

# **Improving Resilient Modulus Test Procedures for Unbound Materials**

## **Proposed Pooled Fund Project**

### **Problem Statement**

**August 6, 2003**

#### **Project Goal**

This pooled fund study has two primary goals:

1. To reduce the variability currently associated with resilient modulus testing of unbound materials.
2. To conduct a precision and bias study of the test procedure.

#### **Project Tasks – Condensed**

The suggested tasks associated with this pooled fund project are:

**Purchase Resilient Modulus Equipment (Optional)**

**Provide Start-up Assistance (Optional)**

**Conduct Ruggedness Test**

**Conduct Precision and Bias Test**

**Adopt Resilient Modulus Test Protocol**

**Develop Educational Workshop**

#### **Background**

The resilient modulus of a soil or unbound aggregate material is the recoverable stress/strain relationship of the soil. The greater the resilient modulus of the soils is; the “stiffer” the soil will be, and the greater the strength will be for supporting transmitted wheel loads. This parameter is considered to be the best indicator of a subgrade’s strength since the test replicates the dynamics of moving wheel loads.

The new 2002 AASHTO Design Guide for Pavement Structures requires that the resilient modulus of the subgrade be used to design the pavement thickness for both asphalt concrete and PCC concrete pavements. Due to the complexity of the test, test results have been inconsistent. For example, data to date has shown that:

- Two different laboratories testing split samples of the same soil or aggregate layer get widely different results.
- Two technicians on the same equipment would also get widely different results.
- Repeated tests on the same sample by one technician on the same equipment would not always produce consistent results.

Many pavement engineers will want to by-pass the resilient modulus test by using a simpler test (CBR or Group Index) and correlate the results of this test to arrive at a resilient modulus value.

Since 1993, the FHWA under the Long Term Pavement Performance Program has done extensive work on the test protocols and procedures. This effort has led to less variability when tested by several State DOT laboratories. Additionally, researchers under NCHRP 1-28A have done extensive work on the test protocols. All in all, four major products are now available for detailed review and analysis:

- NCHRP 1-28A – Final Report that deals with a thorough literature review of the subject, and a draft test method for determining the resilient modulus of unbound materials.
- LTPP Resilient Modulus Test Protocol P46 – This protocol was evaluated by AASHTO SOM and eventually adopted with some modifications as AASHTO Standard T 307, “Standard Test Method for Determining the Resilient Modulus of Soils and Aggregate Materials.”
- Testing Startup and Quality Control Procedures - This protocol was developed to ensure the accuracy of the resilient modulus testing program and was published as FHWA-RD-96-176. Several laboratories (3 SHA’s, FHWA, and 3 others) have applied the resilient modulus start up and quality control procedures to their equipment and technicians. In every case, problems were found that prevented the acquisition of consistent and reliable data. The procedure has proven to be able to go a long way to improve the situation. The procedure has been updated and a report prepared to reflect the lessons learned over the last few years. Additional new techniques that greatly simplify the process were also incorporated. Standard recommended practices are under review in preparation for submittal to AASHTO.
- Education Tools-Videotapes and CD-ROM – The FHWA has developed an interactive CD-ROM that includes interactive resilient modulus guidelines and the Pavement Design Guide report for unbound materials. Also available are three videotapes on the subject, done by LTPP in cooperation with the Minnesota Department of Transportation

**Ruggedness tests and Precision Bias studies have never been conducted for either the LTPP P46 or AASHTO T 307 tests. Without these studies, these standard have no meaningful backing.**

## Discussions

### Specifications for Purchasing Resilient Modulus Equipment

The pooled fund study should develop specifications for purchasing the Resilient Modulus equipment.

### Purchasing Resilient Modulus Equipment (Optional)

The pooled fund study should have an optional task of providing Resilient Modulus equipment for the various State DOT's participating in the study. This task will provide three important benefits:

- Eliminate any budget problems participating State DOT's may have in purchasing the equipment.
- Quickest route for placing equipment in the hands of participating State DOT's.
- Provides uniformity of equipment among participating State DOT's.

### Start-up Assistance (Optional)

Start-up assistance is needed to verify the performance of the dynamic testing systems (primary closed-loop servo-hydraulic before and during the laboratory testing program. The start-up phase will consist of:

- Electronic system performance verification
- Overall system performance verification
- Laboratory testing competence verification

The two primary goals of the start-up process are:

1. To insure that the test system and technicians are capable of performing the test procedures.
2. To develop a benchmark performance standard against which laboratory results can be compared on a continuing basis.

Start up procedures for the Resilient Modulus have been developed and should be adequate for starting the project.

The resilient modulus test is a difficult and complex test. Most participating States will some help in setting up the equipment and developing test procedures. Start-up assistance will be provided by a Contractor for the Pooled-Fund Study if requested by a participating State. **States that are participating in the in the ruggedness testing and precision and basis testing will be required to have the start-up assistance so the testing procedures will be uniform.**

### **Ruggedness Test**

The ASTM standard E 1169-02 states *“In studying a test method, it is necessary to consider the effect of environmental factors on the results obtained using the test method. If this effect is not considered, the results from the original development work on the test method may not be as accurate as expected.”* In this study, “environmental factors” would include: different types of laboratory equipment, different laboratories, different operators, and repeatability of the test procedure.

The standard further states *“The purpose of the ruggedness test is to find the variables (experimental factors) that strongly influence the measurements provided by the test method, and to determine how closely these variables need to be controlled.”*

The pooled fund study should include a ruggedness test to determine the influence of any factors on the results of the resilient modulus test.

### **Precision and Bias Test**

ASTM E 1488 defines precision as: *“A measure of the variability among test results conducted on the same material (or type of material),”* while ASTM E 177 lists the following factors as affecting precision: One operator, day and apparatus, repeated experiments within in a single laboratory, and laboratory experiments in several laboratories The pooled fund study should determine the precision level required considering different types of equipment, laboratories and operators.

Bias can be defined as: *“Bias is a systematic error that contributes to the difference between a population mean of the measurements or test results and an accepted reference or true value.”* The pooled fund study should contain a Bias test to determine if any bias exists.

### **Resilient Modulus Protocol**

The Resilient Modulus test is a difficult and complex test. Pavement engineers need a test protocol that is rugged and simple as possible. Protocols developed for LTPP P46 and AASHTO T 307 should be adequate. The pooled fund study should adopt the protocols that will produce an adequate resilient modulus test procedure.

**The overall goal of the pooled fund study is to create a user-friendly resilient modulus test so that pavement engineers will use the results in designing the pavement thickness.**

### **Educational Workshop**

To meet the spirit of the **2002 AASHTO Design Guide for Pavement Structures**, all SHA’s should conduct resilient modulus testing of the soils and subgrades. An educational workshop is needed for technology transfer of the start-up procedures for the resilient modulus test. This would save considerable time and effort required for each SHA to get up to speed on the test protocols.

### **Suggested Pooled Fund Study Tasks - Expanded**

The following tasks are suggested elements of the study:

Task 1. Assemble Pooled Fund Project Panel – All DOT’s that elect to participate in the study will be afforded the opportunity to attend and participate in the kickoff and periodic meetings. The main purpose of this task is to organize and evaluate the specifics of the pooled fund study tasks.

Task 2. Develop Purchasing Specification - Develop specifications for purchasing Resilient Modulus test equipment.

Task 3. Purchase Resilient Modulus Equipment (Optional) – Purchase Resilient Modulus test equipment for the participating DOT’s.

Task 4. Provide Start-up Assistance (Optional)

Task 5. Conduct Ruggedness Test

Task 6. Conduct Precision and Bias Test

Task 7. Revise/update start-up procedures

Task 8. Revise/update suggested Resilient Modulus Protocol for AASHTO approval

Task 9. Develop Educational Workshop - Develop Educational Workshop for technology transfer of test start-up procedures to the DOT’s.

### **Additional Comments**

Study Management – It is recommended that the study be administered by FHWA with technical management provided by the participating DOT’s through means of a Pooled Fund Project Panel. This method is chosen due to the nature of the scope of work involved, the need to get as many DOT’s as possible involved, and the need to issue purchase orders for the resilient modulus test apparatus, technical services, etc. State DOT’s financially participating may also choose to technically participate, at their discretion. They will be automatically included in the Panel.

Training Tools – The FHWA has completed a project to produce a Resilient Modulus CD-ROM. This CD includes the electronic form of the three LTPP resilient modulus videos, interactive resilient modulus guidelines, and the Pavement Design Guide report for unbound materials.

Precision-Bias Study Details – Only a few DOT laboratories and consultants are experienced and qualified in performing the start up procedure. It is estimated that about one laboratory per month can be trained in its use. Additionally, the laboratories that participated in the original LTPP study need to be revisited to assure that their personnel are still qualified and current. This

would take a total of eight months. The precision and bias testing should begin in about one month, while data analysis would take approximately another three months.

### **Funding Requirements**

Following is a preliminary estimate for the study, assuming a 10-State Study:

\$250,000	Purchase Resilient Modulus Equipment (Optional) – Each apparatus costs approximately \$25,000
200,000	Provide Start-up Assistance (Optional)
5,000	Acquisition, preparation, and distribution of the samples for the ruggedness test and the precision and bias test
40,000	Technical Services – facilitating the study, designing the study, evaluation of the results, and preparing the various reports
20,000	Educational and outreach tools
<u>25,000</u>	<u>Panel Administrative costs, including travel</u>
<b>\$540,000</b>	<b>Total Estimate Cost for a 10-State Study</b>

### **Expected Benefits and Deliverables**

The expected benefits of the pooled fund study are:

- More accurate subgrade input to the pavement thickness design resulting in a more cost-effect product.
- SHA’s agency will enter the learning curve for resilient modulus testing at a much higher level because of the detailed start-up procedures.

The expected deliverables for the study are:

- Start-up procedure for setting up the resilient modulus testing program.
- Practical protocol for running the resilient modulus test

### **FHWA Contact for Further Information**

Contact: Robert Baumgardner  
202-366-4612  
bob.baumgardner@fhwa.dot.gov