the Level 3 global default values are conservative and should be replaced by local Level 2 values and ITD would benefit from routinely conducting M_R testing on most projects. An Excel Spreadsheet contains materials properties for soils encountered and calculated C-Values. The spreadsheet is designed to be updated as new data are collected. Global default values have been developed that may be overly conservative

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This work would not have been possible to complete in the form it was proposed if not for their participation and support. With this assistance and support, Shannon & Wilson (S&W) was able to leverage the project development budgets of these projects and collect this valuable information. S&W is grateful to the agencies and individuals that made this project possible.

Many of the project managers and the agencies they represent are identified in Table 2.1.

Technical Advisory Committee

Each research project is overseen by a Technical Advisory Committee (TAC), which is led by an ITD project sponsor and project manager. The TAC is responsible for monitoring project progress, reviewing deliverables, ensuring that study objectives are met, and facilitating implementation of research recommendations, as appropriate. ITD's Research Program Manager appreciates the work of the following TAC members in guiding this research study.

- Project Sponsor: Chad Clawson, P.E.
- Project Manager: Tyler Coy, P.E.
- TAC Members:

  Dave Richards, P.E.

  John Arambarri, P.E.

  Ken Hahn, P.E.

  Lynn White, P.E.

  Greydon Wright, P.E.

  Chad Clawson, P.E.
- FHWA-Idaho Advisor: Kyle Holman, P.E.

Table of Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms

AASHO .... American Association of State Highway Officials

AASHTO .... American Association of State Highway and Transportation Officials

ACHD .... Ada County Highway District

C-Value .... M_R/E_{FWD} Ratio

E_{FWD} .... Elastic layer moduli from ASTM D 4694 FWD testing

ELMOD 6 .... Evaluation of Layer Moduli and Overlay Design, Version 6

Everpave© .... WSDOT mechanistic based flexible pavement overlay design program

FHWA .... Federal Highway Administration

ITD .... Idaho Transportation Department

LHTAC .... Local Highway Technical Assistance Council

LL .... Liquid Limit

MDD .... Maximum Dry Density

MC .... Moisture Content

ME .... Mechanistic-Empirical

MEPDG .... Mechanistic-Empirical Pavement Design Guide

M_R .... Resilient modulus

NCHRP .... National Cooperative Highway Research Program

NP .... Non-Plastic

NV .... No Value

OMC .... Optimum Moisture Content

PL .... Plastic Limit

PI .... Plasticity Index

PMED .... AASHTOWare Pavement ME Design™ Software

S&W .... Shannon & Wilson

UI or U of I .... University of Idaho

Winflex .... ITD/UI mechanistic-empirical overlay design system for flexible pavements.

WSDOT........................ Washington State Department of Transportation

Executive Summary

AASHTOWare Pavement ME software has been adopted by the Idaho Transportation Department (ITD) for mechanistic-empirical analysis of pavement structures. AASHTOWare analyses are platformed on the laboratory resilient modulus test, AASHTO T 307. The test is appropriate for evaluating "undisturbed" subgrade samples and reconstituted materials. Laboratory tests are conducted to measure the response of materials under conditions simulating moving wheel loads. Falling Weight Deflectometer (FWD) tests also provide field measurements of pavement deflection or response under conditions simulating moving wheel loads. A major benefit of the FWD is the ability to sense actual roadway conditions. To correlate laboratory-established resilient moduli with moduli back-calculated from field tests, AASHTOWare utilizes a ratio called the "C-Value," or Resilient modulus determined from AASHTO T 307 testing divided by Elastic layer moduli from ASTM D 4694 FWD testing (M_R/E_{FWD}) Ratio. Global default values have been developed that may be overly conservative, potentially resulting in thicker pavements. The objective of this study was to develop a database of laboratory resilient moduli together with appurtenant FWD data, such that local Idaho C-Values could be determined.

AASHTOWare Pavement ME defines hierarchal levels of data accuracy, such that Level 1 is site or project-specific, Level 2 is based on local data, and Level 3 is a best estimate for a global default value. The Mechanistic-Empirical Pavement Design Guide (MEPDG) Manual of Practice (2020 Third Edition) lists default C-Values for various materials. Currently, ITD is using Level 3 (default) C-Values of 0.62 and 0.35 for aggregate base/subbase and subgrade soils, respectively.

This study used design-funded projects to collect C-Value data during the duration of the research project and leverage it into a state-wide calibration of the important and analysis-sensitive C-Value. Doing such, eliminated the expense of labor, traffic control subcontractors, drilling, FWD testing, laboratory testing, and data processing from the research. A total of 54 C-Values have been determined from 23 projects sponsored by ITD, Ada County Highway District, (ACHD), and Local Highway Technical Assistance Council, (LHTAC).

This limited research suggests that it may be acceptable to increase the default C-Value of subgrade soils from 0.35 to 0.45 as the new local Level 2 value for subgrade soils and to increase the default C-Value for aggregate base/subbase from 0.62 to 0.70 as the new local Level 2 value based on the limited number of tests during this project.

The results of this work suggest that the global default values are conservative and ITD would benefit from routinely conducting M_R testing on most projects in order to use Level 1 site-specific or Level 2 local value database created with this project.

This study also examined the potential benefits of creating a Level 2 C-Value database to replace the current ITD method of using the MEPDG Manual of Practice (2020 Third Edition) recommended Level 3 default C-Values.

Using Level 1 (project-specific) and Level 2 (local vicinity) C-Values rather than Level 3 will likely lead to more economical pavement thickness recommendations and/or increased reliability in the designer's analyses.

Interstate highways and US highways are ITD's most critical facilities. As such, we recommend project specific or Level 1 modulus determination for these facilities. All Interstate highways and most US routes should use Level 1 input values in the Pavement ME Design process. The laboratory resilient modulus test, AASHTO T 307 should be performed to acquire site-specific M_R values.

Most of the remainder of roadways in Idaho should be identified as the roadways that will benefit the most by C-Value refinement. We recommend utilizing Level 2 modulus determination based on local data compiled in the database. The data collected for this project will allow the designer to correlate laboratory-established resilient moduli with moduli back-calculated from field tests and result in pavement designs that are not overly conservative.

Level 3 M_R determination may be appropriate for low-volume low-risk projects where the benefit of additional testing is not cost effective. However, we recommend using the C-Value Database to find values in the project area or to find comparable soil conditions in the database that are similar to the project conditions.

Engineering judgement and local knowledge should always be factored into decisions to adjust C-Values for individual projects.

This project should be a starting point that ITD will build upon moving forward. As new projects are developed, the test results should be added to the data base to fill in deficient areas. There should also be an effort to strategically test throughout the state to identify soil conditions that will affect the pavement design and allow the designer to optimize the pavement design.

1. Introduction

Background

Resilient modulus is recognized internationally as the fundamental property for characterizing layers of materials used in pavement design. It is a measure of the elastic response of pavement materials subjected to impulse loading, considering certain nonlinear characteristics.

Idaho Transportation Department (ITD) has used a mechanistic-empirical (ME) roadway design methodology for many years, which has analytical and economic advantages over the purely empirical design methodology of the Idaho R-Value Method, under certain conditions, such as pavement rehabilitation. ME design began in the early 1990's with ITD's adoption of Washington State Department of Transportation (WSDOT's) Everpave©. In 1997 ITD adopted the ITD and University of Idaho (UI) developed WinFlex, and in 2020 AASHTOWare Pavement ME software, developed by the American Association of State Highway and Transportation Officials (AASHTO) was adopted by ITD as the standard for ME analysis of pavement structures.

AASHTOWare analyses are platformed on the laboratory resilient modulus test. AASHTO T 307, *Standard Method of Test for Determining the Resilient Modulus of Soils and Aggregate Materials*, is the industry-standard laboratory test for resilient modulus testing. The test is appropriate for evaluating "undisturbed" subgrade samples and reconstituted materials. Laboratory tests are conducted to measure the response of materials under conditions simulating moving wheel loads.

Falling Weight Deflectometer (FWD) tests also provide field measurements of pavement deflection or response under conditions simulating moving wheel loads. A major benefit of the FWD is the ability to sense actual roadway conditions. Another benefit of FWD testing is that it is a non-destructive test that can be performed very quickly and cost effectively with minimal traffic disruption.

When the resilient modulus values are determined by back-calculating elastic layer modulus values from FWD tests (E_{FWD}), those values need to be adjusted to laboratory conditions in order to be used in ME analysis.

To correlate laboratory-established resilient moduli (M_R) with moduli back-calculated from field tests, AASHTOWare utilizes a ratio called the "C-Value," or M_R/E_{FWD} Ratio.

The Mechanistic-Empirical Pavement Design Guide (MEPDG) Manual of Practice (2020 Third Edition) lists some C-Values and recommends they be checked. This research substantially accomplishes this recommendation. Table 10-8 of the MEPDG Manual of Practice suggests a C-Value of 0.62 for aggregate base/subbase and a C-Value of 0.35 for subgrade soils.

AASHTOWare Pavement ME used hierarchal levels of input data accuracy, such that Level 1 is site- or project-specific data, Level 2 is based on local data, and Level 3 is a best estimate for a global default value. Currently, ITD is using Level 3 (default) C-Values for aggregate base/subbase and subgrade soils.

For example, a C-Value of 0.35 is specified for subgrade materials below an unbound aggregate base layer to reduce back-calculated moduli developed from the FWD test. For Idaho's silty and sandy subgrade soils, a C-Value of 0.35 is likely overly conservative.

If a resilient modulus test (AASHTO T 307) were performed for a project subgrade in conjunction with FWD testing, project-specific Level 1 C-Values could be determined for use in ME analyses.

If a database of C-Values is developed, Level 2 C-Values will become available to the designer for increased reliability on projects. Larger C-Values reflect data certainty and may lead to thinner pavement structure designs.

Research Problem Statement

ITD has sponsored many research projects over the past dozen or more years to fully implement Pavement ME as its pavement design methodology. Research projects covering Materials characterization of Idaho materials have been completed and calibration factors have been developed. The next logical step is to establish C-Values for unbound materials across the state.

A research effort targeting the development of a database of laboratory resilient moduli together with appurtenant FWD data, such that C-Values could be developed, is very costly due to the expenses of labor, traffic control subcontractors, drilling, FWD testing, laboratory testing, and data processing. However, the cost can be reduced substantially if the resilient modulus data is collected routinely on a project-by-project basis, where the costs for labor, traffic control, FWD testing, and so forth are already covered within the necessary design scopes of service.

This is a proposal to use design-funded projects to gradually collect C-Value data that could be leveraged into a state-wide calibration of the important and analysis-sensitive C-Value.

The objectives of this study were to:

1. Develop a database of laboratory resilient modulus (M_R) data from AASHTO T 307 testing
2. Develop a database of corresponding elastic layer moduli (E_{FWD}) from ASTM D 4694 FWD testing
3. Develop Level 2 C-Value ratios for a variety of Idaho subgrade conditions as well as some aggregate base/subbase conditions, and
4. Leverage the existing funding of design projects within ITD and across the state to accomplish this work.

Objectives

The objective of this project is to improve the accuracy of the “C-Value,” or M_R/E_{FWD} Ratio needed to correlate laboratory-established resilient moduli with moduli back-calculated from field tests by selective testing on projects within existing design scopes of service and creating a database of Level 2 C-Values for designer to use in lieu of the Level 3 default value.

Project Tasks

Task 1: Planning & Preparation

Coordination. Senior Pavement Engineer at Shannon & Wilson (S&W) will coordinate the research activities with ITD’s State Pavement Engineer, and U of I’s Civil Engineering faculty.

Collaboration Agreement. S&W and U of I will prepare a collaboration agreement between Shannon & Wilson and U of I. S&W will submit the agreement to the State Pavement Engineer for acceptance. The U of I will be a subconsultant to S&W. The collaboration agreement will outline the following partnership:

U of I will perform the following tasks:

- Review and comment on S&W’s instruction for field and laboratory personnel (detailing the sampling and testing protocols) in year 1.
- Review and comment on the database architecture proposed by S&W in year 1.
- Review semi-annual updates of the database issued by S&W and provide commentary.
- Participate with S&W in the development of an early outline of the final Study Report in year 2.
- Review and comment on the final study report at the end of year 3.

S&W will perform the following tasks:

- Prepare the database using Excel format to record and compare data, such as the following:
    - ITD District
    - Project Manager (who facilitated the data collection funding)
    - Roadway/Route (e.g. I-84)
    - Milepost

- Direction of Travel
- Lane #
- Pavement Type
- M_R Sample Type (e.g. 2.5” tube, 4” tube, bulk)
- Classification Sample Type (e.g. bag, bulk, tube)
- Depth of Sample
- Field Sampling Date
- Layer of Study (the layer from which the M_R sample was obtained, e.g. subgrade, base, subbase)
- Layer Thickness
- AASHTO Soil Classification (used in AASHTOWare Pavement ME)
- ASTM Soil Classification (commonly used in Idaho)
- Percent Passing (3”, 1”, 3/4”, 1/2”, 3/8”, No. 4, No. 10, No. 40, No. 100, No. 200)
- Atterberg Limits and Field Water Content
- Test Specimen Type (i.e. undisturbed or remolded)
- AASHTO T 180 Modified Proctor Results (base materials)
- AASHTO T 99 Standard Proctor Results (for subgrade soils, when the specimen is remolded)
- Soil Angularity (if available)
- AASHTO T 100 Specific Gravity (if available)
- AASHTO T 215 Saturated Hydraulic Conductivity (if available)
- M_R Test Values (including regression coefficients k_1, k_2, and k_3)
- E_{FWD} Back-calculated Value(s)
- C-Value Ratio at Test Location

* Issue an updated database semiannually for three years.
* Promote the data collection opportunity with the Districts, ACHD and LHTAC.

- Obtain approval of ITD District project managers to incorporate limited resilient modulus testing in the project scopes of service.

- Arrange for traffic control safety and perform drilling, sampling, logging, and FWD testing through the approved project scopes of service.

- Perform laboratory testing on M_R samples.

- Back-calculate the E_{FWD} values that correspond to the M_R sample locations.

- Perform the AASTHO T 307 tests for the projects.

- Compute project-specific C-Values.

Task 2: Detailed Testing Plan

S&W will submit a detailed testing plan, including instructions for field and laboratory personnel, to the State Pavement Engineer for acceptance.

Task 3: Database Plan

S&W will submit the proposed database architecture to the State Pavement Engineer for acceptance.

Task 4: Report Outline

S&W will provide an early outline of the final study report to the State Pavement Engineer for acceptance.

Task 5: Data Collection and Database Creation

Data collection and database entry will be conducted as follows:

- During the routine course of project participation with ITD, S&W will propose limited resilient modulus testing of subgrade soil and/or unbound aggregates to ITD project manager having responsible charge of the design project. The cost of traffic controls, drilling and sampling, soil classification testing, resilient modulus testing, FWD roadway testing, and engineering labor to develop the project-specific C-Value will be incurred by the district's funded design project under approved scopes of service between S&W and ITD.

- On a project-by-project basis, S&W will record the C-Value ratios, together with soil classification data, M_R, and E_{FWD} values, in the database.

- S&W will transmit to ITD, U of I, and interested parties an updated database semiannually for three years. It is anticipated that 36 to 60 C-Values will be published.

Task 6: Final Report

At the conclusion of the three-year study, a report will be submitted by U of I, S&W, and interested ITD personnel.

Report Organization

This report is organized in 4 chapters as described below:

- Chapter 1 covers the background, problem statement, objectives, and project tasks.
- Chapter 2 presents the methodology for selecting projects and major findings.
- Chapter 3 presents the conclusions of this research as well as recommendations for ITD.
- Chapter 4 presents references

2. Methodology

Project Selection

This research project developed a database of AASHTO T 307 laboratory resilient modulus (M_R) data and corresponding elastic layer moduli (E_{FWD}) from ASTM D 4694 FWD testing, in order to determine the Level 2 C-Value ratios for a variety of Idaho subgrade conditions and select aggregate base/subbase conditions.

As mentioned in the introduction, projects were selected to leverage the subsurface investigations of projects being developed by Shannon & Wilson. This methodology minimizes the costs associated with data collection. Sampling and testing needed for the research project are identical to those needed to develop pavement designs for projects design scope of work.

This approach is efficient for limiting the cost of data collection to the research project, but it does not lend itself to strategically locating projects throughout the districts or accounting for various soil conditions.

During the routine course of project participation with ITD, S&W performed limited resilient modulus testing of subgrade soil and unbound aggregates, approved by ITD project manager having responsible charge of the design project. The cost of traffic control, drilling and sampling, soil classification testing, resilient modulus testing, FWD roadway testing, and engineering labor to develop the project specific C-Value was incurred by the district's funded design project under approved scopes of service between S&W and ITD. On a project-by-project basis, S&W recorded the C-Value ratios, together with soil classification data, M_R, and E_{FWD} values, into a database.

This project spanned 25 months, beginning in May 2020 with completion in May 2022. During this time, S&W leveraged the subsurface investigations on a total of 23 projects sponsored by ITD, ACHD, LHTAC and a county to collect the data needed. Additional data was included in the database from sponsored projects that S&W had in progress at the time this research began.

A list of the Materials Reports that were used in creating the database is in Chapter 4 References.

Please note that during this research project, American Geotechnics was acquired by Shannon & Wilson, therefore equipment photos and most Materials Reports have American Geotechnics logos and letterheads respectively.

Figure 2.1 shows the location of each C-Value as determined by longitude and latitude of each test site depicted by yellow pins. The associated .KMZ file contains M_R and E_{FWD} values along with the soils type associated with the location. The Idaho map shows that the projects are not evenly distributed throughout the state. ITD District's 1 and 2 had one project each represented in the study. District 3 had seven projects including LHTAC and ACHD projects. District 4 had nine projects including LHTAC projects. District 5 had two projects and District 6 had three projects including an LHTAC and a county project.

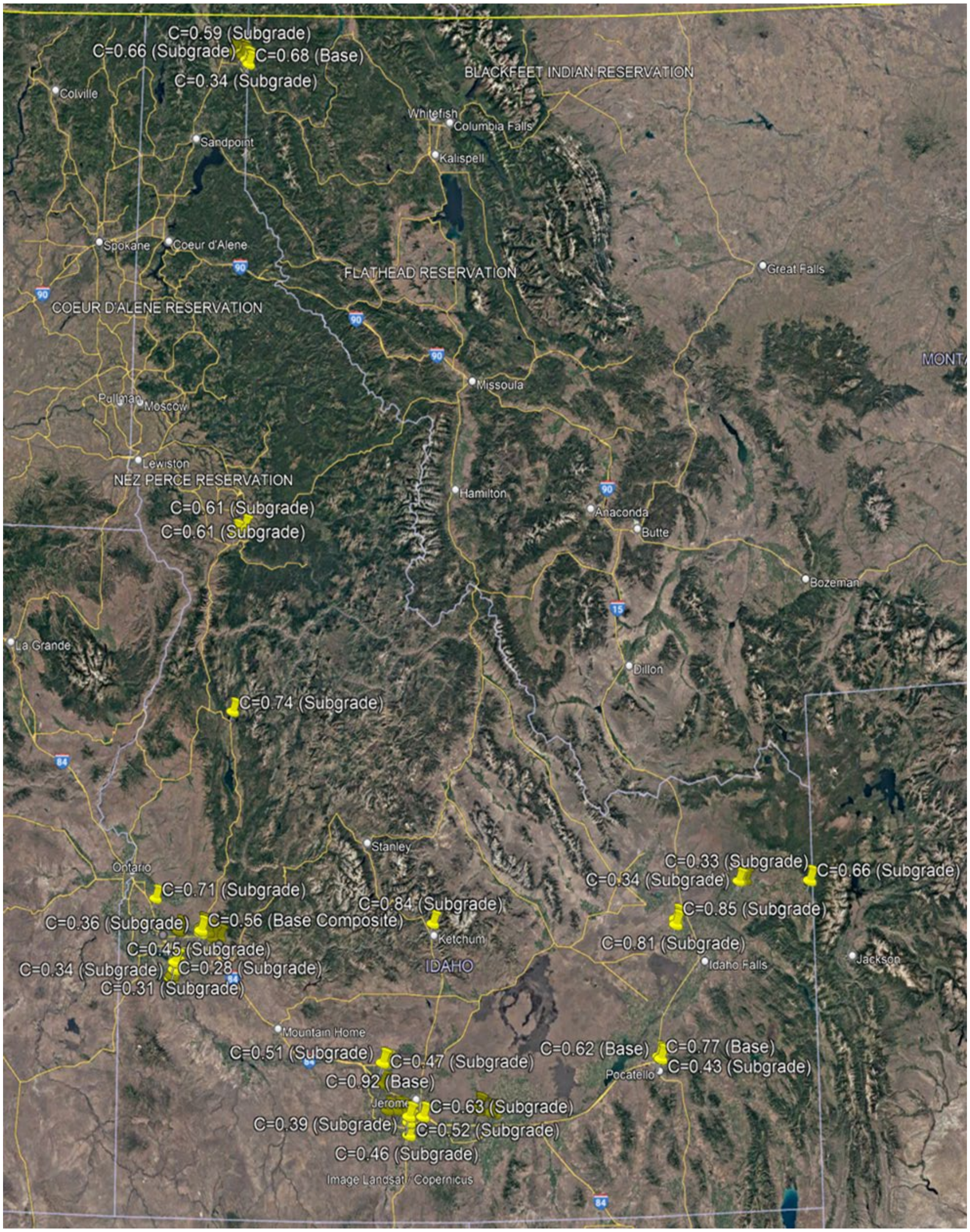


Figure 2.1 C-Value Locations within Idaho

Table 2.1 lists the project name, key number, owner agency, and project roadway or route for each project being developed by Shannon & Wilson that was used in the study. The project manager associated with each project is also listed.

Table 2.1 Project Identification Information

Owner/Client	Key Number	Project Name	Project Manager	Roadway/ Route
ITD D4	20470	I-84, Kasota IC to Burley IC EBL	Steve Hunter - ITD	I-84
LHTAC/West Point HD		1500 E Road Rehabilitation		S 1500 E
LHTAC/Payette County	20019	Sand Hollow Rd. Oasis to Black Canyon Rd.	Muhammad Zubery, P.E. - LHTAC	Sand Hollow
ITD D-3	20506	SH55, State St. to Payette River BR	John Arambarri, P.E. - ITD	SH-55
LHTAC/ Buhl HD	20518	E 4100 N Rehabilitation	Wayne Herbel, P.E. - LHTAC	E 4100 N
ACHD	18701	FY21 Capital Maintenance PH 1		Fairview Ave
ITD D4	18815	State, FY19 D4 Materials Reconnaissance	Lynn White, P.E. - ITD	SH-75
LHTAC/City of Buhl	20633	Burley Ave; Us-30 to Fruitland Ave	Muhammad Zubery, P.E. - LHTAC	Burley Ave.
ITD D6	20071	SH-33, MP 99.3 to 107.0	Bryan Young, P.E. - ITD	SH-33
LHTAC/ City of McCall	20146	Mission St; SCL to Deinhard Ln		Mission St.
ITD D2	20436	SH-13, Mount Idaho Rd to Top Harpster Grade	Janet Zarate, P.E. - ITD	SH-13
ITD D1	20484	US-2, Jct US-95 to MSL	Megan Koski, P.E. - ITD	US-2
LHTAC/Gooding HD	20666 22003	Shoe String Rd Rehab & Safety	Muhammad Zubery, P.E.- LHTAC	Shoe String
ITD D3	21849	SH-45, JCT-78 to Deerflat	Tyler Coy, P.E.- ITD	SH-45
LHTAC/Hillsdale HD	20699	Crestview Rd Rehabilitation, Ph 1	Amanda LaMott, P.E. - LHTAC	Crestview Rd.
LHTAC/Teton County	21983	N 500 W Reconstruction		N 500 W
Jefferson County		2100 E, County Line to 400N		2100 E
ITD D4	22215	US-93, Blue Lakes Blvd to Eastland Dr	Lynn White, P.E. - ITD	US--93
ITD D5	20577	FY21 D5 Planning & Scoping, 5th Ave	Gene Staggs, P.E. - ITD	5th Ave
ITD D5	20577	FY21 D5 Planning & Scoping, 4th Ave	Gene Staggs, P.E. - ITD	4th Ave
ITD D4/ Jacobs	20583 21951 22455	US-93, Hollister to IC 93/30	Lynn White, P.E.- ITD	US-93
ITD D3	22665	SH-55, Eagle Rd, I-84 to SH-44	Shawn Scott, EIT - ITD	SH-55
LHTAC/ City of Nampa	22017	Cherry Lane, Franklin Blvd to 11^{th} Ave N		Cherry Lane

Resilient Modulus Testing

The 1986 Pavement Design Guide introduced the concept of resilient modulus in a rational attempt to better characterize subgrade soil and unbound aggregate materials. (Tutumluer 2013, 69) The structural layer coefficients for base (a_2) and subbase (a_3) were estimated through correlations with resilient modulus. However, these relations for the structural layer coefficients were largely empirical and based primarily on engineering judgment with only limited amounts of data.

Resilient Modulus (M_R) is a measure of subgrade material stiffness. It is stress divided by strain for rapidly applied loads – like those experienced by pavements. It is determined using the triaxial test. The test applies a repeated axial cyclic stress of fixed magnitude, load duration and cycle duration to a cylindrical test specimen. While the specimen is subjected to this dynamic cyclic stress, it is also subjected to a static confining stress provided by a triaxial pressure chamber. The cyclic load application is thought to simulate actual traffic loading more accurately (Pavement Interactive 2022).

Resilient Modulus has been the subject of ITD research projects for many years. ITD Research Project 110-D, Subgrade Resilient Modulus for Idaho Pavements, was completed in 1992 by Hardcastle and it determined a method for estimating seasonal values of resilient moduli of subgrade soils proposed for use with the 1986 AASHTO flexible pavement design guide. Hardcastle (1992). Reference resilient moduli were provided from a literature review for twelve soil classes as a function of grain size and soil plasticity.

ITD Research Project RP 263, Unbound Material Characterization for Pavement ME Implementation in Idaho was completed in 2020 by Mishra, et al. (2020) and it developed statewide information about the materials characteristics of unbound materials used in ITD paving projects that are used by the Pavement ME software to tailor pavement design recommendations to local conditions. They developed correlations between resilient modulus and index properties such as R-value to check the accuracy of correlations currently used during Level 2 and Level 3 design efforts using Pavement ME Design.

Mishra, et al. (2020) performed Resilient Modulus testing on 18 aggregate base/subbase samples and 16 subgrade samples provided by ITD. These samples were obtained from district materials sources that were intended to represent in-place materials on Idaho roadways. NCHRP 1-28A guidance was used to determine the moduli values.

Additional materials should be added to this database in the future by additional research projects and by including the appropriate tests to the Materials Source approval program.

ITD Research Project RP 289 takes the concept of resilient modulus determination to in-service roadways throughout the state. Rather than using literature reviews or ITD aggregate materials sources as the source of data for modulus determination, site specific modulus tests coupled with FWD data were used to develop C-Values.

AASHTO T 307, Standard Method of Test for Determining the Resilient Modulus of Soils and Aggregate Materials, was used to determine the laboratory resilient modulus. A repeated axial cyclic stress of fixed magnitude, load duration (0.1 second), and cycle duration (1.0 to 3.1 second) is applied to a cylindrical test specimen. During testing, the specimen is subjected to a dynamic cyclic stress and a static-confining stress provided by means of a triaxial pressure chamber. The total resilient (recoverable) axial deformation response of the specimen is measured and used to calculate the resilient modulus.

The following text is an excerpt from NCHRP Synthesis 382:

The Resilient Modulus test using Repeated Load Triaxial test (RLT) test equipment is designed to simulate traffic wheel loading on in situ subsoils by applying a sequence of repeated or cyclic loads on compacted soil specimens. (Figure 2-2 shows S&W Resilient Modulus testing system used to determine the resilient modulus of subgrades.)

The AASHTO T-307-99 method is currently followed for determining the resilient modulus of soils and unbound aggregate materials. Prior to this method, a few methods (namely, T-274, T-292, and T-294) were used. The stress levels for testing the specimens are based on the location of the specimen within the pavement structure. The confining pressure typically represents the overburden pressure on the soil specimen with respect to its location in the subgrade.

The axial deviatoric stress is composed of two components, the cyclic stress (which is the actual applied cyclic stress) and a constant stress (which typically represents a seating load on the soil specimen). The constant stress applied is typically equivalent to about 10% of the total axial deviatoric stress. The testing sequences employed for both granular and base or subbase materials and fine-grained subgrade soils are different, and these details can be found in AASHTO test standard procedures. A haversine-shaped wave load pulse with a loading period of 0.1 second and a relaxation period of 0.9 second is used in the testing. A haversine load pulse is recommended in the test procedure, which is based on the earlier AASHO road test research performed in the United States.

The test procedure involves preparation of a compacted soil specimen using impact compaction or other methods, transfer of soil specimen into triaxial chamber, application of confining pressure, and then initiation of testing by applying various levels of deviatoric stresses as per the test sequence. The test process requires both conditioning followed by actual testing under a multitude of confining pressure and deviatoric stresses.

At each confining pressure and deviatoric stress, the resilient modulus value is determined by averaging the resilient deformation of the last five deviatoric loading cycles. Hence, from a single test on a compacted soil specimen, several resilient moduli values at different combinations of confining and deviatoric stresses are determined. From these values, the design resilient modulus value can be established by determining the M_R *value at appropriate confining pressure and the deviatoric stress levels corresponding to the subgrade and unbound base layer location within the pavement system.*

Figure 2.2 Shannon & Wilson Resilient Modulus Testing Machine

Existing Pavement Structure Evaluation

For each project, the existing pavement structure layers were evaluated using data from Falling Weight Deflectometer (FWD), Ground Penetrating Radar (GPR), and pavement borings from a pavement drill rig, as described in the following sections. See Figures 2.3, 2.4, and 2.5 respectively for photographs of the equipment operated by S&W for this research project.

Full details of the data collection and analysis process for each project may be obtained from the specific Materials Report associated with the project. (See Materials Reports references in Chapter 4)

Falling Weight Deflectometer (FWD) Nondestructive Testing

An FWD is a nondestructive and nonintrusive testing device widely used in pavement engineering. FWD data is primarily used to estimate pavement structural capacity for pavement rehabilitation design. The FWD provides rapid and repeatable characterization of the existing pavement layer stiffness in situ and is most often used to calculate stiffness-related parameters of a pavement structure.

FWD pavement deflection measurements were obtained on each project at approximately 200-foot intervals the length of the project. Date tested, travel direction and lane are noted in the spreadsheet.

The testing was performed using a Dynatest 8002-158 FWD, in accordance with ASTM D4694 (2015). The FWD has nine deflection sensors located at 0-Plate, 8, 12, 18, 24, 30, 36, 48, and 60-inches. Each test location included targeted 9000-pound and 12,000-pound drops. A Trimble AG 332 GPS survey instrument located the FWD measurements for subsequent correlation with GPR layer thicknesses. At each test location, infrared pavement surface temperature and air temperature were measured. The FWD equipment annual reference calibration certificate and monthly relative calibrations were up to date.

For pavement structure analyses, layer thicknesses developed from the GPR subsurface data were applied to each of the FWD test locations.

Figure 2.3 Shannon & Wilson Falling Weight Deflectometer

Ground Penetrating Radar Pavement Structure Data

American Geotechnics collected Ground Penetrating Radar (GPR) data on each project to supplement roadway borings.

Figure 2.4 Shannon & Wilson Ground Penetrating Radar

A short-pulse GPR data collection system was used in general accordance with ASTM D4748 (2006). The components of the American Geotechnics GPR system includes a GSSI SIR-30 controller and two antennas at frequencies of 2.0 -gigahertz and 400-megahertz. The 2.0-gigahertz antenna is especially suited for collecting detailed data in the upper 24 inches of the pavement structure. The 400-megahertz antenna was set to collect data to 5 feet below the pavement surface for project-level pavement design.

Borings

American Geotechnics advanced borings as needed for each project to approximately a maximum depth of 5.6 feet through the existing pavement surface and roadway shoulders.

Figure 2.5 Shannon & Wilson Pavement Drill Rig

AC cores were collected from borings along with representative samples of the pavement structure materials and subgrade throughout each project's length. The existing layer thicknesses are noted in the spreadsheet.

After reviewing the deflection data and anticipated truck load limits, American Geotechnics selected the 12,000-pound drop load from each test sequence for analyses. All deflections were normalized to the 12,000-pound target load. The $D_{(0)}$ sensor is a surface response, and the $D_{(48)}$ sensor is an indication of subgrade response.

Layer Moduli

The stiffness or elastic modulus of the asphalt concrete (AC) surface course is sensitive to temperature. Elastic modulus back-calculation for the AC layer stiffness was adjusted to a reference temperature of 77degrees Fahrenheit using the BELLS method (ASTM D7228).

Elastic moduli back-calculation is also sensitive to the thickness of the pavement structure layers. Constructed roadway pavement structure layers may vary significantly. For each FWD drop location, layer thicknesses measured from the GPR imaging were correlated via sub-meter accuracy GPS for true multi-point analyses.

The “deflection basin fit” method was used to back-calculate layer elastic moduli (Dynatest International 2016).

ELMOD 6, an ITD recognized back-calculation program, facilitated the back-calculation of elastic moduli of the layered ballast. ELMOD 6 has the following advantages for the project analyses:

- Allows the use of nine deflection sensors
- Allows the unlimited input of GPR layer thicknesses
- Correlates GPR layer thicknesses with FWD test locations via GPS coordinates for true multi-point analysis
- Allows for analysis of both linear (granular) and non-linear (clayey) subgrades

NCHRP 1-28A Guidance

AASHTO Mechanistic-Empirical Pavement Design Guide; A Manual of Practice. 2020 Third Edition recommends AASHTO T 307 or NCHRP 1-28A test protocol for determining M_R. NCHRP 1-28A guidance (Witczak 2003, A-19) recommends a design resilient modulus for aggregate base/subbase materials that uses a confining stress of 5 pounds per square inch and total axial stress of 15 pounds per square inch. This confining pressure and deviatoric stress level correspond to the subgrade layer location within the pavement system. This confining pressure and deviatoric stress level correspond to sequence number 6 for aggregate base/subbase. It also recommends a design resilient modulus for subgrade materials using the confining stress of 2 pounds per square inch and total axial stress of 6pounds per square inch. This confining pressure and deviatoric stress level correspond to sequence number 13 for subgrade soils.

Figures 2.6 and 2.7 show AASHTO T 307 test reports for subgrade soils and aggregate base/subbase respectively. Figure 2.6 shows results for a subgrade soil and following NCHRP guidance, the value closest to a confining stress of 2 pounds per square inch and total axial stress of 6 pounds per square inch is sequence number 13. The predicted M_R for this soil is 5,881pounds per square inch.

Figure 2.7 shows results for an aggregate base/subbase and following NCHRP guidance, the value closest to a confining stress of 5 pounds per square inch and total axial stress of 15 pounds per square inch is sequence number 6. The predicted M_R for this material is 24,786pounds per square inch.

Resilient Modulus Equation

The resilient modulus equation shown below.

$$M_R = k_1 * P_a * \left(\frac{\theta}{P_a}\right)^{k_2} * \left(\frac{\zeta_{oct}}{P_a} + 1\right)^{k_3}$$

Where:

M_R= Resilient Modulus
P_a = atmospheric pressure (psi)
θ = bulk stress (psi)
ζ_{oct} = octahedral shear stress (psi)
k_1, k_2, k_3= regression coefficients

Regression coefficients k_1, k_2, and k_3, shown in the circles in Figures 2.6 and 2.7, are developed from the T 307 test and will be important to ME design in the future when the software is able to use them directly.

C-Value Database

The database that accompanies this report consists of an Excel Spreadsheet containing the following information:

Project Identification

- Owner/Client
- Key Number, Project name, Project Manager
- Roadway or Route, Milepost or Station, Travel Direction and Lane, Roadway Type

Sample Identification

- Sample Date, Layer Type, M_R Sample type, Test Specimen type, Test Specimen Depth
- ASTM and AASHTO Soil Classification

C-Value Relationships

- M_R, E_{FWD}, and C-Value Using NCHRP 1-28A Guidance using Sequence 6 or 13
- Regression Coefficients, k_1, k_2, k_3; Sampling Location, Latitude and Longitude

Existing layers and materials properties

- Pavement Layer Thickness
- In-situ moisture and density
- Moisture Density Relationships
- Gradation
- Atterberg Limits, LL, PL, PI

Client Name: HMH Engineering
Project Name: E 4100 N Rehabilitation, Ph 2
Project No: 03051
Report Date: 8/29/2019

AMERICAN GEO TECHNICS

Material Information

Boring/Sample ID: AG-05/ST-21 **Lab Number:** 19-0476
Material Type: Type-2 (Subgrade) **AASHTO Clasification:** A4
Type of Sample: 4" Dia Undisturbed **Depth of Specimen (ft.):** 2.00
Dry Density (pcf): 95.49 In-situ **Date Sampled:** 31/Jul/19
Specimen WC (%) 20.4 In-situ **Date Tested:** 24/Aug/19

Test Results

Resilient Modulus Test (AASHTO T-307)

Sequence No	Confining Stress	Total Axial Stress	Bulk Stress	Octahedral Shear Stress	Measured Resilient Modulus	Predicted Resilient Modulus
	σ_3	σ_d	θ	τ_{oct}	M_r	Pred. M_r
	psi	psi	psi	psi	psi	psi
1	6.00	2.04	20.05	0.96	10174	10116
2	6.00	4.11	22.12	1.94	9334	9409
3	6.00	6.14	24.15	2.89	8584	8790
4	6.00	8.13	26.14	3.83	8330	8236
5	6.00	10.11	28.13	4.77	8325	7736
6	4.00	2.04	14.05	0.96	8759	8213
7	4.00	4.08	16.09	1.92	7520	7826
8	4.00	6.08	18.09	2.87	7003	7445
9	4.00	8.10	20.11	3.82	6973	7075
10	4.00	10.08	22.09	4.75	7084	6727
11	2.00	2.03	8.04	0.96	6571	5926
12	2.00	4.08	10.09	1.92	5695	5955
13	2.00	6.07	12.08	2.86	5439	5881
14	2.00	8.08	14.09	3.81	5553	5752
15	2.00	10.09	16.09	4.76	5722	5586

Resilient Modulus Equation

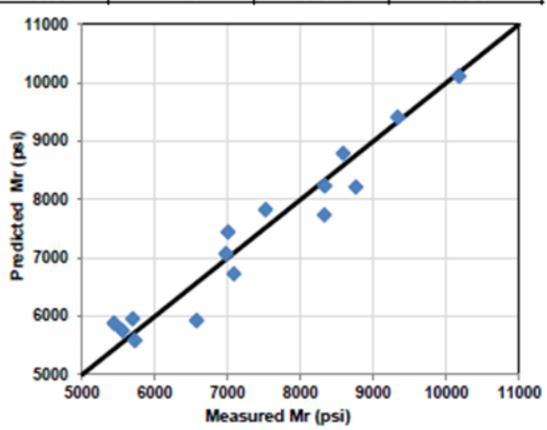
$$Mr = k_1 * Pa * \left(\frac{\theta}{Pa}\right)^{k_2} * \left(\frac{\zeta oct}{Pa} + 1\right)^{k_3}$$

Resilient Modulus Model Parameters

k_1 = 657.338

k_2 = 0.585

k_3 = -2.142



Note: As per NCHRP 1-28A guidance, consider a design resilient modulus for subgrade materials using the confining stress of 2 psi and total axial stress of 6 psi

Tested By: Travis Thomsen **Reviewed By:** Justin Stoffel

American Geotechnics

Figure 2.6 Example Resilient Modulus Test Report for Subgrade Soil

Client Name: ITD District 5
Project Name: FY21 D5 Planning and Scoping
Project No: 03314
Report Date: 30/Oct/20

Material Information

Sample ID: Base Composite (4th Ave.) | **Lab Number:** 20-0751
Material Type: Type-1 (Base) | **AASHTO Clasification:** A-1-b
Type of Sample: 4" Dia Remolded | **Depth of Specimen (ft.):** 3.4-4.1
Dry Density (pcf): 127.3   95% MDD (Modified) | **Date Sampled:** 02/Oct/20
Specimen WC (%) 6.4   Opt. M% (AASHTO T-180) | **Date Tested:** 28/Oct/20

Test Results

Resilient Modulus Test (AASHTO T-307)

Sequence No	Confining Stress	Total Axial Stress	Bulk Stress	Octahedral Shear Stress	Measured Resilient Modulus	Predicted Resilient Modulus
	σ_3	σ_d	θ	τ_{oct}	M_r	Pred. M_r
	psi	psi	psi	psi	psi	psi
1	3.00	3.03	12.04	1.43	14939	14116
2	3.00	6.10	15.11	2.88	15961	16194
3	3.00	9.10	18.11	4.29	17488	18042
4	5.01	5.05	20.06	2.38	20102	19683
5	5.00	10.11	25.12	4.77	22138	22372
6	5.00	15.15	30.16	7.14	23746	24786
7	9.99	10.11	40.09	4.77	30912	30598
8	9.99	20.34	50.32	9.59	34488	34291
9	9.99	30.48	60.46	14.37	36958	37588
10	15.00	10.08	55.07	4.75	36748	37859
11	15.00	15.21	60.21	7.17	38487	39381
12	15.00	30.49	75.48	14.37	44410	43612
13	20.00	15.19	75.20	7.16	45754	45711
14	20.00	20.33	80.32	9.58	48085	46915
15	20.00	40.44	100.44	19.06	52393	51463

Resilient Modulus Equation

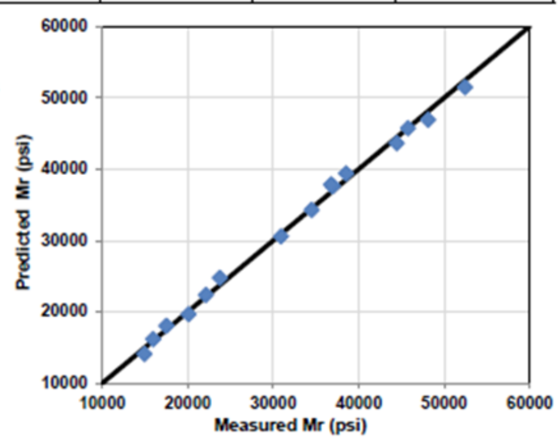
$$Mr = k_1 * Pa * \left(\frac{\theta}{Pa}\right)^{k_2} * \left(\frac{\zeta oct}{Pa} + 1\right)^{k_3}$$

Resilient Modulus Model Parameters

k_1 = 1116.004

k_2 = 0.670

k_3 = -0.174



Note: As per NCHRP 1-28A guidance, consider a design resilient modulus for base/subbase materials using the confining stress of 5 psi and total axial stress of 15 psi

Tested By: Kelli Browning   **Reviewed By:** Mir Tamim

American Geotechnics

Figure 2.7 Example Resilient Modulus Test Report for Aggregate Base/Subbase

Major Findings

The results of this work suggest that the global default values are conservative and ITD would benefit from routinely conducting M_R testing on most projects in order to use Level 1 site-specific or Level 2 local value database created with this project. Table 2.2 is a summary of the data contained in the database.

This project was able to obtain data from existing design projects but the data was not distributed throughout the state.

Modifying the default C-Values recommended in AASHTO Mechanistic-Empirical Pavement Design Guide; A Manual of Practice. 2020 Third Edition and Idaho RP 211B, Idaho AASHTOWare Pavement ME Design User's Guide Version 1.1 should be considered. This limited research indicates that the C-Factors for aggregate base/subbase and subgrade soil could be increased from the current Level 3 default value of 0.35 and 0.62 respectively.

Table 2.2 Summary of C-Value Findings

Owner/ Client	Project Name	Roadway /Route	Roadway Type	Layer Type	ASTM Class.	AASHTO Class.	[a, *] M_r Value (psi)	[a] E_{FWD} (psi)	[a] C-Value	[b] k_1	[b] k_2	[b] k_3	[c] Latitude	[c] Longitude
ITD D4	I-84, Kasota IC to Burley IC EBL	I-84	Flexible	Subgrade	ML	A-4	6700	12800	0.52	758.363	0.682	-2.109	42.576284	-113.886319
ITD D4	I-84, Kasota IC to Burley IC EBL	I-84	Flexible	Subgrade	ML	A-4	6500	12800	0.51	635.847	0.590	-1.382	42.56968	-113.843427
LHTAC/West Point HD	1500 E Road Rehabilitation	S 1500 E	Flexible	Subgrade	SP-SM	A-2-6	4492	12000	0.37	393.701	0.582	-0.777	42.747392	-114.791355
LHTAC/Payette County	Sand Hollow Rd. Oasis to Black Canyon Rd.	Sand Hollow	Flexible	Subgrade	CL	A-4	4789	6300	0.76	576.638	0.633	-2.506	43.80768	-116.747905
ITD D-3	SH55, State St. to Payette River BR	SH-55	Flexible	Subgrade	SM	A-2-4	7040		*	678.802	0.658	-1.232	43.718825	-116.319828
ITD D-3	SH55, State St. to Payette River BR	SH-55	Flexible	Subgrade Composite	CL	A-4	21401		*	1779.946	0.224	-0.878	43.793112	-116.263317
ITD D-3	SH55, State St. to Payette River BR	SH-55	Flexible	Base Composite	GP-GM	A-1-a	21330		*	980.870	0.689	-0.261		
LHTAC/ Buhl HD	E 4100 N Rehabilitation	E 4100 N	Flexible	Subgrade	CL	A-4	5881	18250	0.32	657.338	0.585	-2.142	42.593592	-114.675236
LHTAC/Buhl HD	E 4100 N Rehabilitation	E 4100 N	Flexible	Subbase	ML	A-4	6047	18020	0.34	648.576	0.582	-1.912	42.593596	-114.635637
ACHD	FY21 Capital Maintenance PH 1	Fairview Ave	Flexible	Subgrade	CL	A-6	13481	27200	0.50	1372.677	0.337	-1.888	43.61953	-116.29067
ACHD	FY21 Capital Maintenance PH 1	Curtis Rd	Flexible	Subgrade	CL	A-6	3580	5800	0.62	458.332	0.534	-2.967	43.587378	-116.253663
ACHD	FY21 Capital Maintenance PH 1	Boise Ave.	Flexible	Subgrade	SM	A-4	5405	13400	0.40	677.390	0.785	-2.564	43.589761	-116.192102
ITD D4	State, FY19 D4 Materials Reconnaissance	SH-75	Flexible	Subgrade	GC-GM	A-2-4	10990	16400	0.67	1675.333	0.891	-3.539	43.68199	-114.366184
LHTAC/City of Buhl	Burley Ave; Us-30 to Fruitland Ave	Burley Ave.	Flexible	Subgrade	CL	A-6	5637	10740	0.52	646.424	0.495	-2.382	42.593506	-114.753364
ITD D6	SH-33, MP 99.3 to 107.0	SH-33	Flexible	Subgrade	SM	A-6	6300	19900	0.32	540.106	0.606	-1.51	43.886537	-111.667738
ITD D6	SH-33, MP 99.3 to 107.0	SH-33	Flexible	Subgrade	CL	A-6	6000	18300	0.33	554.431	0.568	-3.649	43.883667	-111.725406
ITD D6	SH-33, MP 99.3 to 107.0	SH-33	Flexible	Subgrade	SM	A-6	6000	17700	0.34	506.275	0.661	-1.213	43.883682	-111.711951
LHTAC/ City of McCall	Mission St; SCL to Deinhard Ln	Mission St.	Flexible	Subgrade	SM	A-1-b	14611	15960	0.92	1514.130	0.568	-1.735	44.898126	-116.105038
ITD D2	SH-13, Mount Idaho Rd to Top Harpster Grade	SH-13	Flexible	Subgrade	CH	A-7-5	2240	5400	0.41	324.027	0.576	-3.613	45.925867	-116.107585
ITD D2	SH-13, Mount Idaho Rd to Top Harpster Grade	SH-13	Flexible	Subgrade	CL	A-7-6	4662	11300	0.41	534.911	0.31	-2.604	45.957223	-116.025383

Owner/ Client	Project Name	Roadway /Route	Roadway Type	Layer Type	ASTM Class.	AASHTO Class.	$^{a,*}M_r$ Value (psi)	$^{a}E_{FWD}$ (psi)	^{a}C-Value	$^{b}k_1$	$^{b}k_2$	$^{b}k_3$	^{c}Latitude	^{c}Longitude
ITD D1	US-2, Jct US-95 to MSL	US-2	Flexible	Subgrade	ML	A-4	6447	14000	0.46	690.440	0.627	-1.857	48.72115	-116.135851
ITD D1	US-2, Jct US-95 to MSL	US-2	Flexible	Subgrade	ML	A-4	6588	16000	0.41	595.680	0.471	-1.078	48.708106	-116.126799
ITD D1	US-2, Jct US-95 to MSL	US-2	Flexible	Subgrade	SP	A-3	6753	18500	0.37	697.393	0.735	-1.537	48.658306	-116.073934
ITD D1	US-2, Jct US-95 to MSL	US-2	Flexible	Subgrade	SM	A-2-4	9317	16900	0.55	1053.033	0.746	-2.031	48.680943	-116.089347
ITD D1	US-2, Jct US-95 to MSL	US-2	Flexible	Subgrade	ML	A-4	9092	22800	0.40	980.243	0.766	-1.743	48.725913	-116.149188
ITD D1	US-2, Jct US-95 to MSL	US-2	Flexible	Base Composite	GM	A-1-b	29815	35200	0.85	1539.511	0.704	-0.583	48.72714	-116.215743
ITD D1	US-2, Jct US-95 to MSL	US-2	Flexible	Base Composite	GP-GM	A-1-a	22600	35200	0.64	1065.763	0.733	-0.406	48.701576	-116.122283
ITD D1	US-2, Jct US-95 to MSL	US-2	Flexible	Base Composite	SM	A-1-b	23787	35200	0.68	1041.083	0.765	-0.276	48.654095	-116.065016
LHTAC/Gooding HD	Shoe String Rd Rehab & Safety	Shoe String	Flexible	Subgrade	MH	A-7-5	5233	11200	0.47	580.666	0.527	-2.166	42.865548	-114.79252
LHTAC/Gooding HD	Shoe String Rd Rehab & Safety	Shoe String	Flexible	Subgrade	SC	A-6	5558	10800	0.51	674.969	0.723	-2.458	42.865557	-114.775191
LHTAC/Gooding HD	Shoe String Rd Rehab & Safety	Shoe String	Flexible	Base	SM	A-2-4	20600	22500	0.92	1248.294	0.513	-0.633	42.865482	-114.798036
ITD D3	SH-45, JCT-78 to Deerflat	SH-45	Flexible	Subgrade	ML	A-4	3700	13000	0.28 **	465.198	0.606	-2.755	43.34037	-116.60423
ITD D3	SH-45, JCT-78 to Deerflat	SH-45	Flexible	Subgrade	CL	A-6	7200	12600	0.57 **	896.574	0.756	-2.544	43.35532	-116.59625
ITD D3	SH-45, JCT-78 to Deerflat	SH-45	Flexible	Subgrade	ML	A-4	6750	22100	0.31 **	702.333	0.464	-1.852	43.39134	-116.57334
ITD D3	SH-45, JCT-78 to Deerflat	SH-45	Flexible	Subgrade	ML	A-4	9200	27200	0.34 **	759.728	0.5	-0.521	43.43464	-116.57327
LHTAC/Hillsdale HD	Crestview Rd Rehabilitation, Ph 1	Crestview Rd.	Flexible	Subgrade	CL-ML	A-6	5390	6380	0.84	594.655	0.483	-2.183	42.586914	-113.990806
LHTAC/Hillsdale HD	Crestview Rd Rehabilitation, Ph 1	Crestview Rd.	Flexible	Subgrade	CL-ML	A-4	4002	6460	0.62	447.393	0.607	-2.118	42.599929	-113.990882
LHTAC/Teton County	N 500 W Reconstruction	N 500 W	Flexible	Subgrade	CL	A-4	6900	10500	0.66	823.173	0.605	-2.49	43.859204	-111.1101
Jefferson County	2100 E, County Line to 400N	2100 E	Gravel	Subgrade	ML	A-4	8461	10500	0.81	923.523	0.614	-1.97	43.639568	-112.282343
Jefferson County	2100 E, County Line to 400N	2100 E	Gravel	Subgrade	CL-ML	A-4	4752	5575	0.85	592.153	0.737	-2.587	43.671995	-112.282371
ITD D4	US-30, Blue Lakes Blvd to Eastland Dr	US-30	Flexible	Subgrade	ML	A-4	6981	11100	0.63	682.84	0.756	-1.204	42.548547	-114.457202
ITD D5	FY21 D5 Planning & Scoping, 5th Ave	5th Ave	Flexible	Subgrade	ML	A-4	5721	13200	0.43	632.214	0.575	-2.087	42.859368	-112.43519
ITD D5	FY21 D5 Planning & Scoping, 5th Ave	5th Ave	Flexible	Base	GP-GM	A-1-a	21431	34600	0.62	1001.871	0.585	-0.114	42.859368	-112.43519

Owner/ Client	Project Name	Roadway /Route	Roadway Type	Layer Type	ASTM Class.	AASHTO Class.	[a, *]M_r Value (psi)	[a]E_{FWD} (psi)	[a]C-Value	[b]k_1	[b]k_2	[b]k_3	[c]Latitude	[c]Longitude
ITD D5	FY21 D5 Planning & Scoping, 4th Ave	4th Ave	Flexible	Subgrade	CL	A-6	4019	10500	0.38	474.99	0.561	-2.484	42.871927	-112.450209
ITD D5	FY21 D5 Planning & Scoping, 4th Ave	4th Ave	Flexible	Base	SM	A-1-b	24786	32400	0.77	1116.004	0.67	-0.174	42.871927	-112.450209
ITD D4/ Jacobs	US-93, Hollister to IC 93/30	US-93	Flexible	Subgrade	SM	A-4	4700	10200	0.46	512.961	0.586	-2.038	42.44066	-114.574795
ITD D4/ Jacobs	US-93, Hollister to IC 93/30	US-93	Flexible	Subgrade	CL	A-4	5500	10600	0.52	642.145	0.595	-2.367	42.515913	-114.574804
ITD D4/ Jacobs	US-93, Hollister to IC 93/30	US-93	Flexible	Subgrade	CL-ML	A-4	1050	10300	0.39	513.125	0.647	-2.757	42.549938	-114.574833
ITD D4/ Jacobs	US-93, Hollister to IC 93/30	US-93	Flexible	Base Composite	SM	A-1-a	15200	29000	0.52	654.994	0.746	-0.194	42.515913	-114.574804
ITD D3	SH-55, Eagle Rd, I-84 to SH-44	SH-55	Flexible	Subgrade	SC	A-6	5119	14300	0.36	520.418	0.915	-1.241	43.606608	-116.354652
ITD D3	SH-55, Eagle Rd, I-84 to SH-44	SH-55	Flexible	Subgrade	CL	A-6	5687	16300	0.35	599.23	0.549	-1.85	43.638844	-116.354243
ITD D3	SH-55, Eagle Rd, I-84 to SH-44	SH-55	Flexible	Subgrade	CL	A-7-6	4850	10800	0.45	590.227	0.298	-2.964	43.622252	-116.354654
ITD D3	SH-55, Eagle Rd, I-84 to SH-44	SH-55	Flexible	Base Composite	GP-GM	A-1-a	27811	50000	0.56	1331.356	0.712	-0.407	———	———
LHTAC/ City of Nampa	Cherry Lane, Franklin Blvd to 11th Ave N	Cherry Lane	Flexible	Subgrade	CL	A-7-6	4323	11000	0.39	509.912	0.462	-2.586	43.619584	-116.544033

[a]NCHRP 1-28A Guidance using sequence 6 or 13

[b]Regression Coefficients

[c]Sampling Location

*FWD Data provided by ITD. M_R values provided by S&W. The resulting C-Values were not reasonable.

** E_{FWD} values provided by ITD. M_R values provided by S&W.

3. Conclusions and Recommendations

Conclusions

This study examined the potential benefits of creating a Level 2 C-Value database to replace the current ITD method of using the MEPDG Manual of Practice (2020 Third Edition) recommended Level 3 default C-Values.

Level 1 (project-specific) and Level 2 (local vicinity) C-Values lead to more economical pavement thickness recommendations and/or increased reliability in our analyses. Level 1 C-Values may not be appropriate for all projects due to the laboratory testing required. A Level 2 C-Value database will provide higher quality data for pavement designs when testing is not available. Level 3 C-Values may be appropriate for smaller projects on low-volume roadways, but the database should be used if possible. Engineering judgement is needed to decide what level of effort is appropriate for each situation.

A default Level 3 C-Value is probably not representative of in-situ site conditions because it may be overly conservative. For example, project-specific Level 1 C-Values for many Idaho soils may typically be in the range of 0.45 to 0.6. It is reasonable to assume that using a local calibration of C-Values rather than the default, could lead to less conservative pavement rehabilitation designs. At $75 per ton for HMA, a one-half-inch reduction in HMA layer thickness could save nearly $40,000 per mile of 2-lane highway.

Figure 3.1 is an example plot showing the relation of increased C-Value to reduced HMA relative to the national default (Level 3) C-Value of 0.35 for various traffic levels (TI).

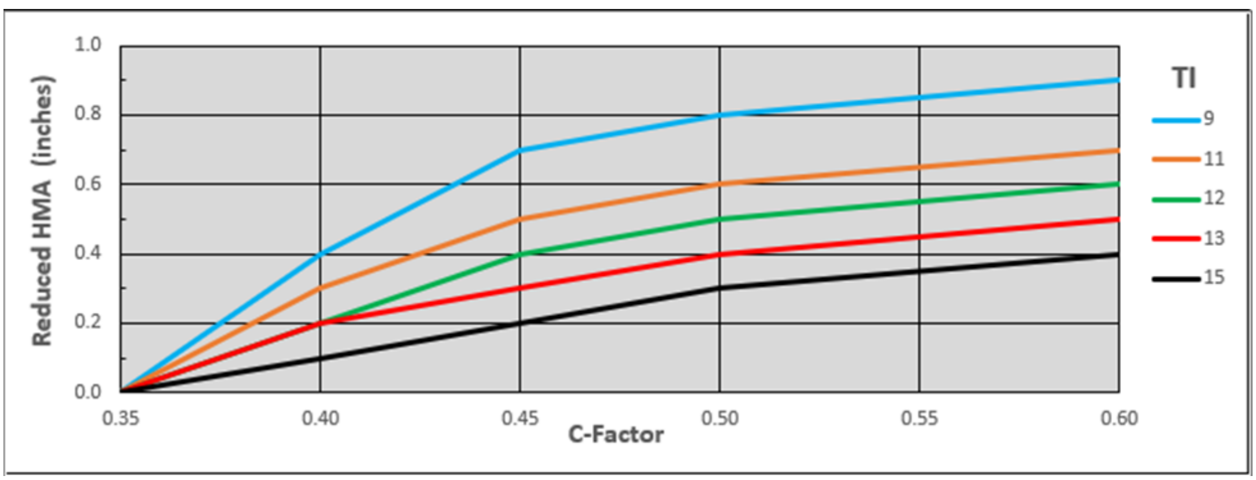


Figure 3.1 Relationship of C-Value to HMA Thickness Relative to Default Values for Various TI's

The data collected during this research project during the past two years and incorporated in the database shows the following:

Forty-three subgrade C-Values were determined on 23 projects and for 35 of them the C-Value increased from the default value, while 8 C-Values decreased from the default value. The average change in C-Value was an increase of 0.14. From the graph above, an increase of the subgrade C-Value of just 0.10 from 0.35 to 0.45 could result in a reduction in HMA of from 0.2-inch to 0.8-inch depending on TI.

Eight base/subbase C-Values were determined on 7 projects and for 6 of them the C-Value increased from the default value, while 2 C-Values decreased from the default value. The average change in C-Value was an increase of 0.1. From the limited data available on aggregate base/subbase in this study, it appears that the default value of 0.62 for aggregate base/subbase is slightly conservative. An increase of 0.08 to the default value resulting in a 0.70 C-Value would reduce the conservatism for aggregate base/subbase.

Recommendations

Interstate highways and US highways are ITD's most critical facilities, as such, we recommend project specific or Level 1 modulus determination for these facilities. All Interstate highways and most US routes should use Level 1 input values in the Pavement ME Design process. The laboratory resilient modulus test, AASHTO T 307 should be performed to acquire site-specific M_R values.

Most of the remainder of roadways in Idaho should be identified as the roadways that will benefit the most by C-Value refinement. We recommend utilizing Level 2 modulus determination based on local data compiled in the database. The data collected for this project will allow the designer to correlate laboratory-established resilient moduli with moduli back-calculated from field tests and result in pavement designs that are not overly conservative.

Level 3 modulus determination may be appropriate for low-volume low-risk projects where the benefit of additional testing is not cost effective. However, we recommend using the C-Value Database to find values in the project area or to find comparable soil conditions in the database that are similar to the project conditions.

This limited research suggests that it may be acceptable to increase the default C-Value of subgrade soils from 0.35 to 0.45 as the new local Level 2 value for subgrade soils.

From the limited number of aggregate base/subbase samples tested during this project, we recommend increasing the C-Value from the Level 3 default value of 0.62 to 0.70 as the new local Level 2 value for aggregate base/subbase.

Future Work

This project should be seen as a starting point that ITD will build upon moving forward. As new projects are developed, the test results should be added to the data base to fill in deficient areas.

In addition, there should be an effort to strategically test throughout the state to identify soil conditions that will affect the pavement design and add them to the database. A robust C-Value database will allow the designer to optimize their pavement design or identify the need to do project specific modulus testing. ITD should consider another research project to analyze the data collected in this work to make predictions.

ITD should also consider the following:

- continue to collect this type of data to enhance the function of the AASHTOWare Pavement ME Design software
- continue to add data to the University of Idaho developed ME Database for traffic, climate, bound and unbound materials, and
- periodically check the local calibration factors.

Shannon & Wilson will continue to support the database included with this report. Future project data will add new data as it is collected, and that information will be shared with ITD.

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