Improving the Quality of Pavement Profiler Measurement

Pooled Fund Project

Problem Statement

Project Objectives

This project is designed to:

- Deliver sample procurement specification, maintenance guidelines and profile analysis software program.
- Establish criteria for verification centers and assist with the development of these locations.
- Develop and deploy a traceable verification center.
- Provide technical review of software that:
    - Locates surface imperfections that require corrective repair during construction.
    - That can relate the bumps to the highway users.
    - And procure for general distribution.

Problem Statement:

Pavement smoothness has been recognized as one of the key measures of pavement performance. Studies have confirmed that highway users judge the condition of the highway system primarily by the ride that they experience when traveling over the roadway. National studies conducted in 1996 and in 2001 by the Federal Highway Administration (FHWA) surveyed frequent public highway users throughout the country. The studies confirmed that road condition was the top priority for what highway users were looking for on their roadways.

Many state highway agencies (SHAs) have identified pavement smoothness as a key issue. This is exhibited in pavement smoothness specifications during construction, in data collection efforts for pavement management, and in reports submitted to FHWA as part of a national database for monitoring pavement performance.

Research has shown that when roads are built smooth they will stay smooth longer. "Initial smoothness has been shown to provide value in the performance and service life of pavements. This serves to justify the importance of achieving high initial smoothness from a pavement structural standpoint, which is in addition to the importance of smoothness to the riding comfort of the user. And, this strongly supports the benefits of employing smoothness specifications, which have been shown to be an effective means of achieving higher levels of initial smoothness."[i] Several Long-Term Pavement Performance (LTPP) studies have addressed certain aspects of pavement smoothness, including roughness development, measurement methods, and modeling.

This pooled fund effort will provide agencies with information and first hand experience to address issues and concerns related to profiler operation, equipment, and procedures. There is an increasing need for State Highway Agencies to purchase and

upgrade profiling equipment to provide network level and project specific smoothness information. This includes profilers operated at close to posted speed limits that are most often used to determine ride quality on a network level and smaller units, such as lightweight profilers (LWP).

At a workshop on pavement smoothness sponsored by NCHRP Project 20-51(01) held in Irvine, California in August 2001, participants from state highway agencies, the Federal Highway Administration (FHWA), asphalt concrete and portland cement concrete paving industries, academia, consulting firms, and research organizations developed a lists of primary issues related to pavement smoothness. The prioritized list included:

1) Accuracy and repeatability of equipment;
2) Reproducibility of equipment;
3) Use of profile data for corrective actions;
4) Knowledge and understanding of equipment and measurements;
5) Relating smoothness to cost and performance;
6) Identifying an appropriate index for smoothness;
7) Standard guide specification;
8) Future use of profile data; and
9) Use of roughness index for monitoring pavement performance during service life.[ii]

A FHWA Expert Task Group (ETG) on Smoothness has developed a draft set of protocols and guidelines that will be submitted to the AASHTO Highway Subcommittee on Materials and AASHTO Joint Task Force on Pavements. The protocols and guidelines are designed to address the top issues dealing with the quality of data obtained from profile equipment.

This pooled fund project is being established to provide direction and funding that will unify the strategies, address implementation efforts, and promote practices that improve accuracy and repeatability of the equipment and promote the knowledge and understanding of profile equipment and measurements. It is anticipated that this study will be completed within four years.

Project Tasks - Condensed

- Profiler Acquisition Specifications and Maintenance Guidelines
- Profiler Calibration Centers
- Profiler Calibration Equipment Production and Delivery
- Profile Bump Identification for Construction Specifications and Highway Users

Background

Equipment Procurement, Maintenance, and Calibration

The technical capabilities of profilers have increased dramatically in the last 5-10 years. Many SHAs are in the process of purchasing or replacing their profilers for network and project level assessments. Additionally, SHAs are constantly trying to determine the cost of data collection to help support pavement decisions. This is especially true in the area of profile data collection for construction quality control and for pavement management

decision-making. Many SHA personnel desire more information on the current state of the art in road profiler calibration, procurement and maintenance in order to optimize their use for profiling.

LTPP has 10+ years of experience using profilers on a daily basis. This experience includes purchasing specifications, maintenance records, and data reduction and application activities. Their experience can be beneficial to SHAs that are looking to develop procurement specifications and to determine a more accurate and cost-effective operations budget.

Quality profile data is a key element in evaluating the long-term performance of pavements. The LTPP effort has identified a need for the calibration and for the verification of the accuracy of these devices. Currently, calibration methods only exist for LTPP equipment and are not available to all highway agencies.

Guidelines and Software Development

Many believe that profile data collected from inertial profilers provide the best information for pavement evaluation. However, there are no standard practices or guidelines to use this information to develop construction specifications or to improve pavement design and rehabilitation decision-making.

LTPP is developing smoothness guidelines for approaches to Weigh-in-Motion (WIM) sites to reduce the impact of dynamic loads. The WIM study will help quantify the effect of an uneven surface on the dynamic loads applied to the pavement. The results of this study can be quantified and used as part of the profile quality study to identify the magnitude and location of profile bumps that result in dynamic impact to pavement. This information can then be used to develop construction specifications and any required correction measures.

Suggested Pooled Fund Study Tasks

Task 1. Administration

Assemble a Technical Working Group (TWG) - It is proposed that all States that elect to participate in the study will be afforded the opportunity to attend and participate in a kick-off and periodic meetings. The main mission is to organize the specifics of the pooled fund study task. The participating SHAs will receive first priority for the all of the developed equipment and procedures. It is envisioned that the TWG will meet twice a year over a four-year time frame.

Task 2. Deliver Profiler Acquisition Specifications, Maintenance Guidelines and Analysis Software

As many SHAs begin implementing the use of inertial profilers for pavement management and construction management practices for the delivery of smooth pavements to the traveling public, the issues of equipment acquisition, maintenance and the use and understanding of acquired data will need to be addressed. The purpose of this task will be to develop and deliver training about the following AASHTO Standards of Practice:

- (DRAFT) AASHTO Designation MP50-02 Standard Equipment Specification for an Inertial Profiler
- (DRAFT) AASHTO PP 51-02 Standard Practice for Certification of Profiling Systems - 04/24/02

- (DRAFT) AASHTO PP 52-02 Standard Practice for Operating Inertial Profilers - 04/24/02
- (DRAFT) AASHTO PP 53-02 Standard Practice for Determining Ride Quality - 04/24/02

Under the direction of the TRB Expert Task Group on LTPP Distress and Profile, profile analysis software has been developed and is currently undergoing beta testing. The training will include the use and distribution of this LTPP product.

Urgency – Many SHAs are currently purchasing or replacing profiling equipment. SHA personnel responsible for developing RFP's for the purchase of profiling equipment must be knowledgeable as to the current technical state of the art. This product will assist personnel in making knowledgeable decisions to optimize their profiling needs and to identify needed funding.

Task 3. Profiler Verification – Establish Verification Centers

The objective of this task is to establish the type of facilities that are needed to ensure the accuracy of profilers as outlined in the (Draft) AASHTO Standard Practice for Certification of Inertial Profiling Systems. The task will assist with determining:

- Is it feasible to develop stationary profiler calibration sites?
- What is the optimum location of calibration sites?
- Is there a need for shared facilities?
- How would calibration centers be financed and maintained?

An anticipated deliverable would be assistance in laying out a certification test facility for participating SHA's.

Urgency - There is a need for calibration facilities to assure the adequacy of profile data for the intended purposes. Variations in profile data hinder construction activities by making it difficult to establish clear measurement standards. The final outcome of the task will be the construction of calibration/verification facilities. Even if Task 4 as outlined below is shown as a feasible concept, it is not anticipated that the actual deployment would be until 2004 at the earliest. The types of facilities outlined in for task 3 could be deployed during the first fiscal year of this pooled fund.

Task 4. Profiler Verification Equipment

The objective of this task is to first determine the feasibility of building a verification operation than can assist with calibration of inertial profile equipment. The concept for the equipment will be to work with full size profiling vans and lightweight devices.

A second phase would be to build a prototype device with the third phase dealing with deployment. One concept, as listed in phase one, would be for the device to be portable, either as a complete unit or it can be assembled and disassembled in a reasonable period of time (1-day). This is presented as one concept and is not intended to direct the study to only portable operations.

Phase 1: Assemble a TWG to direct a feasibility study to determine the technical merits of the verification operation. If the concept is presented as feasible, the study will present costs associated with the building of the equipment and the deployment. The contractor will produce a design specification for the equipment that details the design concepts. The design concept report will provide:

- Guidance for what is required of the verification operation in order for a profiler to perform according to national standards.
- Identify what needs to be improved on a specific profiler to bring it into calibration.
- Equipment design specifications.
- A clear statement of purpose - what the equipment will be capable of.
- Recommendations on deployment, maintenance and support requirements.

Draft Concept (Portable Device): This device will have four independent, actuated, tire pads. The actuated, tire pads will be capable of independent vertical movements of up to 4" in a rapid manner. Two of the pads (front two) will be of a fixed nature. These pads will be capable of holding the vehicle in place during the testing process where all four tires are independently, randomly osculated in a vertical motion.

Two rollers (rear two) will allow each to rotate to a speed of 70 mph. These rollers will be linked to a device that will record and transfer the speed of the tires to the calibration drum. The roller pads will be capable of independently, randomly osculating in a vertical motion. The rear tires will control the speed of the calibration drum.

An interchangeable calibration system will be made to rotate under the profiler sensors (laser or ultrasonic) being tested. This rotating system may be cylindrical or elliptical and balanced to assure minimization of vibration during rotations up to 70 mph. The device needs to be designed such that two individuals can carry this device and install it in position. The rotating system must be of sufficient size so that either a laser or ultrasonic sensor reading does not measure the cylindrical nature of the rotating calibration system. The vertical profile of each calibration device will be traceable to a national standard.

The calibration device and tire pads shall be connected to an electronic device that performs the following tasks:

- Randomly displaces the tire pads.
- Assures that the vehicle speed is equal to the simulated speed of the rotating calibration system.
- Able to continually record the vertical position of each tire (pad/roller) and simultaneously record the exact position of the calibration device.

Phase 2: If the phase 1 study proves feasible, the second phase will provide for the development of a prototype verification system. The system will need to meet the specifications developed by the Smoothness ETG and adopted by AASHTO as a Standard Practice. An operation manual and training manual will be developed for the equipment. The center will be demonstrated first to the states that participate in the pooled fund study.

Urgency – This type of equipment will greatly facilitate acceptance procedures for profilers by providing validation capabilities. Variations in profile data hinder research and maintenance/rehabilitation activities by making it difficult to establish clear trends in performance. The vertical profile of each calibration device will be traceable to a national standard.

Phase 3: The final task will provide for the deployment/demonstration of the verification center. A team would be assembled that has experience in the operation of profiler equipment, such as Federal Lands. Their goal would be to deliver and test the various types

of profiler equipment for the participating SHAs. This could be performed by a consultant or by a participating agency.

Task 5. Investigate methods to identify localized roughness for construction specifications

Under this task, a TWG will direct a consultant to review current methods, develop and present methodology that will address the establishment of thresholds for acceptable vehicle induced dynamic forces; identify the magnitude and location of bumps that induce these levels of dynamic forces, and, finally, develop a computer algorithm that will output the location of undesirable bumps. This process may be incorporated as part of the FHWA Profile Viewer software that is currently in beta testing.

Urgency - This effort aids the development of construction ride specifications and evenness that needs to be maintained to determine user comfort. Every year highway agencies spend thousands of dollars in incentive payments to provide smooth riding pavements. It is essential to know that the smoothness obtained through construction specifications and incentive payments are providing the ride quality that matches user comfort.

Tentative Budget

Item		Cost
Task # 1: Administration		
Meetings		$6,400
Travel		$160,000
Publications		$10,000
	Task 1 Subtotal	**$176,400**
Task # 2: Profiler Specification Deployment		
Meetings		$1,600
Travel		$16,000
Publications		$10,000
Workshops		$60,000
	Task 2 Subtotal	**$87,600**
Task # 3: Profiler Calibration		
Meetings		$4,800
Travel		$36,000
Location Development		$254,000
	Task 3 Subtotal	**$294,800**
Task # 4: Profile Calibration Equipment	**Task 4**	
Phase I: Feasibility Study		
Meetings		$2,400
Consultant		$50,000
Travel		$24,000
Specifications		$5,000
	Phase I Subtotal	**$81,400**
Phase II: Equipment Development		
Consultant (Developer)		$501,000
Travel		$4,800
Meetings		$48,000
	Phase II Subtotal	$553,800
Phase III: Deployment of System		
Meetings		$3,200
Travel		$32,000
Consultant		$144,000
	Phase III Subtotal	$179,200
Task # 5: Profile Bump Identification for Construction Specifications		
Meetings		$3,200
Travel		$32,000
Consultant: Software Development		$225,000
	Task 5 Subtotal	$260,200
	Total	**$1,632,900**

It is anticipated that 20 states need to participate for four years at approximately $20,000 per year. *(As part of the FHWA effort of supporting smooth pavements, FHWA will commit funding for the first year of $40,000. This is a tentative commitment as of June 25, 2002)*

Additional Comments

Study Management – It is recommended that the study be administered by FHWA with technical management provided by the participating DOTs through means of a Technical Working Group. It is anticipated that the current FHWA ETG on Smoothness, which has developed the current draft version of the AASHTO Standards of Practice, would continue to function as an advisory group and participants of this study. This method is chosen due to the nature of the scope of work involved, the need to get many SHAs involved, the need to work with industry groups, etc. The SHAs financially participating may also choose to technically participate, at their discretion. This will automatically include them in the TWG. FHWA will provide study facilitation services and technical specialists either from in-house staff or with contract staff support assistance.

Road Profiler User Group (RPUG) – It is noted that RPUG is an excellent resource for contributing and participating in the Study details. It is proposed that the leadership of RPUG be invited to participate as advisors to the study, if they are not participants via the DOT route. It is also suggested that the vendors that participate in RPUG be included in some capacity in the study.

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Appendix: Recent Documentation

Supporting Documentation on Profiler Technology provided through research by Ewa Rodzik, Highway Engineer, FHWA:

- (DRAFT) AASHTO Designation PP50-02 Standard Equipment Specification for an Inertial Profiler
- (DRAFT) AASHTO PP 51-02 Standard Practice for Certification of Profiling Systems - 04/24/02
- (DRAFT) AASHTO PP 52-02 Standard Practice for Operating Inertial Profilers - 04/24/02
- (DRAFT) AASHTO PP 53-02 Standard Practice for Determining Ride Quality - 04/24/02
- "Continuous Improvement of Pavement Management Data, A Roadmap for the Implementation of AASHTO Provisional Standards on Pavement Management Data Collection," December 22, 2000.
- PIARC EVEN (Longitudinal and Transverse Evenness) draft final report
  - True profile database from U. S., Europe, and Japan
  - European FILTER Reports
- Various published LTPP reports on longitudinal and transverse profile.
- Profile Viewer Software Development Statement of Work, FHWA, April 2001.
- "A High Speed Profiler Based Slab Curvature Index For Jointed Concrete Pavement Curling and Warping Analysis," University of Michigan, 2001, Christopher Byrum (PhD Thesis)
- Research Related to Development of a Dynamic Load Index (Roughness Level that Reduces PCC Pavement Service life), Chatti, et al. Michigan State University
- NCHRP 20-51(02), August 26-28, 2001 National Pavement Smoothness Workshop and supporting material.
- "Analysis of Response to the Environment including FHWA Contract Research on Measurement and Analysis of Slab Curvature in JPC Pavements Using Profiling Technology", 7th International Conference on Concrete Pavements
- 2001 TRB Annual Meeting Presentations

Planned

- FY 2002 FHWA LTPP Data Analysis Project, Characterization of PCC Pavement Curvature, Computed Parameters for the LTPP Database.

[i] NCHRP Web Document 1 (Project 1-31) "Smoothness Specifications for Pavements" pg. 162, para. 3
[ii] NCHRP Web Document 42 (Project 20-51[1]): Contractor's Final Report. "Issues in Pavement Smoothness: A Summary Report"