Study for Establishing Regional Certification Centers for Inertial Profilers

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16. Abstract

The objective of this project was to investigate the viability of establishing regional centers that can serve as certification locations for certifying profilers that collect network level data as well as project level data that is used for smoothness acceptance. The following activities were performed in this study: (1) review existing profiler certification programs, (2) review the capabilities of existing facilities that can potentially serve as regional profiler certification centers, (3) provide recommendations on requirements of a regional profiler certification center, such as surface type of pavements, texture types, roughness ranges of test sections, length of test sections, allowable maximum grade of test sections, grade changes within test sections, testing speeds, frequency of certification etc., (4) identify needs and procedures for profiler operator certification, (5) identify costs associated with setting up a new regional profiler certification center, (6) identify ownership, management, and staffing requirements for a regional profiler certification center, (7) identify possible locations for setting-up regional profiler certification centers, (8) describe procedures to establish a pilot program for a regional profiler certification center, (9) identify funding scenarios for functioning of a regional profiler certification center, (10) identify potential obstacles for setting up regional profiler certification centers, and (11) identify potential obstacles that could prevent SHAs from using a regional profiler certification center.

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ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
ALDOT	Alabama Department of Transportation
ARRB	Australian Road Research Board
Caltrans	California Department of Transportation
CDOT	Colorado Department of Transportation
CRC	Continuously Reinforced Concrete
DMI	Distance Measuring Instrument
DOT	Department of Transportation
ETG	Expert Task Group
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
GPS	Global Positioning System
HPMS	Highway Performance Monitoring System
ICC	International Cybernetics Corporation
IRI	International Roughness Index
JPC	Jointed Plain Concrete
JRC	Jointed Reinforced Concrete
LTPP	Long-Term Pavement Performance
MDOT	Michigan Department of Transportation
MnDOT	Minnesota Department of Transportation
NMDOT	New Mexico Department of Transportation
NCAT	National Center for Asphalt Technology
NHI	National Highway Institute
NJDOT	New Jersey Department of Transportation
ODOT	Ohio Department of Transportation
OGFC	Open-Graded Friction Course
PennDOT	Pennsylvania Department of Transportation
PFC	Permeable Friction Course
MAP-21	Moving Ahead for Progress in the 21st Century
NHI	National Highway Institute
PCC	Portland Cement Concrete
PMS	Pavement Management System
PI	Profile Index
QC	Quality Control
QA	Quality Assurance
RPUG	Road Profiler Users' Group
SHAs	State Highway Agencies
SMA	Stone Matrix Asphalt
SSI	Surface Systems and Instruments
TTCP	Technician Training and Certification Program
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation
UMTRI	University of Michigan Transportation Research Institute

VDOT	Virginia Department of Transportation
VIN	Vehicle Identification Number
VTTI	Virginia Tech Transportation Institute
WisDOT	Wisconsin Department of Transportation

CHAPTER 1. INTRODUCTION

The federal government has provided some form of highway funding to the states for the past 100 years (Kirk, 2013). This funding is allocated to each state through a mathematical formula and can only be spent on highway construction activities for roads that are designated as federal-aid highways (Kirk, 2013). The 2012 surface transportation reauthorization act Moving Ahead for Progress in the 21st Century (MAP-21) requires the use of performance management principles to ensure that the federal investment into the nation's highway system can achieve the greatest possible return. Pavement condition data of high quality are needed in order to use performance management principles to determine whether performance targets related to pavement condition have been met.

State Highway Agencies (SHAs) use roughness data collected on their highway network to keep track of the roughness of their highway network. Some SHAs collect network level roughness data using their own equipment, while others contract this service to vendors. The Federal Highway Administration (FHWA) has been using the roughness data submitted by SHAs to the Highway Performance Monitoring System (HPMS) to assess the condition of the nation's highways. The HPMS field manual (Federal Highway Administration, 2013) describes the highways for which roughness data has to be submitted by the SHAs. The roughness data for these highways have to be submitted in terms of the International Roughness Index (IRI). Profile data collected by an inertial profiler on these highways is needed to compute the IRI. In order to ensure the IRI data submitted by each SHA is accurate, there is a need to verify that the inertial profilers are collecting accurate profile data. This can be performed by subjecting the profiler to a certification procedure before data collection. In the certification procedure, the repeatability and accuracy of the data collected by the profiler is checked to see if they meet specified thresholds. Profilers that meet these thresholds are considered to be certified. Recently there has been an interest in exploring the possibility of setting up regional profiler certification centers to certify profilers that collect network level profile data on state highway systems. Using such certified profilers to collect data will ensure that similar data are collected by all SHAs, which will result in the ability to compare roughness values among the states with a high confidence.

Recognizing that the ride quality of highways is important to the travelling public, SHAs have been using smoothness specifications to ensure that smooth pavements are constructed. Studies have shown that pavements that are built smoother stay smoother longer and provide a longer service life (Smith et al., 1997; Perera and Kohn, 2001), which is another incentive for the SHAs to ensure that pavements that are constructed have a high smoothness level. A smoothness specification indicates the highest level of roughness that may be present on a final paved surface to justify full payment to the contractor. Today, most SHAs use the IRI to judge the roughness of new construction. SHAs require the contractor to correct the surface to address localized roughness areas in new construction as defined in their smoothness specification. Many SHAs apply a negative pay adjustment (i.e., a penalty) when the final surface is rougher than the specified IRI threshold and a positive pay adjustment (i.e., a bonus) when it is smoother.

As described previously, profile data collected by an inertial profiler is needed to obtain the IRI. Some SHAs use their own equipment to collect profile data on new construction to assess the roughness level; other SHAs allow contractors or a testing company to collect this data. SHAs that allow contractors or a testing company to collect data have certification programs to certify profilers that collect such data. Only data collected by a certified profiler is accepted by the SHA. Many SHAs require the profiler operators who collect data for smoothness acceptance to be certified, and have operator certification procedures in place to certify profiler operators. Typical operator certification programs consist of a written test and a practical test. In the practical test, the operators are asked to demonstrate their ability to perform calibration checks on the equipment and demonstrate their ability to collect and analyze the collected data.

There is a wide variation in the level of sophistication of the profiler certification programs that have been set-up by various SHAs. Many SHAs have had difficulties in implementing profiler certification programs and operator certification programs due to a variety of reasons. Some of the obstacles faced by SHAs in setting-up profiler certification programs are:

- Finding a suitable location for setting-up test sections needed for a certification program.
- Finding all of the surface types that are needed for profiler certification at a suitable location.
- Lack of a suitable reference device to perform reference profile measurements due to funding issues.
- Lack of personnel to administer a profiler certification program.
- Knowledge of persons within the SHA to setup and administer a profiler certification program.
- Lack of the expertise needed to resolve disputes.

Some of the obstacles faced by SHAs in setting-up profile operator certification programs are:

- Lack of a suitable training program to provide knowledge to profiler operators.
- Lack of guidelines on how to set-up a profile operator certification program.
- Lack of guidelines on what items should be covered for operator certification.
- Whether a profile operator certification program should include a written exam, and if so where the operators can obtain the knowledge before taking the exam.

Due to these issues, there has been an interest recently to explore the possibility of setting up regional certification centers to certify profilers that collect smoothness data on new construction for Quality Assurance (QA) purposes. This will include profilers owned by contractors and testing companies, as well as SHA owned equipment. There is a possibility some SHAs may use the same profiler to collect network level data, as well as smoothness data on new construction for QA purposes.

The objective of this project is to investigate the viability of establishing regional centers that can serve as certification locations for certifying profilers that collect network level data, as well as for certifying profilers that collect project level data for smoothness acceptance. The following tasks will be performed in this study:

- Review existing profiler certification programs.
- Review the capabilities of existing facilities that can potentially serve as regional profiler certification centers.
- Provide recommendations on requirements of a regional profiler certification center, such as surface type of pavements, texture types, roughness ranges of test sections, length of test sections, allowable maximum grade of test sections, grade changes within test sections, testing speeds, traffic considerations, frequency of certification etc.
- Identify needs and procedures for profiler operator certification.
- Identify costs associated with setting up a new regional profiler certification center.
- Identify ownership, management, and staffing requirements for a regional profiler certification center.
- Identify possible locations for setting-up regional profiler certification centers.
- Identify procedures to establish a pilot program for a regional profiler certification center.
- Identify funding scenarios for functioning of a regional profiler certification center.
- Identify potential obstacles for setting up regional profiler certification centers.
- Identify potential obstacles that could prevent SHAs from using a regional profiler certification center.
- Review the recently updated American Association State Highway and Transportation Officials (AASHTO) standard R 56-14, Standard Practice for Certification of Inertial Profiling Systems and identify any deficiencies that are evident related to the certification of network level inertial profiling systems and provide recommendations on updating the standard.
- Identify whether there is a need for a new AASHTO standard on setting-up of regional profiler certification centers, and if needed, provide recommendations on contents of such a standard.

Chapter 2 of this report presents background information on profile data collection including a description of the types of inertial profilers, reference profile measurements, current procedures used for network level data collection, current procedures used for smoothness data collection for construction acceptance, standards addressing inertial profilers, certification of inertial profilers, types of height sensors used in profilers, and resources that are available for pavement smoothness. Chapter 3 presents information about existing profiler certification programs. Chapter 4 presents information about existing pavement test facilities that has the potential to be used as regional certification centers. Chapter 5 presents results from a survey regarding profiler certification that was performed on behalf of the pooled fund study TPF-5(063), Improving the Quality of Pavement Profiler Measurement. Chapter 6 presents the requirements needed at a regional certification center, such as surface types, texture types, roughness ranges, speed of testing, length of test sections, geometrical requirements of test sections, frequency of certification, and operator certification. Chapter 7 presents information on other issues related to establishing and operating regional certification centers such as ownership, management, and staffing requirements; possible locations for setting-up regional certification centers; costs associated with setting-up a new profiler certification center; costs associated with operating a regional certification center; funding scenarios for running a certification center; potential obstacles for setting-up a regional certification center; need for a new AASHTO standard on setting-up a regional certification facility; and resources needed to establish a pilot program for a regional certification center.

CHAPTER 2. BACKGROUND INFORMATION ON PROFILE DATA COLLECTION

2.1 INERTIAL PROFILERS

2.1.1 History of Inertial Profiler Use in the United States

Inertial profilers record the true profile of a pavement surface that affects ride quality. A schematic diagram of an inertial profiler is shown in figure 2.1. The principal components of an inertial profiler are the height sensors, accelerometers, and the distance measuring instrument (DMI). The height sensor records the height to the pavement surface from the face of the sensor. The accelerometer that is located on top of the height sensor records the vertical acceleration of the vehicle. The acceleration is mathematically converted to vertical displacement. Data from the height sensor and the accelerometer are combined to determine the distance to pavement surface relative to an inertial reference frame. The DMI keeps track of the distance with respect to a reference starting point. A computer program is used to compute the profile at each data recording point using the data recorded by the height sensor and the accelerometer. The computed profile data are then recorded in the computer.

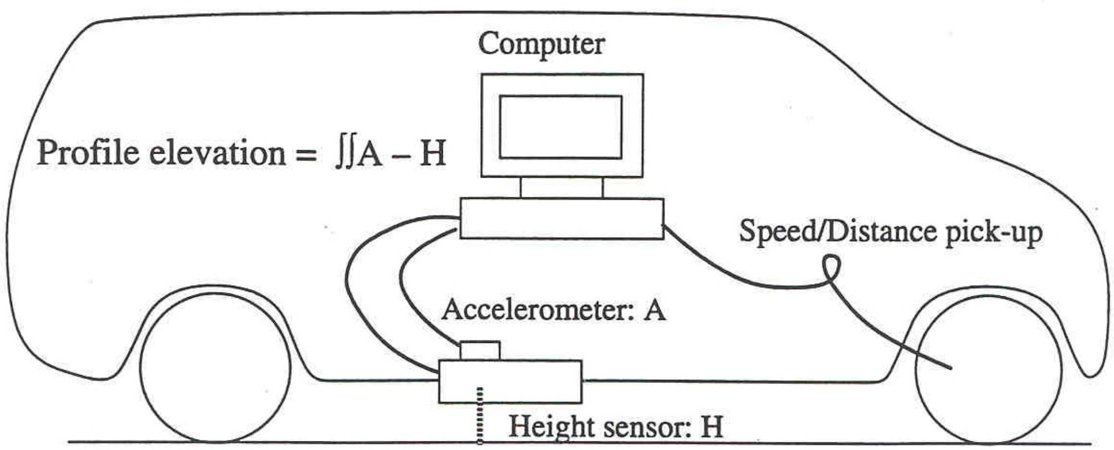


Figure 2.1. Components of an inertial profiler (Sayers and Karamihas, 1998).

The first inertial profiler was developed by Elson Spangler and William Kelley at the General Motors Research Corporation in the early 1960s (Spangler and Kelley, 1964). This profiler was able to collect profile data on pavements at highway speeds. The first company to commercially market inertial profilers in the United States was K.J. Law Engineers; however, these profilers were very expensive, and only a few SHAs were able to purchase the equipment.

In 1981, the South Dakota Department of Transportation (DOT) developed and constructed an inertial profiler that was capable of collecting profile data at highway speeds (Huft, 1984). This profiler was relatively low cost and used ultrasonic height sensors. Several other SHAs used the technology developed by South Dakota DOT and built their own profilers. By early 1990s, several other manufacturers were marketing inertial profilers, and many SHAs in the United

States had inertial profilers that were used to collect profile data at the network level, and then compute a roughness index (typically IRI) from the data. The roughness index was entered into a pavement management system (PMS), and the SHAs used this information to keep track of the roughness of their highway network. During early 1990s, profiler comparisons that were conducted under the auspices of the Road Profiler Users' Group (RPUG) showed that the ultrasonic height sensors overestimated the roughness of textured surfaces such as chip seals (Perera and Kohn 1994; Perera and Kohn, 1995). By then, the cost of laser sensors had decreased. Based on the findings from the RPUG studies, SHAs replaced the ultrasonic height sensors in their profilers with laser height sensors. All profilers in use today use laser height sensors.

Recognizing the importance of ride quality to the travelling public, highway agencies in recent years have ensured that smooth pavements are being built by employing a smoothness specification for new pavement construction and rehabilitation projects. In the early 1990s, most highway agencies were using the Profile Index (PI) obtained from the Profilograph as the ride quality index to judge the smoothness of new and rehabilitated pavements.

However, since early 2000, SHAs started to adopt the IRI as the ride quality measure to judge the smoothness of new and rehabilitated pavements for construction acceptance. An inertial profiler is used to obtain the profile data that are needed for the computation of IRI. Until IRI was adopted as the ride quality index to measure the smoothness of new construction, SHAs used inertial profilers only to measure the roughness of their highway network. After adopting IRI as the index to judge the ride quality of new pavements, SHAs have the additional task of measuring the ride quality of new construction using inertial profilers. Some SHAs perform ride quality measurement of new construction using their own profilers. Some SHAs allow contractors or a testing company hired by the contractor to perform ride quality measurements, with the SHA performing QA testing on a portion of the pavements.

2.1.2 High-speed Profilers

An inertial profiler that collects data at highway speeds is typically referred to as high-speed profiler, with the profiling system typically being housed on a van. Figure 2.2 shows a photograph of a high-speed profiler. In this profiler the sensors that collect profile data are housed inside a sensor bar that is attached to the front of the van.

2.1.3 Lightweight Profilers

As ride quality measurements of new construction was gaining increased acceptance, profiler manufacturers outfitted profiling systems on light utility vehicles so that profiling of Portland cement concrete (PCC) pavements could be performed as soon as the pavement could support the weight of the utility vehicle. Such profilers were referred to as lightweight profilers, and typically the utility vehicle weighed about 950 lb without the operator. A high-speed profiler that is housed on a van would have to wait several days before profiling a new PCC pavement until it gained sufficient strength to carry the weight of the van. Figure 2.3 shows a photograph of a lightweight profiler. A lightweight profiler has all the functionality of a high-speed profiler except that the highest speed at which it could profile is limited to the maximum speed of the utility vehicle, which is typically 15 to 20 mi/h. Although lightweight profilers were primarily developed to measure the profile of newly placed PCC pavements, they can be used to profile both asphalt concrete (AC) and PCC pavements.

Figure 2.2. High-speed profiler.

Figure 2.3. Lightweight profiler.

2.1.4 Portable Profilers

By mid 2000s, profiler manufacturers started to market portable profiling equipment. The portable profiling equipment consists of a bar that houses the height sensors, accelerometers, and a signal processing unit. The portable system can be mounted on the back hitch of a van or a truck (see figure 2.4), or in the front of a vehicle that is specially configured to house the system (see figure 2.5). A separate encoder is attached to a wheel of the host vehicle, and the output from the encoder is sent to the signal processing unit located on the bar. This signal processing unit is then connected to a laptop computer located inside the vehicle by an Ethernet cable. The portable system eliminated the need to have a dedicated vehicle to house the profiler, as this system can be installed in any suitable vehicle. These portable profiling systems have been popular with paving contractors, as they do not need a dedicated vehicle to house the profiler. When not needed, the profiling system is taken off the vehicle, and the vehicle can be used for other purposes. Also, such a system can be shipped to any location, and then fitted onto a van or a truck.

Figure 2.4. Portable profiler mounted on the back of a vehicle.

Figure 2.5. Portable profiler mounted on the front of a van.

2.2 REFERENCE PROFILE MEASUREMENTS

2.2.1 Equipment for Reference Profile Measurements

In order to evaluate the accuracy of an inertial profiler, a reference profile collected at the test section is needed. Initially the rod and level was used to obtain reference profile measurements. Thereafter, in the 1990s the Dipstick and the Australian Road Research Board (ARRB) walking profiler were commonly used to measure reference profiles. The Dipstick recorded data at 12 inch intervals while the ARRB Walking Profiler recorded data at 9.5 inch intervals. With advances in technology, inertial profilers were capable of recording data at 1 inch intervals by late 1990s. Therefore, a reference device that was able to record data at an interval that was comparable with the inertial profilers was needed.

In the early 2000s, International Cybernetics Corporation (ICC) and Surface Systems and Instruments (SSI) developed a rolling device that was capable of recording profile data at 1 inch intervals. A question that was asked at that time was how the data collected by a reference device could be validated. The FHWA sponsored a study called Critical Profiler Accuracy Requirements (Karamihas, 2005) that documented the requirements of a reference device. Thereafter, FHWA sponsored a study that was performed by the University of Michigan to develop a benchmark device that could be used to evaluate potential reference devices (Winkler et al., 2013).

The FHWA sponsored reference profiler evaluation studies in 2009, 2010 and 2013 where data collected by reference devices were compared with data collected with the benchmark device that was developed by the University of Michigan. In these studies, several test sections having a variety of surface textures were used to compare measurements. The results from the evaluations performed in 2009 and 2010 are documented by Karamihas (2011). Karamihas and Perera (2013) describe the results obtained from the evaluation performed in 2013. These reports document the repeatability and the accuracy of the reference devices that participated in these studies. SHAs interested in purchasing a reference device can refer to these documents to see the performance of the different devices.

The following is a brief description of the reference devices that were described above.

2.2.2 Rod and Level

The ASTM standard E 1364-95, Test Method for Measuring Road Roughness by Static Level Method (ASTM, 2014A) describes the procedures to be followed to collect rod and level data at a test section. The most important factor when collecting rod and level data is to make sure that the resolution of the level meets the requirements outlined in the ASTM standard. Rod and levels that are used for standard surveying work do not meet the resolution requirement indicated in ASTM E 1364-95. Another important aspect of collecting data with the rod and level is to setup the level as low as possible so that errors due to the rod being not perfectly vertical during measurements can be minimized.

2.2.3 ARRB Walking Profiler

The walking profiler is manufactured by ARRB. Figure 2.6 shows a photograph of the ARRB walking profiler with its cover off to show the details of the equipment. This device is a multi-wheeled inclinometer based system that is pushed by an operator at walking speed. The typical operation speed is 0.5 mi/h. The device records the relative elevation of successive points at 9.5 inch intervals, and stores the readings on a laptop computer. All incremental changes are totaled giving the height of every measured point and its distance relative to the starting point. The device is reported to be capable of measuring elevations to an accuracy of± 0.0787 inches of height over a distance of 328 ft.

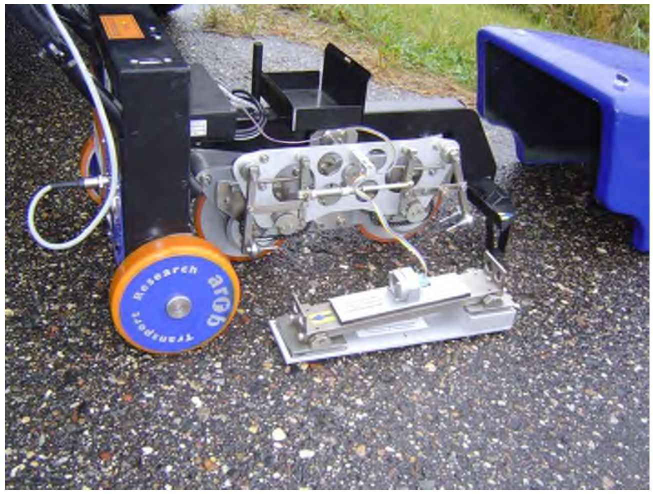


Figure 2.6. ARRB walking profiler.

2.2.4 Dipstick

The Dipstick is a hand held device manufactured by Face Corporation. The Dipstick stands on two swivel feet, and has a stand to support it when it is not in use. The distance between the two swivel feet is usually set to 12 inches. Figure 2.7 shows the operating principle of the Dipstick.

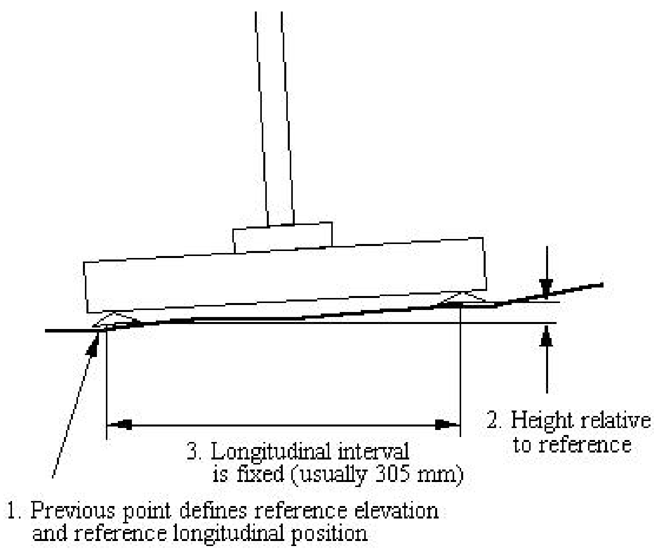


Figure 2.7. Elevation measurements by Dipstick. (Karamihas and Sayers, 1998).

The equipment has two liquid crystal displays at each end that shows the elevation difference between the two swivel feet. The operator walks the unit along the path to be measured by rotating the unit. The reading displayed on the front display is recorded at each position of the Dipstick. An option available with the Dipstick is to use a computer to record the displayed data. The data collected by the Dipstick can be used to obtain the elevation profile.

2.2.5 SurPRO

The SurPRO is manufactured by ICC. Figure 2.8 shows a picture of the SurPRO. The device has two wheels and it is pushed along the pavement to obtain elevation measurements. This device is capable of recording elevation data at 1-inch intervals. The device can be operated at speeds up to 2.5 mi/h, but a slower speed is necessary for best results on rough or coarse textured surfaces.

Figure 2.8. SurPRO.

2.2.6 SSI Walking Profiler

SSI manufactures a walking profiler that is capable of recording elevation data at 1 inch intervals. Figure 2.9 shows a picture of the SSI Walking Profiler. The device has three wheels on one side and two wheels on the other side. The device is pushed with the three wheels traversing the path where measurements are needed. A Panasonic Toughbook computer placed on the stand attached to the handle is used to record the collected data. The device is equipped with an encoder to keep track of the distance and an inclinometer to measure the longitudinal slope. The device can be operated at speeds up to 3 mi/h, but a slower speed is necessary for best results on rough or coarse textured surfaces.

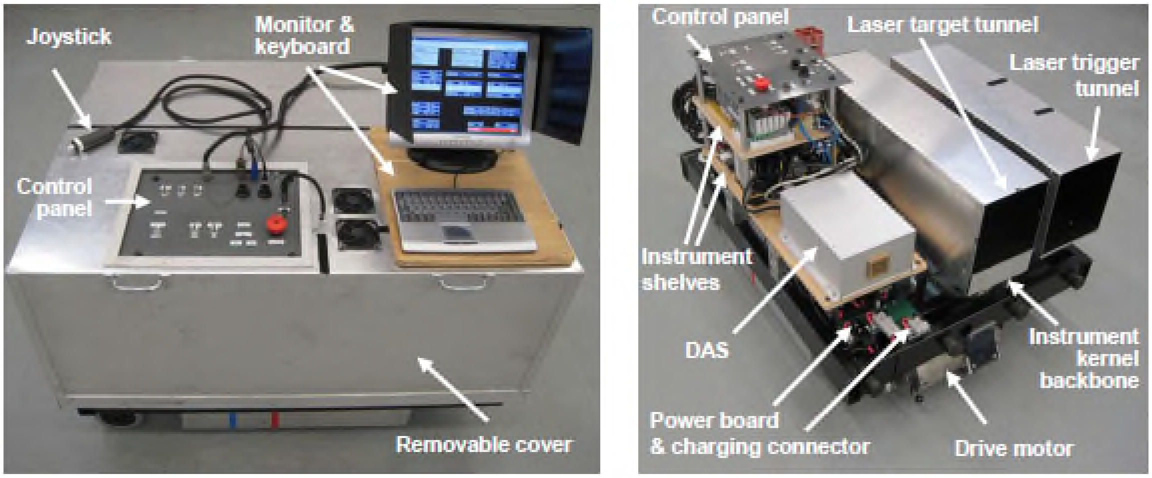
2.2.6 Benchmark Profiling Device

The benchmark profiler is a three-wheeled self-propelled cart equipped with an instrumentation package that allows it to make highly accurate and highly repeatable measurements of road surface profiles (Winkler et al., 2013). This device locates its vertical position by detecting a stable plane that is established using a spinning laser. The device measures the elevation of the road beneath its chassis using a line laser that measures the pavement along a 4 inch width. The device is controlled by the on-board computer and is guided by a machine vision system that senses a nylon-coated steel tape laid down on the road surface adjacent to the longitudinal profile being measured. The device is controlled by an operator using a joystick for transport other than actual profile measurement.

Figure 2.9. SSI CS 8800 Walking Profiler.

Figure 2.10 shows a photograph of the benchmark profiler tracking the guidance tape autonomously with the spinning laser in the background. The key elements of the measurement system, which are the RoLine laser, the laser targets, and the two machine vision cameras, are mounted on a single rigid “backbone” structure. This instrumentation kernel as well as all the other technical elements of the profiler is fully enclosed in an insulated aluminum cover during normal use. Photographs of the benchmark profiler, with and without its cover in place, are shown in figure 2.11.

Figure 2.10. Benchmark profiler (Winkler et al., 2013).



a. From the left, with its cover in place

b. From the left rear, with its cover removed

Figure 2.11. Benchmark profiler with and without cover in place (Winkler et al., 2013).

2.3 CURRENT PROCEDURES FOR NETWORK LEVEL DATA COLLECTION

SHAs collect roughness data in terms of IRI on their highway network and store the data in a PMS. These data can be used to assess the overall roughness of the highway network, track progression of roughness over time, and identify pavement sections for rehabilitation. Usually, the roughness information is stored in the PMS at 0.1 mile intervals. SHAs are required to annually submit the IRI values of their highway network to the FHWA as a part of the data submittal for the HPMS. For the pavements in the state owned highway system, the IRI data stored in the PMS are used to obtain the IRI data needed for this submittal.

Many SHAs have contracted with vendors to collect roughness data of their highway network. As SHAs need other information about their highway network in addition to pavement roughness, these vendors use multi-function data collection vehicles to collect a variety of data. Some SHAs own their own multi-function data collection vehicles and use these vehicles to collect data on their highway network. A typical multi-function data collection vehicle contains a variety of subsystem such as:

- Cameras to collect images of the pavement surface to identify pavement distress.
- Additional cameras to collect the right-of-way view.
- A road profiling system to collect longitudinal profile data.
- A transverse profile data collection system to obtain rut depths.
- An inertial motion system to measure cross fall, grade, and radius of curves.
- A Global Positioning System (GPS) to collect latitude and longitude data.
- A special laser to collect macrotexture data.

The major manufactures of multi-function data collection vehicles in the United States are Dynatest Consulting, Fugro-Roadware, ICC, Mandli Communications, and Pathway. Figures

2.12 through 2.16 show images of multi-function data collection equipment of these manufacturers.

Figure 2.12. Dynatest multi-function data collection equipment.

Figure 2.13. Fugro-Roadware multi-function data collection equipment.

Figure 2.14. ICC multi-function data collection equipment.

Figure 2.15. Mandli communications multi-function data collection equipment.

Figure 2.16. Pathway multi-function data collection equipment.

2.4 CURRENT PROCEDURES FOR SMOOTHNESS DATA COLLECTION FOR CONSTRUCTION ACCEPTANCE

The procedures used today in the United States for collecting smoothness data of new construction for construction acceptance (QA testing) fall into one of the following three scenarios.

- Smoothness Data Collected by SHA: The smoothness data are collected by the SHA and analyzed by the SHA. Contractors may use profilers to obtain smoothness information for their own quality control (QC) purposes. However, data collected by the contractors are not accepted by the SHA for construction acceptance.

- Smoothness Data Collected by the Contractor: The SHA accepts smoothness data collected by the contractor for evaluating the smoothness of new construction. Only profilers that are certified by the SHA are allowed to collect data. In many states, the profiler also has to be operated by an operator who has been certified by the SHA. Data collection is performed in the presence of an official from the SHA. The SHA may elect to profile a limited number of sections for verification of the contractor collected data or if there is a question about the validity of the data collected by the contractor.

- Smoothness Data Collected by a Testing Company Hired by the Contractor: In states that allow contractors to collect smoothness data for construction acceptance, some contractors may not own profiling equipment. The contractor in this case hires a testing company that has profiling equipment to collect the data and submit the data to the SHA. In this case, the testing company's equipment must be certified by the SHA. The SHA may elect to profile a limited number of sections for verification of the testing company collected data or if there is a question about the validity of the data.

2.5 STANDARDS ADRESSING INERTIAL PROFILERS

The first standard that addressed inertial profilers in the United States was ASTM Standard E 950, Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling System, which was first published in 1983. ASTM Standard E 950-09 (ASTM, 2014B) addresses components of the profiler, calibration procedures, and procedures to determine the bias and the precision of the equipment. This standard is currently being revised.

In 2001, the FHWA convened a Pavement Smoothness Expert Task Group (ETG) to develop standards related to pavement smoothness. The ETG developed four standards, and these were first published by AASHTO in 2003 as provisional standards. In 2010, the four provisional standards were accepted as full standards by AASHTO. The following are the four standards related to pavement smoothness:

- M 328-14: Standard Equipment Specification for Inertial Profiler (AASHTO, 2014A).

- R 54-14: Standard Practice for Accepting Pavement Ride Quality when Measured using Inertial profiling Systems (AASHTO, 2014B).

- R 56-14: Standard Practice for Certification of Inertial Profiling Systems (AASHTO, 2014C).

- R 57-14: Standard Practice for Operating Inertial Profiling Systems (AASHTO, 2014D).

AASHTO has another standard R 43-13, Standard Practice for Quantifying Roughness of Pavements (AASHTO, 2014E), which outlines standard procedures for measuring a longitudinal profile and calculating the IRI for highway pavement surfaces to produce consistent estimation of IRI for network-level pavement management.

2.5.1 ASTM Standard E 950-09

ASTM Standard E 950-09 is titled Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference (ASTM, 2014B). This standard covers the following items:

- Components of the profiler.
- Requirements for the height sensor, accelerometer, and DMI.
- Longitudinal data sampling interval for various classes of profilers.
- Data recording and storage medium.
- Calibration procedures for accelerometer, height sensor, and DMI.
- Calibration checks.
- Measuring speed.
- Data filtering.
- Data acquisition.
- Data evaluation for correctness.
- Procedure to determine precision and bias of the system.

The precision of the device is determined by evaluating the repeatability of the profile data collected by the device. The bias of the device is evaluated by filtering the reference profile data with the filter applied to data collected by the profiler and then comparing the two data sets. The profile data used to evaluate precision as well as bias is the profile data that has been subjected to an upper wavelength cut-off filter. Agreement between such profiles is dominated by the long wavelengths. For repeatability, it is possible to have significant differences in shorter wavelengths that affect ride quality and still pass the precision requirement. Also, it is possible to have significant differences in shorter wavelengths between the inertial profiler data and the reference profile data and yet for the inertial profile data to meet the bias criterion. Hence, the bias and precision procedures outlined in this standard are not good methods for evaluating inertial profilers. This standard is currently under revision by ASTM.

2.5.2 AASHTO Standard M 328-14

AASHTO standard M 328-14 is titled Standard Equipment Specification for Inertial Profiler (AASHTO, 2014A). The objective of this specification is to define the required attributes of an inertial profiling system. This specification covers the following items related to an inertial profiler:

- Accuracy and calibration requirements for the height sensor, accelerometer, and the DMI.
- Triggering mechanisms for initiating data collection.
- Wavelength range for the collected data.
- Data recording interval.
- Software requirements.
- System operating functions.
- Operating speed.
- Data storage.

- Capability of the computer such as displaying data.
- Calculation of roughness indices.
- Operating temperature and humidity ranges.
- Warranties.

2.5.3 AASHTO Standard R 54-14

AASHTO standard R 54-14 is titled Standard Practice for Accepting Pavement Ride Quality When Measured Using Inertial Profiling Systems (AASHTO, 2014B). This practice provides guidance and example specification language intended for use by owner-agencies in development of specific contract language when requiring the measurement and evaluation of ride quality and compliance using inertial profiling systems and the IRI as the ride quality measure. The following items are addressed in this practice:

- Detection of areas of localized roughness.
- IRI ranges for localized roughness (based on a 25 ft base length).
- Language to be used in a ride quality specification.
- Pay adjustment schedules for ride quality.
- Deficiencies and corrective work.

2.5.4 AASHTO Standard R 56-14

AASHTO Standard R 56-14 is titled Standard Practice for Certification of Inertial Profiling Systems (AASHTO, 2014C). This standard describes a certification procedure for inertial profilers. The certification of a profiler will ensure that the device can obtain repeatable and accurate data. This specification covers the following items related to certification:

- Block check to check the accuracy of the height sensors.
- Distance measurement check to check the accuracy of the DMI.
- Bounce test to determine if the accelerometers and the height sensors in the profiler are working accurately.
- Procedures to test if the profile operator is qualified to operate an inertial profiler.
- Test sections to be used for dynamic certification testing.
- Procedures to perform dynamic certification testing.
- Procedures to analyze the data to determine equipment repeatability and accuracy using the cross-correlation technique.
- Procedures to verify the computed ride statistics (i.e., IRI) from the systems software and procedures to report results from testing.

2.5.5 AASHTO Standard R 57-14

AASHTO Standard R57-14 is titled Standard Practice for Operating Inertial Profiling Systems (AASHTO, 2014D). This practice describes the procedures for operating and verifying the calibration of an inertial profiling system. Among the items covered in this practice are:

- Procedures to verify if the DMI is within the specified accuracy requirement.
- Procedures to verify if the height sensors are obtaining readings within the specified accuracy requirement.
- Procedure to perform the bounce test, which is an overall integrity test that checks if the accelerometers and the height sensors in the profiler are working correctly.
- Guidelines on establishing control sections.
- Procedures to be followed during data collection such as location of leave-out sections, speed requirements, lead-in distance, and longitudinal path to profile.

2.5.6 AASHTO Standard R 43-13

AASHTO Standard R 43-13 is titled Standard Practice for Quantifying Roughness of Pavements (AASHTO 2014E). This standard outlines standard procedures for measuring longitudinal profile and calculating the IRI for highway pavement surfaces to produce consistent estimation of IRI for network-level pavement management. This standard covers the following items:

- Transverse spacing between the two sensors that collect data.
- Calculation of IRI.
- Reporting requirements.
- Guidelines for developing a quality assurance plan, which covers certification and training, equipment calibration, verification sections, and quality checks.

2.6 CERTIFICATION OF INERTIAL PROFILERS

2.6.1 Profilers Used for Construction Acceptance Testing

SHAs that allow contractors or a testing company to collect smoothness data for construction acceptance have a profiler certification procedure in place to certify profilers. SHAs that do not allow contractors to collect smoothness data for construction acceptance typically have procedures in place to check that SHA owned equipment is collecting accurate and repeatable data.

Several test sections are established for certifying profilers and reference data are collected at these sections using a reference device. Thereafter, the inertial profiler seeking certification collects data at these test sections with data being collected for several repeat runs. The data collected for repeat runs are used to evaluate the repeatability of the profiler. The data collected by the inertial profiler are compared with reference data collected at the test sections to evaluate the accuracy of the profiler. An inertial profiler must meet specified thresholds in order to pass the repeatability and the accuracy criterion. A profiler that passes the repeatability and the accuracy criterion is considered to be certified.

Many certification programs by SHAs include some elements of AASHTO R 56-14. The cross-correlation method is specified in AASHTO R 56-14 to evaluate the repeatability and accuracy of inertial profilers. While some SHAs are using the cross-correlation method specified in R 56-14 for profiler certification, others are using methods that are different. In such methods, the repeatability of a profiler is evaluated by requiring the standard deviation of IRI computed from repeat profiler runs to be lower than a specified amount. The accuracy is determined by requiring the IRI computed from data collected by a profiler to be within a certain tolerance of the IRI computed from data collected with a reference device.

Usually, before collecting data at test sections, several other checks are performed on the profiler to ensure it is functioning properly. Such checks include:

- Block check to ensure the height sensors are collecting accurate data.
- Bounce test to ensure the accelerometer are cancelling out the vehicle motions.
- A check on the DMI in the profiler to ensure that it is measuring distances accurately.

Some SHAs have a procedure in place to certify operators of inertial profilers. Operator certification can include the operator demonstrating the ability to do the following items: perform a block check, perform a bounce test, calibrate the DMI, collect data at test sections, and analyze the collected data. In addition, operator may be required to demonstrate their knowledge about the state's smoothness specification and procedures to submit the collected data to the SHA. In some states the operator must answer a written exam that covers profiler operation, as well as the state's smoothness specification in order to be certified.

2.6.2 Profilers Used for Network Level Data Collection

SHAs usually do not use a formal certification program to certify their own profilers or vendor owned profilers that collect roughness data at network level. Flintsch and McGhee (2009) summarized the procedures used by SHAs to perform quality management of pavement condition data. This document indicated many SHAs that contract out data collection to vendors have data quality management plans in place. Some SHAs set up control sections in various districts, and the vendor has to profile these sections before starting data collection and after completing data collection. The SHA obtains measurements at these verification sections using their own profiler and compares the roughness value obtained from the SHA device with the vendor's device to ensure that the collected data is accurate. Some SHAs that collect their own data have set-up test sections and collect data on these sections with a reference device and then profile the sections with their profiler and compare the IRI values to check the accuracy of the profiler.

As the network level roughness data collected by the SHA or by the vendor are submitted to the HPMS, where the submitted data are used to assess the condition of the nation's highways, it is important that SHAs have some type of a verification or a certification program for the equipment that collect network level roughness data to ensure the collected data are accurate.

2.7 PROFILE HEIGHT SENSORS

Laser height sensors are used in all profilers today to collect profile data. The most common laser height sensor used today to collect profile data is the single-spot laser that projects a small dot that is typically 0.7 to 3 mm in diameter onto the pavement surface. Research studies have shown single-spot laser sensors cannot collect accurate and repeatable profile data on PCC pavements that have a longitudinal texture, such as longitudinal tining, longitudinal grooves, or diamond grinding (Karamihas and Gillespie, 2003; Perera et al., 2009; Fernando and Harrison, 2013; De Leon Izeppi, 2013). A single-spot laser sensor can obtain measurements on the land area between the longitudinal tines (or grooves) as well as on the trough of the tine (or groove) due to lateral wander as the profiler moves along a pavement. These measurements are misinterpreted as roughness and can result in a significant upward bias in the roughness of the pavement. Some profilers use a wide-spot laser that projects a line that is about 19 mm long and 1 mm wide on the pavement surface. This laser is mounted such that the projected line is perpendicular to the travel direction. It is possible this laser might provide more repeatable data than a single-spot laser because its footprint is much larger than the footprint of a single-spot laser.

Line lasers that typically project a 4-inch wide beam (see figure 2.17) on the pavement can overcome the issue that single-spot laser sensors face on such surfaces. The first line laser to be used in the United States was the RoLine line laser. The RoLine line laser obtains about 190 data points within this 4-inch line. LMI-Selcom who manufactured the RoLine laser discontinued the sale of RoLine lasers in December 2013, and offered a sensor called the Gocater to replace the RoLine laser. The data points obtained by the line laser at a location are sorted and a certain percentage of readings at the top and bottom of the sorted readings are discarded, and the remaining readings are used to obtain an average height. This strategy, referred to as a bridging strategy, eliminates the problem that single-spot laser sensors have on longitudinally textured PCC pavements. Therefore, when collecting smoothness data for construction acceptance on pavements that have a longitudinal texture such as longitudinal tining, diamond grinding, or longitudinal grooving, a profiler that is equipped with a line laser must be used to obtain repeatable and accurate smoothness data. The line laser is typically mounted on the profiler such that the projected line is perpendicular to the travel direction.

A single-spot laser can also cause a slight overestimation of roughness on coarse textured AC surfaces (e.g. stone matrix asphalt), open-graded AC surfaces, and chip seals. Data collected by a line laser on such surfaces can result in IRI values that are slightly lower than the IRI computed from data collected with a single-spot laser on the same surface (Perera and Karamihas, 2010; Fernando and Walker, 2013).

2.8 EFFECT OF SURFACE TEXTURE ON DATA COLLECTED BY LASER HEIGHT SENSORS

This section presents information obtained from a literature review on comparison of IRI values obtained on various texture types from profile data collected with a single-spot lasers and a line laser. In all these comparisons, the line laser data were collected with the line laser mounted such that the projected laser line was perpendicular to the travel direction unless noted otherwise. The information presented in this section is used in chapter 6 of this report to recommended pavement surface and texture types needed at a regional profiler certification center.

Figure 2.17. Line laser.

Information regarding IRI values obtained from a single-spot laser and a line laser on the following surface/texture types are presented in this section:

- Dense-graded AC.
- Stone matrix asphalt (SMA).
- Open-Graded Friction Course (OGFC).
- Chip Seal.
- PCC with transverse tining.
- PCC with longitudinal tining.
- PCC with diamond grinding.
- PCC with longitudinal grooving.

2.8.1 Dense-Graded AC

Dense-graded AC mixes designed in conformance with the Superpave mix design procedure are widely used throughout the United States. Perera and Karamihas (2010) presented IRI values obtained on two dense-graded AC surfaces by a profiler that was built by the University of Michigan Transportation Research Institute (UMTRI) that was equipped with a single-spot laser and a RoLine laser. These two sensors were configured such that they collected data along the same path. This profiler collected data at two 200 ft long test sections (sections N3 and N4) at the National Center for Asphalt Technology (NCAT) test track in Opelika, Alabama. Table 2.1 shows the IRI values obtained by the two sensors at the two test sections. The IRI corresponding to the single-spot laser was higher than the IRI corresponding to the RoLine laser at both sections, with the difference in IRI at the two sections being 2.3 and 1.7 in/mi.

Table 2.1. IRI values from a single-spot laser and a RoLine laser for two dense-graded AC sections (Perera and Karamihas, 2010).

Parameter	NCAT Section Number	
	N3	N4
IRI Single-Spot (in/mi)	45.6	62.4
IRI RoLine (in/mi)	43.3	60.7
Difference in IRI (in/mi)	2.3	1.7
Percent Difference in IRI - Note 1	5.3	2.8
Note 1: Percent difference in IRI with respect to RoLine IRI		

Fernando and Walker (2013) presented a comparison of IRI values obtained from a single-spot laser and a RoLine laser for data collected on two types of dense-graded AC surfaces (Type C and Type D) in Texas in 2009. Both sensors were mounted on the vehicle such that they collected data along the same path. Data were collected on two projects for each mix type with data collected on 14.4 miles for the Type C mix and 7.8 miles for the Type D mix. IRI values were computed at 0.1 mile intervals, and the IRI values from the two sensors were compared statistically. The analysis indicated the IRI from the single-spot laser to be higher than the IRI from the RoLine laser for all projects. The 95 percent confidence interval for the difference in IRI for the two projects that had Type C mix was 0.9 to 1.1 in/mi and 3.5 to 3.9 in/mi, while this value for the two projects that had the Type D mix was 1.9 to 2.1 in/mi and 4.4 to 4.7 in/mi.

Fernando and Walker (2013) compared IRI values obtained from data collected by a Dynatest profiler that was equipped with a single-spot laser and a RoLine laser that collected data along the same path. Data were collected at test sections on nine projects in Texas with the length of the test section typically ranging from 0.5 to 1 mile. The IRI values were computed at 0.1 mile intervals and the difference in IRI values from the two lasers were compared statistically. The average difference in IRI from the single-spot laser and RoLine laser (i.e., single point IRI minus RoLine IRI) for these projects were 0.96, 0.67, 0.47, 0.67,-0.84, 0.64, 0.15, 0.66, and 0.77 in/mi. The 95 percent confidence interval for the difference in IRI from the single-spot laser and RoLine laser (i.e., single-spot IRI minus RoLine IRI) was positive for seven of the eight projects. Hence, for seven of the eight projects tested, the IRI from the single-spot sensor was slightly greater than the IRI from the RoLine laser.

Fernando and Walker (2013) reported in 2009 a profiler equipped with a setup that contained a single-spot laser and a RoLine laser configured such that they collected data along the same path measured two test sections at the Texas A&M Riverside campus. One test section was designated as a smooth section and the other as a medium smooth section. The profiler obtained three repeat runs at both sections, and the average IRI obtained from the collected data were compared. On both sections the IRI from the single-spot laser was higher than the IRI from the RoLine laser. The difference in IRI for the smooth and medium smooth sections was 3.6 and 3.2 in/mi, respectively.

Fernando and Walker (2013) also presented a comparison of IRI values obtained from a single-spot laser and a RoLine laser from another profiler assembled by Texas A&M university for another project at the same two sections described above. The two sensors were configured such that they collected data along the same path. The single-spot laser used in this study was a 78 kHz texture laser from which profile data were obtained in addition to texture data. The IRI from the single-spot laser was higher than the IRI from the RoLine laser for both sections. The difference in IRI for the smooth and medium smooth sections was 1.8 and 2.6 in/mi, respectively.

The results presented above show that on a dense-graded AC surface the IRI from a single-spot laser was higher than the IRI obtained from a line laser. The surface texture of a dense-graded AC surface can vary according to the nominal maximum aggregate size and gradation of the aggregate used for the AC mix. Therefore, the difference in IRI between these two sensor types could vary depending on the macrotexture of the pavement surface.

2.8.2 Stone Matrix Asphalt

SMA is a gap-graded AC, and is designed to minimize rutting by providing stone-on-stone contact. Most of the SMA pavements placed in the United States have a 0.5 or a 0.75 inch nominal maximum aggregate size (Brown and Cooley, 1999). A SMA pavement will have a higher macrotexture than a dense-graded AC mix because of the coarse nature of the mix.

Perera and Karamihas (2010) presented the IRI values obtained on a SMA surface by a profiler that was built by UMTRI that was equipped with a single-spot laser and a RoLine laser. The two sensors in the profiler were configured such that they collected data along the same path. This profiler collected data at a 200 ft long SMA test section at the NCAT test track in Opelika, Alabama. The IRI values corresponding to the data collected by the single-spot laser and the RoLine laser were 74.7 and 71.2 in/mi, respectively. Therefore, the single-spot laser obtained an IRI value that was 3.5 in/mi higher than the IRI from the RoLine laser.

Fernando and Walker (2013) presented a comparison of IRI values obtained from a single-spot laser and a RoLine laser from data collected in 2009 on two projects that had SMA surfaces in Texas. Both sensors were mounted on the same vehicle such that they collected data along the same path. Data were collected on two projects totaling 5.5 miles. IRI values were computed at 0.1 mile intervals, and the IRI values from the two lasers were compared statistically. Most of the IRI values for the 0.1 mile sections were between 50 and 100 in/mi. The analysis indicated the IRI from the single-spot laser to be higher than the IRI from the RoLine laser with the 95 percent confidence interval for this difference for the two projects being 2.6 to 3.0 in/mi and 1.8 to 2.4 in/mi.

The results presented above show that on a SMA surface the IRI from a single-spot laser was higher than the IRI obtained from a line laser. The surface texture of a SMA surface can vary according to the nominal maximum aggregate size and the gradation of the aggregate used for the SMA mix. Therefore, the difference in IRI between these two sensor types could vary depending on the macrotexture of the pavement surface.

2.8.3 Open-Graded Friction Course

An OGFC has a high macrotexture compared to a dense-graded AC surface and provides a high level of skid resistance, particularly in wet weather. The OGFC is placed on top of a dense-graded AC or SMA surface. An OGFC also reduces splash and spray, tire-pavement noise, and headlight glare during rain. An OGFC is porous and has interconnected voids, thus providing high permeability to remove water from the pavement surface. According to Huber (2000), the normal thickness of OGFC surfaces used in the United States is 0.75 inches, with the nominal maximum aggregate size being 0.375 inches, and the air voids content in the mix typically being 15 percent. A survey performed in 1998, where 37 of the 50 states responded, indicated 18 states used OGFC at the time of the survey (Huber, 2000). Most of the states using OGFC were not located in areas that experience a harsh winter.

Perera and Karamihas (2010) presented IRI values obtained on four OGFC surfaces by a profiler that was built by UMTRI, which was equipped with a single-spot laser and a RoLine laser. The two sensors in the profiler were configured such that they collected data along the same path. This profiler collected data at four 200 ft long test sections at the NCAT test track in Opelika, Alabama. The IRI values for the data collected by the two sensors are shown in table 2.2. The IRI obtained from the single-spot laser was higher than that for the RoLine laser at all four sections, with the differences ranging from 1.2 to 7.5 in/mile, with the average difference being 4.7 in/mi.

Table 2.2. IRI values from a single-spot laser and RoLine laser for OGFC surfaces.

Parameter	**NCAT Section Number**			
	N11	**N12**	**S3**	**S4**
IRI Single-Spot (in/mi)	68.0	69.3	65.9	69.7
IRI RoLine (in/mi)	60.5	68.1	62.4	63.0
Difference in IRI (in/mi)	7.5	1.2	3.5	6.7
Percent Difference in IRI - Note 1	12.4	1.8	5.6	10.6
Note 1: Percent difference in IRI with respect to RoLine IRI				

Fernando and Walker (2013) presented a comparison of IRI values obtained in 2009 from a single-spot laser and a RoLine laser for data collected on Permeable Friction Course (PFC) surfaces in Texas. A PFC is similar to an OGFC. Both lasers were mounted on the same vehicle such that they collected data along the same path. Data were collected on three projects totaling 21 lanes miles. IRI values were computed at 0.1 mile intervals, and the IRI values from the two sensors were compared statistically. The IRI values for most of the 0.1 mile intervals segments were between 30 and 60 in/mi. The analysis indicated the IRI from the single-spot laser to be higher than the IRI from the RoLine laser with the 95 percent confidence interval for this difference for the three projects being 6.2 to 6.7 in/mi, 5.8 to 6.5 in/mi, and 10.3 to 10.7 in/mi.

Fernando and Walker (2013) compared IRI values computed from data collected by a Dynatest profiler that was equipped with a single-spot laser and a RoLine laser that collected data along the same path on PFC test sections located on six projects in Texas. The length of a test section on a project typically ranged from 0.5 to 1 mile. IRI values were computed at 0.1 mile intervals, and the IRI values from the two sensors were compared statistically. The following are the average IRI differences for the two lasers (i.e., IRI from single-spot laser minus IRI from RoLine laser) for the six projects with the 95 percent confidence interval for the difference in IRI indicated in parenthesis: 3.21 in/mi (2.50 to 3.92 in/mi), 3.73 in/mi (3.03 to 4.43 in/mi), 6.77 in/mi (6.31 to 7.23 in/mi), 5.27 in/mi (4.69 to 5.84 in/mi), 3.72 in/mi (3.28 to 4.17 in/mi), 3.64 in/mi (3.11 to 4.18 in/mi).

The results presented above show that on an OGFC surface the IRI from a single-spot laser was higher than the IRI obtained from a line laser. The macrotexture of an OGFC surface can vary depending on the nominal maximum size of the aggregate used in the mix. Therefore, the difference in IRI between these two sensor types could vary on an OGFC surface depending on the macrotexture of the pavement surface.

2.8.4 Chip Seal

A single chip seal consists of a layer of asphalt binder covered by one stone thick aggregate. Chip seal is a preventive maintenance strategy, with the primary purpose of placing a chip seal being to seal fine cracks in the pavement surface to prevent intrusion of water into the base and the subgrade. The aggregate used in the chip seal improves the skid resistance of the existing pavement by increasing the macrotexture. Most agencies use a nominal maximum aggregate size that ranges from 0.375 to 0.5 inches for a single chip seal, with the most common size being 0.375 inches (Gransberg and James, 2005). The ideal gradation for an aggregate used as a chip seal is one where all of the stone particles are close to one size (Gransberg and James, 2005). Chip seals are not usually placed on high-speed and high-traffic volume roads because of the potential for stone loss and windshield damage.

Fernando and Walker (2013) presented a comparison of IRI values obtained on chip seal surfaces from data collected by a profiler equipped with a single-spot laser and a RoLine laser. The two sensors were mounted on the vehicle such that they collected data along the same path. Data were collected in 2009 on two projects that had a Grade 3 chip seal (total mileage of 13.6 miles) and one project that had a Grade 4 chip seal that was 24.3 miles long. Texas construction specifications indicate the maximum stone size for a Grade 3 chip seal to be 1-3/4 inches, while the gradation for Grade 4 chip seals are indicated on the plans. IRI values were computed at 0.1 mile intervals, and the IRI values from the two sensors were compared statistically. The analysis indicated the IRI from the single-spot laser to be higher than the IRI from the RoLine laser with the 95 percent confidence interval for this difference for the Grade 3 chip seal being 3.0 to 3.3 in/mi, and that for the Grade 4 chip seal being 5.8 to 6.1 in/mi.

Perera and Karamihas (2010) reported IRI values obtained on chip seal surfaces in Texas by a Dynatest profiler that was equipped with a single-spot laser and a RoLine laser that collected data along the same path. Data were collected on a 4.8 mile long section that had a Grade 3 chip seal and a 5.2 mile long section that had a Grade 4 chip seal, with data being collected in both directions. The Grade 3 chip seal had stones that were slightly larger than the Grade 4 chip seal. The Grade 3 chip seal appeared to be older and it was noted that the aggregates were embedded more into the asphalt when compared to the Grade 4 chip seal. The IRI values computed at 0.1 mile intervals were compared. On the Grade 3 chip seal the majority of the 0.1 mile long segments had IRI values between 80 and 130 in/mi. For the Grade 3 chip seal, in one direction, a slight systemic difference in IRI was noted with the IRI from the single-spot laser being higher. On the other direction, a systemic difference in IRI was also noted with the IRI from the single-spot laser being higher by about 5 in/mi, but this value diminished with increasing IRI. On the Grade 4 chip seal the majority of the 0.1 mile long segments had IRI values between 60 and 100 in/mi. For the Grade 4 chip seal a systemic difference in IRI was noted for the two lasers in both directions, with the IRI from the single-spot laser being higher. On average this difference was about 6 to 7 in/mile. The difference between the single-spot laser IRI and RoLine laser IRI was higher on the Grade 4 chip seal when compared to Grade 3 chip seal although the size of stones used for the chip seal on the Grade 4 chip seal was smaller. However, the stones on the Grade 3 chip seal had a greater depth of embedment than the stones on the Grade 4 chip seal and, also, there was more bleeding on the Grade 3 chip seal. These two factors appear to have reduced the macrotexture depth on the Grade 3 chip seal and this is likely why the IRI from the two sensors were closer to each other on the Grade 3 chip seal than the Grade 4 chip seal.

The results presented above show that on a chip seal the IRI from a single-spot laser was higher than the IRI obtained from a line laser. The magnitude of the difference in IRI between the two sensor types can vary depending on the macrotexture of the surface. Factors that can affect the macrotexture of a chip seal surface are the size of the stone used for the chip seal and the depth of embedment of the stone.

2.8.5 PCC with Transverse Tining

Until recently, transverse tining was used in most high-speed PCC pavements constructed in the United States. Recently, most SHAs that constructed PCC pavements with transverse tining have switched over to incorporating longitudinal tining on PCC pavements as the tire-pavement noise generated by longitudinal tines is less than that generated by transverse tines.

Fernando and Walker (2013) compared IRI values computed from data collected by a Dynatest profiler that was equipped with a single-spot laser and a RoLine laser on continuously reinforced concrete (CRC) pavements that had transverse tining. The two sensors in the profiler collected data along the same path. Data were collected at test sections located on six projects in Texas that had a tine spacing of 1 inch. The length of a test section typically ranged from 0.5 to 1 mile. IRI values were computed at 0.1 mile intervals, and the IRI values from the two sensors were compared statistically. The following are the average IRI differences for the two lasers (i.e., IRI from single-spot laser minus IRI from RoLine laser) for the six projects with the 95 percent confidence interval for the difference in IRI indicated in parenthesis: 0.90 in/mi (0.46 to 1.4 in/mi) , 0.11 in/mi (-0.4 to 0.6 in/mi), 0.68 in/mi (0.02 to 1.33 in/mi), 0.83 in/mi (0.20 to 1.46 in/mi), -1.4 in/mi (-2.3 to -0.54 in/mi) , -0.58 in/mi (-1.21 to 0.03 in/mi). In general, the IRI from the single-spot laser was slightly higher than the IRI from the RoLine laser, but there were some cases where the reverse was true.

Fernando and Walker (2013) presented IRI values reported by Dynatest Consulting who collected data on a transversely tined concrete pavement section in Texas with a profiler that was equipped with both a single-spot laser and a RoLine laser. The sensors were configured such that they collected data along the same path, with the RoLine laser being at a 30 degree angle to the travelled surface. The majority of the 0.1 mile long segments within the tested roadway had IRI values between 40 and 60 in/mi. Dynatest reported the RoLine laser seemed to produce marginally lower IRI values compared to the single-spot laser, but the differences were not regarded to be significant.

Fernando and Walker (2013) presented results from a study that compared IRI values collected on transversely tined pavements with a RoLine laser with the laser oriented at different angles. The following three orientations were studied: (1) laser mounted such that the projected line was perpendicular to travel direction (0°), (2) projected line was at a 30° angle to direction of travel (30°), and (3) projected line was at a 45° angle to direction of travel (45°). Testing was performed on three projects. The data indicated the 45° position resulted in the lowest IRI on all three projects. The average difference in IRI between the 0° and 45° positions for the three projects were 1.5, 3.4, and 6.2 in/mi.

Perera and Karamihas (2010) presented results from a profiler comparison study where data collected by the four profilers that collect data for the Long Term Pavement Performance (LTPP) program were compared. Two test sections used in this study had transverse tining and reference data on these sections were collected with a SurPRO. On one section, the difference between the average IRI from the four profilers and the IRI from the SurPRO (i.e., Profiler IRI minus SurPRO IRI) was 3 in/mi. On the other section, the difference between the average profiler IRI and the SurPRO IRI (i.e., Profiler IRI minus SurPRO IRI) ranged from -2.5 to 1.3 in/mi.

The information presented above indicates the IRI obtained from a single-spot laser on a transversely tined PCC section is expected to be close to the IRI obtained from a RoLine laser. Also, the IRI obtained from a single-spot laser is expected to be close to the IRI obtained by a reference device on a transversely tined PCC surface. It was also shown the orientation of a line laser with respect to the travel direction could have an influence on the IRI values obtained on a transversely tined PCC surface.

2.8.6 PCC with Longitudinal Tining

Fernando and Harrison (2013) reported the IRI values obtained on a CRC pavement that had longitudinal tining that was profiled with a profiler equipped with a RoLine laser and two profilers equipped with single-spot lasers. This pavement had a longitudinal tine spacing of 1 inch. The IRI values from both profilers that had single-spot lasers were higher than the IRI from the RoLine laser for both wheelpaths of the test section. The difference in IRI between the average IRI from the two profilers that had single-spot lasers and the profiler with the RoLine laser was 42 and 43 in/mi for the left and the right wheelpaths, respectively.

The information presented above indicates the IRI obtained from a single-spot laser on a longitudinally tined PCC surface could be very large compared to the IRI obtained from a RoLine laser. The difference in the magnitude of IRI between the two laser types will depend on the tine spacing, width of the tine, and the depth of tining.

2.8.7 PCC Surface with Diamond Grinding

Habib et al. (2010) compared IRI values obtained from a profiler with single-spot lasers and a profiler with a RoLine lasers on two diamond ground projects in Virginia. These projects were Battlefield Boulevard project and Interstate 66 project. On both projects the single-spot laser data were collected by a profiler owned by the Virginia Department of Transportation (VDOT). On the Battlefield Boulevard project, the RoLine data were collected by the paving contractor, while on the Interstate 66 project the RoLine data were collected by the FHWA lightweight profiler. On the Battlefield Boulevard project, the average IRI for all lanes from the single-spot laser was 65 in/mi, with the corresponding IRI from the RoLine laser being 36 in/mi. For the Interstate 66 project, the average project IRI for the single-spot and RoLine lasers were 108 and 82 in/mi, respectively. Hence, the IRI from the single-spot laser was higher than the IRI from the RoLine laser by 29 and 26 in/mi for the Battlefield Boulevard and Interstate 66 project, respectively. The authors commented the low IRI obtained from the RoLine laser was not consistent with the "seat of the pants" roughness felt by a road user on the Battlefield Boulevard project. The authors noted there was a difference in spacers in the grinding head of the grinder for the two projects, with the spacers being smaller for the Interstate 66 project. The authors indicated the difference in spacers in the grinding head for the two projects may have had an influence on the IRI values obtained by the profiler with single-spot lasers in these two projects.

De Leon Izeppi (2013) presented IRI values obtained from seven profilers equipped with single-spot lasers and a profiler equipped with a RoLine lasers on a diamond ground pavement that was located at the Smart Road in Blacksburg, Virginia. The IRI values obtained by the seven profilers that had single-spot lasers were averaged and compared to the IRI from the RoLine laser. The average single-spot IRI for the left and right wheelpaths were 129 and 108 in/mi, while the IRI from the RoLine laser for the left and the right wheelpaths were 108 and 92 in/mi. Overall, these data indicated on this surface the IRI from the single-spot laser was higher than the IRI from the RoLine laser by 21 and 16 in/mi for the left and the right wheelpaths, respectively.

Perera et al. (2009) reported a study performed by the Florida Department of Transportation (FDOT) to determine the effect of laser spot size on the IRI obtained on diamond ground pavements. FDOT mounted a single-spot laser and a wide-spot laser on an ICC profiler such that both lasers collected data along the same path. The wide-spot laser had a spot size that was 0.67 inches long, and the laser was fitted such that the 0.67-inch side was perpendicular to the direction of travel. The profiler collected data on two diamond ground projects, I-275 and I-75. The profiled length for the I-275 project was 2.1 miles, while that for the I-75 project was 3.1 miles. The overall IRI for the I-275 project for the single-spot laser and the RoLine laser were 62 and 38 in/mi, respectively. The overall IRI for the I-75 project for the single-spot laser and the RoLine laser were 62 and 54 in/mi, respectively. The IRI difference for the two laser types for the I-275 and I-75 projects were 24 and 8 in/mi, respectively. The IRI values from the single-spot laser were similar for the two projects, but the IRI values from the wide-spot laser indicated the I-275 project was smoother than the I-75 project. The grooves from the diamond grinding operation were deeper on the I-275 project when compared to the I-75 project. The difference in IRI between the two sensor types was higher on I-275, where the diamond grinding created deeper grooves. Although a RoLine laser was not used in these two projects, the data presented show how the laser spot size affects the IRI values on diamond ground surfaces.

The information presented above indicates the IRI obtained from a single-spot laser on a diamond ground PCC surface is higher than the IRI obtained from a RoLine laser. The difference in the magnitude of IRI between the two laser types on a diamond ground surface could depend on blade width of cutters and spacer spacing on the grinding head and the depth of the grooves in the ground surface.

2.8.8 Longitudinally Grooved Concrete Pavement

De Leon Izeppi (2013) presented IRI values obtained from seven profilers equipped with single-spot lasers and a profiler equipped with RoLine lasers on a longitudinally ground and grooved pavement section located at the Smart Road in Blacksburg, Virginia. The IRI values obtained by the seven single-spot profilers were averaged and compared to the IRI from the RoLine laser. The average single-spot IRI for the left and right wheelpaths were 135 and 122 in/mi, while the IRI from the RoLine laser for the left and the right wheelpaths were 38 and 29 in/mi. Overall, these data indicated on this surface the IRI from the single-spot laser was higher than the IRI from the RoLine laser by 97 and 93 in/mi for the left and the right wheelpaths, respectively.

The information presented above indicates the IRI obtained from a single-spot laser on a longitudinally grooved PCC surface can be very large compared to the IRI obtained from a RoLine laser. The difference in the magnitude of IRI from the two laser types on a longitudinally grooved surface could depend on groove spacing, groove width, and the groove depth.

2.8.9 Implications of Laser Sensor Type on Network Level and Smoothness Acceptance Testing

An issue that will be faced at the national level if comparisons are made for roughness of PCC pavements among the states is the type of sensor that was used to collect the roughness data on PCC pavements that have longitudinal tining, longitudinal grooving, or diamond grinding. If some SHAs used single-spot lasers and others use line lasers, then the comparison of roughness levels among states will not be valid.

A SHA that has PCC pavements with longitudinal tining, longitudinal grooving, or diamond grinding needs to make a decision on whether they want to require line lasers to be used for network level data collection. If a profiler equipped with a single-spot laser is used to collect data on such surfaces, the obtained roughness value is expected to have an upward bias. If the percentage of pavements with such surfaces in the SHAs network is small, the upward bias in roughness on such sections may not influence the overall network level roughness much. However, if the SHA has a significant amount of such pavements in its network, the overall network level roughness could be affected. Also, the IRI values obtained by a single-spot laser on such surfaces can vastly overestimate the roughness of such sections, and may create issues when analyzing IRI data in the PMS to analyze roughness level of pavement segments. It should be noted if a SHA decides to use line lasers for network level data collection, that can affect the roughness obtained for other types of pavements also. A noticeable reduction in IRI is expected on OGFC surfaces, while a slight reduction in IRI is expected on dense-graded AC, SMA, and chip seal surfaces.

When collecting data for smoothness acceptance on new construction, line lasers need to be used for PCC pavements that have longitudinal tining, longitudinal grooving, or diamond grinding. A single-spot laser can vastly overestimate the IRI on such surfaces. As described in the previous paragraph, using a line laser to collect data for smoothness acceptance can also have an effect on OGFC, SMA, and dense-graded AC, where a line laser can give lower IRI when compared to a single-spot laser. As a small change in IRI can make a difference between getting a bonus or getting full pay, or getting a higher bonus, or getting full pay or having to pay a penalty, using a profiler equipped with line laser on these surfaces will definitely be an advantage for the contractor.

2.9 RESOURCES RELATED TO PAVEMENT SMOOTHNESS

Over the past several years, the FHWA has undertaken several endeavors to improve the understating of smoothness/roughness issues, develop software for analyzing profile data, and develop standards related to pavement profiling. The standards that were developed through FHWA initiatives were described previously in section 2.5. The following is a description of a document, software, and a training course that have been developed through FHWA initiatives.

2.9.1 Little Book of Profiling

The Little Book of Profiling (Sayers and Karamihas, 1998) presents basic information about measuring and interpreting road profiles. This document described how profilers work, what can be done with measurements obtained by profilers, and procedures to follow to reduce errors during profiling.

2.9.2 ProVAL Software

The FHWA, through a pooled-fund effort, has developed a computer program called ProVAL for evaluation and analysis of profile data collected by inertial profilers and reference devices. This software will be useful for SHAs that plan to implement or are already implementing a ride quality specification based on data collected by inertial profilers. ProVAL has a variety of features that can be used to view profile data, as well as to compute various roughness indices such as IRI and Ride Number. ProVAL also has a feature to detect localized rough spots, and to perform a grinding simulation. This option can be used to evaluate different scenarios to see how the roughness of the pavement will change with different grinding scenarios. ProVAL also has a module for profiler certification, where cross-correlation values for evaluating repeatability and accuracy of profilers can be computed easily.

2.9.3 NHI Course

The FHWA has developed a course titled “Pavement Smoothness: Use of Inertial Profilers for Construction Quality Control.” This course is offered through the National Highway Institute

(NHI). This course provides valuable information on procedures to be followed for collecting accurate profile data and how to analyze the collected data. This course is beneficial to SHAs that are currently using or planning to use a ride quality specification based on data collected by inertial profilers. This course will also be useful to persons involved in network level roughness data collection.

CHAPTER 3. EXISTING PROFILER CERTIFICATION PROGRAMS

Several existing profiler certification programs are described in this chapter. Some of the certification programs are administered by SHAs, while others are administered by a university affiliated institute in cooperation with a SHA. Information about profiler certification programs administered by SHAs and by a university affiliated institute is presented in section 3.1 and 3.2, respectively. Section 3.3 presents a summary of the information included in sections 3.1 and 3.2.

3.1 PROFILER CERTIFICATION PROGRAMS ADMINISTERED BY A STATE HIGHWAY AGENCY

3.1.1 Colorado

Introduction

The Colorado Department of Transportation (CDOT) requires profilers that collect smoothness data on new construction for construction acceptance be certified and operated by a certified operator. The CDOT procedures for certifying profilers are described in CP 78-12, Certification of High Speed Profilers (Colorado DOT, 2012). CDOT does not have a dedicated facility to certify profilers. Each year CDOT selects a site to perform profiler certifications. CDOT does not charge a fee for certifying profilers, and the profiler certification is valid for one year. In order to collect profile data on PCC pavements, CDOT requires the profiler to be equipped with a line laser that is at least a 3 inches wide. Profilers that are not equipped with a line laser are only certified to measure AC surfaced pavements.

Test Sections

According to CP 78-12, the site selected for certification should satisfy the following requirements:

- The site must have sufficient distance for three 0.1 mile long test sections, a lead in distance of at least 300 ft, and a sufficient stopping distance after the end of the last test section.
- The 0.1 mile sections should have a mean IRI between 30 and 90 in/mi.
- The surface of the pavement should be such that surface texture will have a minimal impact on the collected data.
- There should be no cracks along the wheelpaths.
- The site must have minimal traffic and have a stable base.

CDOT has been using an AC surfaced frontage road to set up the certification site. Figure 3.1 shows a photograph the certification site used by CDOT in 2007.

Figure 3.1. Test site used by CDOT in 2007.

Profiler Certification

CDOT measures the reference profile of the test sections using a SurPRO. Ten repeat profile runs are required from the profiler being certified. The profiler must meet the following three criterion for each wheelpath at all three test sections in order to be certified:

- The standard deviation of IRI for each 0.1 mile section must not exceed 3 in/mi.

- The average IRI for each 0.1 mile section computed from the ten repeat must not differ from the reference IRI value by more than 6 in/mi.

- IRI values reported by the profiler operator using the profiler software must match the results determined by CDOT from the profile data within 0.1 in/mi.

A profiler that passes certification is issued a certificate that lists the serial number of profiler, Vehicle Identification Number (VIN) of the host vehicle, make and model of profiler, height sensor serial numbers, accelerometer serial numbers, certification date, and expiration date of certification. The certified profilers are listed on CDOT's website.

Operator Certification

CDOT requires the profiler operator to have a current LabCAT Level S certification. The Rocky Mountain Asphalt Education Center administers an Asphalt Technician Certification Program that provides this certification. The Rocky Mountain Asphalt Education Center offers a class on smoothness measurements using a high-speed profiler and CDOT specifications related to smoothness measurements (Rocky Mountain Asphalt Education Center, 2012). A 45 minute written exam is held after the completion of the class. Thereafter, the operator is tested for proficiency with a high-speed profiler where the operator has to show the ability to perform calibration verification tests on the profiler and perform data collection with the profiler. An operator must pass the written exam as well as the proficiency test in order to be certified. There is no cost for the written test, as well as for the proficiency test. However, a retest, if an operator fails to get certified during the first attempt, has a charge of $150. The operator certification is valid for three years.

3.1.2 Michigan

Introduction

Michigan Department of Transportation (MDOT) requires profilers that collect smoothness data on new construction for construction acceptance be certified and operated by a certified operator. Michigan Test Method 730 (Michigan DOT, 2007) describes the procedure used by MDOT to certify profilers. MDOT does not have a dedicated facility to certify profilers, and the test section for certification is established on an in-service road. MDOT does not charge a fee to certify profilers, and the certification is valid for one year.

Test Sections

MDOT currently uses an AC surfaced 528 ft long test section located on an in-service road to perform profiler certification.

Profiler Certification

MDOT measures the reference profile of the test section using a SurPRO. The profiler must pass system verification tests and satisfy a repeatability and an accuracy criterion to be certified. The system verification tests include a block check to verify the accuracy of the height sensors and a bounce test to check the overall integrity of the equipment. Before collecting profile data, the profiler must also pass a DMI check at a 528 ft long section. To pass the check, the profiler must be able to measure the length of the section within 0.1 percent of the actual distance.

A profiler is required to obtain ten repeat runs on the test section. The profiler must satisfy the following two criteria for each wheelpath in order to be certified.

- Repeatability criterion: The standard deviation of the IRI for the ten runs must not exceed 2 in/mi.

- Accuracy criterion: The average IRI from the ten runs must be within 5 in/mi of the IRI calculated from the reference data.

An inertial profiler that passes certification is furnished with a decal that lists the serial number of the profiler, certification date, and date when the certification will expire.

MDOT Test Method 730 indicates the profiler must be recertified after undergoing any major component repairs or replacements. This document indicates major component repairs or replacements to include changes to the following: the accelerometer or associated hardware, the height sensor or associated hardware, the distance measuring unit and associated hardware, any printed circuit boards necessary for the collection of raw sensor data or the processing of profiles or ride indices, the computer, and software upgrades.

Operator Certification

MDOT certifies profiler operators based on their demonstrated familiarity with the equipment and their ability to operate a profiler and collect data. There is no fee for operator certification.

3.1.3 Minnesota

Introduction

Minnesota Department of Transportation (MnDOT) requires profilers that collect smoothness data on new construction for construction acceptance be certified and operated by a certified operator. MnDOT initiated their profiler certification program in 2002. The procedures that are followed for certifying profilers are described in the MnDOT document 2014 MnDOT Inertial Profiler Certification Program (Minnesota DOT, 2014). MnDOT has a dedicated facility to perform profiler certifications. A company can have up to three profilers tested for certification without a charge. Additional profilers are charged $1000. A profiler must be certified annually. Regardless of when a profiler is certified, the certification is only valid for the remainder of the same calendar year.

The profiler certification is typically held over a two week duration in early May. MnDOT emphasizes that the profiler certification program is not a training program, and all participating operators are expected to be knowledgeable about the operation of the profiler to be certified.

MnDOT provides certification of profilers owned by other SHAs as a courtesy without assessing a fee. Several SHAs from nearby states have had their profilers certified at the MnDOT facility. MnDOT does not certify contractor owned profilers that do not operate in Minnesota.

Test Sections

MnDOT uses two sections located on the low-volume loop at the MnROAD research facility to certify profilers. The low-volume loop is a closed facility and is not open to public traffic.
An AC surfaced and a PCC surfaced test section are used for certification. The PCC section has transverse tining. Each test section is about 528 ft long. One path is marked along each test section where data collection is performed.

Profiler Certification

MnDOT collects the reference data at the test sections using a SurPRO. Each profiler is required to make five passes over each test section and submit the data files to MnDOT. MnDOT requires the profiler to satisfy the following three criteria to pass certification:

- The average IRI from the five runs corresponding to each sensor must be within 5 percent of the reference IRI value at both test sections. In addition, when individually compared against the reference profile, all five profiles must correlate at a level of 85 percent or higher. The average of the five correlations must be at least 90 percent.

- The standard deviation of IRI for the five profiles corresponding to each sensor must be no larger than 3 percent of the average IRI of the five passes at both test sections.

- All five passes on each test section must be within 0.2 percent of the actual length of the test section.

An inertial profiler that passes certification is furnished with a decal. The date of certification, unique identification number of the device, device's make, vehicle to which the device is attached, operational system software version, and signature of a MnDOT representative is indicated on the decal. The software settings used in the profiler at time of certification are recorded. The profilers that pass certification are listed on the MnDOT smoothness website with the associated software settings that were used during certification. The operator of a certified profiler must use these settings when collecting data on MnDOT projects.

MnDOT requires all certified profilers to undergo a mid-season, side-by-side comparison with a MnDOT high speed profiler. This comparison is performed on a current MnDOT construction project on which the certified profiler has collected profile data.

MnDOT requires inertial profilers that experience a major component failure or undergo major component repairs/replacements to be recertified. MnDOT documentation indicates major components of an inertial profiler to include the accelerometer and its associated hardware, the height sensor and its associated hardware, and any printed circuit board necessary for the collection of raw sensor data or the processing of profiles.

Operator Certification

In order to be certified, a profiler operator must take an on-line course (approximately 90 minutes) and pass an on-line exam. There is no fee for taking the on-line exam. The operator certification is valid for three years. The names of certified profiler operators are listed on the MnDOT webpage.

3.1.4 Mississippi

Introduction

Mississippi DOT requires profilers that collect smoothness data on new construction for construction acceptance be certified and operated by a certified operator. The Mississippi DOT certification procedures are described in the document MDOT Inertial Profiler Certification Scope 2014 (Mississippi DOT, 2014). Mississippi DOT does not have a dedicated facility to perform profiler certifications. Mississippi DOT does not charge a fee to certify profilers. The profiler certification as well as the operator certification is valid for one calendar year.

Test Sections

Mississippi DOT currently uses a medium smooth dense-graded AC section that is 528 ft long established on an in-service road to certify profilers.

Profiler Certification

The reference data at the test section are obtained using a SurPRO within 72 hours of the profiler runs. The profiler is required to pass the established thresholds for the block check and the bounce test before performing data collection. The DMI of the profiler is calibrated at the test section before performing the certification runs. The profiler is required to obtain six runs at the test section at a speed of 25 mi/h as well as at a speed of 50 mi/h. The best five runs at each speed are selected and the resulting ten runs are used for analysis. A profiler must satisfy the following criteria in order to be certified:

- Repeatability Criterion: The average IRI-filtered cross-correlation computed according to the procedures described in AASHTO R 56 must be at least 92 percent for each wheelpath at all test sections.

- Accuracy Criterion: The average IRI-filtered cross-correlation of profile data with the reference data computed according to the procedures described in AASHTO R 56 must be at least 90 percent for each wheelpath at all test sections.

- The distance measuring system in the profiler must be able to measure the length of the section accurately to within ± 1 ft.

Operator Certification

Operators are required to show they can calibrate the DMI, do a block check, perform a bounce test, calibrate the accelerometer (if applicable), and perform data collection at the test section without any assistance in order to be certified. There is no fee for operator certification.

3.1.5 New Mexico

Introduction

The New Mexico Department of Transportation (NMDOT) allows only a certified profiler operated by a certified operator to collect smoothness data on new construction for construction acceptance. The New Mexico Technician Training and Certification Program (TTCP) administer the profiler and profiler operator certification program. The certification program is open to anyone, and there is no requirement that the participating profiler should collect data in New Mexico. The profiler certification program is held once a year at end of March. The NMDOT does not have a dedicated facility to perform profiler certifications. The profiler certification is valid for one year. NMDOT charges $500 for certifying a profiler.

Test Sections

The NMDOT certification section is established on the outside lane of an AC surfaced four lane road in front of the district office (see figure 3.2). The established certification section, including a half mile lead in and a half mile lead out, is closed to traffic using traffic control devices. Two 528 ft long sections are established within the certification site. A longer section that encompasses the two 528 ft long sections is used to check the DMI of the profiler. A 1000 ft long DMI calibration section is located adjacent to the certification section that can be used to calibrate the DMI of the profiler before collecting data at the certification section.

Figure 3.2. New Mexico DOT profiler certification track (Legan, 2012).

Profiler Certification

A block check and a bounce test are performed on the profiler before collecting data at the certification sections. The block check and the bounce test must meet specified thresholds. Each profiler is required to collect 12 runs at the certification site at a speed of 55 mi/h. The best 10 runs are used for analysis.

A baseline IRI for each wheelpath of each test section is established using the IRI values obtained from the SurPRO and the two NMDOT owned high-speed profilers. A profiler must satisfy the following criteria in order to pass certification:

- The average IRI from the ten runs must be within 6 in/mi of the established baseline IRI for each wheelpath at both test sections.

- The standard deviations of the IRI computed from the ten runs for each wheelpath at both sections must be less than 3 in/mi.

- The average IRI-filtered cross-correlation between the profile data and the data from the reference device must be at least 90 percent for each wheelpath at both sections.

Profilers passing certification have a sticker affixed to the profiler, and provided with a certification card.

Operator Certification

NMDOT has an operator certification program. The New Mexico TTCP offers an Inertial Profiler Inspector Training Class, and all profiler operators and NMDOT inspectors are required to take this class every three years. The class addresses technology issues related to profiling and the NMDOT smoothness specification. The profiler operator must demonstrate the ability to perform calibration checks on the profiler and collect data without assistance in addition to taking the training class in order to be certified. A fee of $100 is charged for certifying a profiler operator. The operators also have to attend a training class, and there is a fee of $100 for attending that class. The operator certification is valid for three years.

3.1.4 Ohio

Introduction

The Ohio Department of Transportation (ODOT) allows only a certified profiler operated by a certified operator to collect smoothness data on new construction for construction acceptance. The ODOT procedures for profiler and profile operator certification are described in Supplement 1058, Surface Smoothness Equipment and Operator Requirements (Ohio DOT, 2014). ODOT does not have a dedicated facility to perform profiler certifications. The profiler certification is valid for one year. ODOT does not charge a fee for certifying profilers.

Test Sections

ODOT has established a test course that contains a series of test sections on a two lane on-ramp to US 23 in Delaware County. The test courses contain a smooth dense-graded AC pavement, a very smooth diamond ground dense-graded AC pavement, a very rough transverse tined jointed plain concrete (JPC) pavement, a fairly smooth diamond ground JPC pavement, and fairly smooth longitudinally grooved JPC pavement.

Profiler Certification

The certification process is performed in two phases. In the first phase, the profiler must pass a block and a bounce test meeting specified threshold values, and be able to measure the length of an established section with an error within ±0.10 percent of the length of the section. If the profiler passes the first phase, it is allowed to proceed with the second phase that consists of collecting data on the test track. The profiler is required to obtain two sets of data on two designated sections, with five repeat runs being performed on each section. ODOT will select up to four subsections within the two data sets for evaluation. ODOT will establish reference IRI values for these test sections, using the data collected by the ODOT profilers.

A profiler must satisfy the following criterion at all sections in order to be certified to collect data on AC and PCC surfaces:

- Repeatability Criterion: The mean IRI of each run must be within 5 percent of the average mean IRI of the five runs.

- Accuracy Criterion: The average mean IRI of the five runs must be within the greater of the following two items: 5 percent of the reference IRI value or 5 in/mi.

ODOT will allow an additional set of five runs if the profiler is unable to meet the specified criterion for certification.

As profilers with single-spot lasers cannot collect accurate data on diamond ground, longitudinally grooved, or longitudinally tined pavements, such profilers are certified for AC surfaces only. Data collected on these three surface types during certification are not used when analyzing data for profilers with single-spot lasers.

Once a profiler passes certification, the following items will be recorded: make and model of profiler, serial number of profiler, calibration settings, software version and release date, operator name, filter settings, sampling intervals, and any other critical information. These items will be included in the approval letter that is provided to the owner of the equipment. A list of approved profilers with the above mentioned information will be posted on the ODOT Office of Technical Services webpage. Recertification is required if changes are made to equipment settings or software updates are performed.

Operator Certification

There is no fee for certifying profiler operators, and the profiler operator certification is valid for one year. The operator is certified only to operate the equipment that is certified. The profiler operators have to demonstrate their ability to successfully perform the following items in order to be certified:

- Ability to calibrate the DMI and do a check on the DMI.
- Ability to perform a block check on the height sensor.
- Ability to perform a bounce test.
- Ability to generate road profiles in a format that can be loaded to the ProVAL software.
- Ability to generate required smoothness indices using ProVAL.
- Ability to provide pay adjustment calculations using the smoothness values in an Excel file.
- Ability to accurately complete the profile log sheet for profiles collected on the test track.

3.1.4 Pennsylvania

Introduction

Pennsylvania DOT (PennDOT) requires profilers that collect smoothness data on new construction for construction acceptance be certified and operated by a certified operator. PennDOT adopted IRI as the measure to judge the smoothness of new pavements in 2000. PennDOT constructed a facility on a rail-to-trails site in Newville, Pennsylvania to certify lightweight profilers. This test facility cannot handle high-speed equipment because of insufficient distance after the test sections for a high-speed van to safely come to a stop. Therefore, PennDOT does not certify high-speed equipment. Profiler operators are certified at the same time a profiler is certified. The profiler and profiler operator certification program is directed and controlled by PennDOT's Bureau of Maintenance and Operation that falls under the Roadway Inventory and Testing Section. The PennDOT profiler and profiler operator certification procedures are described in the document Light Weight Profiling System, Calibration Verification & Operator Certification Program Manual (Pennsylvania DOT, 2012).

PennDOT emphasizes that the profiler and profiler operator certification program is not a training program, and they expect all profiler operators desiring certification to be well versed in the operation of the profiler that is to be certified. All profilers used by PennDOT or by contractors must be certified each year prior to use on PennDOT construction projects. The profiler and profiler operator certification is performed between May and October, with most of the certifications done between April and June. Regardless when a profiler is certified, the certification is only valid through June 30th of the following year. PennDOT charges $400 to certify a profiler and a profiler operator.

Test Sections

Figure 3.3 shows the layout of the PennDOT profiler certification site, which has four test sections. The 1056 ft long AC and PCC sections each have two 528 long test sections. The test sections were constructed such that they cover a range of roughness levels. The PCC test sections have areas having transverse tining, longitudinal tining, and diamond grinding.

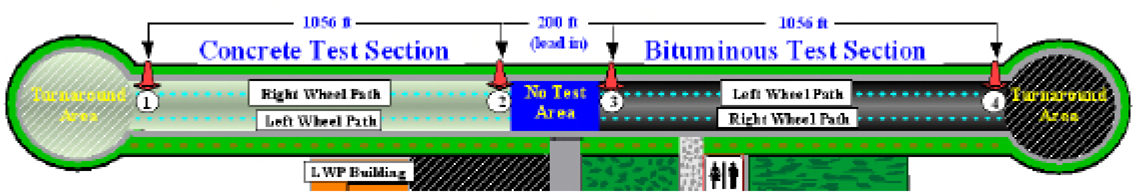


Figure 3.3. Layout of the PennDOT certification site (PennDOT, 2012).

Profiler Certification

Reference profile data at the test sections are collected using a SurPRO. The reference data are collected by PennDOT in the spring prior to start of certification, and these reference data are checked throughout the period during which certifications are performed. Data for five passes collected by the inertial profiler must be submitted for each test section. A profiler must satisfy the following criterion in order to be certified:

- Repeatability Criterion: The average IRI-filtered cross-correlation computed according to the procedures described in AASHTO R 56 must be at least 92 percent for each wheelpath at all test sections.

- Accuracy Criterion: The average IRI-filtered cross-correlation of profile data with the reference data computed according to the procedures described in AASHTO R 56 must be at least 90 percent for each wheelpath at all test sections.

- The IRI values produced by the software in the profiler must match the IRI values computed for the same data by ProVAL.

- The distance measuring system in the profiler must be able to measure a length of a 1056 ft long section within 1 ft (i.e., accuracy within 0.09 percent).

A decal is affixed to the profiler once it passes certification. The decal indicates the device identifier, the date of certification, the date of expiration of certification, the number of sensors in the device, device type, and operational system software version.

A certified profiler may need to be re-verified after certification. Re-verification may be required for the following reasons:

- Questionable results from the profiler.

- The IRI values obtained by the profiler do not match the IRI values obtained by a PennDOT owned profiler.

- The profiler has been repaired, hardware in the profiler has been replaced, or profiler operating/analysis software has been updated.

Operator Certification

As described previously, the fee of $400 that is charged for certifying a profiler includes the certification of the profiler operator. Each additional profiler operator that is certified on the same day that operates the same profiler is charged $150. Profile operator certification does not involve a written exam. The operator must demonstrate familiarity with the equipment, able to collect data at the certification site without assistance, and demonstrate familiarity with the procedures for submitting the data to PennDOT in order to be certified. Operator certifications are valid through June 30th of the third year after certification.

All certified profiler operators are provided a certification card. The name of the operator, employer, date of certification, date of expiration, and profile device type are shown on the card. Certified profiler operators may operate profile devices other than the one used during certification, but only those that are of the same type, owned by the same employer, and designated with a valid verification decal. The certified profilers and profiler operators are shown on the PennDOT website. A certified profiler operator may need to be re-verified after certification if it is observed that incorrect practices are being used by the operator.

3.1.5 Wisconsin

Introduction

Wisconsin Department of Transportation (WisDOT) has a profiler certification procedure and a profiler operator certification procedure in place, and only inertial profilers certified by WisDOT and operated by a certified operator can collect data for QA smoothness testing. WisDOT does not have a dedicated facility to perform profiler certification and does not charge a fee for certifying profilers. Profilers that measure PCC pavements must to be equipped with line lasers. Portable profiling equipment that can be transferred to other vehicles has to be certified for each vehicle on which it may be mounted. The profiler certification is valid for one year.

Test Sections

Each year WisDOT sets up a 600 ft long AC surfaced and a PCC surfaced test section on a new pavement that has not been opened to traffic to perform profiler certifications.

Profiler Certification

A SurPRO is used to measure the reference profile at each test section. Each profiler is required to make five repeat runs on each test section. The profiler must meet the following two requirements for each wheelpath to be certified:

- Repeatability Criterion: The average IRI-filtered cross-correlation computed according to the procedures described in AASHTO R 56 must be at least 92 percent.

- Accuracy Criterion: The average IRI-filtered cross-correlation of profile data with the reference data computed according to the procedures described in AASHTO R 56 must be at least 90 percent.

The list of profilers that pass certification are posted on the WisDOT website. Details about the profiler such as height sensor type (i.e., single spot or line laser), model number of profiler, serial number of profiler, host vehicle type, host vehicle serial number for lightweight profilers, VIN of host vehicle for high-speed and portable profilers, data collection software version, data collection interval, filter settings if applicable, details about selectable settings etc. as well as operators who can operate the profiler are also listed on the website.

Operator Certification

WisDOT has initiated a profiler certification program for profiler operators that is administered by University of Wisconsin, Platteville. As a pre-requisite for attending the profiler certification course, the operator must take a 4 hour on-line course and pass an on-line exam. The profiler certification course consists of 8 hours of classroom and hands-on instruction. In this course, the technician becomes familiar with principles of a profiler, ability to interpret computer printouts from the profiler, WisDOT specifications and special provisions related to smoothness, setting-up the computer for data collection, and hands-on operation of the profiler for field data collection, and maintenance of the profiler. The operator must pass a written exam at the end of the classroom course in order to be certified.

3.2 PROFILER CERTIFICATION PROGRAMS ADMINISTERED BY A UNIVERSITY AFFILIATED INSTITUTE

3.2.1 Alabama – National Center for Asphalt Technology

Introduction

NCAT is affiliated with the Auburn University in Alabama. NCAT's vision is to provide leadership for the asphalt pavement industry and provide a clearinghouse for technical information. NCAT operates a 1.7 mile long oval test track that is located in Opelika, Alabama (see figure 3.4).

Figure 3.4. NCAT test site.

The outside lane of this test track consists of 200 ft long test sections. These test sections are subjected to accelerated loading using truck traffic to study the performance of various asphalt mixes. The research cycle for these test sections is three years. The last construction cycle of these test sections was completed in 2012, and these test sections will be subjected to traffic until spring 2015. Thereafter, these test sections will be reconstructed for a new research cycle. The inside lane of the test track serves as a haul route and work platform when the test sections in the outside lane are reconstructed every three years. The inside lane is a perpetual pavement, which has a thick AC surface, and is not subjected to accelerated loading as the outside lane. Hence, there is very little change in the condition of the inside lane with time.

NCAT has established four test sections for certifying profilers on the inside lane of the test track (Powell, 2012). The profiler certification program is administered by NCAT personnel. NCAT offers profiler certification for any SHA, vendor, or contractor owned profiler. Alabama Department of Transportation (ALDOT) has certified their profilers at this facility. The Alabama DOT procedure for profiler certification is described in the document ALDOT-448, Evaluating Pavement Profiles (Alabama DOT, 2012). The procedures described ALDOT-448 for certifying ALDOT profilers are described in this section. The profiler certification will be valid for one year. The profiler certification program at NCAT so far has been funded through a project sponsored by ALDOT. In the future, NCAT expects to charge $2,000 per profiler for profiler certification.

Test Sections

Four 528 ft long test sections have been established on the inside lane of the test track for profiler certification. Three test sections have dense-graded AC surfaces while the other section has an open-graded asphalt surface. The approximate mean IRI of the three dense-graded AC sections are 55,100 and 165 in/mi. The approximate IRI of the open-graded friction course section is 55 in/mi. As the outside lane is rebuilt every three years, NCAT has the ability to construct test sections at that time in the inside lane to any desired roughness level. The test track currently does not have any PCC surfaced test sections. NCAT has indicated they can consider constructing PCC test sections on the test track or in an adjacent area, if there is sufficient interest in using such test sections for profiler certification.

Profiler Certification

Reference profile data at the test sections are collected using a SurPRO. The inertial profiler is required to obtain ten repeat measurements at each test section. The performance of the profiler is differentiated between the dense-graded and open-graded test sections.

In order to pass certification on the dense-graded surfaces, the profiler must meet the following repeatability and accuracy criterion for each wheelpath at all three sections:

- Repeatability Criterion: The average IRI-filtered cross-correlation computed according to the procedures described in AASHTO R 56 must be at least 92 percent.

- Accuracy Criterion: The average IRI-filtered cross-correlation of profile data with the reference data computed according to the procedures described in AASHTO R 56 must be at least 90 percent.

In order to pass certification for open-graded mixes, the profiler must pass the above mentioned repeatability and accuracy requirements for dense-graded mixes, and also produce an IRI that is within 5 percent of the IRI determined from the SurPRO data for each wheelpath.

In addition to passing the repeatability and accuracy criteria, the DMI of the profiler must be accurate to within 0.15 percent of the actual distance in order to pass certification.

NCAT will provide separate certification for dense-graded pavement surfaces and open-graded pavement surfaces. It is possible to pass the certification for dense-graded sections but fail for open-graded surfaces. A decal will be placed on the profiler after successfully passing certification. Separate decals will be provided to indicate that the profiler has passed certification on dense-graded and open-graded surfaces. The decal will indicate the month and year of certification and the month and year the certification expires.

ALDOT-448 indicates recertification of the profiler is required if repair or replacement of the following major components is performed: accelerometer and its associated hardware, height sensor and its associated hardware, DMI, any printed circuit boards necessary for the collection of raw sensor data or the processing of the inertial profiles and IRI.

Operator Certification

NCAT also provides profiler operator certification. Operators of inertial profilers used for construction acceptance testing in Alabama must be certified. The profile operator certification program is administered by NCAT personnel. In order to be certified an operator must pass a written exam and a practical exam. The written exam will test the operator’s knowledge of ALDOT smoothness specification and procedures for profile data collection. In the practical exam, the operator must demonstrate the ability to perform a block check, a bounce test, calibrate the DMI, and collect profile data on a designated route. Once an operator successfully passes the written exam and the practical test, an identification card indicating the operator is certified to operate inertial profilers is provided. The card identifies the specific types or brands of inertial profilers for which the operator certification is valid and also indicates the expiration date of certification. The profiler operator is annually required to demonstrate their proficiency by performing the items described previously for the practical exam when the inertial profiler is certified. However, an operator is only required to take the written exam every three years.

The profiler certification program at NCAT has been funded through a project sponsored by ALDOT. As indicated previously, in the future, NCAT expects to charge $2,000 per profiler for profiler certification. This fee will also include operator certification.

3.2.2 California – University of California

Introduction

California Department of Transportation (Caltrans) requires profilers that collect smoothness data on new construction for construction acceptance be certified and operated by a certified operator. Caltrans constructed a profiler certification facility at the Regional Transit Light Rail

Station parking lot near Sacramento in 2012. This site is on the median of I-80. The profiler certification program is administrated by the University of California Pavement Research Center and Caltrans Materials Engineering and Testing Services division. A fee of $1000 is charged for certifying a profiler, and the certification is valid for one year. Caltrans expects to provide profiler and operator certification over a 2-day period in March, May, and July of each year.

Test Sections

The facility has two 0.1 mile long test sections, one surfaced with AC and the other surfaced with PCC.

Profiler Certification

The reference profile data at the test sections are collected using a SurPRO. The DMI of the profiler is first checked to determine if it meets a specified threshold. The profiler obtains repeat measurements at each test section. The profiler must satisfy the following two requirements for each wheelpath at both test sections in order to be certified:

- Repeatability Criterion: The average IRI-filtered cross-correlation computed according to the procedures described in AASHTO R 56 must be at least 92 percent.

- Accuracy Criterion: The average IRI-filtered cross-correlation of profile data with the reference data computed according to the procedures described in AASHTO R 56 must be at least 90 percent.

A profiler can get certified for collecting data only on AC pavements by meeting the certification requirements at the AC section. A profiler that is certified for collecting data on PCC pavements must meet the certification requirements at both the AC and PCC section. Equipment passing calibration is issued a decal. A list of the certified profilers is posted on the Caltrans smoothness website. The following information about each profiler is shown on this website: the manufacturer of the profiler, model number of profiler, type of laser sensor (i.e., single-spot or line laser), the serial number of laser sensors, and the VIN of the vehicle.

Operator Certification

Caltrans requires the operator of the profiler to be certified, and certification of the operator is provided in conjunction with profiler certification. A $500 fee is charged for operator certification for the first time an operator is certified, while the fee is reduced to $250 for each successive year. The operator certification is valid for one year. The operator certification consists of a written exam and a practical exam. A 2 to 4 hour classroom session on inertial profilers is first conducted at the Caltrans facility in Sacramento, which is then followed by a written exam. The practical exam checks the operator’s ability to calibrate the DMI of the profiler, ability to perform a block check and a bounce test, and ability to operate the profiler and collect data. Operators passing certification are issued a certification document. The document will indicate the make of the profiler including a description of hardware and software in the profiler that the operator is certified to operate. The names of certified profiler operators are listed on the Caltrans smoothness webpage. The webpage shows the profiler make and model the operator is certified to operate, the issue date of certification, and certification end date.

3.2.3 Florida – University of North Florida

FDOT is planning to construct a profiler certification course in summer 2014. The certification course will be constructed at Williston Airport, which is located in Levy County. The airport is owned by the City of Williston. The certification track will be 4000 ft long and will consist of AC surfaced test sections as well as test sections that have an OGFC. Two test sections, one smooth and one medium smooth, will be constructed for each surface type. A building that will function as a calibration bay and office will also be built at this site. The profiler certification program will be administrated by the University of North Florida.

3.2.4 New Jersey – Rutgers University

New Jersey Department of Transportation (NJDOT) has constructed a pavement profiler certification site at a former rest area on Interstate 295. The site contains a straight roadway that is surfaced with AC and contains two 0.1 mile long test sections. An existing road in the rest area was resurfaced to serve as the certification course. Figure 3.5 shows a view of the certification site. One test section is designated as the smooth section and has an approximate mean IRI of 50 in/mi, while the other test section is designated as a medium smooth section and has an approximate mean IRI of 120 in/mi. NJDOT is planning to certify profilers owned by NJDOT at this site. The profiler certification program is administered by the Rutgers University. The reference profile data at test sections are collected using a SurPRO.

Figure 3.5. NJDOT profiler certification site.

3.2.5 Texas – Texas A&M Transportation Institute

Introduction

Texas Department of Transportation (TxDOT) has established a pavement profiler evaluation facility at the Texas A&M University, Riverside Campus, which is located in College Station, Texas to perform the following two functions:

- Support pavement management activities of TxDOT by testing the fleet of profilers that TxDOT uses to collect data for pavement management purposes.

- Provide pavement smoothness specification implementation support by certifying profilers that are used to collect smoothness data for construction acceptance.

The profiler certification program, which includes certification of profilers as well as profiler operators, is administrated by the Texas A&M Transportation Institute (TTI). Only inertial profilers that are certified at this facility and operated by a certified operator can be used to collect data for quality assurance of the final pavement surface for smoothness. The profiler and profiler operator certification procedures are described in TxDOT standard Tex-1001-S (Texas DOT, 2012). TTI will certify any profiler regardless whether they collect data in Texas. Many private companies, as well as SHAs, have had their profilers certified at TTI.

TTI typically sets aside two days each month for profiler certification, and anyone who is interested in getting their profiler certified can make an appointment on the specified days. TTI charges $2,000 for the profiler certification process for each profiler. If a profiler fails to pass certification, TTI charges $800 for the next attempt, if that attempt can be scheduled during the same week. The profiler certification is valid for one year.

A review of the profilers that have been certified by TTI that is shown on the TTI Pavement Profiler Evaluation Facility website shows equipment from all major manufacturers have been certified by TTI. These include Ames Engineering, Dynatest, Fugro-Roadware, ICC, Pathway, and SSI. The certified equipment includes equipment that is used for network level data collection, as well as those used for QA testing of smoothness of new construction.

Test Sections

Two AC surfaced test sections at the pavement profiler evaluation facility are used for certifying profilers. One test section is designated as a smooth section, and the other is designated as a medium smooth section. Each test section is 528 ft long. Figure 3.6 shows a photograph of a test section.

Profiler Certification

TTI collects the reference data at the test sections prior to certification using a SurPRO. The profiler owner, through the profiler manufacturer, has to provide TTI an executable file that can be used to apply the upper wavelength cut-off filter that is applied to the profile data to the reference data. The software in the profiler must be set such that an upper wavelength cut-off filter of 200 ft is applied to the profile collected at the test sections. Each profiler is required to submit data for 10 runs at each test section. The collected data are used to evaluate equipment repeatability and accuracy. In order to be certified, the equipment must pass the following requirements:

Figure 3.6. Texas DOT profiler certification site.

- Equipment Repeatability: The standard deviation of the profile data from the ten repeat runs at each data recording interval is computed for each wheelpath. Thereafter, the average of the standard deviations is computed. The average standard deviation must not exceed 35 mils for the profiler to pass the repeatability criterion.

- Equipment Accuracy: The average profile computed from the ten repeat runs for each wheelpath is compared with the reference device data for that wheelpath that has been filtered with the same filter that is applied to the data collected by the profiler. The difference between the two profiles is computed for each data recording interval. The standard Tex-1001-S presents the procedure to analyze this difference to determine if the profiler meets the accuracy requirement.

- IRI Repeatability: The standard deviation of IRI computed from the ten runs must not exceed 2 in/mi for each wheelpath.

- IRI Accuracy: The difference between the average profiler IRI and the reference device IRI must not exceed 6 in/mi for each wheelpath.

The above requirements are different from the procedures outlined in AASHTO R 56 to certify profilers. The procedures presented in R 56 for evaluating the repeatability and accuracy of a profiler is based on IRI-filtered cross-correlation.

A decal is provided to be affixed to the profiler once it passes certification. The certified profilers are shown on the Pavement Profiler Evaluation Facility webpage. According toTxDOT standard Tex-1001-S, a profiler must be recertified after major component repairs or replacements. This standard describes the following items as major components: the accelerometer and its associated hardware, the height sensor and its associated hardware, the DMI, and any printed circuit board necessary for the collection of raw sensor data or the processing of the profile data and IRI.

Operator Certification

TTI offers profiler operator certifications four times a year, with the fee for operator certification being $300 per operator. The operator certification is valid for 3 years. In order to be certified, a profiler operator must pass a proficiency test, which consists of a closed book exam and a practical exam. In the closed book exam, the operator is tested in the areas of current specifications and special provisions for ride quality in Texas, standard Tex-1001-S, inertial profiler components, verification of profiler calibration, profile measurements with inertial profilers etc. In the practical exam, the operator must demonstrate the ability to verify profiler calibration, and ability to collect data with the profiler. Operators who successfully complete these requirements are issued an identity card that is valid for three years. The card will indicate the specific type of inertial profiler (i.e., manufacturer and model) for which the operator certification is valid, the issue date, and the expiration date of the certification.

3.3 SUMMARY

Table 3.1 presents the following information for existing profiler certification programs: whether the program is administered by the SHA or a university affiliated institution, whether the SHA has a dedicated facility to perform profiler certifications, whether profiler operator certification is required, the period of validity for profiler certification and operator certification, whether or not there is a fee for profiler certification and operator certification, and the device that is used to collect the reference data.

Table 3.2 presents the following information for existing profiler certification programs: test sections that are used for certification, whether a DMI check is performed, if a DMI check is performed the DMI criterion, number of profiler runs required at a test section for certification, whether the certification procedure is based on cross-correlation, the repeatability and accuracy criterion for passing certification, and other criterion required for certification.

Table 3.1. Summary of profiler certification programs.

State	Program Administered by SHA or University?	Dedicated Facility for Certification?	Operator Certification Required?	Period of Validity for Profiler Certification	Period of Validity for Operator Certification	Fee for Profiler Certification?	Fee for Operator Certification?	Device Collecting Reference Data
Colorado	SHA (Note 1)	No	Yes	1-Year	3-Years	No	No	SurPRO
Michigan	SHA	No	Yes	1-Year	Unknown	No	No	SurPRO
Minnesota	SHA	Yes	Yes	End of Calendar Year	3-Years	No (Note 2)	No	SurPRO
Mississippi	SHA	No	Yes	1-Year	1-Year	No	No	SurPRO
New Mexico	SHA (Note 1)	No	Yes	1-Year	3-Years	$500	$200	SurPRO
Ohio	SHA	No	Yes	1-Year	1-Year	No	No	Note 3
Pennsylvania (Note 4)	SHA	Yes	Yes	30th June Next Year	3-years	$400	Included in Profiler Certification Fee	SurPRO
Wisconsin	SHA (Note 1)	No	Yes	1-Year	Unknown	No	Unknown	SurPRO
Alabama	University	Yes	Yes	1-Year	3-Years	Note 5	Note 5	SurPRO
California	University	Yes	Yes	1-Year	1-Year	$1,000	$500 first year and $250 Subsequent years	SurPRO
Florida (Note 6)	University	Yes	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
New Jersey (Note 7)	University	Yes	Unknown	Unknown	Unknown	Unknown	Unknown	SurPRO
Texas	University	Yes	Yes	1-Year	3-Years	$2,000	$300	SurPRO

Note 1: Operator certification is performed by an institute training technicians.
Note 2: Certification is free for three devices owned by a company, $1000 for additional devices.
Note 3: Reference IRI established based on IRI values obtained by Ohio DOT owned profilers.
Note 4: Only lightweight profilers are certified.
Note 5: NCAT has certified ALDOT profilers through an existing project. NCAT hopes to charge $2000 per profiler in the future, which will include operator certification.
Note 6: Construction of the facility is expected to start in late 2014.
Note 7: NJ DOT owned profilers are expected to be certified at this facility.

Table 3.2. Summary of criteria for passing profiler certification.

State	Test Sections for Certification	Is a DMI Check Used?	DMI Criterion	Number of Profiler Runs	Is Certification Based on Cross-Correlation	Repeatability Criterion	Accuracy Criterion	Other Criterion
Colorado	Three AC sections, IRI between 30 to 90 in/mi	No	Not Applicable	10	No	Standard deviation of IRI for each wheelpath ≤ 3 in/mi	Average IRI for each wheelpath within 6 in/mi of reference IRI	Line lasers required for profilers collecting data on PCC pavements
Michigan	One AC section	Yes	Within 0.1% of distance at DMI section	10	No	Standard deviation of IRI for each wheelpath ≤ 2 in/mi	Average IRI from 10 runs for each wheelpath within 5 in/mi of reference IRI	--
Minnesota	One AC and one PCC with transverse tining	Yes	All passes at test section within 0.2% of actual length	5	Yes, but IRI is also used	Standard deviation of IRI for each sensor ≤3% of average IRI of all runs	IRI for each sensor within 5% of reference IRI. Each run at each test section have a cross-correlation of at least 85% with reference, and average of these values be at least 90%	--
Mississippi	One AC section	Yes	Within 1 ft of actual length of test section, which is typically 528 ft	6 runs at 25 mi/h and 6 runs at 50 mi/h, best five runs at each test speed used for analysis	Yes	AASHTO R 56 Criterion (Note 1)	AASHTO R 56 Criterion (Note 2)	--
New Mexico	Two AC sections	Yes	Unknown	12 runs, best 10 used	Yes, but IRI also used	For each wheelpath, standard deviation of IRI must be less than 3 in/mi	Average IRI for each wheelpath within 6 in/mi of reference IRI, and AASHTO R 56 Criterion (Note 2)	--

Table 3.2 (Continued).

State	Test Sections for Certification	Is a DMI Check Used?	DMI Criterion	Number of Profiler Runs	Is Certification Based on Cross-Correlation	Repeatability Criterion	Accuracy Criterion	Other Criterion
Ohio	Two AC and three PCC sections. (Note 3)	Yes	Within 0.1% of distance at DMI section	5	No	Standard deviation of mean IRI within 5% of average mean IRI from ten runs	Average mean IRI within greater of 5% of reference mean IRI or 5 in/mi	Profilers with single-point lasers certified for AC only omitting data collected on sections with longitudinal texture
Pennsylvania	Two AC and two PCC (Note 4)	Yes	Within 1 ft at a 1056 ft long section	5	Yes	AASHTO R 56 Criterion (Note 1)	AASHTO R 56 Criterion (Note 2)	IRI values from profiler software must match ProVAL
Wisconsin	One AC and one PCC	Unknown	Unknown	Unknown	Yes	AASHTO R 56 Criterion (Note 1)	AASHTO R 56 Criterion (Note 2)	Line lasers required for PCC pavements
Alabama	Three AC sections and an Open-Graded Friction course section	Yes	Within 0.15% of actual distance at all sections	10	Yes	AASHTO R 56 Criterion (Note 1)	AASHTO R 56 Criterion (Note 2)	A profiler can obtain certification only for dense-graded AC. Note 5
California	One AC and one PCC	Yes	Unknown	Unknown	Yes	AASHTO R 56 Criterion (Note 1)	AASHTO R 56 Criterion (Note 2)	--
Florida (Note 6)	Two AC and two OGFC	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
New Jersey	Two AC sections	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Texas	Two AC sections	No	Not Applicable	10	No	Average standard deviation of profiler data for each wheelpath must be ≤35 mils. Standard deviation of IRI for each wheelpath must be ≤2 in/mi	Tex-1001-S procedure that gives agreement between profile data and filtered reference profile data. For each wheelpath average IRI from repeat runs should be within 6 in/mi of the reference IRI	--

Note 1: AASHTO R 56 repeatability criterion requires an average IRI-filtered cross-correlation of at least 92 percent along a wheelpath.
Note 2: AASHTO R 56 accuracy criterion requires average IRI-filtered cross-correlation between profiler data and reference data to be at least 90 percent along a wheelpath
Note 3: One AC section is diamond ground. The three PCC sections have transverse tining, longitudinal grooving, and diamond grinding.
Note 4: PCC sections have areas that have transverse tining, longitudinal tining, and diamond grinding
Note 5: In order to pass certification on the open graded friction course, must also obtain an IRI within 5% of the SurPRO IRI for each wheelpath
Note 6: Construction of the facility is expected to commence in late 2014.

CHAPTER 4. PAVEMENT TEST FACILITIES

4.1 INTRODUCTION

This chapter presents details about the following four pavement test facilities that have a variety of test sections:

- MnROAD test facility.
- TTI test facility.
- NCAT test track.
- Virginia Smart Road.

These test facilities have the potential for serving as regional profiler certification centers, as they have a variety of pavement test sections. All of these facilities have controlled access and are not subjected to public traffic.

Two test sections located at MnROAD test facility, two test sections located at the TTI test facility, and four test sections located at the NCAT test track are currently used for profiler certification by MnDOT, TTI, and NCAT, respectively. However, these facilities have other test sections, and a description of all test sections available at each facility is presented in this chapter.

The Virginia Tech Transportation Institute (VTTI) operates the Smart Road facility, which is located in Blacksburg, Virginia. This test road contains a variety of surface types. VTTI does not currently offer profiler certification. However, VTTI organizes an annual profiler comparison at the Smart Road.

The profiler certification facility in New Jersey that is operated by Rutgers University, and the proposed certification facility in Florida, which were described in the previous chapter also have the potential to be used as regional certification centers. The facility in New Jersey has two test sections and the proposed facility in Florida will have four test sections. Details about the test sections available at these two locations were described in the previous chapter.

4.2 MnROAD TEST FACILITY

The MnROAD test facility is located in Albertville, Minnesota and is operated by MnDOT. Pavement test sections are located on the mainline, as well as on the low volume road. The mainline is located on I-94 and is subjected to normal traffic, while access is controlled and only authorized vehicles can enter the low volume road. This facility also has a large garage that is suitable for performing checks on the equipment, such as the block check and bounce test.

Figure 4.1 shows the layout of the test sections on the low volume road. This road consists of two lanes with traffic on the inside lane travelling in the clockwise direction and the traffic on the outside lane travelling in the counter-clockwise direction. The inside lane is subjected to traffic from a semi-tractor trailer that is loaded to 80,000 lb, which makes about 50 laps per day during weekdays.

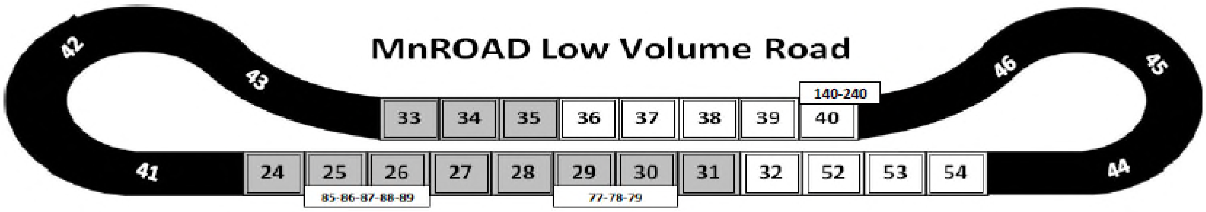


Figure 4.1. Layout of the test sections on the low volume road.

Table 4.1 shows the surface type including the texture type, length, and the mean IRI of the test sections on the low volume road. This table also shows the joint spacing for PCC pavements.

The information shown in Table 4.1 was reviewed to identify test sections that can be established for various surface and texture types. A test section must be at least approximately 500 ft long in order to be selected as a certification section. The ability for a high-speed profiler to successfully profile a section was a factor that was considered in selecting suitable sections. A high-speed profiler needs at least a 300 ft lead-in along a straight path before the start of the section, and be able to maintain a constant speed when collecting data within the test section. These two factors rule out using cells 33 and 140 because of either insufficient lead-in or because the profiler will not have sufficient room after the end of the test section to reduce speed before entering the loop located at the two ends of the low volume road.

The following are the possible test sections that can be established on the low volume road:

- Dense-Graded AC: The dense-graded AC sections were evaluated to identify the smoothest and the roughest test section that could be established. It appears the smoothest test section that can be established will be on cell 24, where the mean IRI of the inside and outside lanes are 89 and 62 in/mi, respectively. It appears the roughest test section can be established by encompassing cells 77, 78, and 79 where the mean IRI of the inside and outside lanes are expected to be approximately 150 and 125 in/mi, respectively. Cell 31 is another candidate for a rough AC section that has a mean IRI of 126 and 120 in/mi for the inside and outside lanes respectively.

- Transverse Tined PCC: The available test sections were evaluated to identify the smoothest and the roughest test section that could be established. It appears portions of cells 36 and 37 can be combined to establish the smoothest test section, which is expected to have a mean IRI between 80 and 90 in/mi. The roughest test section that can be established is on cell 38, where the mean IRI of the inside and outside lanes were 148 and 122 in/mi, respectively.

- Chip Seal: Cell 28 is a 500 ft long chip seal section where the mean IRI of the inside and outside lanes were 204 and 177 in/mi, respectively.

Table 4.1. Test sections on the low volume road at MnROAD.

Cell	Surface Type	Length (ft)	Joint Spacing for PCC Sections (ft)	Mean IRI (in/mi) (Note 1)	
				Inside Lane	Outside Lane
24	AC, Dense-Graded	507	-	89	62
27	AC, Dense-Graded	499	-	108	129
28	Chip Seal	500	-	204	177
31	AC, Dense-Graded	500	-	126	120
32	PCC, Astro Turf	460	10	62	69
33	AC, Dense-Graded	500	-	87	88
34	AC, Dense-Graded	499	-	111	85
35	AC, Dense-Graded	499	-	111	87
36	PCC, Transverse Tined	480	15	92	86
37	PCC, Transverse Tined	504	12	88	80
38	PCC, Transverse Tined	480	15	148	122
39	PCC, Pervious	440	-	71	90
52	PCC, Astro Turf	285	15	112	149
53	PCC, Transverse Broomed	118	15	163	125
54	PCC - Astro Turf	194	15	106	98
77	AC, Dense-Graded	286	-	143	134
78	AC, Dense-Graded	365	-	151	108
79	AC, Dense-Graded	325	-	148	122
85	PCC, Pervious	216	-	290	275
86	Porous AC	235	-	185	130
87	AC, Dense-Graded	225	-	140	134
88	Porous AC	225	-	180	168
89	PCC, Pervious	217	-	408	295
140	PCC, Longitudinally Tined	459	5	93	92
Note 1: IRI computed from data collected with a line laser (i.e., RoLine) in October 2013					

- PCC with an Astro Turf Finish: Cell 32 has an astro turf finish and is 460 ft long. The IRI of the inside and outside lanes are 62 and 69 in/mi, respectively. Minnesota uses an astro turf finish on PCC pavements constructed on high-speed facilities. However, other states do not use this texture type on high-speed facilities.

The low volume loop has a longitudinally tined PCC section that is 459 ft long (cell 140). This section is an unbonded PCC overlay with panel sizes that are 5 ft by 6 ft. The mean IRI of the inside and outside lanes are 93 and 92 in/mi, respectively. However, this section is adjacent to the east loop of the low volume loop. Therefore, profiling this test section in the east-west direction is not possible because the profiler will be entering the section as it comes out of the curve, and therefore a sufficient straight lead-in distance is not available. It may be possible to profile this section in the west to east direction, but this will have to be done at a low speed as the vehicle will be entering a curve soon after the end of the section.

There are two pervious asphalt pavement sections on the low volume loop. These can serve as a surrogate for an OGFC surface. However, the lengths of the two test sections are 225 and 235 ft, and they are not adjacent to each other. Therefore, because of insufficient length, these cannot be used as certification sections.

Many test sections are located on the MnROAD mainline section, including PCC pavements that are diamond ground as well as longitudinally tined. As mentioned previously, the mainline is subjected to traffic. MnDOT closes the mainline to traffic several days each month to collect data at the test sections. It might be possible to use test sections located on the mainline during this period as certification sections. However, this will require coordination with MnDOT staff, as MnDOT will be doing their own testing on the mainline sections during this period.

An issue with the MnROAD facility is that some test sections at the facility go out of study from time to time and are reconstructed based on a research cycle. The next construction activities at MnROAD are expected to occur in 2016. At this point, it is unknown what test cells in the low volume loop will be reconstructed in 2016.

MnDOT currently uses an AC surfaced and a PCC surfaced test section located on the low-volume loop to certify inertial profilers.

4.3 TTI TEST FACILITY

TTI administers the profiler certification program in Texas. Two AC surfaced test sections located at the Texas A&M Riverside campus are used to certify inertial profilers.

TxDOT recently constructed test sections having the following surface types at this facility (Fernando and Harrison, 2013):

- Longitudinally tined CRC pavement (1-inch tine spacing).
- Transverse tined CRC pavement (1/2-inch tine spacing).
- Transverse tined CRC pavement (1-inch tine spacing).
- Permeable friction course.
- Inverted prime.
- Chip seal.

An inverted prime is a pavement where the first course of a chip seal is placed to provide a temporary wearing course for traffic. All three CRC test sections are located along the CRC test track, while the three flexible test sections are located along the flexible pavement test track. The CRC test track, as well as the flexible pavement test track, are 2100 ft long and 10 ft wide, and were constructed adjacent to each other (see figure 4.2). Each test section is at least 550 ft long. Each CRC section has an approximate mean IRI of 55 in/mi (Fernando and Harrison, 2013).

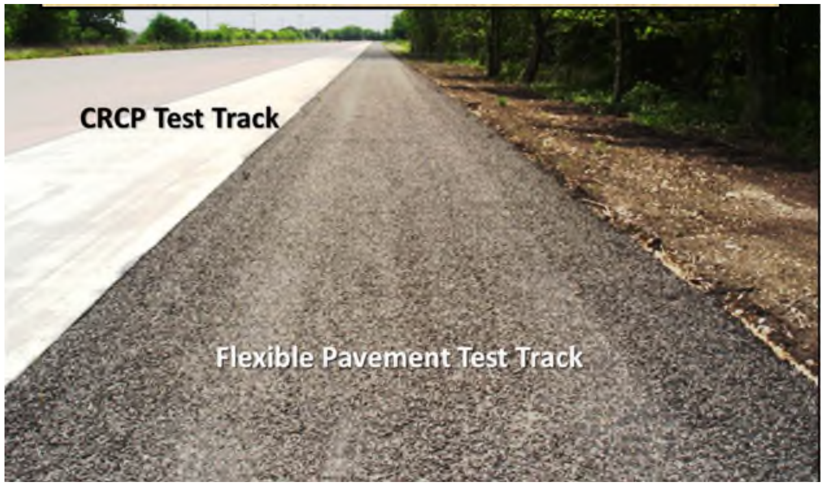


Figure 4.2. New test tracks at the TTI Riverside Campus (Fernando, 2013).

The purpose of building these test tracks was to evaluate pavement surfaces that are currently covered by existing TxDOT ride specifications (e.g., CRC), as well as to evaluate surfaces on which data are collected during TxDOT's annual network level ride quality program (e.g., chip seal). TxDOT also has a flexible base ride quality specification that is used for chip seal pavements. The ride quality measurements are performed on the inverted prime surface before the placement of the second chip seal course. This is the reason for the construction of the inverted prime section. After evaluating the profile data collected at these new test sections, TxDOT is planning to expand its current profiler certification program to include these new surface types.

4.4 VIRGINIA SMART ROAD

The Virginia Smart Road is a controlled access roadway located adjacent to VTTI in Blacksburg, Virginia. This facility is managed by VTTI, and has controlled access. Figure 4.3 shows a view of the smart road. Table 4.2 shows the test sections that are located on the smart road including the surface type, length, the approximate grade of the test section, and the approximate mean IRI of the test sections in the upgrade direction. The Smart Road was constructed in 1999. Section K that has an OGFC surface was reconstructed in 2006. The Jointed Reinforced Concrete (JRC) pavement section was diamond ground in 2011. The CRC pavement section has transverse tining, but in 2011, a 530 ft long section in the middle of the CRC section was diamond ground and grooved.

VTTI administrates a regional pooled fund project, known as the Pavement Surface Properties Consortium that was set up in 2006 to enhance the level of service provided on roadways by optimizing surface texture characteristics. Connecticut, Georgia, Pennsylvania, Mississippi, South Carolina, and Virginia are members of this consortium. VTTI annually hosts a profiler comparison for the member states of the consortium. Typically, five test sections are laid out on the uphill direction of the Smart Road, and reference profile measurements are obtained at these sections using a SurPRO. Thereafter, profilers collect data at the test sections.

Figure 4.3. Smart Road at Virginia Tech.

Table 4.2. Test sections at Smart Road.

Section (Note 1)	**Surface Type (Note 2)**	**Length (ft)**	**Approximate Grade (%)**	**Approximate IRI (in/mi)**
A	AC	347	2-3	123
B	AC	289	2-3	164
C	AC	292	2-3	77
D	AC	407	2-3	195
E	AC	268	3 to 4	90
F	AC	302	3 to 4	99
G	AC	304	3 to 4	108
H	AC	292	3 to 4	112
I	AC	338	3 to 4	93
J	AC	280	3 to 4	105
K	OGFC	302	4 to 6	134
L	SMA	326	4 to 6	113
CRC	PCC	2290	6	-
JRC	PCC	591	6	94

Note 1: CRC - Continuously Reinforced Concrete, JRC – Jointed Reinforced Concrete
Note 2: AC - Asphalt Concrete, OGFC – Open-Graded Friction Course, SMA - Stone Matrix Asphalt, PCC - Portland Cement Concrete

VTTI prepares a report that compares IRI values at the test sections among the devices, how the IRI of each device compares with the IRI obtained by the reference device, the IRI-filtered cross correlation between the SurPRO and each profiler, and the repeatability of each profiler in terms of the IRI-filtered cross correlation. Although this is not a profiler certification program, participating states are able to compare the results for their device with the other profilers that participated in the comparison, as well as with results from the reference device.

An issue with the Smart Road is that all of the test sections have a grade, which can affect the measurements made by in inertial profilers, because the accelerometer will be tilted from the vertical direction. This issue is explained by Karamihas et al. (1999).

4.5 NCAT TEST TRACK

NCAT operates a pavement test track located in Opelika, Alabama. Some details about this test track were presented in section 3.2.1. NCAT currently uses four test sections located on the inside lane of the test track to certify profilers. The locations of the test sections are shown in figure 4.4 with the mean IRI values of the test sections. (Note: The 2012 IRI values of the test sections are shown in red with the units being in/mi.)

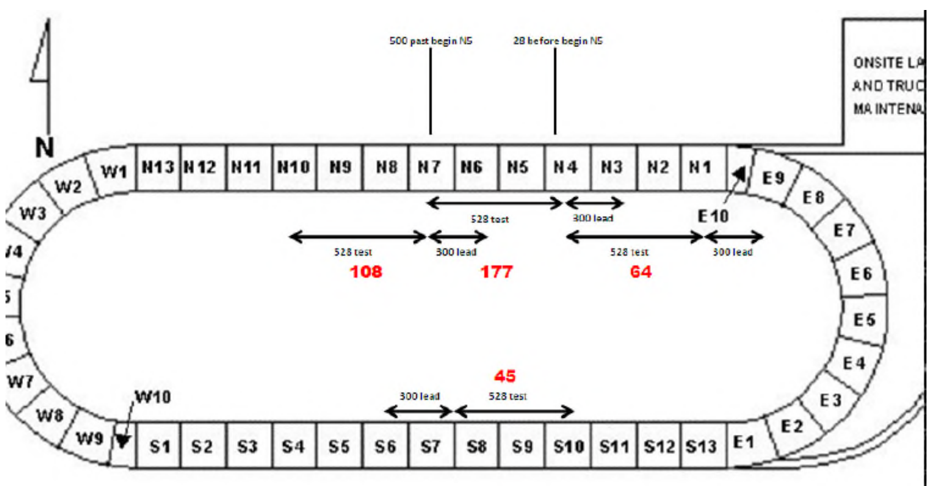


Figure 4.4. Location of profiler test sections on the NCAT test track (Powell, 2012).

Three of the test sections, that are located on the north portion of the test track, have a dense-graded AC surface The other test section, which is located on the south portion of the test track has an open-graded surface. No PCC sections are present on this test track.It may be possible to locate other test sections that have different roughness levels at this test track. As the outside lane of the test track is rebuilt every three years, NCAT has the ability to construct test sections at that time in the inside lane to any desired roughness level.

CHAPTER 5. SURVEY ON REGIONAL CERTIFICATION CENTERS

In March 2012, Dave Huft of South Dakota Department of Transportation performed a survey of highway agencies to get their input on a variety of questions dealing with profiler certification and establishing regional certification centers for inertial profilers. The primary purpose of the survey was to gauge the interest of SHAs in establishing regional certification centers for profilers. This survey was performed on behalf of the pooled fund study TPF-5(063), Improving the Quality of Pavement Profile Measurement. The survey was sent to SHAs in the United States, Canadian provincial highway agencies, highway agency in Puerto Rico, and the FHWA Long Term Pavement Performance Program. The results from this survey were presented at the 25th Annual RPUG meeting (Huft, 2013).

The research team obtained the responses to the survey from Dave Huft and extracted the responses provided by SHAs in the United States and analyzed that data. This section presents the questions that were asked in the survey and the responses provided by the 38 SHAs in the United States that responded to the survey.

Question 1: How does your agency measure roughness of your highway network (check all that apply)?

☐ By agency staff using agency-owned equipment
☐ By contractor using contractor-owned equipment
☐ Other, please specify:

Response	Number	Percentage (%)
Agency Using Agency Owned Equipment	19	50
Contractor Using Contractor Owned Equipment	7	18
Agency with Agency Owned & Contractor with Contractor Owned	12	32

The responses showed 32 percent of the SHAs use a combination of state owned equipment operated by agency personnel and contractor owned equipment operated by contractor personnel to collect roughness data of their highway networks.

Question 2: How does your agency assess smoothness of newly constructed pavements (check all that apply)?

☐ By agency staff using agency-owned equipment
☐ By contractor using contractor-owned equipment
☐ Other, please specify:

Response	Number	Percentage (%)
Agency Using Agency Owned Equipment	16	43
Contractor Using Contractor Owned Equipment	11	30
Agency with Agency Owned & Contractor with Contractor Owned	10	27

It is possible for the agencies that selected the response "Agency with Agency Owned Equipment" and "Contractor with Contractor Owned Equipment" that the contractor collects the smoothness data and the SHA verifies the data on a sample of the project for QA purposes. It is likely that for agencies that responded "Contractor with Contractor Owned Equipment" the SHA performs verification testing on a sample of the project for QA purposes.

Question 3: For which pavement types does your agency use high- or low-speed inertial profilers to assess construction quality (check all that apply)?

- ☐ Asphalt concrete (AC)
- ☐ Portland cement concrete (PCC)
- ☐ Other, please specify:

Response	Number	Percentage (%)
AC Only	36	100
AC & PCC	24	67

One SHA indicated they do not have PCC pavements. There could be other SHAs that do not have PCC pavements that resulted in the lower percent for the answer AC & PCC pavements. Another SHA indicated they get the PI value from the data collected by profilers and use that index for construction acceptance. Some of the SHAs may still be using profilographs to measure smoothness on PCC pavements, which could be another reason for the lower value for the response AC & PCC pavements.

Question 4: How does your agency certify agency-owned inertial profilers (check all that apply)?

- ☐ (a) Certification by equipment vendor
- ☐ (b) Certification at national calibration facility
- ☐ (c) Certification at facility operated by my state DOT
- ☐ (d) Certification at facility operated by another state DOT
- ☐ (e) Certification at a university-operated facility
- ☐ (f) Other, Please Specify

Response	Number
(a) Certification by equipment vendor	9
(b) Certification at national calibration facility	0
(c) Certification at facility operated by my state DOT	12
(d) Certification at facility operated by another state DOT	2
(e) Certification at a university operated facility	3
(a) & (b) Certification by equipment vendor and at a national calibration facility	2
(a) & (c) Certification by equipment vendor and at a facility operated by my state DOT	3
(c) & (d) Certification at a facility operated by my state DOT and another DOT	1
At calibration sections established by the SHA	4
Not performed	1

Question 5: How does your agency certify contractor-owned inertial profilers (check all that apply)?

- ☐ (a) Certification by equipment vendor
- ☐ (b) Certification at national calibration facility
- ☐ (c) Certification at facility operated by my state DOT
- ☐ (d) Certification at facility operated by another state DOT
- ☐ (e) Certification at a university-operated facility
- ☐ (f) Other, Please Specify

Response	Number	Percentage (%)
(a) Certification by equipment vendor	4	15
(b) Certification at national calibration facility	0	0
(c) Certification at facility operated by my state DOT	19	73
(d) Certification at facility operated by another state DOT	0	0
(e) Certification at a university operated facility	3	12

The question did not specify if the contractor owned profilers were those used for network level data collection or those used to collect data on new construction for construction acceptance. Responses were provided by 26 SHAs to this question. As 21 agencies indicated they allow contractors to collect data on newly constructed pavements (see question 2), it is likely the answers provided to this question relate to profilers that collect data on new construction for construction acceptance.

Question 6: If your agency operates its own calibration facility, what types of pavements does it include (check all that apply)?

- ☐ My agency does not operate its own facility
- ☐ Dense-graded asphalt concrete
- ☐ Open-graded asphalt concrete
- ☐ Stone mastic asphalt (SMA)
- ☐ Portland cement concrete (PCC)
- ☐ Other, Please Specify

Response	Number	Percentage (%)
My agency does not operate its own facility	18	48
AC & PCC	6	16
Dense-graded AC only	11	30
Dense-graded AC & SMA	1	3
Dense-graded AC and open-graded AC	1	3

Nineteen SHAs indicated they operate their own facility. Twenty one agencies indicated they allow contractors to collect data on newly constructed pavements (see question 2). It is likely the SHAs that operate calibration facilities are those that allow contractors to collect smoothness data on new construction for construction acceptance. Some agencies establish calibration sections on in-service roads, while some use calibration facilities in their states that are operated by a university affiliated institute. There is a possibility some of these states may have indicated they do not operate its own "facility", as the calibration sections are established on in-service roads or because it is operated by a university affiliated institute.

Question 7: Please identify the profiler certification facility your agency used most recently:

- ☐ My agency has not used a certification facility recently
- ☐ My agency most recently used (please specify):

Response	Number	Percentage (%)
My agency has not used a certification facility recently	17	45
Certification sites on in-use pavements (within state)	7	18
State owned or university operated certification facility (within state)	7	18
Other test track, closed to traffic (within state)	1	3
Airport facility (within state)	1	3
Out of state facility	5	13

SHAs that have established certification sites on in-service roads have established such sites on low volume roads (e.g., frontage roads). As shown in the above table, some SHAs have gone to certification facilities out of state. Some SHAs have gone to certification facilities operated by another SHA, while others have gone to a facility operated by a university affiliated institute.

Question 8: When does your agency require profilers to be certified (check all that apply)?

- ☐ (a) When the profiler is purchased
- ☐ (b) Annually
- ☐ (c) When inaccuracy is suspected
- ☐ (d) After significant repairs
- ☐ (f) Other, Please Specify

Response	Number
(a) When profiler is purchased	4
(b) Annually	10
(c) When accuracy is suspected	1
(d) After significant repair	1
(b) & (d) Annually and after significant repair	1
(b) & (c) Annually and when accuracy is suspected	3
(c) & (d) When accuracy is suspected and after significant repair	1
(a), (c) & (d) When purchased, when accuracy is suspected, and after significant repair	1
(b), (c) & (d) Annually, when accuracy is suspected, and after significant repair	3
(a), (b) & (d) When purchased, annually, and after significant repair	1
(a), (b), (c), & (d) When purchased, annually, when accuracy is suspected, and after significant repair	7

Question 9: What standard procedures does your agency require for certification (check all that apply)?

- ☐ AASHTO R56
- ☐ ASTM E950
- ☐ Other, Please Specify

Response	Number	Percentage (%)
AASHTO R56	5	15
ASTM E950	7	21
AASHTO R56 & ASTM E 950	3	9
State specific procedure	18	55

Several agencies that indicated they use state specific procedures indicated their procedures have some elements of AASHTO R56.

Question 10: Does your agency honor profiler certification granted by other state DOTs?

- ☐ No
- ☐ Yes, Please describe

Response	Number	Percentage (%)
No	29	78
Yes	3	8
Maybe	5	14

The SHAs that indicated "Yes" usually listed some of the adjoining states whose certification they will accept. It appears for the states that indicated "Maybe" this situation has nor arisen, and these states indicated they will have to see the procedures that were used by the SHA or institute that certified the profiler before accepting their certification.

Question 11: Please rate how valuable a regional certification facility would be for certifying the following types of profiling equipment (select one response for each question)

The number of responses for each category and the percentage of responses are both shown in the table below.

Response	Number and Percentage (within parenthesis)			
	No Value	Limited Value	Moderate Value	High Value
Agency-owned profilers used for network-level measurement	9 (24%)	4 (11%)	13 (33%)	12 (32%)
Agency-owned profilers used for project-level measurement	6 (15%)	4 (11%)	9 (24%)	19 (50%)
Contractor-owned equipment used for network-level measurement	13 (34%)	4 (11%)	9 (23%)	12 (32%)
Contractor-owned equipment used for project-level measurement	10 (26%)	3 (8%)	9 (24%)	16 (42%)

Question 12: What would be an acceptable distance for your agency to travel to use a regional certification facility (check one)?

- ☐ Only within my state
- ☐ 250 miles or less
- ☐ 500 miles or less
- ☐ 750 miles or less
- ☐ 1000 miles or less
- ☐ No limit
- ☐ Other, please specify

Response	Number	Percentage (%)
Only within my state	7	21
≤ 250 miles	10	29
≤ 500 miles	12	35
≤ 750 miles	3	9
≤ 1000 miles	1	3
No Limit	0	0
Other (≤ 100 miles)	1	3

Question 13: Please rate the importance of potential barriers to your agency's using a regional certification center:

The number of responses for each category and the percentage of responses are both shown in the table below.

Response	Number and Percentage (within parenthesis)			
	Not Important	Somewhat Important	Very Important	Critically Important
Travel distance	1 (3%)	12 (32%)	17 (44%)	8 (21%)
Out-of-state travel restrictions	2 (5%)	14 (37%)	10 (26%)	12 (32%)
Scheduling difficulties	4 (11%)	20 (53%)	13 (33%)	1 (3%)
Cost	0 (0%)	15 (39%)	16 (43%)	7 (18%)
Demand for staff time	4 (11%)	18 (47%)	14 (37%)	2 (5%)
Loss of state control	15 (39%)	13 (35%)	7 (18%)	3 (8%)

Question 14: Please rate the importance of potential benefits of your agency's using a regional certification center:

The number of responses for each category and the percentage of responses are both shown in the table below.

Response	Number and Percentage (within parenthesis)			
	Not Important	Somewhat Important	Very Important	Critically Important
Credibility	2 (5%)	6 (16%)	16 (42%)	14 (37%)
Technical validity	2 (5%)	4 (11%)	16 (42%)	16 (42%)
Relief from burden of establishing own certification process	11 (28%)	12 (32%)	11 (29%)	4 (11%)
Comparability of roughness performance measures among states	7 (18%)	14 (37%)	12 (32%)	5 (13%)

Question 15: What would your agency consider a reasonable cost for certifying a single profiler (check one)?

- ☐ $3,000 or less
- ☐ $5,000 or less
- ☐ $10,000 or less
- ☐ Other, please specify

Response	Number	Percentage (%)
≤ $3,000	20	80
≤ $5,000	3	12
≤ $10,000	0	0
≤ Other $1,000	2	8

Several SHAs who currently operate their own facility indicated they provide certification free of charge or at a minimal cost, typically less than $500.

Question 16: Assuming a regional certification center existed, how would your agency prefer that it be supported financially (check one)?

- ☐ Per use charges to profiler owners
- ☐ Per state charge by pooled funding mechanism
- ☐ As an AASHTO Technical Services Program for participating states
- ☐ Other, please specify

Response	Number	Percentage (%)
Per use charge to profiler owners	16	47
Per state charge by pooled fund mechanism	9	27
As an AASHTO technical services program for participating states	8	24

Several SHAs indicated per use charge should be assessed for contractor owned equipment, while a pooled fund mechanism should be used to cover costs for SHA owned equipment.

CHAPTER 6. REQUIREMENTS OF A REGIONAL CERTIFICATION CENTER

6.1 EVALUATION OF POTENTIAL SURFACE TYPES, TEXTURE TYPES, AND ROUGHNESS RANGES AT A CERTIFICATION CENTER

6.1.1. Introduction

In this section, profilers that collect network level data on a state highway system are referred to as network level profilers, while profilers that collect data on new construction for smoothness acceptance are referred to as project level profilers. Profilers that collect data at HPMS sections that are located on the off-state system are also considered to be network level profilers. The data collected by a network level profiler is referred to as network level data, while data collected by a project level profiler is referred to as project level data. Some SHAs may use the same profiler to collect network as well as project level data.

Potential surface types and texture types needed at a regional certification center are addressed in section 6.1.2, while the required roughness ranges of test sections are addressed in section 6.1.3. The recommended surface types, texture types, and roughness ranges for test sections needed at a regional certification center are described in Section 6.2.

6.1.2. Evaluation of Potential Surface and Texture Types Needed at a Regional Certification Center

The height sensor types currently used in profilers are single-spot lasers, wide-spot lasers, and line lasers. Research studies have shown a profiler with a single-spot laser cannot collect repeatable data on PCC surfaces that have a longitudinal texture, such as longitudinal tining or diamond grinding (Karamihas and Gillespie, 2003). If a profiler with a single-spot laser is used to collect data on such surfaces, the IRI computed from the data is expected to have an upward bias (see sections 2.8.5 through 2.8.7). The performance of a wide-spot laser on a longitudinally tined surface is expected to be similar to a single-spot laser, but on a diamond ground surface a wide-spot laser might show better repeatability than a single-spot laser because of its larger footprint. Data collected with a line laser with a bridging algorithm applied to the collected data is needed to collect repeatable and accurate data on surfaces that have longitudinal texture such as longitudinal tinning and diamond grinding.

Table 6.1 shows the surface/texture types that are typically present as the final paved surface on highways in the United States. SMA and OGFC surfaces have “negative” texture while a chip seal surface will have a “positive” texture. Chip seals are usually used in secondary roads, and SHAs have a maximum value of average daily traffic above which a chip seal is not considered to be viable (Gransberg and James, 2005). Burlap drag or a broom finish is commonly present on PCC surfaces that have a speed limit of less than 45 or 50 mi/h. A particular state may not have all of these surface/texture types shown in table 6.1, and most states only have a limited number of surface/texture types shown in table 6.1. For example, there are some states that do not have PCC pavements in their state highway network. Also, there are many states that do not construct an OGFC surface.

Table 6.1. Surface/Texture types typically present as the final paved surface on highways in the United States

Surface/Texture Types
Dense-Graded Asphalt Concrete
Stone Matrix Asphalt
Open-Graded Friction Course
Chip Seal
Burlap Drag/Broom Finished Concrete
Transversely Tined Concrete
Longitudinally Tined Concrete
Diamond Ground Concrete

Table 6.2 shows the surface/texture types shown in table 6.1 with the "Comment" column indicating the effect of the height sensor type (i.e., single-spot laser and line laser) in collecting data on these surface types and the relevance of including the surface/texture type at a regional certification center.

Table 6.2. Surface types and their relevance at a regional certification facility.

Surface Type	Comment
Dense-Graded Asphalt Concrete	This is the most common surface type for highways in the United States. IRI values obtained by single-spot lasers and line lasers on the same section are expected to be close to each other for this surface type. However, the IRI from a line laser could be slightly lower than the IRI obtained from a single-spot laser (see section 2.8.1). The magnitude of the difference in IRI for data collected by the two sensor types is expected to increase with increasing macrotexture of the pavement surface. This surface type should be mandatory at a certification center.
Stone Matrix Asphalt	IRI values obtained by single-spot lasers and line lasers on the same section are expected to be close to each other for this surface type. However, the IRI from a line laser is expected to be slightly lower than the IRI obtained from a single-spot laser (see section 2.8.2). The magnitude of the difference in IRI for data collected by the two sensor types is expected to increase with increasing macrotexture of the pavement surface. This difference in IRI is unlikely to have an impact on network level data, but could have an impact on project level data, where a slight difference in IRI can mean the difference between getting a bonus or just the full pay. SHAs that construct SMA without placing an OGFC on the SMA, may like to have a SMA surface at a certification center.
Open-Graded Friction Course (OGFC)	The IRI values computed from data collected by a line laser is expected to be lower than the IRI computed from data

Surface Type	Comment
	collected with a single-spot laser on the same section by amounts up to 6 in/mi or more (see section 2.8.3). This difference in IRI can have an effect on the overall network IRI in a state that has a significant amount of pavements with OGFC. This difference in IRI is very likely to have an impact on project level data, where a difference in IRI of this magnitude can mean the difference between getting a bonus or just the full pay. Therefore, an OGFC surface is needed at a regional center located in an area where adjacent states use OGFC.
Chip Seal	The IRI obtained from data collected by a line laser is expected to be slightly lower than the IRI computed from data collected with a single-spot laser on the same section (see section 2.8.4). However, this difference in IRI may not be significant for network level profiling. This surface type will not be relevant for project level profilers, as SHAs typically do not specify a ride quality requirement when chip seal surfaces are constructed.
PCC (Burlap Drag/Broom Finish)	This surface type is typically used when the speed limit is 50 mi/h or lower. Tining is typically used as the surface texture on PCC pavements that have a speed limit higher than 50 mi/h. No information about differences in IRI between single-spot lasers and line lasers are available for this surface/texture type. No issues have been raised regarding the performance of single-spot lasers on this surface type. Therefore, this surface type is not considered to be included at a certification center.
PCC (Transverse Tining)	Most SHAs used transverse tining as the texture type on PCC pavements that generally have a speed limit greater than 50 mi/h until recently. However, SHAs that used transverse tining have switched to using longitudinal tining because longitudinal tining has less tire-pavement noise. The IRI computed from data collected by a line laser is expected to be similar to IRI computed from data collected by a single-spot laser on the same section (see section 2.8.5). Past studies have not shown that laser sensors used for road profiling is sensitive to pavement color, with good data being obtained for AC as well as PCC pavements (Perera, 2010). Past studies have also shown single-spot lasers can obtain IRI values on transversely tined PCC that compare well with reference IRI values (Perera, 2010). Therefore, a profiler that satisfactorily passes certification requirements on a dense-graded AC section is expected to collect accurate data on a PCC surface with transverse tining that has a similar roughness level. However, SHAs

Surface Type	Comment
	that have a significant amount of PCC pavements may like to have the profiler pass certification on a PCC section to ensure there are no issues with respect to pavement color.
PCC (Longitudinal Tining)	Most SHAs use this texture type currently on PCC pavements that have a speed limit greater than 50 mi/h. IRI computed from data collected by a line laser on this surface type is expected to be significantly lower than the IRI computed from data collected by a single-spot laser on the same section (see section 2.8.6). A profiler with a single-spot laser is unlikely to meet certification requirements on this surface type. If a SHA constructs this pavement type, project level and network level profilers with line lasers that operate in the state should be certified on this surface type.
PCC (Diamond Ground)	Diamond grinding results in a longitudinally textured surface. The IRI computed from data collected by a line laser is expected to be lower than the IRI computed from data collected by a single-spot laser on the same section (see section 2.8.7). The magnitude of this difference can depend on groove spacing, the width of the land area between the grooves, and the groove depth. A profiler with a single-spot laser is unlikely to meet certification requirements on this surface type. If a SHA constructs this pavement type, project level and network level profilers with line lasers that operate in the state should be certified on this surface type.

6.1.3. Roughness Levels for Test Sections

The AASHTO Standard R 56-14 recommends using a smooth section with a mean IRI of between 30 and 75 in/mi and a medium smooth section with a mean IRI between 95 and 135 in/mi for certifying project level profilers. This standard recommends in addition to these two sections, a medium rough section having a mean IRI up to 200 in/mi should be used for certifying network level profilers. The roughness ranges given in R 56-14 are considered adequate for certifying profilers, and table 6.3 presents the recommended roughness ranges over which network level and project level profilers should be certified. The selected medium rough section should not have distress along the wheelpaths.

Table 6.3. Roughness levels needed at a certification center.

Roughness Category	Mean Roughness Range (in/mi)	Applicable Profiler Type
Smooth	30 to 75	Project and Network
Medium-Smooth	95 to 135	Project and Network
Medium-Rough	150 to 200	Network

6.2 RECOMMENDED SURFACE TYPES, TEXTURE TYPES, AND ROUGHNESS RANGES AT A CERTIFICATION CENTER

6.2.1. Overview

Table 6.4 shows the mileage of pavements that are classified as interstates and other freeways in each state categorized according to the surface type (i.e., AC, PCC, and composite, where composite pavements are PCC pavements that have been overlaid with AC). The information shown in this table was summarized from the information available in the 2012 HM-51 table that is available on the highway statistics website (Federal Highway Administration, 2012). The percentage distribution of the surface types are also shown in this table. As seen in this table, there are some states that have no PCC or little PCC pavements on the freeway system. The states that have no PCC pavements will not have an interest in the capabilities of profilers in measuring PCC pavements. The states that have little PCC pavements may not have much interest in the capabilities of network profilers in measuring the various texture types in PCC pavements, but may have some interest in this area if new PCC pavements are being constructed in the state.

Many SHAs currently require line lasers to be used to collect project level data for smoothness acceptance on longitudinally tined and diamond ground PCC surfaces. Contractors are aware that IRI computed from data collected with a single-spot laser on such surfaces will result in an upward bias in IRI, and will not use a profiler with single-spot lasers to collect data on such surfaces. There are several states that do certify project level profilers on longitudinally tined PCC, with some these states also certifying project level profilers on diamond ground PCC.

Many states that construct PCC pavements do not certify project level profilers on a PCC surface, with certification only being performed on dense-graded AC surface. This is not considered to be a suitable strategy to adopt at a regional certification center because: (1) the capability of the profiler in collecting accurate data on longitudinally textured PCC surfaces in not checked, and (2) the states that certify project level profilers on longitudinally textured PCC surfaces are unlikely to accept certification that is only performed on dense-graded AC surfaces.

There are vendors who collect network level data throughout the United States, and there are contractors who collect project level data in multiple states. Hence, a profiler that is certified at a regional certification center should be able to collect data anywhere in the United States. Therefore, the surface/texture types and roughness levels should be consistent at all regional certification centers. If there are differences, there could be a perception it is easier to pass certification at a particular regional certification center rather than at another regional certification center.

The information presented in sections 6.1.2 and 6.1.3 is used in this section to provide the recommended surface/texture types and roughness levels for test sections at a certification center.

Table 6.4. Distribution of surface type of interstate and freeways/expressways in states.

State	Miles				Percentage Miles (%)		
	Interstate and Other Freeways/Expressways				Interstate and Other Freeways/Expressways		
	AC	PCC	Composite	Total	AC	PCC	Composite
Alabama	861	38	30	930	93	4	3
Alaska	1,081	0	0	1,081	100	0	0
Arizona	1,146	37	210	1,393	82	3	15
Arkansas	375	295	149	819	46	36	18
California	1,763	1,252	0	3,014	58	42	0
Colorado	892	414	0	1,306	68	32	0
Connecticut	205	13	406	625	33	2	65
Delaware	5	24	42	71	7	33	60
Dist. of Columbia	1	6	21	28	3	23	74
Florida	341	47	250	638	53	7	39
Georgia	868	526	0	1,393	62	38	0
Hawaii	55	34	0	88	62	38	0
Idaho	480	125	7	612	78	20	1
Illinois	19	277	1,982	2,278	1	12	87
Indiana	1,128	113	151	1,393	81	8	11
Iowa	58	410	314	781	7	52	40
Kansas	583	640	241	1,464	40	44	16
Kentucky	498	200	462	1,160	43	17	40
Louisiana	236	577	136	949	25	61	14
Maine	386	0	0	386	100	0	0
Maryland	499	20	246	766	65	3	32
Massachusetts	874	8	11	892	98	1	1
Michigan	426	951	573	1,950	22	49	29
Minnesota	223	481	370	1,075	21	45	34
Mississippi	654	100	13	767	85	13	2
Missouri	1,538	988	150	2,677	57	37	6
Montana	1,138	54	0	1,192	95	5	0
Nebraska	68	445	411	924	7	48	44
Nevada	327	51	6	384	85	13	2
New Hampshire	296	0	2	299	99	0	1
New Jersey	638	24	250	912	70	3	27
New Mexico	929	16	55	1,000	93	2	6
New York	938	226	1,487	2,651	35	9	56
North Carolina	1,107	365	160	1,632	68	22	10
North Dakota	0	396	175	571	0	69	31
Ohio	408	211	1,422	2,041	20	10	70
Oklahoma	522	426	175	1,123	46	38	16
Oregon	462	174	141	777	59	22	18
Pennsylvania	406	565	1,688	2,659	15	21	63
Rhode Island	133	0	21	155	86	0	14
South Carolina	291	165	442	898	32	18	49
South Dakota	33	502	153	689	5	73	22
Tennessee	1,099	27	136	1,262	87	2	11
Texas	3,181	1,578	0	4,760	67	33	0
Utah	750	199	0	949	79	21	0
Vermont	338	0	0	338	100	0	0
Virginia	1,086	242	0	1,328	82	18	0
Washington	1,257	389	135	1,781	71	22	8
West Virginia	428	134	0	562	76	24	0
Wisconsin	232	374	659	1,264	18	30	52
Wyoming	692	224	0	917	76	24	0
TOTAL	31,953	14,365	13,283	59,600	54	24	22

Three options for profiler certification centers are presented:

- Option 1: Recommendations for an ideal certification center.
- Option 2: Recommendations for an intermediate level certification center.
- Option 3: Recommendations for a basic level certification center.

Option 1 will be the most expensive option to construct a certification center or upgrade an existing facility to be a certification center. Also, the cost associated with certifying a profiler will be the most expensive for this option because of the amount of data that has to be collected and analyzed. Option 3 will be the least expensive option to construct a certification center or upgrade an existing facility to be a certification center. Also, the cost associated with certifying a profiler will be the least for this option because this option will result in the least amount of data that are collected and analyzed.

For each option, project level and network level profilers are dealt with separately. The criteria a project level profiler and a network level profiler need to meet in order to pass certification can be different, with the criteria for network level profilers being less rigorous. This issue is addressed in the next chapter. A profiler that collects project level data as well as network level data will have to meet the requirements needed for both profilers.

6.2.2. Option 1 – Requirements at an Ideal Regional Certification Center

In order to assess the performance of a profiler on surface/texture types that are commonly found on the highway types in the United States, the ability of the profiler to collect accurate profile data on the following surface/texture types must be evaluated.

- Dense-graded AC.
- Stone matrix asphalt.
- Open-graded friction course.
- Chip seal.
- Transversely tined concrete.
- Longitudinally tined concrete.
- Diamond ground concrete.

The above list is consistent with the surface/texture types recommended by Karamihas (2005) for evaluating the capabilities of profilers.

An OGFC as well as a SMA surface has negative texture, and typically the macrotexture level on an OGFC will be higher than that of a SMA surface. Therefore, an OGFC can serve as a surrogate for a SMA surface, and evaluation of profilers on an SMA surface can be omitted, as it can be assumed that a profiler that shows acceptable performance on an OGFC will show acceptable performance on a SMA surface.

Table 6.5 shows the surface/texture types and the roughness levels required at an ideal regional certification center for project level and network level profilers. A project level profiler need not be evaluated on the chip seal section as ride quality requirements are not specified for chip seal surfaces. Only a network level profiler needs to be evaluated on a medium-rough section as project level profilers are not expected to collect data on such a surface. However, profilers that collect both network level and project level data must satisfy the requirements for network level profilers, as well as project level profilers.

A properly functioning profiler equipped with a line laser should be capable of meeting the certification requirements indicated for project level and network level profilers on all surface types. A properly functioning profiler equipped with a single-spot or a wide-spot laser should be capable of meeting the certification requirements indicated for project level and network level profilers on the dense-graded AC and the transverse tined PCC pavement. Such a profiler is unlikely to meet certification requirements on the longitudinally tined PCC pavement. Such a profiler is also expected to have difficulty in passing certification on the OGFC, chip seal, and diamond ground PCC pavement.

Table 6.5. Surface/Texture types and roughness levels required at an ideal certification center.

Surface Type	**Roughness Level (Note 1)**		
	Smooth	**Medium Smooth**	**Medium-Rough**
Dense-Graded AC	Project & Network Profilers	Project & Network Profilers	Network Profilers Only
Open-Graded Friction Course	Project & Network Profilers		
Chip Seal		Network Profilers Only	
Transversely Tined PCC		Project & Network Profilers	
Longitudinally Tined PCC	Project & Network Profilers		
Diamond Ground PCC	Project & Network Profilers		
Note 1: Smooth: IRI between 30 and 75 in/mi, Medium-Smooth: IRI between 95 and 135 in/mi, Medium-Rough: IRI between 150 and 200 in/mi			

As each surface/texture type has its unique texture that will challenge a profiler, the profiler’s ability to pass certification on each surface/texture type has to be documented.

Each SHA can decide on what surface types a project level profiler collecting data in their state should be certified. However, as dense-graded AC surfaces are present in all states, certification of all project level profilers on the smooth and medium smooth dense-graded AC surfaces should be mandatory. The provided certification documentation will indicate all surface types on which the profiler has been certified. For example, a project level profiler, such as one that has single-spot laser sensors may be able to pass certification only on the dense-graded AC and the transversely tined PCC.

Each SHA can decide on what surface types a network level profiler collecting data in their state should be certified. As dense-graded AC surfaces are present in all states, certification of all network level profilers on the smooth, medium smooth, and medium rough dense-graded AC surfaces should be mandatory.

Vendors that collect data on many states may elect to get their profiler certified for project level and network level data collection on all surface/texture types, so they can say their profiler is certified to collect profile data on all of the surface types available at the certification center.

Another use for establishing an ideal certification center as described in this section is that Type Testing of profilers can be performed at the certification center. A Type Test is used in industry to conduct an independent evaluation on an equipment to see if it complies with a set of specifications. Once a profiler passes a Type Test, the manufacturer can then indicate the specific make and model of the equipment has met the requirements of a specification that describes the requirements of Type Testing. This information will be useful for SHAs or any other agency or company that will be procuring profiling equipment. This information will also be useful for SHAs when selecting a vendor to collect profile data as the Type Test report will indicate the performance of the equipment that the vendor is planning to use to collect profile data.

6.2.3. Option 2 – Requirements at an Intermediate Level Certification Center

An intermediate level certification center will have less pavement sections than an ideal certification center. An intermediate level certification center will have the following surface types:

- Dense-graded AC.
- Open-graded friction course.
- Transversely tined concrete.
- Longitudinally tined concrete.

Table 6.6 shows the surface/texture types and roughness levels at such a center, and indicates the type of profilers that should be certified for each surface/texture type and roughness level.

Table 6.6. Surface/Texture types and roughness levels required at an intermediate level certification center.

Surface Type	Roughness Level (Note 1)		
	Smooth	**Medium Smooth**	**Medium-Rough**
Dense-Graded AC	Project & Network Profiler	Project & Network Profiler	Network Profiler
Open-Graded Friction Course	Project & Network Profiler		
Transversely Tined PCC		Project & Network Profiler	
Longitudinally Tined PCC	Project & Network Profiler		
Note 1: Smooth: IRI between 30 and 75 in/mi, Medium-Smooth: IRI between 95 and 135 in/mi, Medium-Rough: IRI between 150 and 200 in/mi			

A chip seal surface is omitted at this center. A ride quality specification is not typically specified on a chip seal pavement. Therefore, omitting this surface type will not affect project level profilers. It will not be possible to evaluate the performance of network level profilers on a chip seal section at this center. Past experience has indicated a profiler equipped with a single-point laser might overestimate the IRI of chip seal surface slightly (see section 2.8.4).

A diamond ground surface is omitted at this center. Therefore, it will not be possible to evaluate the performance of both project and network level profilers on this surface type. An assumption will have to be made that a profiler that passes certification on the longitudinally tined surface will be able to collect accurate data on a diamond ground section.

A properly functioning profiler equipped with a line laser should be capable of meeting the certification requirements indicated for project level and network level profilers on all surface types. A properly functioning profiler equipped with a single-spot or a wide-spot laser should be capable of meeting the certification requirements indicated for project level and network level profilers on the dense-graded AC and the transverse tined PCC pavement. Such a profiler is unlikely to meet certification requirements on the longitudinally tined PCC pavement, and will likely have difficulty in passing certification on the OGFC section.

Each SHA can decide on what surface types a project level profiler collecting data in their state should be certified. However, as dense-graded AC surfaces are present in all states, certification of all project level profilers on the smooth and medium smooth dense-graded AC surfaces should be mandatory. The provided certification documentation will indicate all surface types on which the profiler has been certified. For example, a project level profiler, such as one that has single-spot laser sensors may be able to pass certification only on the dense-graded AC and the transversely tined PCC.

Each SHA can decide on what surface types a network level profiler collecting data in their state should be certified. The provided certification documentation will indicate all surface types on which the profiler has been certified. As dense-graded AC surfaces are present in all states, certification of all network level profilers on the smooth, medium smooth, and medium rough dense-graded AC surfaces should be mandatory.

The transversely tined concrete section is provided specifically to evaluate the performance of profilers equipped with single-spot lasers on this section, as it is unlikely that such a profiler will pass certification on the longitudinally tined PCC section. Evaluation of the profiler on surfaces that have different colors, black for AC and white for PCC, will address any questions regarding the effect of pavement color on the profiler's performance. A PCC section with a drag or broom texture can be used instead of a PCC section with transverse tining to address the pavement color issue.

6.2.4. Option 3 – Requirements at a Basic Level Certification Center

The basic level certification center will only have dense-graded AC surfaces. Table 6.7 shows the roughness levels at such a center, and indicates the type of profilers that should be certified for each roughness level.

Table 6.7. Surface/Texture types and roughness levels required at a basic level certification center.

Surface Type	**Roughness Level (Note 1)**		
	Smooth	**Medium Smooth**	**Medium-Rough**
Dense-Graded AC	Project & Network Profiler	Project & Network Profiler	Network Profiler
Note 1: Smooth: IRI between 30 and 75 in/mi, Medium-Smooth: IRI between 95 and 135 in/mi, Medium-Rough: IRI between 150 and 200 in/mi			

Profilers equipped with line lasers as well as single-spot lasers are expected to meet the project level and network level certification requirements at this center. The certification documentation will indicate the surface type (i.e., dense-graded AC) for which the certification is valid.

To address the issue if pavement color will affect measurements, a transversely tined PCC section or a PCC section with a drag or broom surface can be provided at the certification center as an option.

6.2.5. Surface Type Requirements at a Regional Certification Center

The following are some important considerations regarding the surface types at a regional certification center:

- The AC mix used for the dense-graded AC surface at all certification sites should have the nominal maximum aggregate size that is predominantly used in the United States.
- The gradation used for the OGFC section at all certification sites should be consistent with the OGFC gradation that is predominantly used in the United States.
- The tine spacing, tine width, and tine depth in both the transversely tined and longitudinally tined PCC sections at all certification sites should be those that are predominantly used in the United States.
- The groove width, grove depth, and spacing of grooves in the diamond ground surface at all certification sites should be selected such that they are consistent with those that are predominantly used in the United States. It should be noted that the groove width, groove depth, and spacing of grooves in the diamond ground surface has a large influence on the quality of the data collected by profilers that have single spot-lasers. The results that are obtained on a diamond ground pavement by a profiler with a single-spot laser are valid

only for the dimensions of these parameters that were present at the certification site. Changes in these parameters can affect the quality of the data collected by profilers with single-spot lasers.

6.3 SPEED OF TESTING

High-speed and portable profiler manufacturers typically indicate they can collect profile data at speeds ranging from 15 to 70 mi/h. The maximum speed of a lightweight profiler is typically 20 mi/h, and each profiler manufacture specifies the valid speed range for the equipment.

De Leon Izzippi (2013) presented IRI values obtained from a profiler comparison that was held at the Virginia Smart Road in 2013. Eight profilers participated in this comparison, and the profilers made measurements at the test sections at speeds of 25 and 45 mi/h. Table 6.8 shows the IRI obtained by each profiler at each test speed along each wheelpath for the data collected at a dense-graded AC section. This table also shows the difference in IRI between 25 and 45 mi/h for each profiler for each wheelpath. Overall, there was good agreement in the IRI obtained for the two test speeds, with the IRI difference being within ±3 in/mi except for two cases.

Table 6.8. Comparison of IRI values obtained at different speeds at a dense-graded AC section.

Profiler	IRI (in/mi)				Difference in IRI, in/mi	
	Left Wheelpath		Right Wheelpath		Left Wheelpath	Right Wheelpath
	25 mi/h	45 mi/h	25 mi/h	45 mi/h		
1	98	96	98	101	2	-2
2	96	96	96	98	0	0
3	95	95	96	96	0	-1
4	99	100	93	93	-1	7
5	98	98	96	96	0	2
6	97	98	98	101	-1	0
7	93	94	97	99	-1	-3
8	96	96	101	101	0	-5
Note: Difference in IRI = IRI at 25 mi/h - IRI at 45 mi/h						

There are no reports of concerns being raised by SHAs about the effect of speed of testing on the collected data, and typically profiler certification programs in-place today test profilers only at one test speed.

AASHTO Standard R 56-14 recommends the performance of a high-speed profiler be checked at the minimum speed and maximum speed at which profiler will collect most data. At a regional certification center, all profilers must be certified for a specified standard and it will not be possible to establish speed of certification for individual profilers depending on the maximum and minimum operational speed of each device.

Network profilers typically collect data at the prevailing speed limit, which can be close to 70 mi/h on high-speed roadways. Project level data collection with high-speed profilers will likely be done at a lower speed if the highway has not been opened to traffic because of safety considerations as other construction activities may be going on in the project at the time of data collection.

The speed used for certifying high-speed profilers will be constrained by the layout and other safety considerations at the certifying center. A sufficient lead-in length is needed for the profiler to come to a constant speed before the start of the section and a sufficient length is needed after the end of the section for the profiler to safely come to a stop. The lead-in and stopping distance required at a site will vary with test speed. The next section presents length requirements for lead-in and stopping distance for various speeds. A constant speed at which certification should be performed on high-speed profilers should be determined based on the layout of the roadways at the certification center. Preferably, this speed should be between 50 and 60 mi/h. The selected speed must be consistent at all regional certification centers. A lightweight profiler should be tested at the operating speed recommended by the manufacturer.

A section that is about 1000 ft long should be used to test the ability of the profilers to collect data at different speeds ranging between the minimum speed recommended by the manufacturer and the maximum speed recommended by the manufacturer (or the highest speed possible at the center if the maximum speed cannot be achieved at the center). For example, if a manufacturer indicates the operating speed range to be between 20 and 70 mi/h, testing can start at 20 mi/h, and then proceed at 10 mi/h increments until a the last test is done at a speed of 70 mi/h. The 1000 ft long section should be established encompassing the smooth and medium-smooth dense graded AC sections. If a new facility will be constructed for a regional certification center, the section on which this test is performed (i.e., smooth AC and medium-smooth AC) can be constructed in the middle of the test track, which will provide the maximum lead in distance and the maximum lead out distance in order for the profiler to obtain measurements on this section at the highest possible speed.

6.4 LENGTH OF TEST SECTIONS

Each test section at the certification center must be at least 528 ft long. This recommended length is consistent with the recommendations in AASHTO R 56-14. A sufficient lead-in distance must be available before the start of the test section and a safe stopping distance must be available after the end of the test section. The lead-in distance must be of sufficient length such that the profiler can be at the desired speed of testing before the start of the section. The lead-in distance is required for the profiler to attain a constant speed before the start of the section and also for the filters used in the software to stabilize before the start of the section. A safe stopping distance must be available after the end of the section such that the profiler can safely come to a stop after the end of the test section.

Table 6.9 shows the recommended lead-in distance and the stopping distance at a test section for different test speeds. The values shown in this table for lead-in distance is the distance for the profiler to come to the testing speed accelerating at a rate of 0.1 g from a dead stop plus the distance travelled in one second to allow adjusting acceleration to obtain a constant speed. The stopping distance shown is the distance required for profiler to come to a stop decelerating at a rate of 0.1g to 0.15g after the end of the section.

Table 6.9. Lead-in distance and stopping distance for different speeds.

Speed (mi/h)	Lead-In Distance (ft)	Stopping Distance (ft)
40	593	535
50	909	836
60	1292	1204

Several test sections can be placed along a test track, and the above mentioned lead-in and stopping distances will be applicable to the distance needed before the start of the first section and the distance needed after the end of the last test section, respectively.

6.5 GEOMETRICAL REQUIREMENTS OF TEST SECTIONS

6.5.1 Alignment

The test sections, lead-in distance, and the stopping distance must be located on a straight portion of roadway. Test sections located on roadway sections that have a horizontal curvature can contaminate accelerometer signals because of lateral acceleration, and thus introduce errors into the profile data (Karamihas et al., 1999).

6.5.2 Grade

The accelerometer in a profiler travelling along a roadway with a grade will be tilted from the vertical, and this will introduce an error to the accelerometer signal, and therefore to the computed profile. The error introduced to the accelerometer reading will be constant on a steady grade. Karamihas et al. (1999) indicated on a steady grade the constant error introduced to the accelerometer because of the tilt of the accelerometer will be usually removed during the bias removal in the profile computation algorithm. Karamihas et al. (1999) indicated on a 12 percent grade the error caused to the accelerometer signal because of the tilt will be 0.007 g and indicated this error is small because the accelerometer signal in a typical profile measurement covers a range of at least 0.4g. Starodub (2002) that conducted a detailed investigation of accelerometers at two test sections that had a grade of 1.4 and 2.4 percent indicated the error in accelerometer readings caused by the grade was small.

De Leon Izeppi (2013) presented results from a profiler comparison study done at the Smart Road in Blacksburg, Virginia, where seven profilers equipped with single-spot lasers and one profiler equipped with RoLine lasers participated. Data were collected at several test sections in this study in the uphill direction at speeds of 25 and 50 mi/h. One test section that had a 4 to 6 percent grade included a portion of SMA pavement and a portion of OGFC. Another section that had a 3 to 4 percent grade was surfaced with dense-graded AC. Results from this study showed that the profilers were usually able to collect repeatable profile data at both test sections. When data from both wheelpaths were evaluated, the AASHTO R 56 specified repeatability criterion was not achieved for only 2 cases out of 32 cases (2 speeds x 2 wheelpaths x 8 profilers) at the SMA/OGFC section and 5 cases out of 32 cases at the dense-graded AC section. At both sections, the IRI values for the profilers usually agreed well with the IRI values obtained from the reference device data. However, at both sections, except for a few cases, the profilers did not achieve the AASHTO R 56 specified cross-correlation value of at least 90 percent between profile data and reference data. It is not clear if the grade of the sections was a factor that caused the profilers to not meet the AASHTO specified cross-correlation with the reference device data.

The available information related to the effect of grade on profile data is limited. Based on the information presented above, it appears a grade of less than 3 percent should not affect profile measurements. It is possible that even a higher grade level may be acceptable, but further studies using field data are needed to confirm this. The recommendation regarding grade for a certification center is to limit the grade of test sections at the certification center to less 3 percent, unless a field study shows a higher grade level can be accepted. If potential test sections are to be located on a higher grade, it is recommended a field study be performed at that section to evaluate the effect of grade on the collected data before accepting the section as a suitable test section. The field study should involve a comparison of data collected with a reference device with the data collected with profilers.

6.5.3 Grade Changes

Karamihas et al. (1999) indicated transitioning from one level of grade to another has the potential to contaminate the accelerometer signal because the error will not be steady and it will not be eliminated by bias removal. Grade changes can include going from a flat or nearly flat surface to an upgrade or a downgrade, changing from an upgrade to a downgrade, or changing from a downgrade to an upgrade. Karamihas et al. (1999) performed a theoretical study to determine the effect of grade changes on IRI when transitioning from a downgrade to an upgrade, and reported the error in IRI due to the tilt in accelerometer for this situation was very small until a grade of about 12 percent, which is a very steep grade.

The available information related to the effect of grade changes on profile data is limited. The recommendation regarding grade change for a certification center is to avoid grade changes within a test section. If an existing facility that is suitable for a regional certification center has sections that have grade changes, a field study is recommended at such sections to investigate the potential impact of grade changes on the profile data. The field study should involve a comparison of data collected with a reference device with the data collected with profilers.

6.6 FREQUENCY OF CERTIFICATION

Most profiler certification programs in-place today issue a certification for the profiler that is valid for one year from date of certification. The current certification procedure followed by MnDOT indicates that the certification ends at the end of the year in which the profiler is certified. This procedure does have some merit as in Minnesota the profiler is stored during the winter and is brought out of storage at the start of the construction season next year. Hence, the profiler is certified again at the start of the construction season.

At a regional certification center it is recommended that the profiler certification provided be valid for one year from the date of certification. As a certification offered by a regional center is expected to be valid anywhere in the United States, where profile data collection can be performed in winter months in several areas, imposing a limitation such as in Minnesota is not recommended.

A regional certification center can select several time periods during the year to perform profiler certifications. It is recommended that the regional certification center establish dates on which certification will be held at the start of the year and publish them on a web page. TTI follows such a procedure and establishes two days in each month that is available for profiler certification. Certification can commence around May at certification centers located in areas experiencing winter weather conditions. By this time, the ground would have reached equilibrium conditions after the freeze-thaw. At such centers, certification can be offered at a closer frequency in the May to June period, as this is the period when network level profile data collection and construction activities typically commence in areas experiencing winter weather.

6.7 OPERATOR CERTIFICATION

It is recommended the profiler operator be certified at the regional certification center at the same time the profiler is certified. Certifying the profiler operator will ensure the operator will have sufficient skills to operate a profiler. The following is the recommended structure to certify profiler operators.

1. Provide an Avenue for Profiler Operator to Gain Knowledge about Profiling: It is recommended that the FHWA develop an on-line training course on profiling. The training course should be developed in modules such that the operator can take each module separately. The training course should cover principles of profiling, calibration checks to be performed on the profilers, and correct operational procedures for collecting accurate data. It is desirable that this training module be available free of charge. The profile operator can gain knowledge about profiling by following such a training course and operators should be encouraged to take this course before travelling to a regional certification center to be certified. Another avenue to offer training is to have several webinars that will provide training on the above mentioned topics.

2. Written Exam: The profiler operators should be given a written exam at the certification center, and they should pass this exam in order to be certified. The exam should include the items covered in the on-line course. Separate exams should be available for lightweight profiler operators and high-speed profiler operators.

3. Demonstrate Ability to Perform Calibration checks and Collect Data: The operator should demonstrate the ability to perform the following calibrations or calibration checks: (1) block check on height sensors, (2) bounce test, (3) calibrate accelerometers (if needed on the device), and (4) calibrate the DMI. Thereafter, the operator should demonstrate the ability to collect profile data at the test sections, and compute the IRI values of the test sections.

An operator must pass the written exam and demonstrate the ability to perform calibration checks and collect data in order to be certified.

Most SHAs that currently allow contractors or a testing company to collect profile data for construction acceptance have a profiler operator certification program in-place. Some SHAs provide a training session that includes basic information about profiling and calibration checks and also information about the SHAs smoothness specification, the method to analyze the collected data, and procedures to submit the collected data to the SHA. Some SHAs require the operator to pass a written exam and demonstrate the ability to perform calibration checks on equipment and collect data in order to be certified. Other SHAs do not have a written exam but the operator must demonstrate ability to perform calibration checks on equipment, collect data, and show they are knowledgeable about the SHAs smoothness specification and procedures to submit data in order to be certified.

Certifying profiler operators to indicate they are knowledgeable about state specific smoothness specification, state specific procedures to analyze data, and state specific procedures for submitting data could be problematic at a regional center because of the following reasons:

- Profiler operators who collect network level profile data do not need to be knowledgeable in these areas, and there is no reason to test their knowledge in these areas.

- Smoothness specifications, procedures to analyze data, and procedures to submit data to the SHA vary from state to state, and individual training modules that are applicable to each state will have to be developed in order to provide knowledge to profiler operators.

- Checking the operator’s knowledge on state specific smoothness specifications, state specific procedures to analyze data, and state specific procedures to submit data to the SHA could take a significant amount of time at the regional center. The certification in these areas will have to be provided for individual states. If an operator indicates they want to be certified in several states this will mean operator’s knowledge about procedures for each state the operator wants to be certified will have to be checked.

- The persons who will be checking the operator’s knowledge in these areas will have to be proficient about procedures of all states from which profilers are expected at the regional center.

Because of these issues, it is recommended the operator certification provided at the regional center be limited to certifying that the operator can successfully perform calibration checks on equipment, collect data, and compute IRI values from the collected data. Certifying that the operator is knowledgeable about the smoothness specification of the state, state specific data analysis procedures, and state specific data submittal procedures should be performed by each SHA. This certification has to be provided only to operators who collect smoothness data for construction acceptance.

CHAPTER 7. ISSSUES RELATED TO SETTING-UP AND OPERATING A REGIONAL CERTIFICATION CENTER

7.1 COST FOR CONSTRUCTING A NEW PROFILER CERTIFICATION CENTER

7.1.1 Recommended Test Track Configuration

The recommended configuration of a test track for options 1, 2, and 3 (see sections 6.2.2 through 6.2.4) are described in this section.

Option 1

This option consists of constructing the following pavement sections (see section 6.2.2):

- Three dense-graded AC sections that have varying roughness levels.
- A chip seal section.
- An OGFC section.
- A PCC section that is transversely tined.
- A PCC section that is longitudinally tined.
- A PCC section that is diamond ground.

It is recommended that the three AC sections and the chip seal section be constructed on one test track and the three PCC sections and the OGFC section to be constructed on another track that is parallel to the first test track, with the distance between the parallel tracks being about 24 ft, with a drainage swale between them.

Two parallel tracks are recommended instead of constructing the test sections in two adjacent lanes of a single track because of the following reasons:

1. The three AC sections will have to be constructed at different roughness levels and this can cause problems when matching the longitudinal joint between the lanes if two lanes are constructed adjoining each other.

2. The total pavement thickness (i.e., surface plus base) will be different for the AC and PCC sections, and if the test sections are constructed on lanes adjacent to each other, differences in vertical movement of the pavement at the longitudinal joint between the lanes can occur because of frost heave effects and/or shrink/swell behavior of the subgrade.

The two parallel test tracks should be connected by a turnaround area at each end. The total paved width of the pavement of each track is recommended to be 16 ft, with a 12 ft travel lane. This will result in a 2 ft wide AC shoulder on each side. A 2 ft wide gravel shoulder is recommended along the two edges of the pavement. Travel along each track will be limited to one direction.

Option 2

This option consists of constructing the following pavement sections (see section 6.2.3):

- Three dense-graded AC sections that have varying roughness levels.
- An OGFC section.
- A PCC section that is transversely tined.
- A PCC section that is longitudinally tined.

It is recommended that the three AC sections to be constructed on one track and the two PCC sections and the OGFC section to be constructed on a track that is parallel to the first track, with the distance between the parallel tracks being about 24 ft, with a drainage swale between the tracks. The reason for recommending parallel tracks was described under Option 1. The two parallel tracks should be connected by a turnaround area at each end. The total paved width of the pavement is recommended to be 16 ft, with a 12 ft travel lane. This will result in a 2 ft wide AC shoulder on each side of the track. A 2 ft wide gravel shoulder is recommended along the two edges of the pavement. Travel along each track will be limited to one direction.

Option 3

This option consists of constructing three dense-graded AC sections that have varying roughness levels (see section 6.2.4). It is recommended that the test track consist of two lanes, with turnaround areas at each end such that the profiler can travel along one lane when profiling the sections, and return along the other lane. Two lanes are recommended for safety reasons because if the track consists of a single lane, this will require the profiler to travel back along the same track after reaching the end of the track. The total paved width of the pavement is recommended to be 28 ft, with two12 ft travel lane marked on the paved surface. A 2 ft gravel shoulder is recommended along the two edges of the pavement. Travel along two directions will be possible on this test track.

7.1.2 Construction Cost

This section presents the estimated construction cost for constructing the pavements and an office building at a regional certification center for the three options described in section 7.1.1.

A lead-in distance and a lead-out distance of 1,300 and 1,200 ft, respectively was assumed for all three options. These values are consistent with the values required for a facility where testing can be performed at 60 mi/h (see section 6.4). Each test section was assumed to be 528 ft long, with a 100 ft long transition area between the test sections. It was assumed that the test sections will be constructed one after the other between the end of the lead-in distance and the start of the lead-out distance. This configuration will result in the following lengths for the test track for each option:

- Option 1: Two parallel tracks with the length of each track being 4912 ft.
- Option 2: Two parallel tracks with the length of each track being 4284 ft.
- Option 3: One track is provided with the length of the track being 4284 ft.

The following assumptions were made in estimating the construction costs:

- The cost does not include land acquisition cost, any fencing needed for the facility, and the cost associated with providing electricity, phone services, water, and sewerage facilities to the office building.

- The area in which the facility will be constructed was assumed to be a level area that will require minimal cut and fill operations during construction. It was also assumed that the site will be free of trees.

- All lead-in and lead-out areas and turnaround areas will be surfaced with AC.

- The pavement section used for all AC surfaced test sections, OGFC section, chip seal section, lead-in, lead-out, and turnaround areas was assumed to be 4 inches of AC over 12 inches of aggregate base. It was assumed that the chip seal and OGFC will be placed on the AC surface.

- It was assumed that all PCC test sections will consist of an 8 inch thick PCC slab placed on 6 inches of aggregate base.

- It was assumed that a building having an area of 1,500 sf will be constructed at the site to serve as an office building and also to provide an area that will be suitable for performing calibration checks on profilers.

The unit costs shown in table 7.1 were used for computing the construction cost. As construction of the pavements at the test track is a small scale project compared to a large construction project, the unit cost associated with each activity will be much higher than the costs associated with a large scale project. Another factor that will result in higher unit cost for the AC and PCC pavement is the costs associated with constructing the test sections at specified smoothness levels.

Table 7.1. Unit costs used in estimating construction cost.

Activity	**Unit**	**Cost ($)**
Land Clearing and Leveling	Acre	5,000
Excavation	cyd	20
Compact/Prepare Subgrade	sf	0.1
AC Pavement	sf	10
PCC Pavement	sf	20
Placing Chip Seal	sf	4
Placing OGFC	sf	8
Gravel Shoulder	sf	2.5
Building for Office	sf	125

The estimated construction cost for the three options are shown in table 7.2. The item called engineering and other costs is the cost for preparing plans, construction supervision, and other costs such as striping and site clean-up etc. This item was assumed to be 15 percent of the sum of all items before that in the table. A contingency of 10 percent is also included in the construction cost.

Table 7.2. Construction cost for the three options.

Activity	**Cost ($)**		
	Option 1	**Option 2**	**Option 3**
Clearing Site	$42,096	$36,984	$17,907
Site Drainage	$87,237	$76,084	$20,606
Compact/Prepare Subgrade	$20,848	$18,336	$13,709
AC Pavement	$1,382,400	$1,281,920	$1,199,520
PCC Pavement	$570,880	$369,920	--
OGFC	$67,584	--	--
Chip Seal	$33,792	--	--
Gravel Shoulders	$101,240	$88,680	$42,840
Grinding PCC Section	$25,000	--	--
Office Building	$187,500	$187,500	$187,500
Engineering etc. (15%)	$377,787	$308,914	$222,312
Contingencies (10%)	$289,636	$236,834	$170,439
TOTAL COST	$3,186,000	$2,605,171	$1,704,394

The construction cost can be reduced slightly by reducing the maximum test speed from 60 mi/h to 50 mi/h, which will reduce the lead-in and lead-out distances. Construction cost can also be reduced for option 1 and option 2 by providing a 10 ft travel lane instead of a 12 ft travel lane, and also reducing the distance by which the paved surface extends beyond the edge of the travel lane by 2 ft to 1 ft. This will reduce the paved width of the pavement from 16 ft to 12 ft. For option 3, a narrower test track can be constructed; if this is done, only one vehicle should be allowed on the test track at a time for safety reasons.

The cost for constructing a new profiler certification center is high. If the construction of such a center is contemplated, the potential use of the center for other types of testing such as texture, tire-pavement noise, friction, and rolling resistance must be explored. Also, the use of such a center for safety related testing, such as tests for stopping distance etc. can also be explored.

7.2 COST OF EQUIPMENT FOR SETTING-UP A PROFILER CERTIFICATION CENTER

The following equipment will be needed at a regional certification center:

- A reference profiler to obtain reference profile measurements.
- Benchmark profiler.
- Equipment for sweeping the test sections.

- Other miscellaneous equipment such as laptop computers, measuring tapes, measuring wheels, and chalk lines. Supplies such as chalk and paint will also be needed.

Reference Profiler

A reference device will be needed at each certification center to obtain reference measurements at the test sections. The cost of purchasing a reference device is estimated to be $40,000. The personnel at the regional center who will be operating the equipment will have to be trained by the manufacturer of the reference device. The cost of training will have to be accounted for budgeting purposes.

Benchmark Profiler

Questions about the accuracy of the reference device that is used at a certification center can be raised. The FHWA is in possession of a benchmark profiler that has been used in the past to evaluate the performance of reference devices (Winkler et al., 2013; Karamihas, 2011; Karamihas and Perera, 2013). This device can be used to check the accuracy of reference devices that are being used at certification centers. The benchmark profiler can be stored at a certification center, and at the beginning of each year before profiler certifications begin, all regional certification centers can send their reference profiler to the center where the benchmark device is stored. Then the benchmark device can be used to evaluate the performance of all reference profilers that are used at regional centers. Another option is to provide a benchmark device for each certification center such that personnel at each center can evaluate the performance of their reference device with the benchmark device. This evaluation can be performed at the start of the year before profiler certifications begin, and also whenever a potential error in the reference device is suspected. It costs approximately $350,000 to construct a benchmark device, and this has to be budgeted if a benchmark profiler is to be provided for each regional center.

Equipment for Sweeping

Equipment that can sweep and clean the test sections of any debris, leaves, etc. before measurements are obtained at the test sections is needed at each certification center. A John Deere skid steer with a broom attachment will cost approximately $35,000. If the center is managed by a university affiliated institute, they may possess such equipment, or be able to get it from another unit of the university and pay a rental charge for its use.

Miscellaneous Equipment and Supplies

Two laptop computers, external hard drives for data backup, a measuring tape and a measuring wheel will be needed at each regional certification center. These items are expected to cost approximately $2,800. Supplies such as stakes, chalk lines, chalk, paint etc. that are needed for marking the test sections will also be needed.

7.3 OWNERSHIP, MANAGEMENT, AND STAFFING REQUIREMENTS FOR A REGIONAL PROFILER CERTIFICATION CENTER

7.3.1 Ownership

A SHA may be willing to take ownership of a regional certification center as SHA owned and contractor owned profilers in the state can be certified at this center without travelling to a certification center that is located out of state. In such a scenario, the SHA will take ownership of the center, but the certification of profilers will have to be performed by a separate entity that is not affiliated with the SHA. A SHA may be willing to provide the land to construct such a center if the SHA has control over land that is suitable for such a center. However, a SHA is unlikely to invest their own funds to construct a center as the cost for constructing such a facility will be very expensive. However, if an outside agency (e.g., FHWA) funds the construction of such a facility, the SHA may be willing to take ownership of the facility. Another advantage for a SHA to take ownership of a certification center is that they can make use of the pavements at the center to perform other research and testing activities.

A university affiliated institute may be willing to take ownership of a regional certification center. Such an institute might have land available for constructing such a center, and may be able to offer the land to construct such a certification center. However, such an institute is unlikely to invest their own funds to construct such a facility for the sole purpose of certifying profilers. However, if an outside agency (e.g., FHWA) funds the construction of such a facility the university affiliated institute might be willing to take ownership of the facility, provided they are allowed to make use of this facility to perform other activities at the facility such as vehicle tests, other pavement research, etc. The revenue that a regional certification center will generate is unlikely to be attractive enough for a university affiliated institute to take ownership of a profiler certification center if that facility will only be used for certifying profilers.

Another option is for the FHWA to build such a certification center on federal land, and then to employ a consultant to maintain the center.

The main consideration of a SHA or a university affiliated institute in taking ownership of a regional certification center would be how to fund the fixed cost that is associated with running the center. Fixed costs associated with taking ownership of a certification center include:

- Staff cost for personnel overseeing the facility.
- Cost of maintaining the facility such as landscaping, cutting grass, weed control, snow removal etc.
- Providing security to ensure unauthorized persons do not enter the facility to make use of the pavements at the facility for unauthorized activities.
- Routine maintenance costs such as crack sealing and fog sealing of the pavement surfaces.

If the total cost for operating a regional center is to be funded by the fee that is charged for certifying profilers, the charged fee will have to cover the cost of labor of the personnel performing profiler certifications as well as the fixed cost that is associated with maintaining a certification center. Eighty percent of respondents to the survey by Huft indicate the cost of certifying a profiler should be $3,000 or less (Chapter 5, Question 15). This level of fee may be sufficient to cover the labor cost of personnel certifying profilers, but it is unlikely the total cost of maintaining a certification center can recovered by the fee that is charged for profiler certifications. Therefore, the provision of a funding mechanism to cover some or all of the cost associated with maintaining the center will be an incentive for a SHA or a university affiliated institute to take ownership of a certification center.

If the facility can be used for other purposes apart from certifying profilers, there is a possibility that a university affiliated institute might be willing to spend its own funds to cover part or all costs associated with maintaining the facility.

7.3.2 Management

The management of a profiler certification center will involve the following two functions:

- Management of the Facility: This will involve maintaining the facility (e.g., cutting grass etc.), security measures to keep unauthorized access to the facility, sweeping the test sections prior to certification so they will be clean etc.

- Technical Management of Profiler Certification Program: This involves managing all activities associated with profiler certification such as: coordination of testing dates with profiler owners, ensuring proper markings are present at the test sections, obtaining reference measurements at the test sections, coordination of testing at test sections once profilers arrive at the facility, coordinating profiler operator certification, addressing disputes with profiler owners, etc.

If a SHA is maintaining the facility, it is expected that the SHA will only manage the facility, and that an outside party (e.g., university affiliated institute or a consultant) will be in charge of the technical management of the profiler certification program.

If a university affiliated institute is maintaining the facility and also in charge of the profiler certification program, ideally two separate people are needed for these two functions. As these are not full time jobs, the persons who are involved in these activities will need to have full time employment in another capacity. Ideally, the person managing the facility should be working close to the facility so that person can regularly visit the facility, and take necessary action when issues are identified. The person managing the profiler certification program will need to visit the site before profilers are scheduled to be certified to check on the test sections, and take appropriate action if there are issues with the test sections (e.g., surface is dirty and needs to be cleaned, markings have faded and they have to be re-painted etc.). Thereafter, this person needs to be present at the site only when profilers are being certified.

If a consultant is managing the facility, the office of that consultant should be close to the facility so that the person in charge of managing the facility can visit the facility at regular intervals to inspect the facility. If a consultant is also managing the profiler certification program, that consultant need not be the same consultant who is managing the certification facility.

If a consultant is managing the profiler certification program at a facility, this consultant will need to visit the site before profilers are scheduled to be certified to check on the test sections, and take appropriate action if there are issues with the test sections (e.g., surface is dirty and needs to be cleaned, markings have faded and they have to be re-painted etc.) and be present to certify the profilers. Ideally, the office of such a consultant should be located close to the facility. Otherwise, significant travel costs can be incurred by the consultant's personnel in travelling to the certification center.

7.3.3 Staffing Requirements

The following personnel will be needed for proper functioning of a certification center:

- Facility manager.
- Technical manager of profiler certification program.
- Engineer to perform profiler certifications.
- Technician to assist with profiler certifications.
- Profiling expert.

All of these positions are not full time positions, and these personnel should be having other full time work assignments. The facility manager must be an employee of the organization that has assumed the ownership of the facility. The other personnel could also be employees of the organization that has assumed the ownership of the facility, or they could be working for another organization.

Facility Manager: As indicated previously, the function of this person will be to coordinate the activities that are required to maintain the facility (e.g., cutting grass, sweeping the test sections) and to ensure security measures are in-place to keep unauthorized persons from accessing the facility.

Technical Manager of Profiler Certification Program: This person will be in charge of all technical activities associated with profiler certification. This person should be knowledgeable about inertial profilers, inertial profiler operations, profile data collection, and profiler certification.

Engineer to Perform Profiler Certifications: The technical manager of the profiler certification program and the engineer performing profiler certifications can be the same person. This person must be knowledgeable about inertial profilers, inertial profiler operations, profile data collection, and profiler certification, and must be present when individual profilers are certified. This person will oversee and assist with reference profile data collection, oversee data collection by profilers, analyze the collected data, perform operator certifications by checking the operators' familiarity with the equipment etc.

Technician to Assist with Profiler Certifications: A technician is needed to perform reference profile data collection and assist with overseeing data collection by the profilers at the test sections. This person must be knowledgeable about the reference device that is used to collect reference data and also must be knowledgeable about inertial profilers and data collection with inertial profilers.

Profiling Expert: The services of a profiling expert should be available when the profiler certification program is set-up initially to provide input on technical issues. It is advisable to have the services of a profiling expert be available even after a certification facility is set-up to provide input if technical questions or issues crop-up. It is not necessary for the profiling expert to be an employee of the organization that is conducting the profiler certifications. If the technical manager of the profiler certification program is an expert on all aspects of inertial profiling, the services of a profiling expert may not be needed.

7.4 COSTS ASSOCIATED WITH OPERATING A REGIONAL PROFILER CERTIFICATION CENTER

7.4.1 Cost Categories

The costs associated with operating a regional profiler certification facility can be divided into the following two categories:

- Cost of maintaining the facility.
- Cost incurred by personnel who certify profilers.

7.4.2 Cost of Maintaining the Facility

As described previously, a facility manager is needed to coordinate the activities that are needed to maintain the facility. The following are some fixed costs that will be incurred for operating the facility:

- Landscaping, cutting grass, weed control, snow removal etc.
- If the facility is fenced, repairs that needs to be performed to the fence.
- Utility bills for the office such as electricity, phone, water etc.
- Cost for sweeping test sections, if needed, before profiler certification.
- Updating markings at test sections when they fade.
- Cost for maintaining pavements such as crack sealing, fog sealing (AC pavements), joint sealing (PCC pavements).

Assuming the facility manager devotes 6 hours biweekly for work associated with maintaining the facility, which will include a biweekly site visit; this will mean 156 hours of work per year. At a billing rate of $140 per hour, this will mean a cost of $21,840 per year. The other costs described above, omitting the cost for maintaining the pavement, may be in the range of $20,000 to $40,000 per year, with the lower cost associated with an option 1 center and higher costs associated with option 2 and option 3 centers. The pavement maintenance activities will not occur every year, but they are expected to occur at scheduled intervals. Therefore, funds should be available to address pavement maintenance costs.

7.4.3 Cost Incurred by Personnel Certifying Profilers

Assuming a billing rate of $140/hr for the engineer certifying profilers and a billing rate of $80/hr for the technician involved with certification, the total cost for a week of work (40 hours) for these two persons will be $8,800. Additional travel charges will be incurred if these personnel are not located close to the certification center. There will be some additional charges if there is a technical manager who will be overseeing the work of these personnel. It is expected that 8 to 10 profilers can be certified during a week.

As certification will have to be offered during several different time periods, the number of profilers requesting certification could vary depending on the time of the year. The earliest a regional center located in an area experiencing winter can start to certify profilers would be May. This would give the ground sufficient time to stabilize after the freeze-thaw period. Such regional centers are expected to see the greatest demand for certification immediately after the center is opened for certification as this would be the start of construction season and also when SHAs will begin their network level profiling activities.

TTI currently charges $2,000 for certifying a profiler, with data collection being performed at the two test sections located at the TTI facility. TTI also charges $300 for certifying a profiler operator. NCAT has indicated they probably will be charging about $2,000 to certify a profiler, with data collection being performed at four sections. This charge includes the cost for operator certification. Eighty percent of the respondents to the survey performed by Huft (see chapter question 15) indicated the fee charged for certifying a profiler should be $3,000 or less. As indicated in sections 6.2.2 through 6.2.4, the certification document will indicate the surface/texture types on which the profiler is certified. The profile owner will be able to select the surface types on which the profiler is to be certified. It appears having a minimum charge of $2,000 for a profiler that tests three test sections at a certification center, with an additional $500 per each section tested, seems to be a reasonable amount to charge for profiler certification.

It will be more economical from a labor cost point of view to have the maximum number of profilers certified during a week. Therefore, if eight profilers are tested in a week, and each profiler only tests three surfaces, this would bring in revenue of $16,000 for that week. This amount would be more than adequate to cover the labor cost associated with certifying profilers. However, scheduling will have to be made based on requests from those requesting certification, and it is possible that only one profiler will be available to be certified on some days. Therefore, if only five profilers are certified during the week, it would just cover the labor cost for certifying the profilers for that week.

7.5 POSSIBLE LOCATIONS FOR SETTING-UP REGIONAL CERFICATION CENTERS

Certification of high-speed profilers is currently performed at the following facilities, all of which have controlled access:

- MnROAD located in Albertville, Minnesota where certifications are performed by MnDOT.
- NCAT test track located in Opelika, Alabama, where certifications are performed by NCAT.
- TTI test track located in College Station, Texas, where certifications are performed by TTI.
- Caltrans test track located in Sacramento, California, where certifications are performed by the University of California.
- New Jersey test track located in a former rest area, where certifications are performed by Rutgers University.

A profiler comparison is performed annually at the Smart Road located in Blacksburg, Virginia, where profilers from several SHAs participate. The Smart Road also has controlled access. VTTI conducts this profiler comparison and prepares a report. Although this is not a profiler certification program, the SHAs that participate in this study can compare results for their profiler with results from other SHA profilers as well as with results from the reference device.

Table 7.3 shows the profile/texture types required at an ideal certification center (see option -1, section 6.2.2) that is present at the facilities described above. In this table, the three dense-graded AC surfaces are separated and presented according to the roughness levels as these three roughness levels are recommended even for a basic level (see option 3, section 6.2.4) certification center.

Table 7.3. Availability of surface/texture types at test facilities.

Surface /Texture Types (Note 1)	Test Facility (Note 2)					
	MnROAD (Note 3)	NCAT	TTI	Caltrans	New Jersey Rutgers	Smart Road
Dense-Graded AC, Smooth	X	X	X		X	
Dense-Graded AC, Medium Smooth	X	X	X	X	X	X
Dense-Graded AC, Medium-Rough		X				X
Open-Graded Friction Course		X	X			Note 4
Chip Seal	X		X			
Transversely Tined PCC	X		X			X
Longitudinally Tined PCC	X		X	X		
Diamond Ground PCC	X					X

Note 1: Smooth - IRI between 30 and 75 in/mi; Medium-Smooth - IRI between 95 and 135 in/mi; Medium-Rough - IRI between 150 to 200 in/mi.
Note 2: Presence of surface/texture type is indicated by X.
Note 3: Some of the sections are located on the mainline. There are porous asphalt sections on the low-volume loop that can act as a surrogate for OGFC; however these sections are about 225 ft long and are considered to be too short to be used as certification sections.
Note 4: The OGFC section is 302 ft long and is considered to be too short to be used as a certification section.

MnDOT may allow MnROAD to be used as a regional certification center. However, the certification program will have to be administered by a consultant or a university affiliated institute.

The following observations are noted from the information presented in table 7.3 about the availability of the three dense-graded AC sections recommended to be present at a basic level certification center (see option 3, section 6.2.4):

- Only the NCAT test track has the three dense-graded AC sections with the recommended roughness levels.

- MnROAD, TTI, and the New Jersey test track do not have a medium-rough dense-graded AC section.

- The Caltrans test track has only a medium-smooth dense-graded AC section.

- Smart Road does not have a smooth dense-graded AC section.

Based on the above information, at least two of the dense-graded AC sections required for a basic level certification center are available at the following facilities: MnROAD, NCAT, TTI, New Jersey site, and Smart Road. All of these are potential locations where a basic level regional certification center can be established. However, an additional test section will be needed at all of these locations except at NCAT to have the three dense-graded AC sections with the recommended roughness levels that are needed at a basic level certification center. It may be possible to construct the needed additional test section or rehabilitate an existing section at the facility to obtain a section with the required roughness level.

7.6 ESTABLISHING A PILOT PROGRAM FOR A REGIONAL PROFILER CERTIFICATION CENTER

As described in section 7.5, it might be feasible to initiate a pilot program for a basic level (option 3, see section 6.2.4) regional profiler certification center at one of the following facilities: MnROAD, NCAT, TTI, New Jersey site, or Smart Road. NCAT appears to be the only facility that has the three dense-graded AC sections that meet the roughness levels recommended for a basic level profiler certification center. At the other facilities, it may be possible to construct a new test section or rehabilitate an existing section in order to obtain the test section with the needed roughness level.

The following are the recommended steps for establishing a pilot program for a regional certification center:

1. (a) Contact NCAT, TTI, Rutgers, and VTTI and inquire about the interest of these institutions in establishing and administrating a regional profiler certification facility. Contact MnDOT to inquire about the possibility of letting MnROAD be used as a regional certification center, and if so, if there is a charge for using the facility.

(b) Inquire from NCAT, TTI, Rutgers, VTTI, and MnROAD about the availability of three dense-graded AC sections that meet the recommended roughness levels for a basic level certification center at their facilities. If a particular section is not available, inquire about possibility of constructing a new section, rehabilitating an existing section, or availability of a test section close to the center that can fill the gap of the dense-graded AC section that is missing at the facility. The FHWA should indicate if they can provide the funding that is needed for constructing a new section or rehabilitating an existing section.

(c) If VTTI shows an interest in using Smart Road as a regional certification center, perform a study to analyze reference and profile data collected at test sections in previous studies or collect additional data and analyze the data to determine if the grade of the sections affects the quality of data collected by inertial profilers and the ability of operators to control speed.

2. From the institutions that indicate they can provide the three dense-graded AC sections, inquire about the potential cost they will need to certify an inertial profiler and a profiler operator. An estimate of the number of profilers that may be certified in a year as well as a schedule for certification will have to be provided to these institutions so they can come up with a cost. The cost should include the labor cost associated with certifying profilers and profiler operators as well as any costs associated with the use of the facility. If MnROAD is a potential site for establishing a regional certification center, a cost estimate will have to be obtained from a university affiliated institute or a consultant who can perform the profiler certifications. As many of the potential certification sites are being currently used for other activities, the institutions might consider waiving the cost associated with maintaining the facility or only include a minimal cost for maintaining the facility when they come up with the cost estimate for certifying profilers.

3. After evaluating the potential for making available the three dense-graded AC sections that have the required roughness ranges to meet criterion for a basic level certification center (option 3) and the cost for certifying a profiler submitted by each institution, select an institution for establishing a pilot program for a regional certification center. Availability of other surface/texture types at the facility can also be a consideration in selecting the institution.

   Eighty percent of the respondents to the survey performed by Huft (see chapter 5, question 15) indicated the cost for certifying a profiler should be less than $3,000. If the cost quoted by the selected institute is higher, the FHWA will have to provide a grant to cover the difference in cost. Also, as there will be a start-up cost associated with establishing a certification center, additional funding may have to be provided to the institution to cover these costs.

4. The selected institute should develop the profiler certification protocols for network level and project level profilers and profiler operator certification with the input from FHWA and other profiling experts. The profiler certification protocols can be developed using the information in AASHTO R 56-14. Thereafter, the protocol should be checked using several profilers that can include SHA owned profilers in the state where the center is located or government

owned profilers (e.g., LTPP profilers) to see how the profilers perform. Based on this evaluation, make necessary updates if needed to the protocols.

5. Advertise the setting-up of the regional profiler certification center and perform profiler certifications.

6. At the end of the year, evaluate how the pilot program performed and determine whether improvements are needed to the protocols and the program. Obtain feedback from profiler owners who got their profilers certified at the regional center about their experience. Also, perform a cost evaluation to determine the actual cost that is associated with certifying a profiler and a profiler operator. If the pilot program was set-up as a basic certification center where only three AC surfaced test sections are included, look into the possibility of including other surface/texture types that can be offered for certification at this center. Also, evaluate possibility of setting-up additional profiler certification centers at other institutions or for constructing new centers.

7.7 FUNDING SCENARIOS FOR FUNCTIONING OF A REGIONAL CERTIFICATION CENTER

The following types of profilers are expected to be certified at a regional certification center:

- Profilers owned by a SHA that collect network level data, project level data, or both network and project level data.
- Profilers owned by vendors that typically collect network level data.
- Profilers procured by an agency that have to be a certified by vendor before the agency takes delivery.
- Profilers owned by paving contractors or a testing company that collect project level data.

A SHA can contribute money to a pooled-fund, and this money can be used to fund the certification of the SHA owned profilers. The amount of money the SHA contributes to the pooled-fund should be based on the number of profilers that the SHA expects to certify at the certification center. The funds from the pooled-fund can be used to cover labor cost associated with certifying a profiler as well as funds needed for the upkeep of the certification center. A pooled-fund study can be led by a SHA, the FHWA, or by AASHTO.

Profilers owned by vendors, contractors, and testing companies will have to pay a fee for each profiler that is certified.

If the regional center is operated by a university affiliated institute, the FHWA could provide a grant to that center to cover the cost of operating the center that cannot be recouped from charges levied on profilers that are certified.

Another scenario is for the FHWA to award a contract to a consultant to maintain the center and another contract to certify profilers. The contractor can bill the FHWA for the incurred cost on a cost reimbursed basis.

7.8 POTENTIAL OBSTACLES FOR SETTING-UP REGIONAL PROFILER CERTIFICATION CENTERS

The following are some potential obstacles for setting-up regional profiler certification facilities:

- Constructing new regional centers for certifying profilers can be very expensive, and it could be difficult to find funding for such an undertaking.

- Existing facilities that could be used for setting-up a regional certification center may not have all of the surface/texture types and roughness levels that are needed at a certification center. Upgrading such facilities to include additional test sections could be costly.

- The charge that is levied from a profiler owner for certifying a profiler must be kept at a reasonable level. Eighty percent of respondents to the survey performed by Huft (Chapter 5, Question 15) indicated the cost of certifying a profiler must be less than $3,000. Therefore, the charge levied from a profiler owner for certifying a profiler may not be sufficient to meet the labor cost associated with certifying profilers, as well as the cost needed for operating a regional certification center. Therefore, additional funds may be needed to run a regional certification center and finding a source for this funding could be an issue.

- Some SHAs may not see any value in establishing a regional certification center for certifying either project level or network level profilers. The survey performed by Huft indicated about 35 percent of the SHAs that responded to the survey see no value or a limited value in establishing regional certification centers (see chapter 5, question 11).

- Some SHAs may not want to get project level profilers operating in their state to be certified at a regional certification center because of the loss of state control over certification of profilers. In the survey performed by Huft (see chapter 5, question 13) 26 percent of the SHAs that responded to the survey indicated loss of state control was either a very important or a critically important barrier for the SHA in using a regional certification center.

7.9 POTENTIAL OBSTACLES THAT COULD PREVENT A SHA FROM USING A REGIONAL CERTIFICATION CENTER

The following are some potential obstacles that could prevent a SHA from using a regional certification center:

- Distance to Certification Center: The distance a profiler needs to travel to the regional certification center could be a major issue that can prevent a SHA from utilizing a regional certification center. In the survey performed by Huft (see chapter 5, question 12), 21 percent of SHAs that responded indicated they can travel to a regional certification center only if it was located within their state. Twenty nine percent and 35 percent of the respondents indicated the maximum distance they were willing to travel was 250 and 500 miles, respectively.

- Out-of-State Travel Restrictions: Fifty eight percent of the respondents to the survey by Huft (see chapter 5, question 13) indicated out-of-state travel restrictions to be a very important or a critically important factor that could prevent the SHA from using a regional certification center.

- Cost of Certification: The highest fee that is charged for profiler certification currently is in Texas, where a fee of $2,000 is charged by TTI for certifying a profiler with an additional $300 charged for certifying a profiler operator. Many SHAs currently provide profiler certification free of charge (e.g., Colorado, Michigan, Minnesota, Mississippi, Ohio, and Wisconsin). Paving contractors who are used to getting their profilers certified within the state free of charge could protest about the cost and time associated with certification if the state requires contractors to get their profilers certified at a regional center that is located outside the state. The SHA will also incur costs to get the SHA owned profilers certified as travel cost to a regional center as well as fee for certifying profilers will have to be borne by the SHA.

- Surface/Texture Types at the Regional Center: If the regional certification center does not have a surface/texture type that is important to a state for certifying profilers, the state may not want to make use of the regional certification center for certifying profilers.

- Re-Certification of Profilers: Currently SHAs that allow paving contractors to collect smoothness data for construction acceptance have a profiler certification program in place. These SHAs have requirements that the profiler must be re-certified if a major component of the profiler is replaced (e.g., a height sensor), if software upgrades are performed, or if there is a question about the data collected by the profiler. If re-certification is required, the contractor will have to wait until the next scheduled date when the regional certification center is performing certifications, and incur expenses to travel to the regional center to get the profiler re-certified. The contractors who have to undergo this might protest about the delay in getting their profiler certified and the cost associated with re-certification.

7.10 REVIEW OF AASHTO R 56-14 AND NEED FOR A NEW AASHTO STANDARD ON SETTING-UP OF REGIONAL CERTIFICATION CENTERS

AASHTO Standard R 56-14 that addresses profiler certifications indicates: "Perform dynamic certification testing on sections over a range of roughness. The reference profiles on the smooth section shall have an average IRI within the range of 30 to 75 in/mi while the corresponding reference profiles on the medium-smooth section shall have an IRI within the range of 95 to 135 in/mi. An Owner-Agency may elect to perform testing only on the smooth section for a profiler that is used for QC/QA testing. If pavements with considerable distress are to be measured, as in network data collection, a third medium-rough site should be selected with roughness up to 200 in/mi."

AASHTO Standard R 56-14 also indicates the repeatability as well as the accuracy of a profiler should be evaluated based on the IRI-filtered cross-correlation. The standard indicates for pavements with IRI values less than 150 in/mi, an IRI-filtered repeatability value of 0.92 or greater is required for a profiled path to provide IRI values within 5 percent with a 95 percent confidence level. This standard indicates an IRI-filtered accuracy value of at least 0.90 is required between data collected with a profiler and a reference device in order for the profiler to pass the accuracy requirement. This standard indicates a lower agreement score may be acceptable for repeatability as well as accuracy on the medium rough section that has an IRI greater than 150 in/mi, which is not used to evaluate profilers that collect data for construction quality control and acceptance. However, no recommendation regarding this lower value is provided in the standard.

In the Critical Profiler Accuracy Requirement Report, Karamihas (2005) proposed that network level profilers should have an IRI-filtered cross-correlation of at least 0.88 for repeatability and accuracy. Karamihas (2005) indicated at this level of cross-correlation, IRI values are expected to agree within 10 percent of each other 95 percent of the time. The AASHTO standard R 56-14 does not provide separate cross-correlation requirements for project level and network level profilers on the smooth and the medium-smooth section; the same requirements are specified for both project level and network level profilers. The cross-correlation values specified in AASHTO R 56-14 may have to be re-evaluated if a lower value is suitable to be used for certifying network level profilers if difficulties are faced by network level profilers in meeting the threshold indicated in AASHTO R 56-14. In addition, a suitable cross-correlation value will have to be selected for the medium rough section that will be used to certify network level profilers.

Currently, there is no need to develop a new AASHTO standard for setting-up of regional certification centers. However, it is recommended input be sought from members of pooled-fund TPF 5(063), Improving the Quality of Pavement Profiler Measurement, on the issues described in the previous paragraph. Based on the input, future revisions for AASHTO R 56-14 can be considered to address network level profilers.

CHAPTER 8. SUMMARY

The objective of this project was to investigate the viability of establishing regional centers that can serve as certification locations for certifying profilers that collect network level data as well as project level data that is used for smoothness acceptance. This report addressed the following items:

- A review of existing profiler certification programs.

- A review of the capabilities of existing facilities that can potentially serve as regional profiler certification centers.

- Recommendations on requirements of a regional profiler certification center, such as surface type of pavements, texture types, roughness ranges of test sections, length of test sections, allowable maximum grade of test sections, grade changes within test sections, testing speeds, frequency of certification etc.

- Needs and procedures for profiler operator certification.

- Costs associated with setting up a new regional profiler certification center.

- Ownership, management, and staffing requirements for a regional profiler certification center.

- Possible locations for setting-up regional profiler certification centers.

- Procedures to establish a pilot program for a regional profiler certification center.

- Funding scenarios for functioning of a regional profiler certification center.

- Potential obstacles for setting-up regional profiler certification centers.

- Potential obstacles that could prevent SHAs from using a regional profiler certification center.

- Review of AASHTO R 56-14 for necessary updates related to setting-up of regional certification centers and identify if there is a need for a new AASHTO standard on setting-up of regional profiler certification centers.

This report presented three options for setting-up regional certification centers which were referred to as:

- Option 1: Requirements at an ideal regional certification center.
- Option 2: Requirements at an intermediate level regional certification center.
- Option 3: Requirements at a basic level regional certification center.

An option 1 facility will have all of the surface types that are considered necessary to test the capability of a profiler on all common surface/texture types that are found in highways in the United States. An option 3 facility will have the minimum number of test sections that are considered necessary to certify a profiler.

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