COMPARISON OF NEW TECHNOLOGY

FOR MEASURING RIDE QUALITY

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COMPARISON OF NEW TECHNOLOGY

FOR MEASURING RIDE QUALITY

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COMPARISON OF NEW TECHNOLOGY

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THESIS ABSTRACT

COMPARISON OF NEW TECHNOLOGY

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Ride quality of a pavement is quantified by a statistical index. The statistical index and the profile device used to assess the index are major variables in pavement smoothness. Due to the wide range of these variables across the United States, a nationwide review of the current ride quality specifications was conducted. A major effort in the industry for acceptance testing is the concept of specifying ride quality based on a percent improvement in ride quality of the layer immediately below the new surface.

In order to determine the least variable method of profiling pavement surfaces, three different profile devices were used to collect longitudinal profiles at the National

Center for Asphalt Technology Test Track. Profiles were collected on the existing lanes and the reconstructed lanes. The profiles collected made it possible to determine repeatability precision for the profile devices. This information also provided insight in determining if and how ride quality improves with increasing pavement layers.

The findings of this research indicate that the type of surface profiled have an affect on the repeatability of the profile device. Also, the length of the test section profiled affect repeatability. Through the placement of each structural layer in the pavement section, the final surface smoothness was improved. However, bumps located in the initial layer profiled were reflected in the final surface. This indicates that every effort should be made to ensure the smoothest possible initial layer.

Computer software used Microsoft Word, Microsoft Excel, ProScan System, Australian Road Research Board Walking Profiler System, ProVal 2.5

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

Pavement smoothness is an important element of pavement construction. Smooth pavements provide comfort and safe passage to the driving public and prevent increases in travel cost. Rough (i. e. lack of smoothness) roads increase travel costs by causing vehicle damage and increasing fuel consumption. There is much concern from state highway agencies about pavement smoothness because it is primarily how the public perceives pavement quality. Additionally, the contractors responsible for constructing pavements are concerned with pavement smoothness since it affects them financially by pay adjustment factors (incentives, disincentives) used by state agencies to ensure pavement smoothness.

The pay factors used to ensure ride quality vary widely across the United States. One major variable is the ride quality (statistical index) used to quantify pavement smoothness. Another variable is the type of devices that can be used to assess the index. The selection of indices and profiling devices used significantly affect the quantification of the ride quality and deserve serious investigation. Also, it is important to research the correlations of these parameters to their effect on the quantification of pavement smoothness. A major effort in the pavement industry for acceptance testing is the concept of specifying ride quality for mill and overlay based on a percent improvement in ride quality of the layer immediately below the new surface. Therefore, research is needed to investigate the process of measuring smoothness on different structural layers of the pavement.

OBJECTIVES

The objectives of the thesis were to:

- Review Literature on the topic of road profile measurement devices, profile indices, and existing research of correlating profile indices.
- Assess and summarize the current methods of specifying ride quality in the United States.
- Evaluate if and how ride quality improves with increasing layers.
- Determine the most realistic and least variable method of profiling various types of surfaces for assessing the improvement in ride quality as each layer is added to the pavement structure.

CHAPTER II. LITERATURE REVIEW

INTRODUCTION

Pavement smoothness has evolved into an important aspect of pavement construction. Smooth pavements provide comfort and safe passage to the driving public and prevent increases in traveling cost while rough roads increase vehicle repair costs, fuel consumption, and unsafe driving conditions. State agencies use statistically based ride quality indices such as the Profile Index (PI) and International Roughness Index (IRI) to quantify the driving public's perception of an acceptable road. From a contractor's perspective, the initial smoothness of the pavement is very important because in most states ride quality specifications determine incentives and disincentives for contractor pay adjustments. The smoothness of a pavement is not only used in specifications, but it is also used for an overall evaluation of the condition of the pavement over the life of the facility. It is not unusual for the initial ride quality statistic to be different from the one used to monitor pavement condition during the life of the pavement.

While a number of statistical methods have been used to represent a user perception of ride quality, the most common quantitive expressions of ride quality today are the PI and IRI. The PI is a mechanical filter based index that measures the roughness of a profilograph trace (1). IRI is defined as the reference average rectified slope

($RARS_{80}$) of a standard quarter-car simulation at a traveling speed of 50 mi/hr (80 km/hr) measured in units of length/length (in/mile or m/km) (1). Regardless of the quantitive measurement used, all expressions of ride quality are based on the longitudinal profile of the surface.

There are a number of devices available for documenting surface profiles. These devices range from very simple hand operated units to complicated devices that involve today's advanced technology.

Objectives of Literature Review

The objectives of the literature review were to:

- Investigate how road profile measurement devices are used to obtain longitudinal profiles.
- Define how longitudinal profiles from each device are used to indicate ride quality.
- Investigate how state agencies across the United States use these devices and the ride quality associated with each device for acceptance testing.

The objectives of the literature review were researched in order to select the types of devices included in the Research Program.

The types of devices used to document the longitudinal profile of the roadway, as well as brief explanations of the mathematical approaches used to quantify profile characteristics are summarized in the following sections. The state of the practice review (Appendix A) documents how each state is currently measuring ride quality and the state's ride quality specifications. A thorough investigation of the current ride quality specifications for the state of Alabama is also included in the report.

Scope

The literature review was conducted to identify publications providing information on current specifications enforced by state agencies within the United States as of 2003. The majority of the specifications were found on state agency web sites. In order to find the most current specifications, contacts were made to the state agencies that did not display the specifications on their web site. Publications providing information on indices and equipment used to measure pavement smoothness were also reviewed.

BACKGROUND

Road Profile Measurement Devices

Profiles are used to examine the smoothness or, conversely, the roughness of a pavement surface. Roughness, typically defined as the lack of smoothness, occurs when there is a variation in surface elevation that induces vibrations in traversing vehicles, and it is defined over an interval of profile (2). Sayers et al. describe vibrations as follows: (2)

> *"There are many kinds of vibration, ranging from sickening heaves due to long wavelengths, to the rapid teeth-jarring impacts and irritating noises caused by short wavelengths."*

The definition of a profile is a two-dimensional slice of the road surface, taken along an imaginary line (2). For the purpose of measuring a pavement surface, an imaginary line is usually considered in both the left and right wheel paths. Longitudinal and transverse profiles are the two types of roadway profiles. Longitudinal profiles can be used to show the design grade, roughness, and texture of the pavement surface while transverse profiles are used to measure rut depth (2). However, rutting can contribute to the level of roughness of a pavement because over time rutting results in a reduction of pavement section and premature cracking will occur which will increase roughness of a pavement. In terms of measurement, if the depth of rutting along the measured longitudinal profile is not consistent then rutting will affect ride quality. The collection, profile analysis, and use of ride quality statistics are the main focus of this literature review.

There are a number of profile measuring devices designed to be hand operated, operated at low speeds, or operated at highway speeds. The hand-operated units include rolling straightedges, walking profilographs, and inclinometers. Inertial profilers, while originally designed to be operated at highway speeds (typically 40 to 55 mph), now have smaller versions, referred to as lightweight profilers, that can be operated at slower speeds (i.e., 10 to 20 mph).

Walking Profilograph (Hand Operated)

The California Profilograph (Figure 2-1) was developed by Francis N. Hveem while at the California Division of Highways in the 1940s (3). There are a number of manufacturers that supply this type of profilograph; the profilograph shown in Figure 2-1 was manufactured by McCracken. The profilograph records the profile by the deviations of the center bicycle wheel. A cable connects the center wheel to a pen on a printer that records the profile trace as the machine is pushed along the pavement. The printer drum is connected to the center wheel with chains and gears which allows the printer to feed paper to the recording pen. The Profile Index (PI) can be calculated from a profilograph trace. The PI and its calculation will be discussed later.

Figure 2-1. McCracken Model California Profilograph.

Inclinometers (Hand Operated)

Inclinometer-based profilers use a small straightedge beam up to 12 inches in length to measure profile. The beam is placed on the pavement surface and its inclination is measured and recorded. The beam is then moved its length along the pavement surface and the same measurements are repeated (4). One type of inclinometer is the Australian Road Research Board (ARRB) walking profiler (Figure 2-2). The ARRB walking profiler uses a 9.5 inch beam. The process of moving the beam along the pavement surface is called a step. After each step the distance and elevation is recorded. The profiler uses these measurements to create a profile and calculate the IRI. The IRI is an index that is used to measure roughness of the pavement and will be discussed later.

Figure 2-2. ARRB Walking Profiler (5).

Inertial Profilers (Low to High Speed)

Inertial profilers determine the profile by using a combination of non-contact height sensors, an accelerometer, and a distance measuring instrument. The height sensors measure the distance from the vehicle chassis to the ground. Height sensor types include laser, optical, infrared, and ultrasonic sensors, but the most common sensor today is the laser height sensor (6). The accelerometer is usually located on top of the height sensor to measure vertical acceleration (6). The accelerometer measures the force of the up and down movement of the vehicle chassis during a data run and uses the data to compensate the height measurements made by the laser (6). The distance measuring instrument simply measures the longitudinal distance of the section being profiled (6).

Inertial profilers are separated into two groups: lightweight and full-size. The lightweight profilers (Figure 2-3) are generally operated at low speeds between 10-20 mi/hr and are used by the contractor immediately after the Hot Mix Asphalt (HMA) mat is placed. Testing is completed before the pavement is opened to traffic. Many contractors have implemented the use of the lightweight profiler for measuring pavement smoothness because of its maneuverability and speed compared to the California-style profilograph. In addition, since the lightweight profilers weigh less than the full size profilers some state agencies allow their use on green (i.e., not fully cured) Portland Cement Concrete (PCC). Most lightweight profilers produce a trace from which the PI and IRI can be calculated. In fact, the PI and IRI values are produced along with the trace by an onboard computer.

The full-size profilers (Figure 2-4) are generally operated at speeds between 45 and 55 mph, although they can be used at speeds as low as 22 mph. These units are used to evaluate the ride quality of pavement that has already been opened to traffic. The inertial profiler system is usually mounted to a multi-passenger van. The Roadware ARAN van (Figure 2-4) is one example of a full size inertial profiler that can obtain pavement profiles at highway speeds. This allows state agencies to evaluate pavements on a network level. The ARAN van software is capable of producing smoothness indices in PI and IRI. Most full size inertial profilers are employed for acceptance or performance evaluation.

Figure 2-3. ICC Lightweight Inertial Profiler (7).

Figure 2-4. Automatic Road Analyzer – ARAN (8).

Profile Indices

Among the many statistics used to quantify ride quality from a longitudinal profile, the two used in state specifications today are PI and IRI. Therefore, this thesis will focus on these indices. Twenty five state agencies use PI to report pavement smoothness, but some of these agencies are planning to make a transition from PI to IRI at some future date.

Profile Index (PI)

The profile index is a mechanical filter based index which measures the roughness of a profilograph trace, generally from the California style-profilograph. In order to calculate the PI, a blanking band must be applied optimally between the highs and lows of the profile trace depicting at least 100 ft (30 m). The blanking band used is chosen by the state agency and it can be 0.2, 0.1, or 0.0 in (5 mm, 2.5 mm, or 0.0 mm). The PI is calculated by summing the excursions that are outside the applied blanking band and dividing by the length of the test section (9). The purpose of a blanking band is to allow small deflections in the profile trace to be nulled out of the measurements to compensate for equipment vibrations and other minor movements. The amount of deflection to be nulled out is determined by the specification of a blanking band. Therefore, only deflections occurring outside of the blanking band are recorded as deviations from a smooth surface. Figure 2-5 shows a sample calculation of PI. In Figure 2-5, the solid black line is the best fit linear line which is used as a reference to measure the excursions. This best fit line is a major difference in the two methods of reducing a profilograph trace. The manual method involves a template centered on the trace which represents the best fit linear line. The automated method involves a scanner used to digitize the trace and perform a least-square error analysis to determine the best fit linear line from which to measure the excursions. Prior research has shown that the automated method is more reliable and faster than the manual method, and the automated method reduces the influence of the experience and subjectivity of the individual performing the manual reduction method (10).

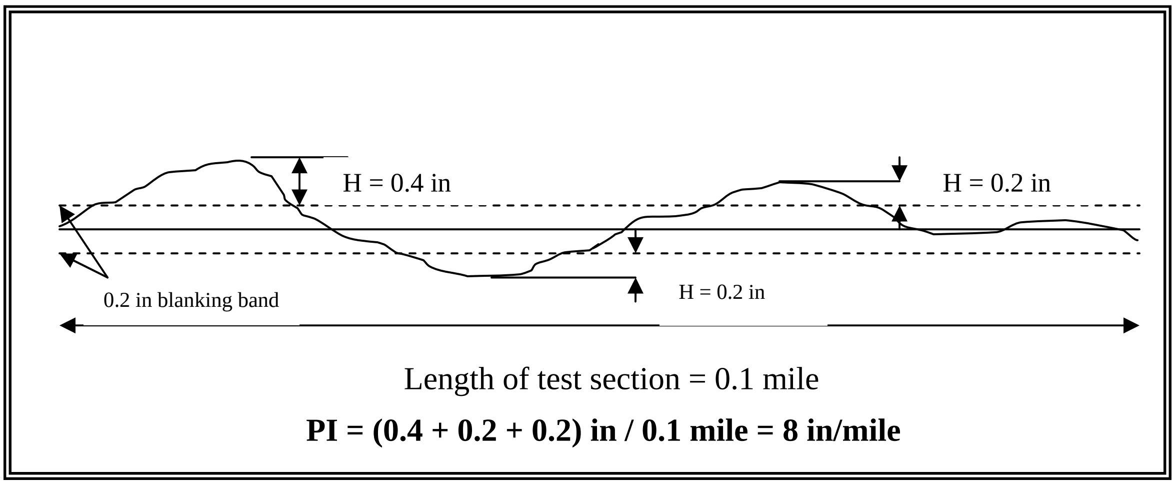


Figure 2-5. Sample PI Calculation.

International Roughness Index (IRI)

The IRI is calculated for one longitudinal profile and is defined as the reference average rectified slope ($RARS_{80}$) of a standard quarter-car simulation at a traveling speed of 50 mi/hr (80 km/hr) measured in units of length/length (in/mile or m/km) (2). The profile is filtered with a 250 mm moving average to smooth the profile or weaken the small wavelengths. The profile is then filtered with a quarter car simulation (Figure 2-6) with standardized parameters of a sprung mass, unsprung mass, suspension spring rate, tire spring rate, and suspension linear damping (10). These parameters are standardized to allow the model to simulate response properties typical of most highway vehicles. The output of the filter is the relative displacement of the sprung mass and unsprung mass (or suspension motion) at a speed of 50 mph (80 km/hr) (10). The absolute value of the suspension motion is accumulated and divided by the profile length to obtain IRI in units of in/mile or m/km.

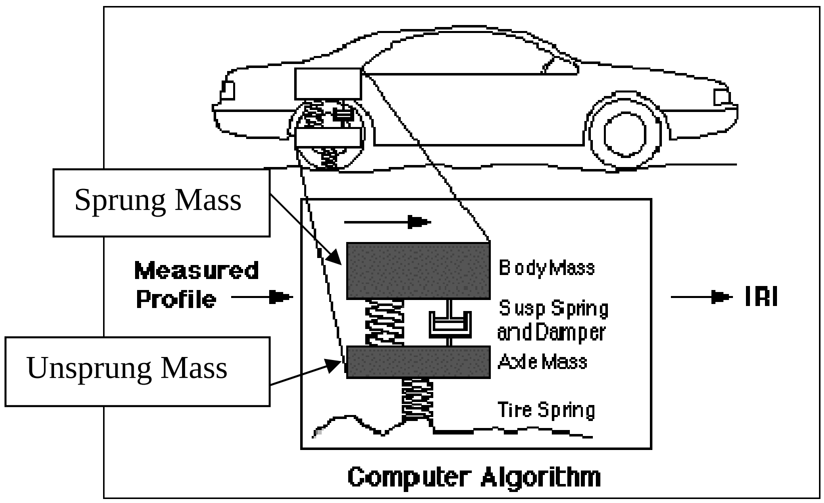


Figure 2-6. Quarter Car Model (1).

Correlations Between PI and IRI

With the advance of technology, many state agencies are trying to advance the ride quality specifications for pavements. Most specifications are listed in terms of PI, but some are transitioning into IRI. Many studies have been performed to relate PI and IRI in order to do this.

In a recent study involving the relationship of smoothness index values, several researchers from the Federal Highway Administration (FHWA) analyzed the profile data from the Long-Term Pavement Performance (LTPP) database (11). The profile data extracted from LTPP included PI and IRI values for flexible and rigid pavements using the 0.0 in, 0.1 in, and 0.2 in blanking bands (11). The purpose of the study was to provide recommendations for smoothness specification acceptance limits for new and rehabilitated flexible and rigid pavements, based upon IRI and PI (11). In other words, the study was conducted to recommend how agencies make the switch from current PI-based specifications to IRI specifications, and to show what levels of IRI would be comparable or equivalent to current PI levels. The results of the study provided numerous figures and tables which can be found in reference 11. The results show that a reasonable correlation can be developed between IRI and PI (11). For example, the following equation represents a model that can be used to relate IRI to PI using a 0.0 in blanking band on flexible pavement (11):

$$IRI = 2.66543 * PI + 213.009 \qquad R^2 = 0.89482$$

where

IRI = mm/km

PI = mm/km with zero blanking band

Other results show that correlations between PI values using the zero blanking band and PI values using the 0.1 in and 0.2 in blanking bands can be developed (11). If a state agency wanted to improve its specifications without converting to IRI, then this study provides the agency with equations to calculate PI with a reduced blanking band width. Pavement types evaluated in this study included Asphaltic Concrete (AC), AC/AC, and AC/Portland Cement Concrete (PCC), and the climatic regions analyzed were dry-freeze, dry-nonfreeze, wet-freeze, and wet-nonfreeze (11). Although the conclusions of this study stated that pavement type and climate are significant factors in the correlation between IRI and PI, there were no clear trends regarding the effect of climate and pavement type on the IRI-PI relationship (11). However, climatic conditions have the effect of increasing the slope of the IRI-PI relationship for AC/AC pavements in dryer climatic regions (11). It was recommended to agencies which plan to use the IRI-PI relationship equations to evaluate the validity of the research based on that agencies conditions and experiences.

State of the Practice

Specifications

Each of the fifty United States' smoothness specifications were reviewed and recorded as a part of this study. The information collected include the method of measurement, ride quality statistic to be used, test section length, time of testing, and the acceptance limits including full pay and incentives/disincentives if applied for both flexible and rigid pavements. The specifications are summarized in Appendix A.

Figure 2-7 summarizes the prevalence of the various types of equipment used across the United States. The California-style profilograph is used by 25 states for acceptance of the ride quality of flexible pavements, and 17 states use inertial profilers such as the ARAN inertial profiler, General Motors Profilometer, or Lightweight inertial profiler. Seven states use devices other than the California-style profilograph and inertial profiler. These other devices include the straightedge, Mays Ride Meter, or South Dakota Profiler. The type of device used for four states were undetermined. Out of the 50 state specifications reviewed, 43 have flexible pavement smoothness specifications (Table A-

2). The remaining 7 states do not have smoothness specifications, or no information was able to be obtained for these states.

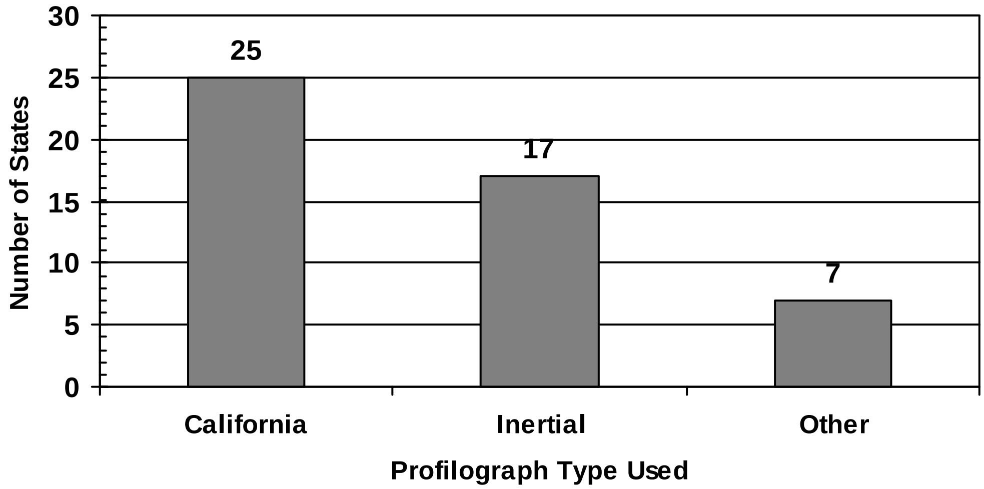


Figure 2-7. Flexible Pavement

Of the 43 states enforcing specifications, 29 have both pay incentives and disincentives, 14 use no incentives, 5 use incentives only, and 2 use disincentives only (Figure 2-8). The states that do not have disincentives require corrective action to the pavement if the smoothness index exceeds the full pay range. Some states do not require corrective action if the smoothness index has exceeded full pay range; however, a penalty or price adjustment is usually enforced.

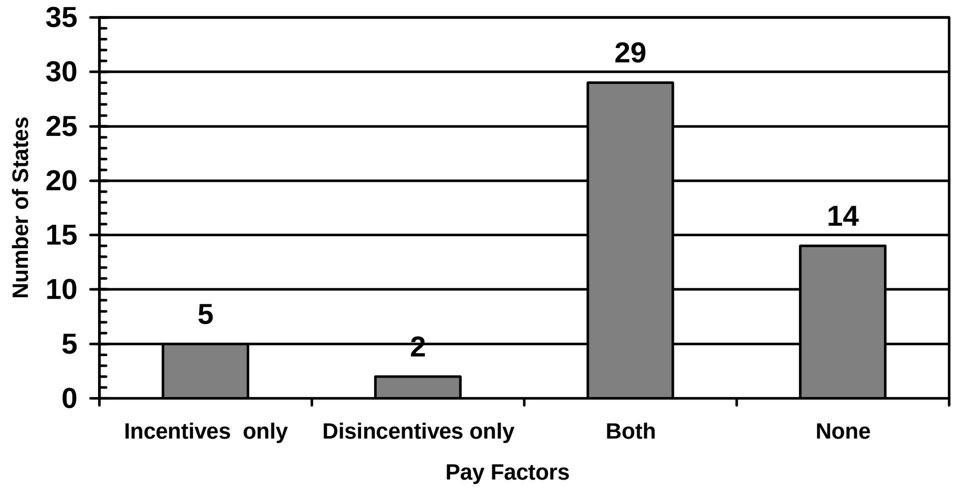


Figure 2-8. Flexible Pavement Pay Factors Used

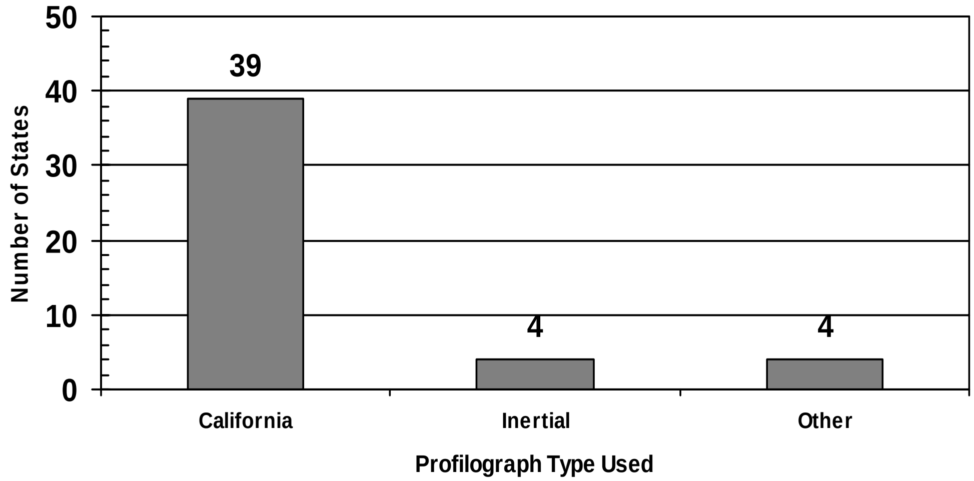


Figure 2-9. Profilographs Used for Rigid Pavement

Smoothness specifications are enforced by 44 out of 50 states for newly constructed rigid pavements (Table A-3). Within the 44 states, 24 apply both incentives and disincentives, 13 have no pay factors, 7 apply incentives only, and 6 apply disincentives only (Figure 2-10). The California profilograph is used by 39 states for acceptance of the ride quality of rigid pavements, and 4 states use an inertial profiler (Figure 2-9). The remaining states use devices such as the straightedge, or Mays Ride Meter.

Acceptance Limits

Acceptance limits for pavements vary a great deal within the United States. For instance, the ranges of Profile Index in in/mile representing 100 percent pay are plotted in Figure 2-11. There are nineteen ranges of Profile Index for 100 percent pay, and only three ranges include more than one state (Figure 2-11). The PI ranges vary from 0 in/mile to 18.1 in/mile for a lower limit and 3 in/mile to 30 in/mile for an upper limit (Figure 2-11). It can be determined from Figure 2-11 that state agencies do not agree on one particular range of PI values to assign 100 percent pay to the contractor for flexible pavements. The same follows for the specifications written for rigid pavements. It can be seen from Figure 2-12 that state agencies are inconsistent in assigning PI values to award 100 percent pay to the contractor for rigid pavements.

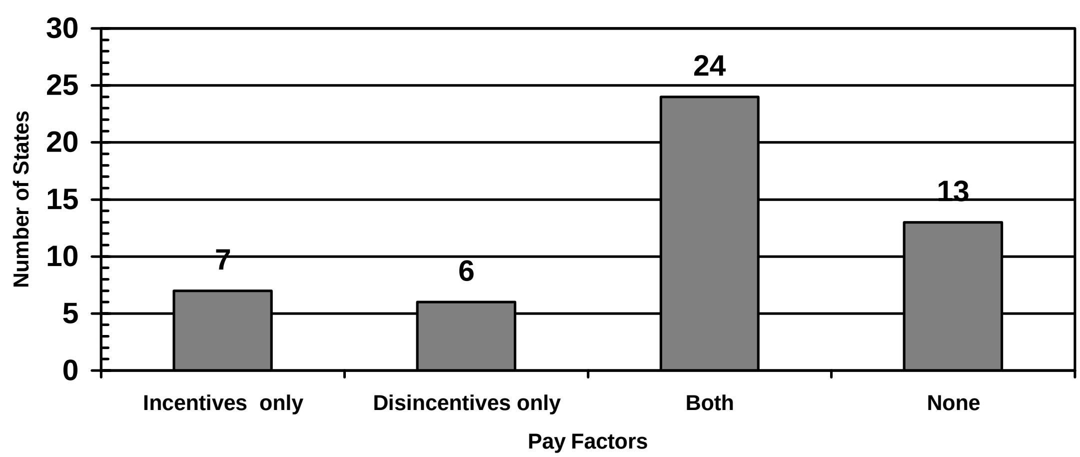


Figure 2-10. Pay Factors Used for Rigid Pavements

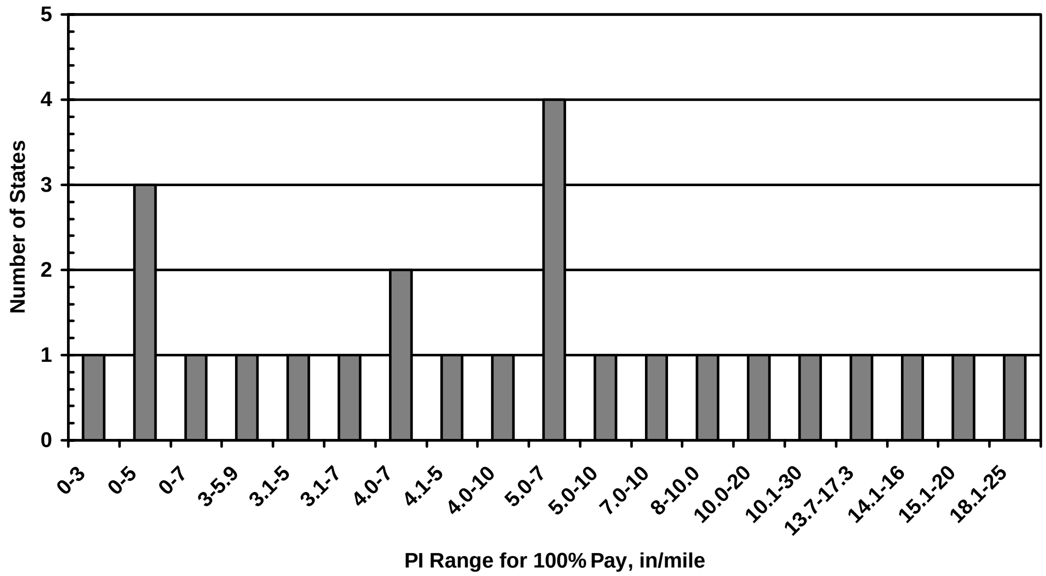


Figure 2-11. Profile Index Ranges for California Profilograph on Flexible Pavement

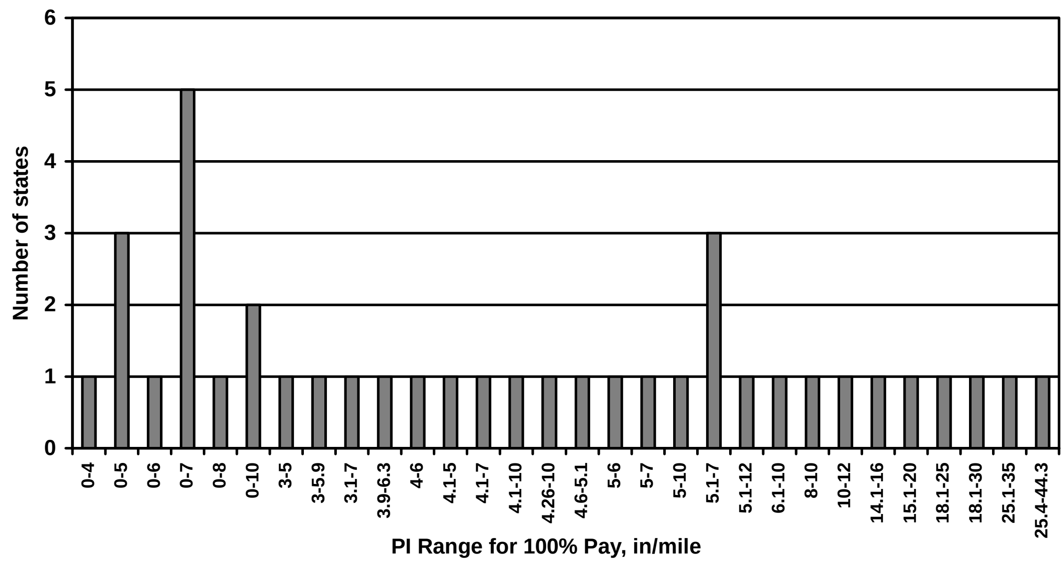


Figure 2-12. Profile Index Ranges for California Profilograph on Rigid Pavements

The data in Table 2-1 show acceptance limits for 100 percent pay on flexible pavements for the states listed using an inertial profiler. The index used by these states in Table 2-1 is the IRI. The data show that no two states agree on a particular range.

However, some states do agree on lower limits alone and upper limits alone. Connecticut and Washington agree on an approximate IRI = 60 in/mile for a lower limit; Pennsylvania, South Dakota, and Wyoming agree on and IRI = 70 in/mile as an upper limit for 100 percent pay (Table 2-1).

Table 2-1. 100% Pay Acceptance Limits for Flexible Pavements using Inertial Profiler

State	Type of Inertial Profiler	Acceptance Limits: International Roughness Index, in/mile	
		Lower Limit	Upper Limit
Connecticut	ARAN[A]	60	80
Georgia	Laser Profiler	0	47.5
Maine	Inertial Profiler	36	60
Massachusetts	Inertial Profiler	0	95
Montana	Laser Profiler	46	65
Pennsylvania	Lightweight	0	70
South Dakota	Inertial Profiler	55.1	70
Vermont	Inertial Profiler	54	65
Washington	Lightweight	60.1	95
Wyoming	Inertial Profiler	55	70

A = Automatic Road Analyzer

Pay Factors

State agencies apply pay factors such as incentives and disincentives to promote quality construction by the contractor. As discussed previously, the number of states applying incentives and disincentives are expressed in Figures 2-8 and 2-10. Table A-1 in Appendix A lists the range of incentives and disincentives used across the nation; Figures 2-13 and 2-14 summarize this information based on the number of states that use similar incentives or disincentives. This information is presented in terms as a percent of the pavement unit bid price. From Figure 2-13 it can be seen that the incentive range of 0-5% is the most common among the specifications, and Figure 2-14 shows that the disincentive range of 0-10% is the most commonly used penalty. Figures 2-13 and 2-14 list a column titled “Other” which means the state agency uses a method other than percent of pavement unit bid price. The other methods used for incentives/disincentives include equations which are a function of PI or IRI, price increase/decrease per square yard, and price increase/decrease per lot.

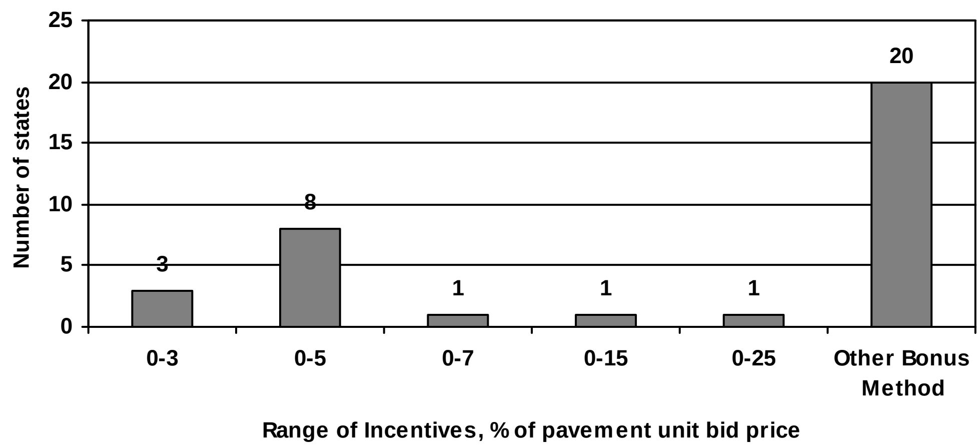
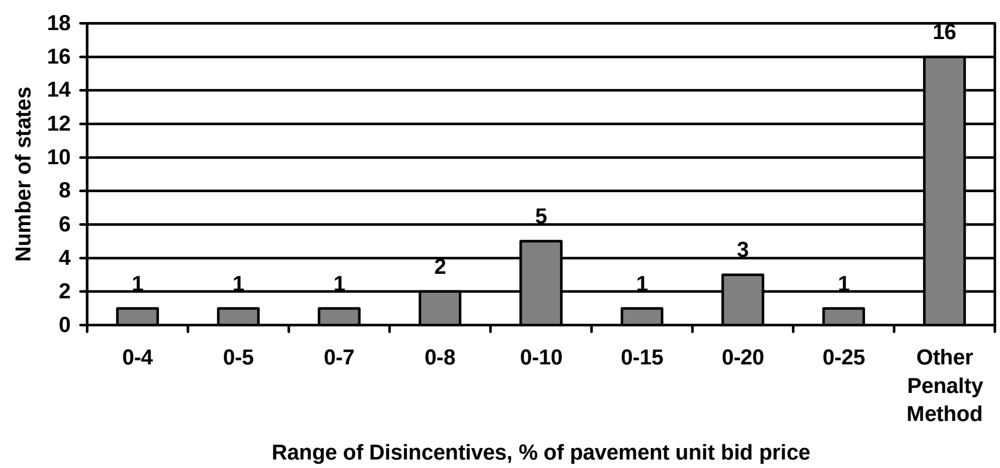


Figure 2-13. Range of Incentives Specified for Flexible Pavement



Figur 2-14. Range of Disincentives Specified for Flexible Pavement

Current Alabama Specifications

Table 2-2 lists the current specifications for flexible and rigid pavements in the state of Alabama. Table 2-2 specifies that a California-style profilograph is suitable for measuring flexible and rigid pavement. The section length for testing is 0.1 miles for both types of pavement. The specifications are listed in PI with corresponding price adjustments in percent of pavement unit bid price.

Recent research shows that there are disadvantages to the current ride quality specifications in Alabama. An analysis by the Alabama Department of Transportation (ALDOT) indicates that more than three-quarters of all the 0.1 mile sections tested since the implementation of the specification have fallen in the 5 % bonus range without an improvement in pavement ride quality (10). One disadvantage of the older Alabama specifications is that a 0.2 inch (5 mm) blanking band is specified in manually analyzing the profilograph trace (10). Studies have indicated that using a wide blanking band, such as the one specified by Alabama, allow minor defects in the pavement to go unnoticed, and these defects affect ride quality but are not measured because they fall inside the blanking band (10). It was recommended by Bowman et al. to change the blanking band width to 0.0. This recommendation was subsequently adopted by ALDOT.

Another disadvantage of the specifications noted by Bowman et al. was the fact that a step function with 5% increments is used. It was stated that the large increments between payment levels results in the potential for a large payment difference between two borderline segments (10). Bowman et al. suggested that a combination step function/continuous linear relationship function be used to determine pay factors. The suggested pay function (10) is as follows:

Bonus:

Percent Pay = (-1.667 * PI) + 124.5

Penalty:

Percent Pay = (-1.667 * PI) + 133.33

where,

PI = Profile Index, in/mile.

Table 2-2. Current Alabama Ride Quality Specifications

Pavement Type	Equipment	Section Length	Time of Testing	Price Adjustments		
				Profile Index, mm/km 0.2 in Blanking Band	**Profile Index, in/mile 0.2 in Blanking Band**	**Contract Price Adjustment, % of pavement unit bid price**
Flexible	California profilograph	0.1 mile	same day	Under 47.3	Under 3.0	105
				47.3 to < 94.6	3.0 to < 6.0	100
				94.6 to < 126.2	6.0 to < 8.0	95
				126.2 - 157.7	8.0 - 10.0	90
				over 157.7	over 10.0	Corrective work required
Rigid	California profilograph	0.1 mile	immediately after curing	Under 45	Under 3.0	105
				45 to < 95	3.0 to < 6.0	100
				95 to < 125	6.0 to < 8.0	95
				125 to 160	8.0 to 10.0	90
				over 160	Over 10.0	Corrective work required

SUMMARY AND RECOMMENDATIONS

Pavement smoothness has become and will remain an essential element of the construction industry. There are numerous technical papers dealing with pavement smoothness, and each author has a different idea of how to achieve or specify pavement smoothness. Through research of the literature and current state specifications it can be determined that PI is still the main index used, and the California-style profilograph is still the predominant measuring device used. However, many states are currently in the process of transitioning to other means of measuring pavement smoothness such as inertial profilers. Alabama is one of the states that are beginning to investigate the possibility of phasing out the use of the California – style profilograph in favor of an inertial profiler. Therefore, the devices of concern in this thesis are the California – style Profilograph and the Automatic Road Analyzer (ARAN) high-speed inertial profiler.

A third hand operated inclinometer style profiler, the Australian Road Research Board (ARRB), was added to the research program for several reasons: Some states are currently evaluating specifying a percent ride quality improvement rather than fixed upper and lower ride statistics. This means that the profile of the existing surface is needed in order to calculate the percent change. In the case of mill and fill overlay projects, this means that the milled profile would need to be obtained. In Alabama, this means that the profile needs to be collected between the milling and the paving operation as the constructions process moves down the road. This will require the use of a hand-operated unit that can be operated over short distances and move with the stop and start processes associated with a number of paving projects. A second reason, also associated with exploring the extent of the percent improvement due to the addition of the layer in the pavement structure, is that an easily movable hand-operated unit is needed when trying to profile cut areas in pavement construction and/or unbound surface materials. The third reason for including the ARRB unit is that Roadware is starting to market the ARRB along with the ARAN van for possible establishment of a reference profile for field verification of profile measurements. For these reasons, it was deemed important to include an evaluation of this unit in this study.

An investigation of transitioning current specifications from PI to IRI must be performed. The first step in achieving this transition is the development and comparison of the precision and correlation of both methods. This is the focus of this research project.

CHAPTER III: RESEARCH PROGRAM

INTRODUCTION

This research program was designed to:

- Determine McCracken California profilograph repeatability precision for recording longitudinal pavement profiles so that statistical differences between the new methods for obtaining pavement profiles could be established.
- Determine ARRB repeatability precision for recording longitudinal pavement profiles.
- Determine ARAN repeatability precision for recording longitudinal pavement profiles.
- Compare profile traces of the ARRB and the ARAN van.
- Evaluate the influence of subsequent pavement layers, starting with the subgrade profile, on the smoothness of the final HMA surface.

The ARAN van was used to evaluate smoothness of HMA pavement layers only due to the fact that this equipment is not made for measuring pavement layers such as the subgrade and granular base layers.

SCOPE

The Auburn University National Center for Asphalt Technology (AU-NCAT) test track was used for this research. This test track is a 1.76 mile closed loop two lane roadway. A total of 46 test sections were constructed around the loop with 13 sections in each of the North and South tangents and 10 sections in each of the east and west curves. Tangents were constructed with a cross slope of 2% and varied between 2% and 15% in the curves. The inside lane was essentially untrafficked, except for occasional passenger vehicles and for a safety lane for the truckers. This lane was used for estimating the repeatability of longitudinal profiles (tangents only) of the McCracken profilograph, ARRB profiler, and ARAN van, so that differences in the profiles due to traffic would be minimized.

The outside lane was used to evaluate the longitudinal profiles of each layer of pavement during reconstruction of the test track. The reconstruction of the North tangent was used to assess the repeatability of longitudinal profiles obtained with the McCracken profilograph and ARRB on subgrade and granular base course surfaces. These profiles in conjunction with the inside lane tangent were used to determine the ability of the ARRB profiler to accurately reproduce a profile over extended lengths (approximately 600 meters) and a range of surface types.

The McCracken profilograph traces were analyzed using the ProScan device to achieve the profile index (PI) with a 0.2 in blanking band. The ProScan device is an automated profilogram reduction system which is used by the Federal Highway Administration (FHWA) and ALDOT to reduce profilograph traces. The ARAN van was used to produce IRI of the inside lane at 45 mi/hr and 15 mi/hr.

The McCracken profilograph was physically pushed around the track three times in order to receive three sample profiles for the inside lane on the North tangent and the South tangent. Samples of the subgrade, granular base course, HMA layer 2, HMA layer 1, and wearing course were profiled during reconstruction of the outside lane on the North tangent. Figure 3-1 shows the typical section of the reconstruction of the outside lane on the North tangent. Table 3-1 summarizes the number of samples tested for each layer using the McCracken profilograph. Logistics was a factor in determining the amount of samples taken for each layer. Each layer was profiled as much as logistically possible; however, some samples were interrupted by the paving train. Each layer profiled with the McCracken profilograph produced a profile trace which was reduced by the ProScan device which will be discussed later.

The process for the ARRB walking profiler was similar to the process for the McCracken profilograph. Table 3-1 summarizes the number of samples tested for each layer using the ARRB walking profiler.

The ARAN van was used to profile the inside lanes of the North and South tangents at speeds of 15 mi/hr and 45 mi/hr. Three samples were obtained for each tangent at 15 mi/hr and 45 mi/hr. Table 3-1 summarizes the number of samples tested for each layer using the ARAN van.

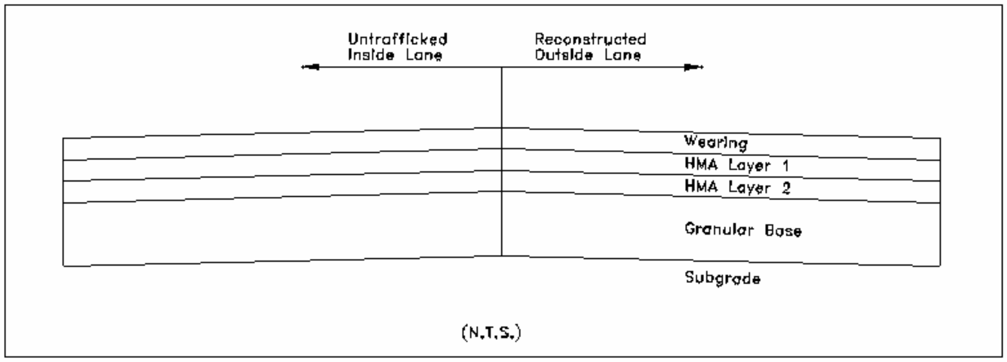


Figure 3-1. Typical Section of Reconstructed Lane on North Tangent.

Table 3-1. Number of Replicate Measurements with Each Device on Each Layer.

	North Tangent Reconstructed Lane					**North Tangent Inside Lane**	**South Tangent Inside Lane**
Unit	**Subgrade**	**Granular Base**	**HMA Base Layer 2**	**HMA Base Layer 1**	**Wearing**	**HMA**	**HMA**
McCracken	2	3	3	3	2	3	3
ARRB	1	3	3	3	2	3	3
ARAN	N/A	N/A	N/A	N/A	N/A	3	3

DATA COLLECTION

Data collection for this research involved measuring longitudinal profiles with the McCracken model California profilograph, ARRB walking profiler, and the ARAN van. The inside (untrafficked) lane was measured using all three of the measuring devices mentioned above. A homemade guide was placed on the McCracken model California profilograph and the ARRB walking profiler to line up with a reference point in order to approximately measure the same tract with each device (Figures 3-2, 3-3). The test path chosen was in between the inside wheel path and outside wheel path due to destructive testing in each wheel path of the existing pavement. Three replicates of the inside (untrafficked) lane were measured with the McCracken profilograph and ARRB profiler. There were six replicates measured with the ARAN van. Three replicates were measured at a speed of 45 mi/hr, and three replicates were measured at a speed of 15 mi/hr.

Figure 3-2. McCracken Model Profilograph with guide.

Figure 3-3. ARRB Walking Profiler with guide.

McCracken California Style Profilograph Data

The McCracken Profilograph was used to obtain the Profile Index for the North tangent and South tangent of the NCAT test track. Also, during the reconstruction of the North tangent outside lane, measurements were taken with the McCracken profilograph to obtain the Profile Index. The pavement layers profiled include the following:

1. Subgrade,
2. Granular base layer,
3. HMA base layers, and
4. HMA wearing course.

Only the inside wheel path was profiled for each layer of reconstruction. Due to reconstruction logistics some layer test section lengths were shorter than others, and each layer could not be profiled three times for three complete samples.

The ProScan device was used to reduce the profile traces produced by the McCracken profilograph. This device digitizes the profile trace in order to perform a least-square error analysis to determine the best fit line and locates the deviations from this line. The deviations are summed and divided by the length of pavement being evaluated resulting in the Profile Index in in/mile. The ProScan device is capable of reducing a profile trace quickly, and is able to produce roughness indices for 0.0 in blanking band, 0.1 in blanking band, and 0.2 in blanking band. The ProScan device used for this research was on loan from the FHWA, but due to the limited availability only the profile index using a 0.2 in blanking band was reported. The layers profiled which are defined as follows:

North Tangent: Untrafficked lane on the North tangent.

South Tangent: Untrafficked lane on the South Tangent.

Wearing: Wearing course on the reconstructed lane of the North tangent.

HMA Base Layer 1: Base course on the reconstructed lane of the North tangent.

HMA Base Layer 2: Base course on the reconstructed lane of the North tangent.

Granular Base: Granular base course on the reconstructed lane of the North tangent.

Subgrade: Subgrade on the reconstructed lane of the North tangent.

Figure 3-1 shows the typical section of the reconstructed lane on the North tangent. This figure also indicates how the layers are labeled.

ARRB Walking Profiler Data

The ARRB Walking Profiler was used to obtain the PI and IRI for the untrafficked lanes of the North tangent and South tangent of the NCAT test track. Also, during the reconstruction of the North tangent outside lane, measurements were taken with the ARRB to obtain the PI and IRI. The pavement layers profiled during reconstruction include the following:

1. Subgrade,
2. Granular base layer,
3. HMA base layer 2,
4. HMA base layer 1, and
5. Wearing.

The inside wheel path was profiled for each layer of reconstruction using the ARRB. Due to reconstruction logistics some layer test section lengths were shorter than others, and some layers could not be profiled three times for three complete samples.

The information collected with the ARRB profiler consists of profile height and distance every 9.5 inches. The raw data collected with ARRB walking profiler are listed in Appendix B. Due to the large amount of surface profiled and the extensive number of measurements (i.e., one every 9.5 inches), the first 9.5 feet of the raw data is shown in the tables of Appendix B as an example of the data collected. The ARRB data was processed with the Profile Viewing and Analysis 2.5 (ProVal 2.5) software to produce IRI values using 25 ft., 52.8 ft., and 528 ft. intervals and PI values using 0.0, 0.1, and 0.2 blanking bands (12). The ProVal 2.5 software simulates a California profilograph when processing

PI values and reports PI of each 0.1 mile (528 ft) segment. The processed IRI and PI data are listed in Appendix C.

ARAN Van Data

The ARAN van was used to obtain the IRI for the untrafficked lanes of the North tangent and South tangent of the NCAT test track. Six samples of the North and South tangent were profiled. Three samples were profiled at 15 mi/hr and three samples were profiled at 45 mi/hr. The ARAN View software provides an engineering research development (ERD) file which lists profile height and distance of the longitudinal profiles. The profile height and distance is then used to create a profile trace. The tables in Appendix D list the profile height and distance for the longitudinal profiles created with the ARAN van. Due to the large amount of surface profiled and the minute measuring increments only the first 3.7114 feet of the raw data is listed in the tables of Appendix D. The ProVal 2.5 software uses the ERD file to calculate ride statistics at intervals such as IRI using a base length of 52.8 ft and 528 ft. The IRI data obtained with the ARAN van are shown in Appendix E. The base length of 25 ft was not calculated for the ARAN data due to errors in the ProVal 2.5 software. ProVal 2.5 is software that is updated as researchers and those in the industry use it. During the IRI calculations using ProVal 2.5 it was found that it could not calculate the IRI using a base length of 25 ft. The engineer that wrote the program for ProVal 2.5 was contacted about this problem and further investigation showed that there was a programming error with the latest version of ProVal 2.5. The error was corrected and the engineer explained that the error was directly related to the base length of 25 ft, and the results using the base lengths of 52.8 ft and 528 ft are correct.

CHAPTER IV: DATA ANALYSIS

REPEATABILITY OF WALKING PROFILERS

McCracken California Style Profilograph

Table 4-1 shows the Profile Index (PI) for each of the replicate profiles. In order to establish estimates of repeatability for the McCracken Profilograph, the average PI and standard deviation for each set of replicate values for each of the sections tested were calculated for the 0.2 inch blanking band. Multiple segments were treated as additional replicates for a given pavement layer. Table 4-2 lists the average PI and standard deviation for each of the inside (untrafficked) lanes and the reconstructed lanes (outside lane), North tangent.

Table 4-3 presents the statistics for each layer type. The average PI for the unbound layers is at least 10 times larger than either of the HMA base or surface layers. The PI of the HMA base layers is slightly lower than that of the HMA surface mix; the HMA base PI values are significantly less variable than those obtained for the HMA surface. These results suggest that the compaction effort used to obtain density in the surface layers may actually be increasing both the roughness and variability in roughness of the finished surface.

Table 4-1. Profile Index obtained with McCracken Profilograph

0.2 in. Blanking Band						
Layer Profiled	Sample 1		Sample 2		Sample 3	
	Segment	Profile Index, in/mile	Segment	Profile Index, in/mile	Segment	Profile Index, in/mile
North Tangent	1	6.1	1	5.4	1	6.2
	2	9.8	2	10.2	2	9.1
	3	3.5	3	5.3	3	3.3
	4	6.6	4	7.2	4	6.7
	5	18.0	5	25.2	5	22.6
South Tangent	1	6.0	1	6.3	1	6.2
	2	10.4	2	12.5	2	12.1
	3	6.2	3	4.6	3	3.0
	4	9.0	4	9.2	4	7.3
	5	2.7	5	3.5	5	5.2
Wearing	1	1.4	1	1.7	1	N/A
	2	6.2	2	5.6	2	N/A
	3	0.9	3	0.6	3	N/A
HMA Base Layer 1	1	3.6	1	4.0	1	4.0
	2	4.2	2	3.9	2	4.0
HMA Base Layer 2	1	4.1	1	5.5	1	3.6
Granular Base	1	46.9	1	53.5	1	38.2
	2	46.1	2	46.3	2	46.5
	3	24.0	3	40.4	3	14.9
	4	48.9	4	N/A	4	102.5
Subgrade	1	39.7	1	63.7	1	N/A
	2	61.4	2	62.3	2	N/A
	3	74.5	3	61.7	3	N/A
	4	70.6	4	160.0	4	N/A

***Segment = 0.1 mile interval (528 ft)**
N/A = not able to obtain measurement

Table 4-2. Analysis of Profile Index Obtained With McCracken Profilograph.

Layer Profiled	PI Information, in/mile (0.2 Blanking Band)		
	n	Avg	Std Dev
Subgrade	8	74.24	28.20
Granular Base	12	48.66	20.30
HMA Surface North Tangent	15	9.68	7.15
HMA Surface South Tangent	15	6.95	3.19
HMA Surface New Wear	6	2.73	2.77
HMA Base 2	3	4.40	0.98
HMA Base 1	6	3.95	0.12

Table 4-3. McCracken Profiler PI Statistics for each Layer Type.

Layer Type	PI Repeatability, in/mile (0.2 Blanking Band)			
	Average	Variance	Standard Deviation	Coefficient of Variation
Unbound Layers	61.45	588.06	24.25	39.47
HMA Base Layers	4.18	0.30	0.55	13.21
HMA Surfaces	6.45	19.10	4.37	67.72

ARRB Walking Profiler

In order to establish preliminary estimates of repeatability for the ARRB walking profiler the average PI, average IRI, and the associated standard deviations for the test sections were calculated. Table 4-4 lists the average PI and standard deviation for the inside (untrafficked) lanes and the reconstructed outside North tangent lanes.

Figure 4-1 compares the average values for each of the three layer types. The average PI values for the ARRB decrease with increasing size of blanking band, as expected. The average PI values (0.2 blanking band) are similar for both devices. Table 4-5 lists the statistics for each layer type using the ARRB profiler, and Figure 4-2 compares the standard deviations for the different types of layers. On the unbound layers, the standard deviations obtained with the McCracken profilograph are approximately five times greater than the standard deviations obtained with the ARRB. This is most likely a function of the ease of use of the different equipment on unpaved surfaces. That is, it is easier to maneuver the small ARRB unit compared to the 25 ft McCracken truss-like structure.

Table 4-4. Analysis of Profile Index Obtained With ARRB Profiler.

Layer Profiled	Profile Index, in/mile								
	0.0 in. Blanking Band			0.1 in. Blanking Band			0.2 in. Blanking Band		
	*n	Average	Standard Deviation	*n	Average	Standard Deviation	*n	Average	Standard Deviation
North Tangent	15	30.57	4.84	15	17.95	4.91	15	9.71	4.85
South Tangent	15	25.73	3.72	15	13.78	4.40	15	7.33	4.39
Wearing	3	19.98	1.88	3	8.09	1.48	3	2.38	1.08
HMA Base Layer 1	9	26.67	1.63	9	14.73	2.72	9	6.38	3.00
HMA Base Layer 2	6	27.28	4.22	6	15.32	3.14	6	8.60	3.88
Granular Base	9	81.10	2.38	9	67.39	4.19	9	51.66	5.08
Subgrade	3	102.80	11.40	3	89.92	8.93	3	73.82	5.81

***n = number of 0.1 mile intervals (528 ft)**

Table 4-5. ARRB Profiler PI Statistics for each Layer Type.

Blanking Band Size	Layer Type	PI Repeatability, in/mile			
		Average	Variance	Standard Deviation	Coefficient of Variation
0.0 Blanking Band	HMA Surfaces	25.43	12.11	3.48	13.68
	Base Layers	26.98	8.58	2.93	10.86
	Unbound	91.95	47.47	6.89	7.49
0.1 Blanking Band	HMA Surfaces	13.27	12.96	3.60	27.13
	Base Layers	15.03	8.58	2.93	19.49
	Unbound	78.66	43.03	6.56	8.34
0.2 Blanking Band	HMA Surfaces	6.47	11.83	3.44	53.17
	Base Layers	7.49	11.83	3.44	45.93
	Unbound	62.74	29.70	5.45	8.69

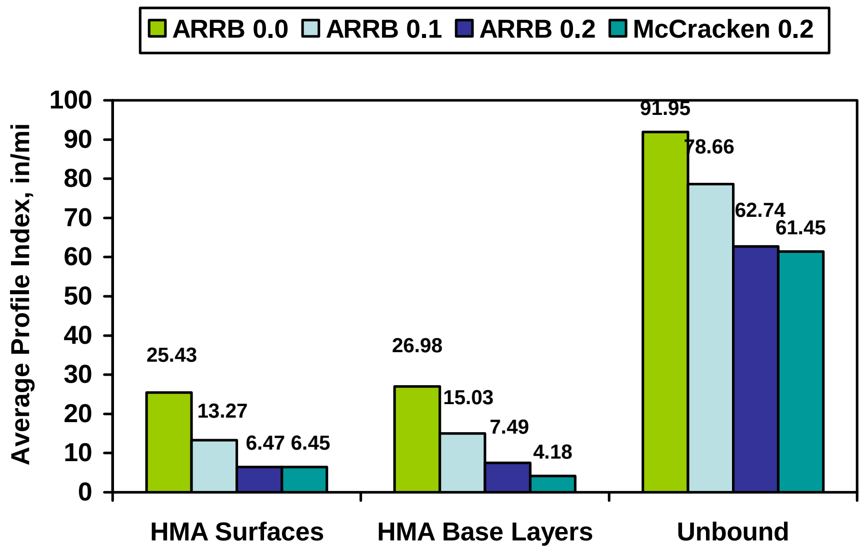


Figure 4-1. Average PI for Different Devices and Layer Types.

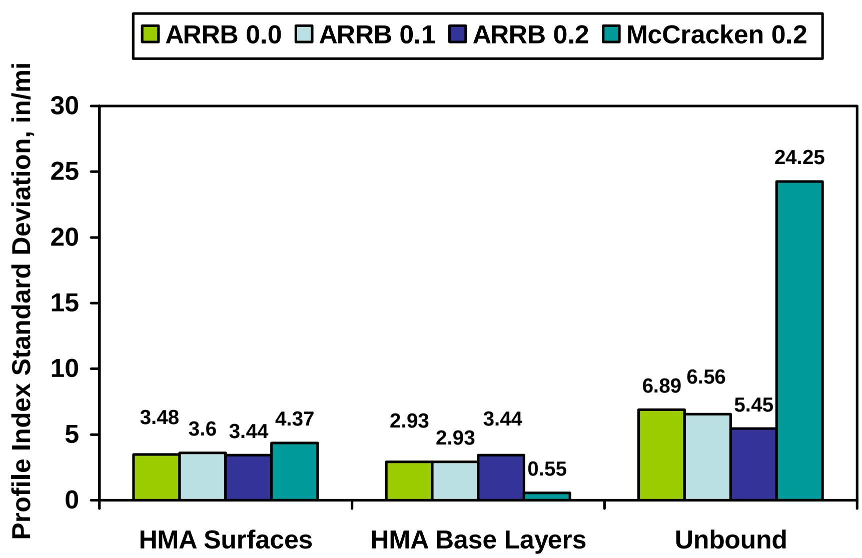


Figure 4-2. PI Standard Deviations for Different Devices and Layer Types.

Table 4-6 shows the average IRI and standard deviation for the inside (untrafficked) lanes and the reconstructed lanes calculated from the same ARRB profile used for the PI calculations. The standard deviations of IRI are greater in the layers which are not paved with HMAC compared to the standard deviations of the layers which are paved with HMAC. The variability is expected to be higher for the underlying layers due to the difficulty of testing these layers versus the bound layers. The underlying layers are more difficult to test because they consist of loose material or are not compacted as well as a bound material such as HMAC.

Table 4-6. Analysis of IRI Obtained With ARRB Profiler.

Layer Profiled	IRI, in/mile								
	25 ft Interval			52.8 ft Interval			528 ft Interval		
	*n	Average	Standard Deviation	*n	Average	Standard Deviation	*n	Average	Standard Deviation
North Tangent	102	77.05	49.04	49	78.99	47.10	5	79.40	25.59
South Tangent	101	69.70	40.85	49	82.76	94.76	5	78.94	18.99
Wearing	16	62.52	38.26	8	66.69	38.24	1	62.10	1.45
HMA Base Layer 1	63	84.81	101.96	30	80.59	50.44	3	73.21	5.59
HMA Base Layer 2	32	88.51	72.65	15	76.84	30.17	2	89.58	24.02
Granular Base	54	206.57	200.25	27	246.32	277.01	3	616.13	625.88
Subgrade	63	288.31	302.12	30	279.74	192.84	3	276.27	15.51

***n = number of intervals**

The large IRI value and standard deviation for the longer 528 foot interval was unexpected. Longer intervals are expected to provide a smoother estimate of ride quality. In order to further investigate the repeatability of the ARRB profile traces, the inside (untrafficked) lane in the tangents were plotted and statistically analyzed. Each tangent consists of thirteen 200-foot test sections for a total longitudinal profile length of approximately 2600 feet. Longitudinal profiles were not collected for the curves since the inclinometer-based units have a limitation of 5^o or less for sideways tilt of the unit. Figure 4-3 shows the three profiles obtained for the North tangent. There is very close agreement between the profiles at the start of the testing. However, as the distance increases, the profiles show progressively more difference. In order to explore the significance of this difference, the variance between the three profiles for each of the 13 test sections in both tangents was calculated.

Figure 4-4 shows these calculated variances for each test section in the two tangents. There is a trend of increasing variance between the three profiles with increasing distance for the North tangent from 200 ft to 1000 ft and from 1400 ft to 2600 ft, and much less of a tendency for the variance to increase for the South tangent profiles. One possible reason for this difference is that the outside lane of the North tangent was under construction at the time the testing was conducted. The right lane had already been removed down to the subgrade, leaving a steep, uneven edge along the centerline. Since the centerline was used as the profile reference, it is possible that it was more difficult to accurately track this portion of the pavement. The South tangent, which has a much more consistent variance over the length of the tangent, was not under construction. There is, however a slight tendency for the variance to increase with increasing length of the profile. For the North tangent data the statistics indicate that a standard deviation of 0.92 inches is reasonable for profile measurements obtained over 200 foot longitudinal distances. Also, for the South tangent and granular base data the statistics indicate a reasonable standard deviation of 0.41 inches and 0.67, respectively. The increasing variability with increasing distance agrees with the findings presented by Fernando (13).

Figure 4-5 shows that the average variance also increases with distance for the granular base, HMA Layer 1, and HMA Layer 2. The variance of the wearing layer was inconclusive due to the length of the sample which was approximately 400 feet. The general magnitude of the variance on the granular base is similar to that for the North tangent profiles. While it was anticipated that the base profiles would be more variable, it was actually easier to track the same profile on the granular base since the ARRB unit left small foot prints in the surface which acted as a marked line for the replicate measurements.

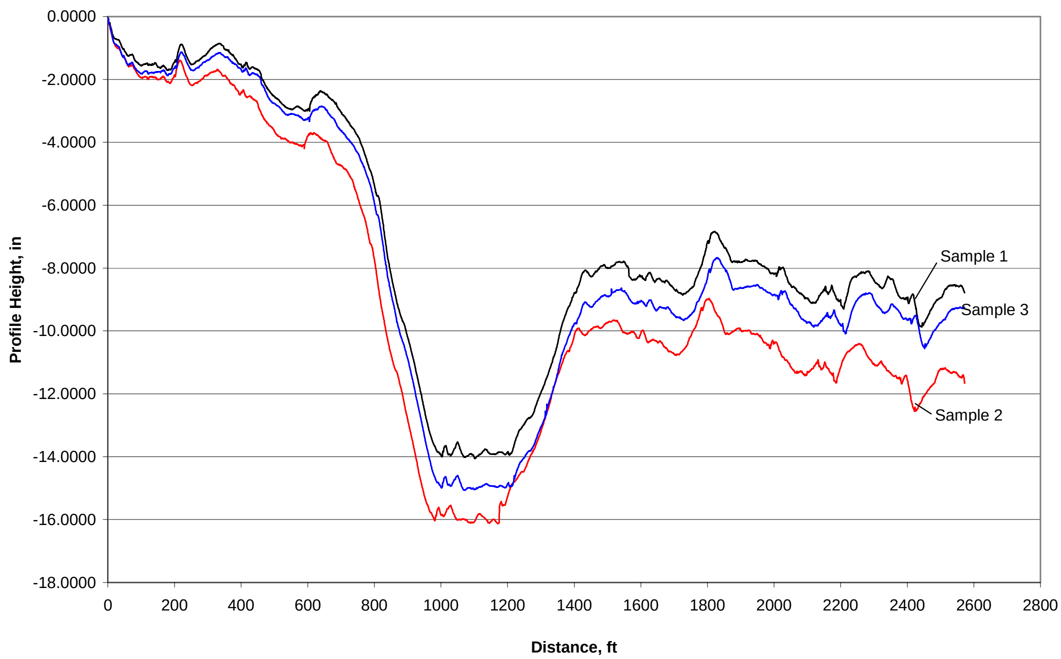


Figure 4-3. ARRB Profile Traces of Inside Lane North Tangent.

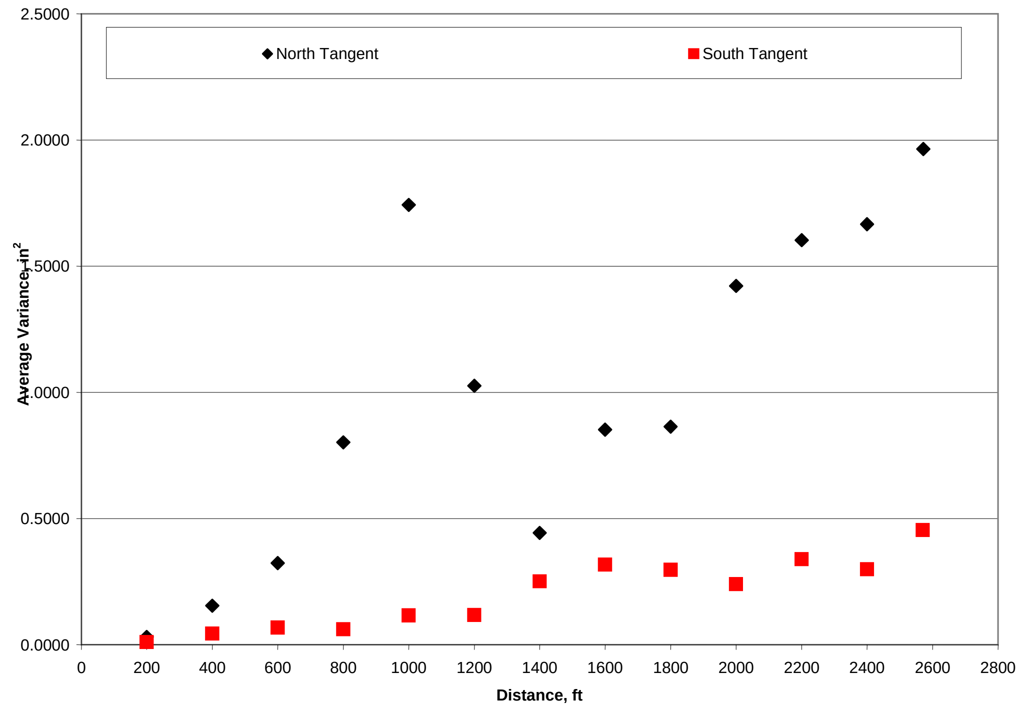


Figure 4-4. Variance in ARRB Profile Traces of Inside Lanes.

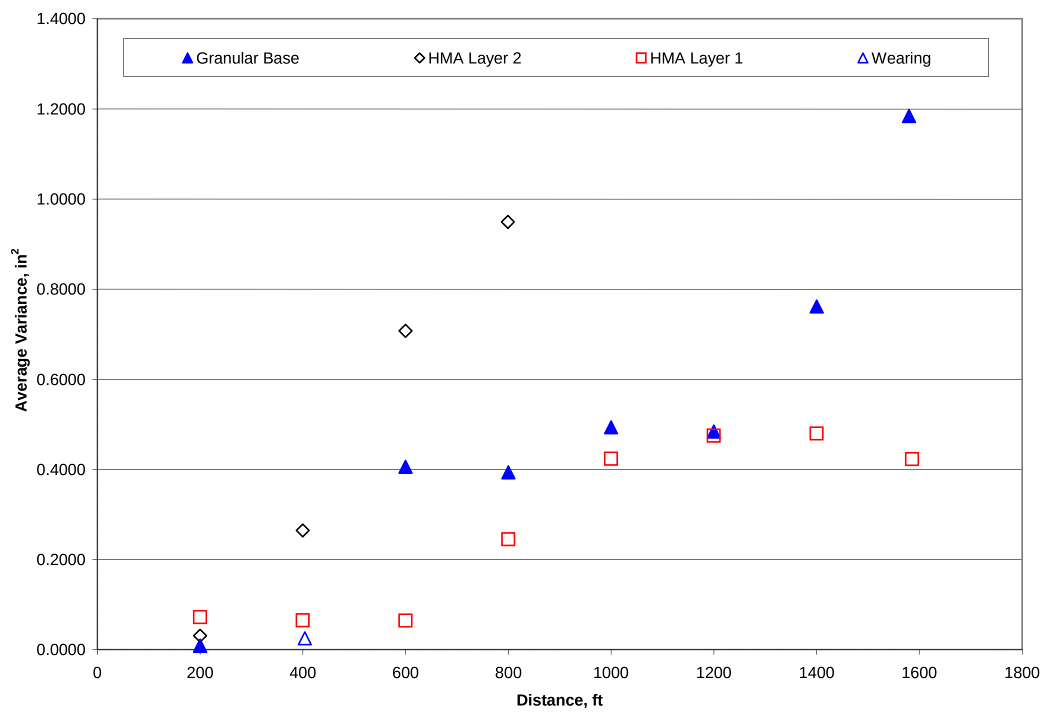


Figure 4-5. Variance in ARRB Profile Traces of Reconstructed Lane.

REPEATABILITY OF INERTIAL PROFILER

ARAN Van

In order to estimate repeatability for the ARAN van, the average IRI and standard deviation were determined for the HMA surface courses used in the previous analyses. Table 4-7 lists the average IRI and standard deviation for the inside (untrafficked) lanes at 45 mi/hr, and Table 4-8 lists the average IRI and standard deviation at 15 mi/hr. The standard deviations of the inside (untrafficked) lanes using two different speeds are similar, while the average IRI values are slightly higher using the speed of 15 mi/hr. The standard deviations are approximately two to three times greater when using the shorter interval of 52.8 ft. This is as expected because the IRI is averaged over a shorter distance (2).

Table 4-7. Analysis of IRI Obtained With ARAN Van at 45 mi/hr.

Layer Profiled	IRI, in/mile					
	52.8 ft Interval			528 ft Interval		
	*n	Average	Standard Deviation	*n	Average	Standard Deviation
North Tangent	50	70.25	33.65	5	70.24	19.14
South Tangent	50	61.67	36.23	5	61.57	11.79

***n=number of intervals**

Table 4-8. Analysis of IRI Obtained With ARAN Van at 15 mi/hr.

Layer Profiled	IRI, in/mile					
	52.8 ft Interval			528 ft Interval		
	*n	Average	Standard Deviation	*n	Average	Standard Deviation
North Tangent	50	79.24	24.47	5	79.55	19.59
South Tangent	50	73.74	36.96	5	73.73	14.92

***n=number of intervals**

The ARAN van profile traces for the inside (untrafficked) lane in the tangents were plotted and statistically analyzed. Longitudinal profiles were not collected for the reconstructed lanes because the ARAN van is not made for measuring granular base or subgrade. The ARAN could not be used on the HMA base layers of the reconstructed lane due to logistics of the paving schedule. Figures 4-6 and 4-7 show the three profiles obtained for the North tangent at 45 mi/hr and South tangent at 45 mi/hr respectively. Figures 4-8 and 4-9 show the three profiles obtained for the North tangent at 15 mi/hr and South tangent at 15 mi/hr respectively. There is very close agreement between the profiles measured at 45 mi/hr, but the profiles measured at 15 mi/hr are visibly more variable. One reason for this difference is the horizontal shift of the starting point for the 15 mi/hr test. In order to obtain repeatable ride quality statistics, the longitudinal profiles need to be shifted horizontally until the starting points and the large scale profile features of each longitudinal profile match. Programs such as ProVal now have an option for cross correlation which will automatically horizontally shift the profiles until the best match of large scale profile features is obtained. Other possible reasons for the difference in profile height are the difficulty to track the same path at slow speeds and susceptibility to wind influence (2).

In order to explore the significance of this difference, the variance between three profiles for each of the 13 test sections in both tangents was calculated for each speed. Figure 4-10 shows the calculated variances for the North tangent and South tangent at 45 mi/hr. Figure 4-11 shows the calculated variances for the North tangent and South tangent at 15 mi/hr. These figures show that the calculated variances for the inside lanes recorded at 15 mi/hr are much higher than those recorded at 45 mi/hr. For the North tangent data recorded at 45 mi/hr the statistics indicate that a standard deviation of 0.11 inches is reasonable for profile measurements obtained over 200 foot longitudinal distances. The statistics indicate that a standard deviation of 0.08 inches is reasonable for the South tangent data recorded at 45 mi/hr. For the North tangent data recorded at 15 mi/hr the statistics indicate that a standard deviation of 0.84 inches is reasonable for profile measurements obtained over 200 foot longitudinal distances. The statistics indicate that a standard deviation of 1.12 inches is reasonable for the South tangent data recorded at 15 mi/hr. The differences in variability for 45 mi/hr and 15 mi/hr are important because the results of a 15 mi/hr test would influence pay adjustments if specifications were developed for 45 mi/hr and the tests were run at 15 mi/hr. The device can be used at 15 mi/hr, but the user should expect the ride quality statistics to be more variable. The 15 mi/hr test speed is good for process control but not for determining pay adjustments.

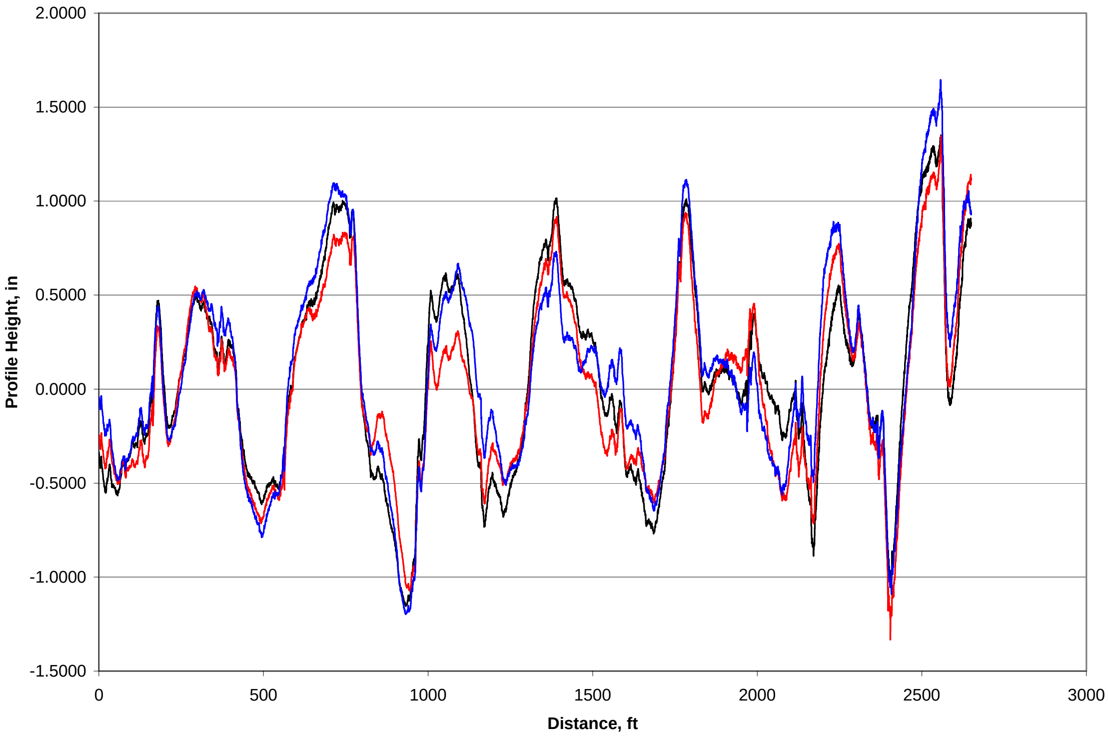


Figure 4-6. ARAN North Tangent Profile Trace at 45 mi/hr.

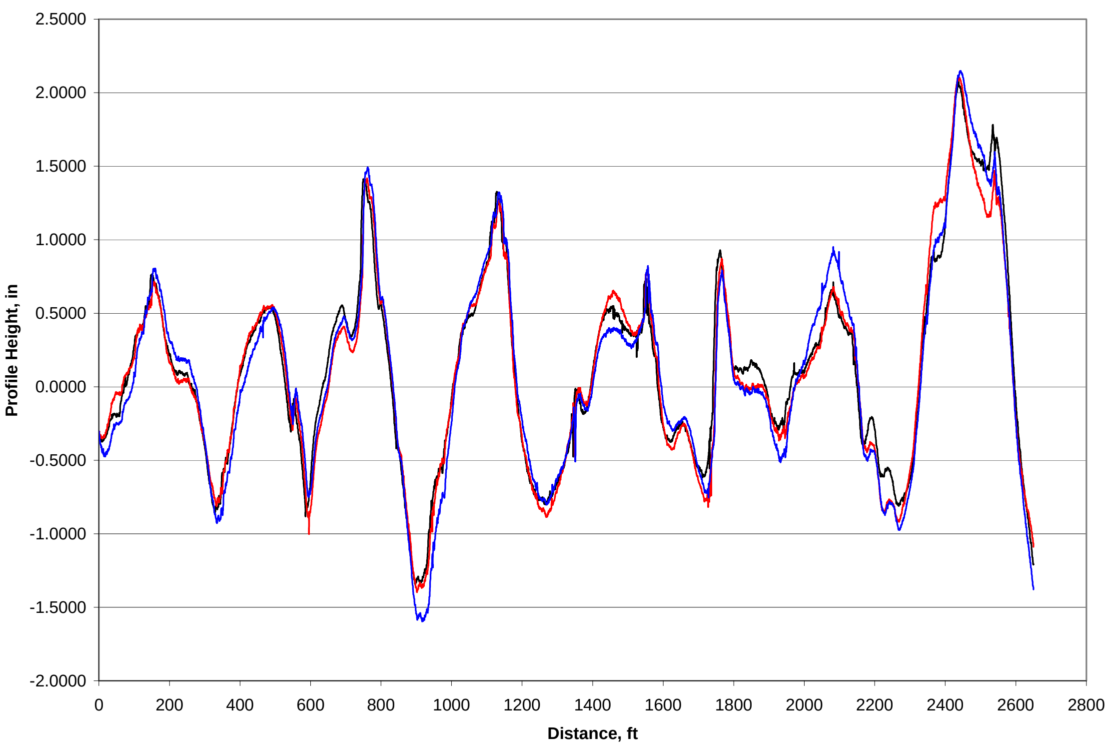


Figure 4-7. ARAN South Tangent Profile Trace at 45 mi/hr.

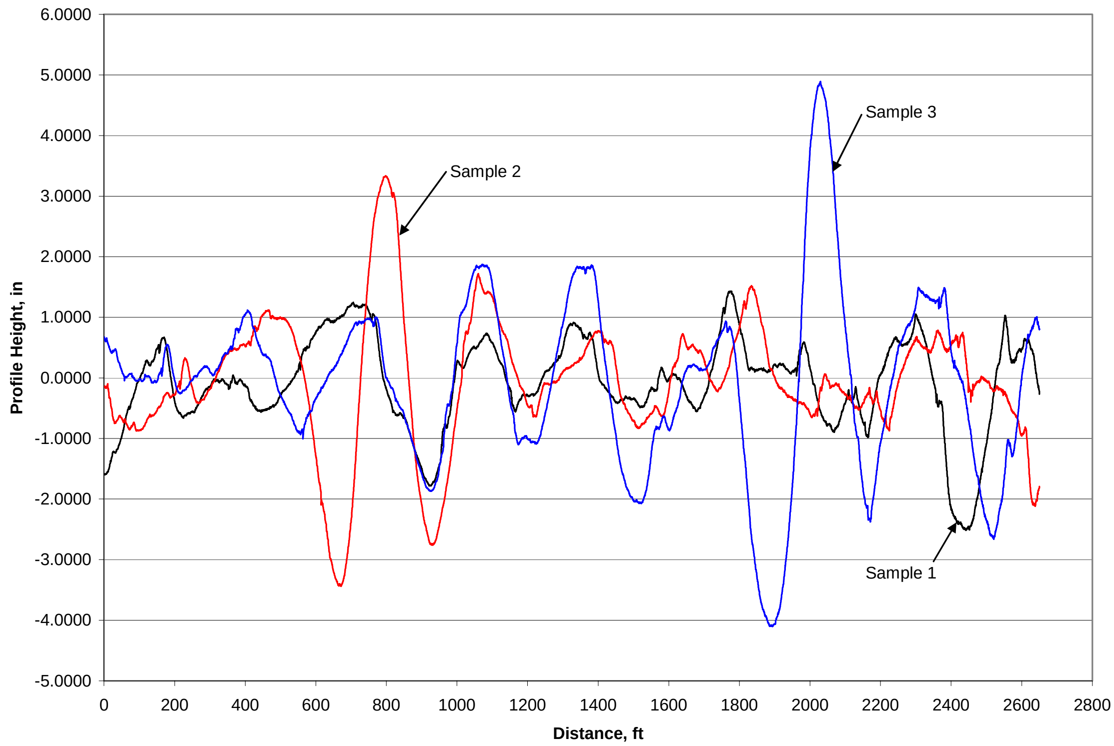


Figure 4-8. ARAN North Tangent Profile Trace at 15 mi/hr.

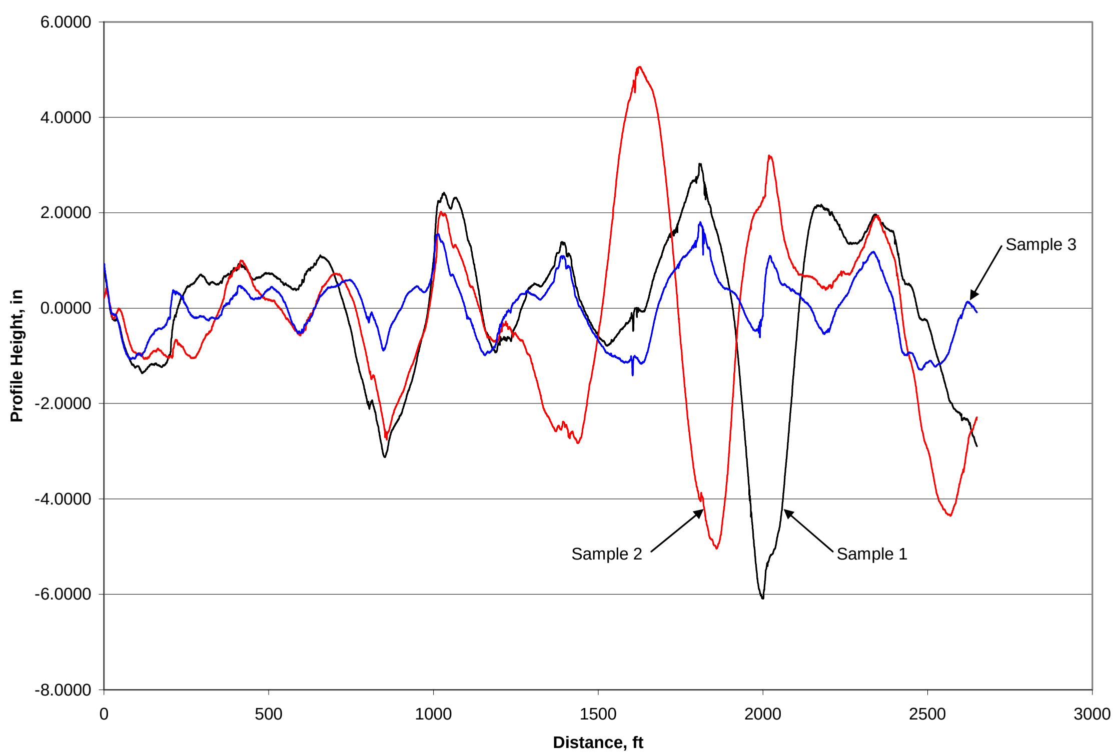


Figure 4-9. ARAN South Tangent Profile Trace at 15 mi/hr.

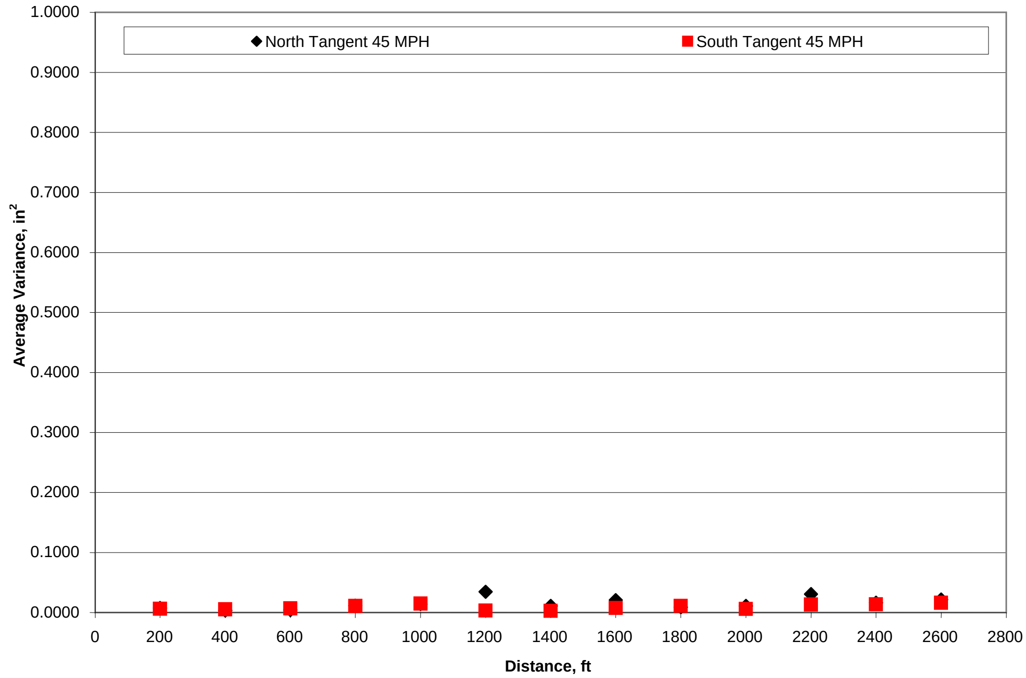


Figure 4-10. Variance in ARAN Profile Traces of Inside Lanes at 45 mi/hr.

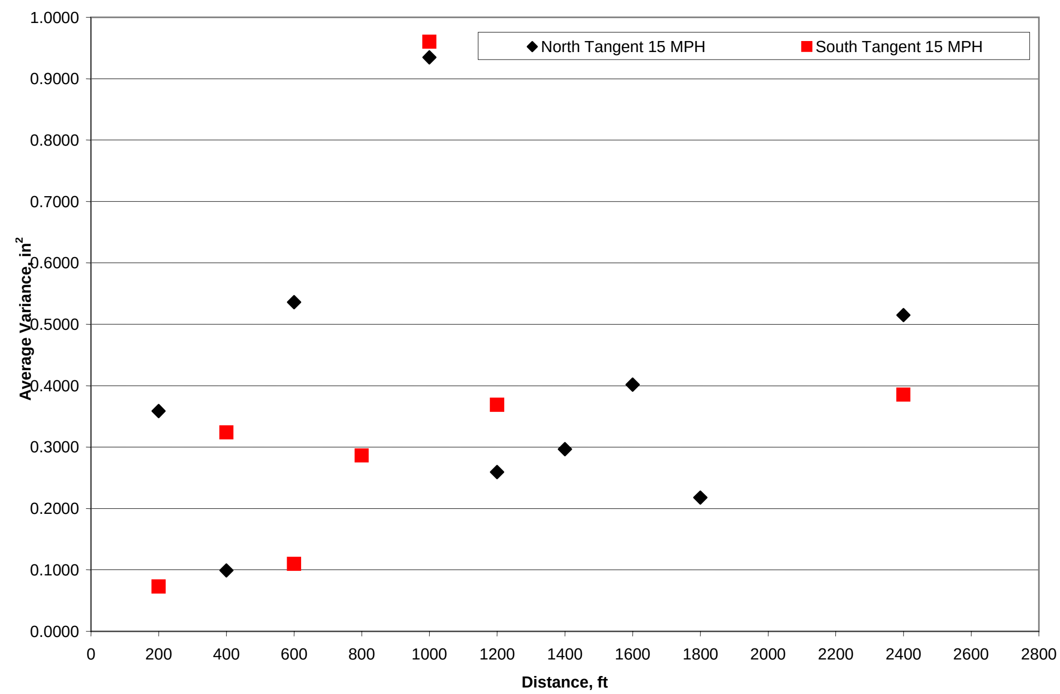


Figure 4-11. Variance in ARAN Profile Traces of Inside Lanes at 15 mi/hr.

ARRB AND ARAN PROFILE TRACE COMPARISON

The profile traces obtained with the ARRB and the ARAN were plotted for each device on the North tangent inside (untrafficked) lane and South tangent inside (untrafficked) lane. Figure 4-12 shows the complete North tangent obtained with the ARRB and ARAN devices. The full profile of the South tangent is shown in Figure 4-13. These two figures highlight one of the problems with trying to replicate profiles, especially with different devices. Note on Figure 4-12 the two sets of arrows indicating the points in each profile that have the same shape characteristics. This shows that there is a slight horizontal offset between the two profiles. Figure 4-13 shows that the offset is considerably more for the South tangent. Figures 4-12 and 4-13 show that the vertical elevations are different between the ARRB and ARAN. This is because the ARAN and ARRB do not use the same reference elevation. The ARAN uses a moving inertial reference therefore it does not obtain rod and level survey information. The ARRB evaluates elevation changes and uses its starting point as a reference elevation.

The average IRI statistic was calculated for each of the profile traces. Figure 4-14 shows the calculated average IRI obtained with the ARRB using an interval of 52.8 feet for the North tangent on the x-axis and the calculated average IRI obtained with the ARAN (at a speed of 45 mi/hr) using an interval of 52.8 feet for the North tangent on the y-axis. Figures 4-15 through 4-17 show the same comparison for the North tangent at 15 mi/hr, the South tangent at 45 mi/hr, and the South tangent at 15 mi/hr, respectively. The large horizontal offset in the 45 mi/hr profiles, particularly in the South tangent (Figure 4-13), is seen in the IRI data as a very poor correlation between the two devices. The profiles at 15 mi/hr and the ARRB matched much better, hence the better correlation between the devices.

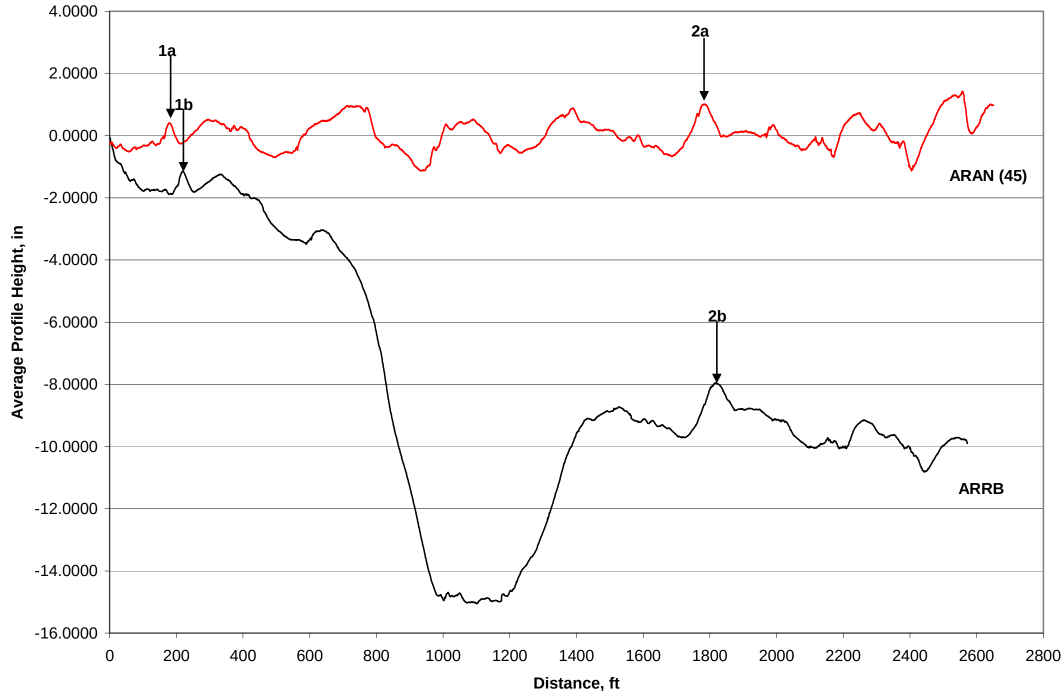


Figure 4-12. ARRB and ARAN (45 mi/hr) Average Profile Trace of North Tangent.

Figure 4-13. ARRB and ARAN (45 mi/hr) Average Profile Trace of South Tangent.

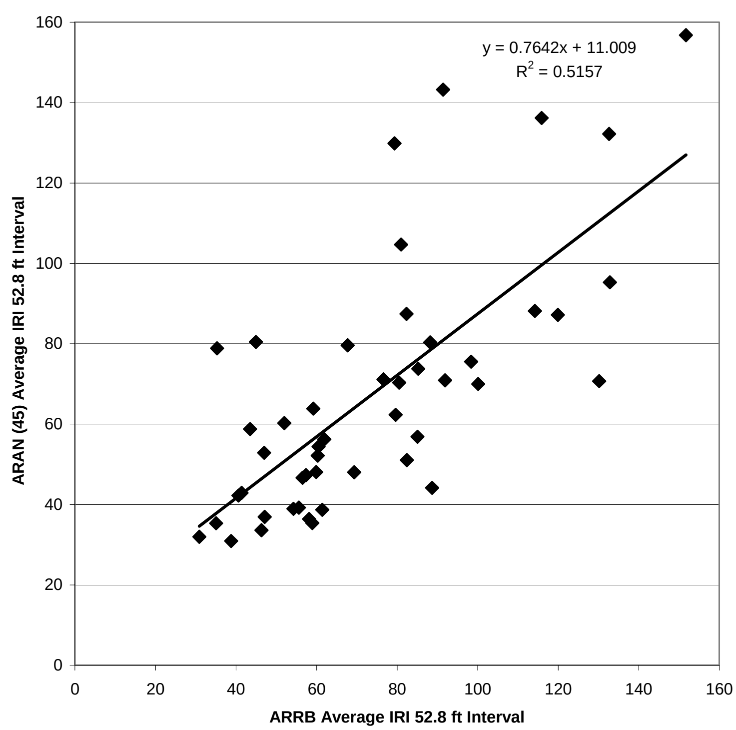


Figure 4-14. North Tangent ARRB vs. ARAN (45 mi/hr) Average IRI.

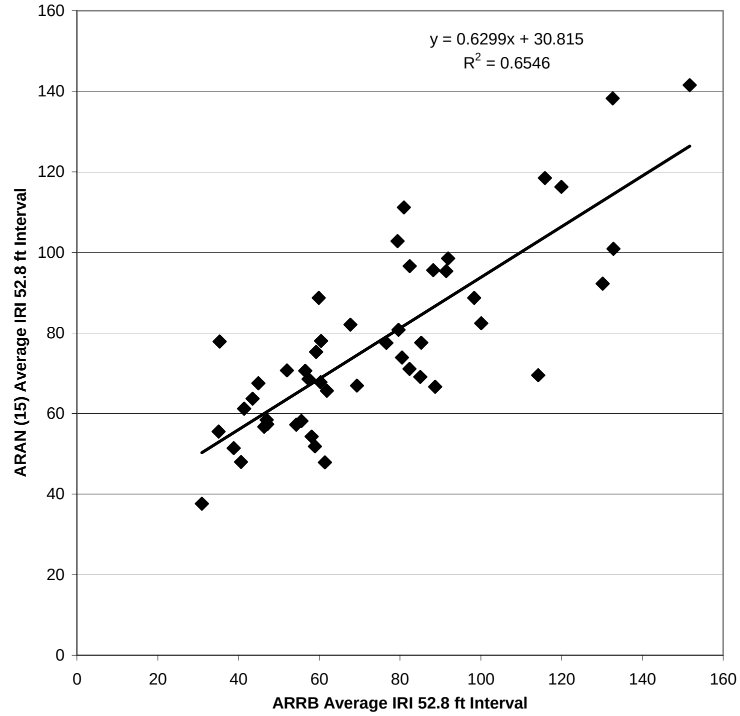


Figure 4-15. North Tangent ARRB vs. ARAN (15 mi/hr) Average IRI.

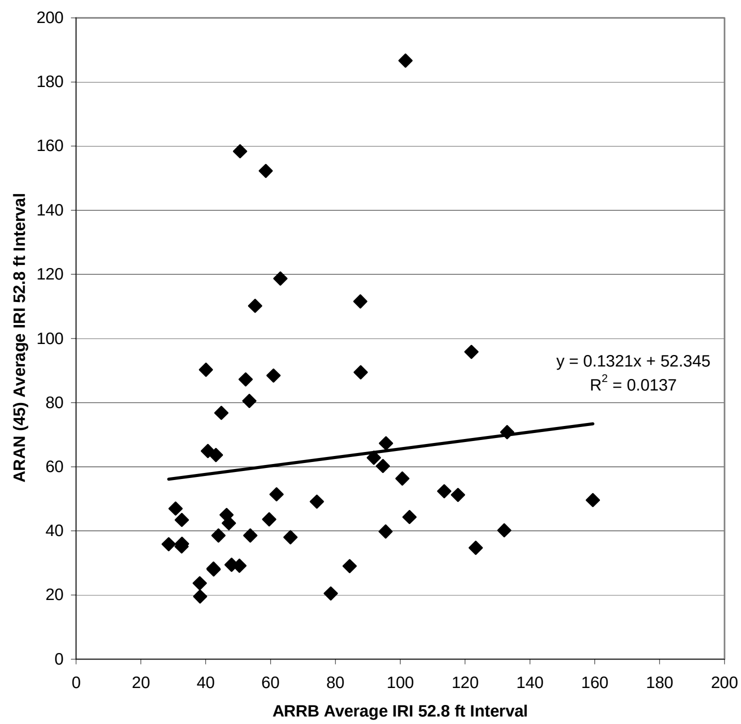


Figure 4-16. South Tangent ARRB vs. ARAN (45 mi/hr) Average IRI.

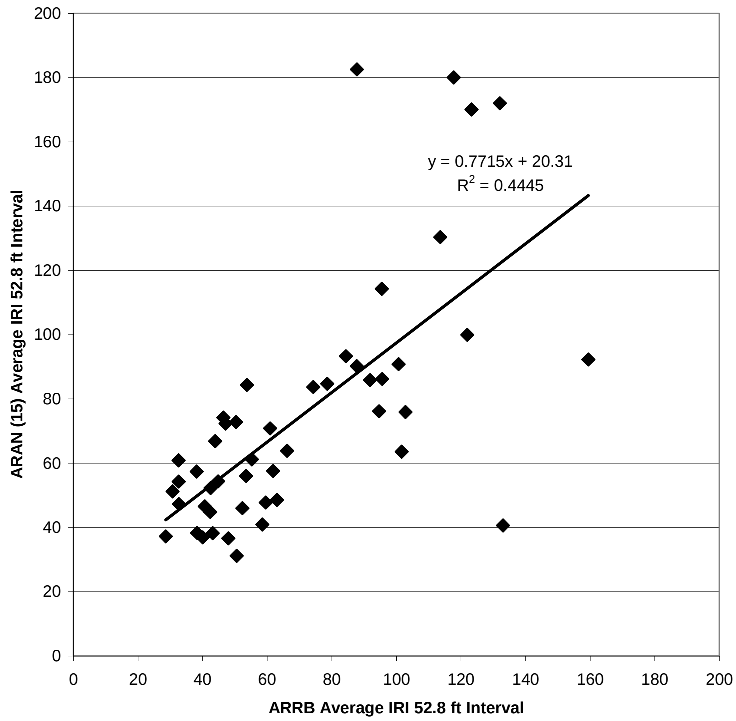


Figure 4-17. South Tangent ARRB vs. ARAN (15 mi/hr) Average IRI.

EVALUATION OF SMOOTHNESS ON RECONSTRUCTED LANES

The average profile height and distance was plotted to get the profile trace on the reconstructed lanes through the placement of structural layers using the data from the ARRB device. Figure 4-18 shows the entire North tangent profiles for the subgrade and the granular base layer. The "bumps" occur at the same longitudinal position, but the heights of the vertical displacements were reduced by the placement of the base on top of the subgrade. The large drop in the vertical distance in the base layer is due to the reduction in the base thickness for the structural design study.

Figure 4-19 shows the typical reduction in vertical displacements due to the placement of subsequent layers for the first 400 ft of the North tangent, which is just after the change in base thickness. The incremental decrease in vertical displacement, which indicates an incremental increase in smoothness with each additional layer, can be seen in the peaks at about 175 and 225 ft.

Table 4-9 shows the PI calculated for the reconstructed lanes using the McCracken profilograph and the PI and IRI for the reconstructed lanes using the ARRB profiler. The table shows that the pavement does become smoother in terms of PI and IRI using both devices. The wearing is 96% smoother than the subgrade when calculated using the PI obtained with the McCracken Profilograph with a 0.2 inch blanking band. The wearing is 97% smoother than the subgrade when calculated using the PI obtained with the ARRB with a 0.2 inch blanking band. The wearing is 76% smoother than the subgrade when calculated using the IRI obtained with the ARRB with a 52.8 foot interval.

Table 4-9. Smoothness Indices for the Reconstructed Lanes

Layer Profiled	McCracken	ARRB	ARRB	ARRB	ARRB	ARRB	ARRB
	Average PI, in/mile	Average PI, in/mile	Average PI, in/mile	Average PI, in/mile	Average IRI, in/mile	Average IRI, in/mile	Average IRI, in/mile
	0.2 in. Blanking Band	0.0 in. Blanking Band	0.1 in. Blanking Band	0.2 in. Blanking Band	25 ft. Interval	52.8 ft. Interval	528 ft. Interval
Wearing	2.73	19.98	8.09	2.38	62.52	66.69	62.10
HMA Base Layer 1	3.95	26.67	14.73	6.38	84.81	80.59	73.21
HMA Base Layer 2	4.40	27.28	15.32	8.60	88.51	76.84	89.58
Granular Base	48.66	81.10	67.39	51.66	206.57	246.32	616.13
Subgrade	74.24	102.80	89.92	73.82	288.31	279.74	276.27

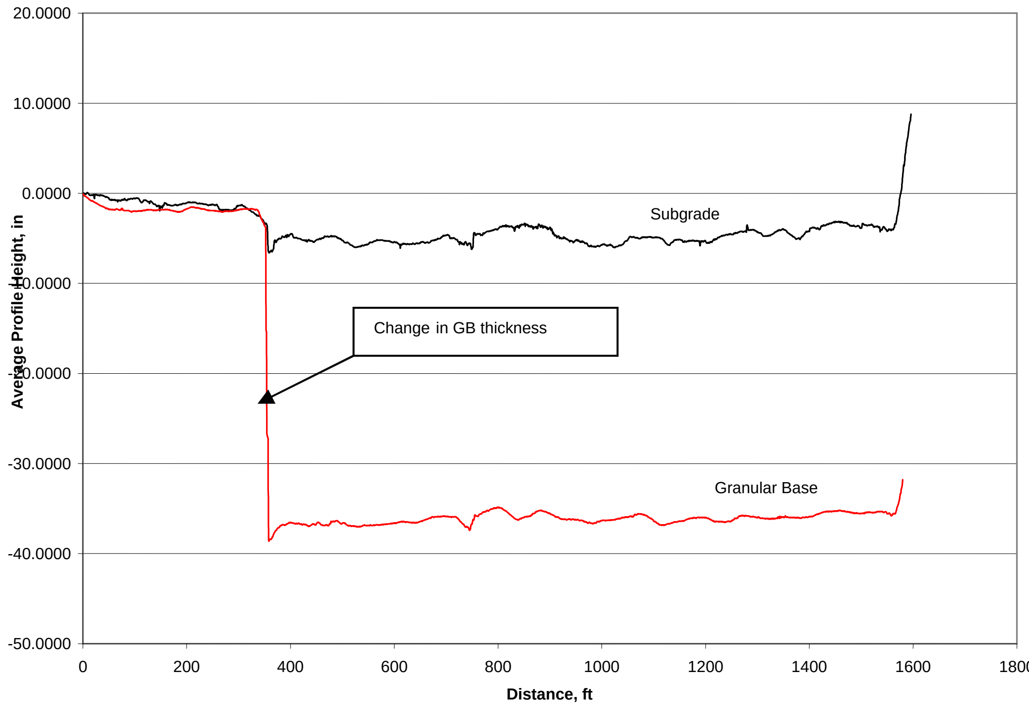


Figure 4-18. Average Profile Height vs. Distance for Unbound Layers.

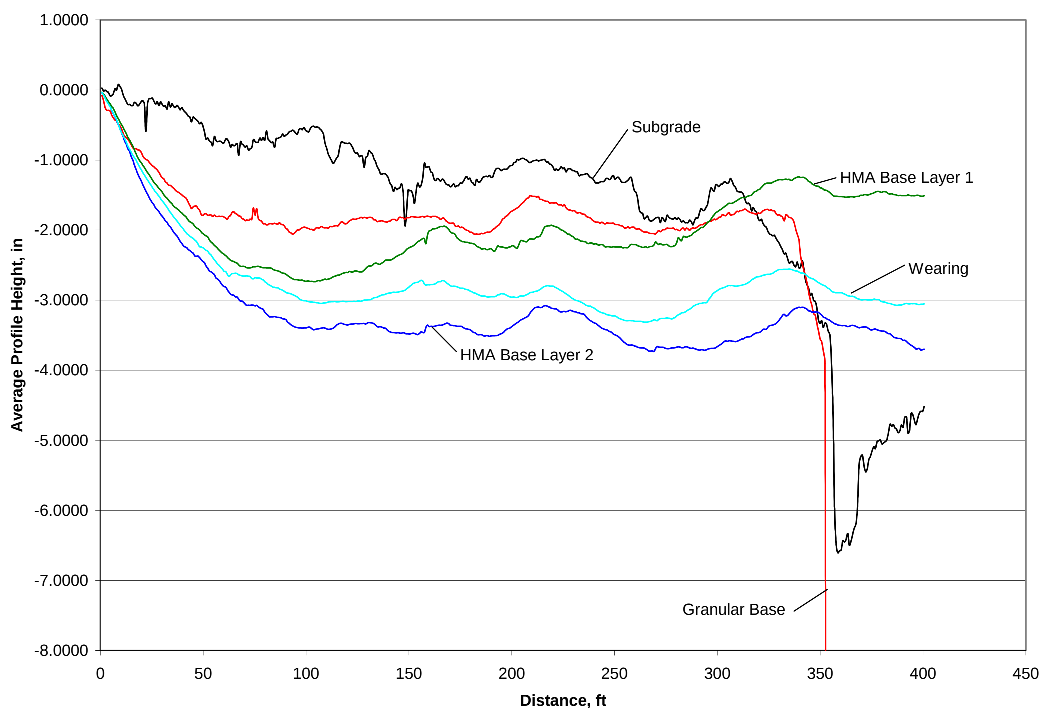


Figure 4-19. Average Profile Height vs. Distance for Reconstructed Layers (400 ft).

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

Based upon the completion of the field work at the AU NCAT test track and a complete review of data collected the following conclusions and recommendations were determined.

GENERAL CONCLUSIONS

1. The analysis of the PI obtained with the McCracken Profilograph suggests that the McCracken is more repeatable on paved surfaces such as HMAC versus surfaces which are not paved such as a granular base or subgrade. However, if the improvement of profile with subsequent layers is needed (from the subgrade up), this style of profile can be used to obtain reasonable information. This profiler is not useful on surfaces with horizontal curves due to the difficulty in rolling the device in a straight line.
2. The analysis of the PI ride quality statistic calculated from the profile obtained with the ARRB Walking Profiler suggests that the ARRB is more repeatable on paved surfaces such as HMAC versus surfaces which are not paved such as a granular base or subgrade. This device would also be acceptable for determining the relative improvement of each layer on the smoothness of the next layer. The

main limiting consideration for this device is that over longer horizontal distances, there is progressively more difference between replicate profiles. This device would be useful for profiling shorter distances associated with obtaining profiles during milling operations where the profiler is positioned between the miller and the paver, and the profiling operations can be intermittently stopped and started.

3. The profile obtained with the ARRB Walking Profiler can also be used to calculate the IRI ride quality statistic. Again, the data indicate that the ARRB is more repeatable when used to profile shorter distances.
4. Because of the impact of increasing longitudinal distance on the repeatability of replicate profiles obtained with the ARRB walking profiler, the variability in the ride quality statistics increases as the distance increases.
5. An additional evaluation of the ARAN van for use during construction processes for acceptance testing was added to the study. In order to use an inertial profiler within a traffic-controlled construction work zone, the van needs to be operated at slower speeds, such as 15 mi/hr. The standard deviations of the IRI obtained with the ARAN Van inside (untrafficked) lanes using speeds of 45 mi/hr (standard speed) and 15 mi/hr (construction speeds) are similar. Shortening the interval over which the ride quality statistics are calculated influences the standard deviations of the IRI obtained at 45 mi/hr and 15 mi/hr. The average IRI values obtained at 15 mi/hr are slightly higher than average IRI values obtained at 45 mi/hr. The variability approximately doubles from 14.92 in/mile to 36.96 in/mile when the sample interval is decreased from 528 ft to 52.8 ft.

6. The ability to obtain repeatable, well correlated ride quality statistics depends on the ability to match the starting point for the horizontal distance. If a poor correlation is obtained between either replicate testing with a given device, or between different devices, the raw profiles should be examined to make sure that the “bump” characteristics are shifted horizontally until the characteristics occur at the same distance. It is important to match large scale profile features before analyzing replicate profiles. This can be done by manually identifying the starting point on each profile or by using newer profiling analysis software packages that include an option for cross correlation.
7. Bumps recorded in the profile trace of subgrade were reflected in the profile trace of the lifts following the subgrade such as the granular base layers and HMAC layers. However, through the placement of the layers following the subgrade, the bumps became less severe.
8. In terms of PI and IRI using both the McCracken profilograph and the ARRB profiler the reconstructed lane does become smoother, or less rough, through the placement of granular base, HMAC base courses, and HMAC wearing course.

RECOMMENDATIONS

1. In the event that a specification is to be written on percent improvement from unbound base layers to HMAC surfaces, it is important to note that the McCracken Profilograph and ARRB walking profiler are less repeatable on unbound layers.

2. The initial starting point of each replicate data set should be confirmed by evaluating the raw data profile vertical displacement characteristics.
3. Since bumps in the subgrade will be carried through to the wearing course, every effort should be made to ensure the smoothest possible subgrade.
4. If the ARRB device is to be used for collecting longitudinal profiles, the length of the profile section should be kept to a minimum due to the increasing variability with distance. Incremental profiles can be stitched together at the outset of the ride quality analysis.

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APPENDIX A

Table A-1. Smoothness Specifications for the United States

ALABAMA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per section	Price Adjustments: Profile Index, in/mile per section	Price Adjustments: Contract Price Adjustment, % of pavement unit bid price
Flexible	California-style profilograph	PI = 6 in/mile	0.1 mile	same day	Under 47.3	Under 3.0	105
					47.3 - 94.6	3.0 - 6.0	100
					94.6 - 126.2	6.0 - 8.0	95
					126.2 - 157.7	8.0 - 10.0	90
					over 157.7	over 10.0	Corrective work required

ALABAMA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per section	Price Adjustments: Profile Index, in/mile per section	Price Adjustments: Contract Price Adjustment, % of pavement unit bid price
Rigid	California-style profilograph	PI = 6 in/mile	0.1 mile	immediately after curing	Under 45	Under 3.0	105
					45 to less than 95	3.0 to less than 6.0	100
					95 to less than 125	6.0 to less than 8.0	95
					125 thru 160	8.0 thru 10.0	90
					over 160	Over 10.0	Corrective work required

ALASKA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 1.0 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment
Flexible	16 foot Straight Edge	3/16" deviation	---	same day	---	---	---

ALASKA
No rigid info

ARIZONA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Mays Ride Number, mm/km	Price Adjustments: Mays Ride Number, in/mile	Price Adjustments: Adjustment
Flexible	General Motors Profilometer	Mays Ride Number = 710 mm/km	0.1 mile	---	< 520	< 33	Bonus
					520 - 710	33 - 45	Full Pay
					711 - 1578	46 - 100	Penalty
					> 1578	> 100	Corrective work required

ARIZONA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 1.0 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment
Rigid	California-style profilograph	PI = 9 in/mile	0.1 mile	same day	N/A	7.0 or less	plus ($0.20)*[7.0-(PI)] per square yard
					N/A	7.1 to 8.0	minus $0.50 per square yard
					N/A	8.1 to 9.0	minus $1.00 per square yard

ARKANSAS

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 1.0 km section	Profile Index, in/mile per 0.1 mile section	Adjustment, % of payment of Unit Bid Price
Flexible	California-style profilograph	PI= 75mm/km (5in/mile)	200m (0.1mile)	Next Day	15 or less	1 or less	+3.0%
					Over 15 to 30	Over 1 to 2	+2.0%
					Over 30 to 45	Over 2 to 3	+1.0%
					Over 45 to 75	Over 3 to 5	0
					Over 75 to 90	Over 5 to 6	-2.0%
					Over 90 to 110	Over 6 to 7	-4.0%
					Over 110	Over 7	Corrective work required

ARKANSAS

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 200m section	Profile Index, in/mile per 0.1 mile section	Adjustment, % of payment of Unit Bid Price
Rigid	California-style profilograph	PI= 75mm/km (5in/mile)	200m (0.1mile)	Next Day	30 or less	2 or less	+6.0%
					Over 30 to 35	Over 2 to 3	+4.0%
					Over 45 to 60	Over 3 to4	+2.0%
					Over 60 to 75	Over 4 to 5	0
					Over 75 to 90	Over 5 to 6	-2.0%
					Over 90 to 110	Over 6 to 7	-4.0%
					Over 110	Over 7	Corrective work required

CALIFORNIA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 1.0 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Flexible	California-style profilograph	PI = 80 mm/km	0.1 km	same day	--	--	--

CALIFORNIA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Price Adjustments: Profile Index, in/mile per section	Price Adjustments: Adjustment
Rigid	California-style profilograph	PI – 110 mm/km	0.1 km	same day	110 or less	7 or less	0
					more than 110	more than 7	Corrective work required

COLORADO

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 1.0 km section	Profile Index, in/mile per 0.1 mile section	Adjustment
Flexible	California-style profilograph	PI = 16 in/mile	0.1 mile	same day	N/A	8 or less	+ $0.16/ sq yd
					N/A	8.1-10	+ $0.12/ sq yd
					N/A	10.1-12	+ $0.08/ sq yd
					N/A	12.1-14	+ $0.04/ sq yd
					N/A	14.1-16	+ $0.00/ sq yd
					N/A	16.1-18	- $0.04/ sq yd
					N/A	18.1-20	- $0.08/ sq yd
					N/A	20.1-22	- $0.12/ sq yd
					N/A	22.1-24	- $0.16/ sq yd
					N/A	24.1 or more	Corrective work required

COLORADO

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 1.0 km section	Profile Index, in/mile per 0.1 mile section	Adjustment
Rigid	California-style profilograph	PI = 16 in/mile	0.1 mile	same day	N/A	8 or less	+ $1.40/ sq yd
					N/A	8.1-10	+ $1.05/ sq yd
					N/A	10.1-12	+ $0.70/ sq yd
					N/A	12.1-14	+ $0.35/ sq yd
					N/A	14.1-16	+ $0.00/ sq yd
					N/A	16.1-18	- $0.35/ sq yd
					N/A	18.1-20	- $0.70/ sq yd
					N/A	20.1-22	- $1.05/ sq yd
					N/A	22.1-24	- $1.40/ sq yd
					N/A	24.1 or more	Corrective work required

CONNECTICUT

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**IRI, mm/km**	**IRI, in/mile**	**Adjustment**
Flexible	ARAN Inertial Profiler	IRI = 80 in/mile	0.1 mile	---	< 950	< 60	Bonus
					950 - 1260	60 - 80	Full Pay
					1261 - 1894	80.1 - 120	Penalty
					> 1894	> 120	Corrective Work Required

CONNECTICUT

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Profile Index, mm/km per 150 meter section**	**Profile Index, in/mile per 150 meter section**	**Adjustment, percent of pavement until bid price**
Rigid	California-style profilograph	PI = 190 mm/km	150 meters	same day	0-95	N/A	106%
					95-125	N/A	104%
					125-160	N/A	102%
					160-190	N/A	100%
					190-220	N/A	98%
					220-250	N/A	96%
					250-285	N/A	94%
					285-315	N/A	92%
					over 315	N/A	Corrective work required

DELEWARE

No flexible info

DELEWARE

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 1.0 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Contract Unit Price Adjustment
Rigid	California-style profilograph	PI = 15 in/mile	---	same day	N/A	Less than 5.0	+ $1.50
					N/A	5.0 to 15.0	($0.30)*(10.0-"Initial PI")
					N/A	Over 15.0	Corrective Work Required

FLORIDA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Ride Number (RN)	Price Adjustments: Unit Price Adjustment per 0.1 km	Price Adjustments: Unit Price Adjustment per 0.1 mile
Flexible	Laser Profiler	RN = 3.7	0.1 mile	same day	4.47<= RN	$380 per lot	$600 per lot
					4.45 <= RN < 4.47	$180 per lot	$300 per lot
					4.43 <= RN < 4.45	$60 per lot	$100 per lot
					4.10 < RN < 4.43	0	0
					4.09 to 3.70	Engineer's Ride Test	Engineer's Ride Test
					3.69 to 3.50	Corrective Work Required	Corrective Work Required
					Less Than 3.50	Remove and Replace	Remove and Replace

FLORIDA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 1.0 km section	Profile Index, in/mile per 0.1 mile section	Contract Price Adjustment, % of HMA unit bid price
Rigid	California-style profilograph	PI = 7 in/mile (110 mm/km)	0.1 mile	same day	PI <= 45	PI <= 3	103
					45 < PI <= 60	3 < PI <= 4	102
					60 < PI <= 80	4 < PI <= 5	101
					80 < PI <= 95	5 < PI <= 6	100
					95 < PI < 110	6 < PI < 7	99
					PI = 110	PI = 7	98
					PI > 110	PI > 7	Corrective Work Required

GEORGIA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					IRI, mm/km	IRI, in/mile	Adjustment
Flexible	Laser Road Profiler	IRI = 750 mm/km	1.0 mile	same day	---	---	Bonus
					<= 750	<= 47.5	Full Pay
					---	---	Penalty
					> 750	> 47.5	Corrective Work Required

GEORGIA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 0.5 km section	Profile Index, in/mile per 0.25 mile section	Adjustments
Rigid	Rainhart (Model 860) Profilograph	7 in/mile	0.25 mile	same day	Over 100	Over 7	Correct to 7 in/mile (100 mm/km)

HAWAII

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 1.0 km section	Profile Index, in/mile per 0.1 mile section	Adjustment, dollars per 0.1 mile section
Flexible	California-style profilograph	PI = 10 in/mile	0.1 mile	same day	N/A	less than 3.0	+ $1000
					N/A	3.0 to 3.9	+ $800
					N/A	4.0 to 4.9	+ $600
					N/A	5.0 to 5.9	+ $400
					N/A	6.0 to 6.9	+ $200
					N/A	7.0 to 10.0	0
					N/A	10.1 to 11.0	- $200
					N/A	11.1 to 12.0	- $400
					N/A	12.1 to 13.0	- $600
					N/A	More than 13.0	- $800

HAWAII

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 1.0 km section	Profile Index, in/mile per 0.1 mile section	Adjustment, percent of pavement unit bid price
Rigid	California-style profilograph	PI = 15 in/mile	0.1 mile	same day	N/A	10 or less	100
					N/A	Over 10 but less than 11	98
					N/A	Over 11 but less than 12	96
					N/A	Over 12 but less than 13	94
					N/A	Over 13 but less than 14	92
					N/A	Over 14 but less than 15	90
					N/A	Over 15	Corrective Work Required

IDAHO

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Flexible	California-style profilograph	PI – 80 mm/km (5 in/mile)	0.1 mile	same day	---	---	Bonus
					<= 80	<= 5	Full Pay
					---	---	Penalty
					> 80	> 5	Corrective Work Required

IDAHO

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Rigid	California-style profilograph	PI = 80 mm/km (5 in/mile)	0.1 mile	same day	---	---	Bonus
					<= 80	<= 5	Full Pay
					---	---	Penalty
					> 80	> 5	Corrective Work Required

ILLINOIS

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 160 m section	Profile Index, in/mile per 0.1 mile section	Adjustment, % of payment of Unit Bid Price
Flexible	California-style profilograph	PI = 160 mm/km (10 in/mile)	160 m (0.1 mile)	same day	Over 8 to 160	Over .5 to 10	100
					Over 160 to 175	Over 10 to 11	98
					Over 175 to 190	Over 11 to 12	96
					Over 190 to 205	Over 12 to 13	94
					Over 205 to 220	Over 13 to 14	92
					Over 220 to 235	Over 14 to 15	90
					Over 235	Over 15	Corrective Work Required
					Profile Index for entire project, mm/km	**Profile Index for entire project, in/mile**	**Adjustment, % of payment of Unit Bid Price**
					3 or less	0.20 or less	103
					Over 3 to 6	Over 0.20 to 0.25	102
					Over 6 to 8	Over 0.25 to 0.50	101

ILLINOIS

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 160 m section	Profile Index, in/mile per 0.1 mile section	Adjustment, % of payment of Unit Bid Price
Rigid	California-style profilograph	PI = 160 mm/km (10 in/mile)	160 m (0.1 mile)	same day	over 67 to 160	over 4.25 to 10	100
					over 160 to 175	over 10 to 11	98
					over 175 to 190	over 11 to 12	96
					over 190 to 205	over 12 to 13	94
					over 205 to 220	over 13 to 14	92
					over 220 to 235	over 14 to 15	90
					over 235	over 15	Corrective Work Required
					Profile Index for entire project, mm/km	**Profile Index for entire project, in/mile**	**Adjustment, % of payment of Unit Bid Price**
					36 or less	2.25 or less	103
					Over 36 to 53	Over 2.25 to 3.25	102
					Over 53 to 67	Over 3.25 to 4.25	101

INDIANA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 160m section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Flexible	California-style profilograph	PI [illegible] 188mm/km (12 in/mile)	160m (0.1 mile)	same day	Over 0 to 30	0 to 2	105
					Over 30 to 63	2 to 4	104
					Over 63 to 125	4 to 8	102
					Over 125 to 156	8 to 10	100
					Over 156 to 175	10 to 11	96
					Over 175 to 188	11 to 12	92
					Over 188	Over 12	Corrective Work Required

INDIANA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 160 m section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Rigid	California-style profilograph	PI [illegible] 238 mm/km (15 in/mile)	160 m (0.1 mile)	immediately after curing	0 to 188	0 to 12	100
					Over 188 to 206	12 to 13	98
					Over 206 to 225	13 to 14	96
					Over 225 to 238	14 to 15	92
					Over 238	Over 15	Corrective Work Required

IOWA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 160 m section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, dollars per segment
Flexible & Rigid	California-style profilograph	PI = 110 mm/km	0.1 mile	same day	0-16	0-1.0	$650
					16.1-32	1.1-2.0	$550
					32.1-48	2.1-3.0	$450
					48.1-110	3.1-7.0	$0
					110-160	7.1-10.0	Corrective Work or -$300
					160.1 & over	10.1 & over	Corrective Work Required

KANSAS

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Contract Price adjustment	Profile Index, in/mile per 0.1 mile section	Contract Price adjustment
Flexible	California-style profilograph	PI = 30 in/mile (475 mm/km)	0.1 mile (0.1 km)	same day	110 or less	+ $100.00	7.0 or less	+ $152.00
					111 to 160	+ $50.00	7.1 to 10.0	+ $76.00
					161 to 475	$0.00	10.1 to 30.0	$0.00
					476 to 630	Corrective Work Required	30.1 to 40.0	Corrective Work Required
					631 or more	Corrective Work Required	40.1 or more	Corrective Work Required

KANSAS

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Contract Price adjustment	Profile Index, in/mile per 0.1 mile section	Contract Price adjustment
Rigid	California-style profilograph	PI = 30 in/mile (475 mm/km)	0.1 mile (0.1 km)	same day	95 or less	+ $760.00	6.0 or less	+ $1200.00
					96 to 160	+ $630.00	6.0 to 10	+ $1000.00
					161 to 240	+ $470.00	10.1 to 15.0	+ $750.00
					241 to 285	+ $240.00	15.1 to18.0	+ $370.00
					286 to 475	$0.00	18.1 to 30.0	$0.00
					476 to 630	Corrective Work Required	30.1 to 40.0	Corrective Work Required
					631 or more	Corrective Work Required	40.1 or more	Corrective Work Required

KENTUCKY

					Price Adjustments	
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Rideability Index**	**Adjustment, unit multiplied by HMAC mixture payment**
Flexible	ASTM E 950, Class 1 Device Inertial Profiler	RI = 3.45 or greater	1 mile	same day	4.15 or higher	+0.15
					4.10 to 4.14	+0.10
					4.05 to 4.09	+0.05
					3.70 to 4.04	0.00
					3.60 to 3.69	-0.05
					3.50 to 3.59	-0.10
					3.45 to 3.49	-0.15
					3.44 or lower	Corrective Work Required

KENTUCKY

					Price Adjustments			
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Rideability Index**	**Unit Bid Price Adjustment (per sq m)**	**Profile Index, in/mile per 1000 feet section**	**Unit Bid Price Adjustment (per sq yd)**
Rigid	Rainhart (Model 860) Profilograph	PI = 12 in/mile	1000 feet	same day	4.15 or higher	+ $0.03	8 or less	$0.00
					4.10 to 4.14	+ $0.02	over 8 to 9	- $0.02
					4.05 to 4.09	+ $0.01	over 9 to 10	- $0.05
							over 10 to 12	- $0.08
							over 12	Corrective Work Required

LOUISIANA

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Profile Index, mm/km per lot**	**Profile Index, in/mile per lot**	**Adjustment, Percent of Contract Unit Price / lot**
Flexible	California-style profilograph	Average PI = 3.0 in/mile (47 mm/km)	length based on 500 tons placed in continuos operation	Next Day	0 to 47	0.0 to 3.0	100%
					48 to 63	3.1 to 4.0	95%
					64 to 95	4.1 to 6.0	80%
					Over 95	Over 6.0	50% or remove

LOUISIANA

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Profile Index, mm/km per lot**	**Profile Index, in/mile per lot**	**Adjustment, Percent of Contract Unit Price / lot**
Rigid	California-style profilograph	Average PI = 6.0 in/mile (94.5 mm/km)	--	same day	---	6.0 or less	100%
					---	6.1 to 7.0	98%
					---	7.1 to 8.0	95%
					---	over 8.0	Correct or remove and replace

MAINE

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**International Roughness Index, IRI, m/km**	**International Roughness Index, IRI, in/mile**	**Pay Factor**
Flexible & Rigid	Inertial Profiler	IRI = 0.947 m/km	1000 meters	same day	0.552	35	1.05
					0.947	60	1.00
					1.26	80	0.75
					>1.26	>80	Corrective Work Required

*For IRI values between those listed in the table, the pay factor shall be determined by the following formula (based on units of in/mile):
Pay Factor = 1.05 - (4.2164066E-13*IRI^6.2279)

MARYLAND

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**International Roughness Index, IRI, mm/km**	**International Roughness Index, IRI, in/mile**	**Pay Factor**
Flexible	California-style profilograph	PI = 110 mm/km (7 in/mile)	0.1 km (0.1 mile)	same day	<=63	<=4.0	Bonus
					64-110	4.1-7	Full Pay
					111-190	7.1-12	Penalty
					>191	>12	Corrective Work Required

MARYLAND

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**International Roughness Index, IRI, mm/km**	**International Roughness Index, IRI, in/mile**	**Pay Factor**
Rigid	California-style profilograph	PI = 110 mm/km (7 in/mile)	0.1 km (0.1 mile)	same day	<=63	<=4.0	Bonus
					64-110	4.1-7	Full Pay
					111-190	7.1-12	Penalty
					>191	>12	Corrective Work Required

MASSACHUSETTS

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: International Roughness Index, IRI, mm/km	Price Adjustments: International Roughness Index, IRI, in/mile	Price Adjustments: Pay Factor
Flexible	Inertial Profiler	IRI = 1500 m/km (95 in/mile)	0.2 km (0.12 mile)	same day	---	---	---

MASSACHUSETTS
No rigid info

MICHIGAN

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Flexible and Rigid	California-style profilograph	PI = 158 mm/km (10 in/mile)	0.1 mile	same day	<= 63	<= 4	Bonus
					64 - 158	4.1 - 10	Full Pay
					---	---	Penalty
					> 158	> 10	Corrective Work Required

MICHIGAN

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Ride Quality Index	Price Adjustments: Adjustment
Flexible and Rigid	GM Type Rapid Travel Profilometer	RQI = 45.00	0.1 mile	same day	< 45	Bonus
					45 - 53	Full Pay
					---	Penalty
					> 53	Corrective Work Required

MINNESOTA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments			
					Profile Index, mm/km per 0.1 km section	Adjustment, dollars per segment	Profile Index, in/mile per 0.1 mile section	Adjustment, dollars per segment
Flexible	California-style profilograph or Lightweight Inertial Profiler	PI = 394.7 mm/km (25 in/mile)	0.1 km (0.1 mile)	same day	0-176.9	190	0.0-11.2	300
					177.0-195.2	130	11.3-12.4	200
					195.3-213.5	70	12.5-13.6	100
					213.6-272.8	0	13.7-17.3	0
					272.9-314.1	-70	17.4-19.9	-100
					315.7-353.6	-130	20.0-22.4	-200
					355.2-393.1	-190	22.5-24.9	-300
					Over 394.7	Corrective Work Required	Over 25.0	Corrective Work Required

MINNESOTA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments			
					Profile Index, mm/km per 0.1609 km section	Unit Bid Price Adjustment (per sq m)	Profile Index, in/mile per 0.1 mile section	Unit Bid Price Adjustment (per sq yd)
Rigid	Computerized California-style profilograph	PI = 94.7 mm/km (6.00 in/mile)	0.1609 km (0.1 mile)	same day	less than 63.13	+ (63.1-PI)*0.0212	less than 4.00	+ (4.0-PI)*0.28
					63.13-94.70	$0.00	4.00-6.00	$0.00
					94.7-126.26	- .006*(PI)^2 - .15156(PI) + 8.372	6.00-8.00	- .125(PI)^2 - 2(PI) +7
					Greater than 126.26	Corrective Work Required	Greater than 8.00	Corrective Work Required

MISSISSIPPI

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Flexible	California-style profilograph	PI = 110 mm/km (7 in/mile)	0.1 mile	same day	<= 79	<= 5	Bonus
					80 - 110	5.1 - 7	Full Pay
					111 - 158	7.1 - 10	Penalty
					> 158	> 10	Corrective Work Required

MISSISSIPPI

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Rigid	California-style profilograph	PI – 110 mm/km (7 in/mile)	0.1 mile	same day	---	---	Bonus
					<= 110	<= 7	Full Pay
					111 - 190	7.1 - 12	Penalty
					> 190	> 12	Corrective Work Required

MISSOURI

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 1.0 km section	Price Adjustments: Profile Index, in/mile per 0.5 mile section	Price Adjustments: Adjustment, % of Contract Price
Flexible	California-style profilograph	PI = 25 in/mile (395mm/km)	0.5 mile (1 km)	same day	158 or less	10.0 or less	107
					159-237	10.1-15.0	105
					238-284	15.1-18.0	103
					285-395	18.1-25.0	100
					396-553	25.1-35.0	97 with correction
					555-711	35.1-45.0	95 with correction
					712 or greater	45.1 or greater	93 with correction

MISSOURI

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 1.0 km section	Price Adjustments: Profile Index, in/mile per 0.5 mile section	Price Adjustments: Adjustment, % of Contract Price
Rigid	California-style profilograph	PI = 25 in/mile (395mm/km)	0.5 mile (1 km)	same day	158 or less	10.0 or less	107
					159-237	10.1-15.0	105
					238-284	15.1-18.0	103
					285-395	18.1-25.0	100
					396-553	25.1-35.0	97 with correction
					555-711	35.1-45.0	95 with correction
					712 or greater	45.1 or greater	93 with correction

MONTANA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Class I Price Adjustments*		
					IRI, m/km per 0.2 mile section	IRI, in/mile per 0.2 mile section	Pay Factor
Flexible	Class I Laser Road Profiler	IRI = 65 in/mile (1.03 m/km)	0.2 mile	same day	<0.63	<40	1.25
					0.63-0.71	40-45	1.10
					0.72-1.03	46-65	1.00
					>1.03	>65	0.80

Class II Price Adjustments*		
IRI, m/km per 0.2 mile section	IRI, in/mile per 0.2 mile section	Pay Factor
<0.71	<45	1.25
0.71-0.87	45-55	1.10
0.88-1.19	56-75	1.00
>1.19	>75	0.80

Class III Price Adjustments*		
IRI, m/km per 0.2 mile section	IRI, in/mile per 0.2 mile section	Pay Factor
<0.88	<56	1.1
0.88-1.26	56-80	1
>1.26	>80	0.9

Class IV Price Adjustments*		
IRI, m/km per 0.2 mile section	IRI, in/mile per 0.2 mile section	Pay Factor
<0.96	<61	1.1
0.96-1.42	61-90	1
>1.42	>90	0.9

*Class I Projects:

Target IRI Values - 46 to 65 inches per mile (0.72 to 1.03 meters per kilometer)
Projects with three or more opportunities for improving the ride.

Projects with a pre-paving IRI <140 in/mi (2.21 m/km); with two opportunities for improving the ride.

Single lift overlays with a pre-paving IRI value <90 in/mi (1.42 m/km).

*Class II Projects:
Target IRI Values - 55 to 75 inches per mile (0.88 to 1.19 meters per kilometer)
Projects with a pre-paving IRI = >140 in/mi (2.21m/km); with two opportunities for improving the ride.
Projects with a single opportunity for improvement with a pre-paving IRI value of >90 in/mi (1.42 m/km) and <140 in/mi (2.21 m/km).

*Class III Projects:
Target IRI Values - 56 to 80 inches per mile (0.88 to 1.26 meters per kilometer)
Projects with a single opportunity for improvement with a pre-paving IRI value of >140 in/mi (2.21 m/km) and <190 in/mi (3.00 m/km).

*Class IV Projects:
Target IRI Values - 61 to 90 inches per mile (0.95 to 1.42 meters per kilometer)
Projects with a single opportunity for improvement with a pre-paving IRI value of >190 in/mi (3.00 m/km).

MONTANA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Rigid	California-style profilograph	PI = 158 mm/km (10 in/mile)	0.1 mile	---	<=94	<= 6	Bonus
					95 - 158	6.1 - 10	Full Pay
					159 - 237	10.1 - 15	Penalty
					> 237	> 15	Corrective Work Required

NEBRASKA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 160m section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Flexible	California-style profilograph	PI = 7 in/mile	160m (0.1 mile)	same day	---	0-2	105
					---	2-4	102
					---	4-5	101
					---	5-7	100
					---	7-8	98
					---	8-9	95
					---	9-10	90
					---	>10	Corrective Work Required

NEBRASKA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 160 m section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Rigid	California-style profilograph	PI = 10 in/mile	160 m (0.1 mile)	same day	---	0-2	105
					---	2-3	104
					---	3-4	103
					---	4-5	101
					---	5-10	100
					---	10-11	98
					---	11-12	96
					---	12-13	94
					---	13-14	92
					---	14-15	90
					---	>15	Corrective Work Required

NEVADA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Flexible	California-style profilograph	PI = 80 mm/km (5 in/mile)	0.1 km (0.1 mile)	same day	<=80	<=5	100
					>80	>5	Corrective Work Required

NEVADA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 160 m section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Rigid	California-style profilograph	PI = 80 mm/km (5 in/mile)	0.1 km (0.1 mile)	same day	<=80	<=5	100
					>80	>5	Corrective Work Required

NEW HAMPSHIRE

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: ---	Price Adjustments: ---	Price Adjustments: ---
Flexible	General Motors Inertial Profiler	RN = 4.1	0.1 km (0.1 mile)	same day	---	---	---

NEW HAMPSHIRE

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: ---	Price Adjustments: ---	Price Adjustments: ---
Rigid	---	---	---	---	---	---	---

NEW JERSEY

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					—	—	—
Flexible	Rolling Straightedge	—	—	—	—	—	—

NEW JERSEY

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					---	---	---
Rigid	Rolling Straightedge	---	---	---	---	---	---

NEW MEXICO
New Construction

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 0.1 km section	Profile Index, in/mile per 0.1 mile section	Adjustment, % of payment of Unit Bid Price
Flexible	California-style profilograph	PI = 80 mm/km (5.0 in/mile)	0.1 km (0.1 mile)	same day	<=15	<=1.0	105.0
					15.1-30.0	1.1-2.0	103.0
					30.1-45.0	2.1-3.0	102.0
					45.1-65.0	3.1-4.0	101.0
					65.1-80.0	4.1-5.0	100.0
					80.1-95.0	5.1-6.0	98.0
					95.1-110.0	6.1-7.0	96.0
					110.1-125.0	7.1-8.0	94.0
					125.1-140.0	8.1-9.0	92.0
					140.1-160.0	9.1-10.0	90.0
					>=160.1	>=10.1	Corrective Work Required

NEW MEXICO
Single Lift Overlay

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Percentage of Improvement, %I *	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Flexible	California-style profilograph	PI = 80 mm/km (5.0 in/mile)	0.1 km (0.1 mile)	same day	>=65.1	105.0
					60.1-65.0	103.0
					55.1-60.0	102.0
					50.1-55.0	101.0
					30.1-50.0	100.0
					<=30.0	Corrective Work Required

NEW MEXICO
Multiple Lift Overlay

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Percentage of Improvement, %I *	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Flexible	California-style profilograph	PI = 80 mm/km (5.0 in/mile)	0.1 km (0.1 mile)	same day	>=85.1	105.0
					80.1-85.0	103.0
					75.1-80.0	102.0
					70.1-75.1	101.0
					50.1-70.0	100.0
					<=50.0	Corrective Work Required

* %I = ((Initial PI - Final PI) / Initial PI)*100

* Regardless of the percentage of improvement, additional corrective work will not be required when the actual profile index is 10.0 in/mile (160.0 mm/km) or less.

NEW MEXICO

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Rigid	California-style profilograph	PI = 110 mm/km (7.0 in/mile)	0.1 km (0.1 mile)	same day	<=45.0	<=3.0	105.0
					45.1-65.0	3.1-4.0	104.0
					65.1-80.0	4.1-5.0	102.0
					80.1-110.0	5.1-7.0	100.0
					110.1-125.0	7.1-8.0	98.0
					125.1-140.0	8.1-9.0	96.0
					140.1-160.0	9.1-10.0	94.0
					160.1-175.0	10.1-11.0	92.0
					175.1-190.0	11.1-12.0	90.0
					>=190.1	>=12.1	Corrective Work Required

NEW YORK

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Profile Index, in/mile per 0.1 mile section	Adjustment, % of payment of Unit Bid Price
Flexible	--	--	--	--	--	--	--

NEW YORK

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Profile Index, in/mile per 0.1 mile section	Adjustment
Rigid	California-style profilograph	PI = 190 mm/km (12.0 in/mile)	0.1 km (0.1 mile)	--	<=79	<=5	Bonus
					80-190	5.1-12.0	Full Pay
					>190	>12.0	Corrective Work Required

NORTH CAROLINA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: PI	CSI	Adjustment
Flexible	Hearne Straightedge	*CSI = 30,40	0.76 km (0.47 mile)	--	--	10,20	Bonus
					--	30,40	Full Pay
					--	11,21,31,41,50,51, 60,61	Penalty

* CSI = Cumulative Straightedge Index

NORTH CAROLINA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: PI, mm/km	PI, in/mile	Adjustment
Rigid	Rainhart Profilograph	PI = 63 mm/km (4 in/mile)	0.18 km (0.11 mile)	--	--	--	Bonus
					<=63	<=4	Full Pay
					--	--	Penalty
					>63	>4	Corrective Work Required

NORTH DAKOTA

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Profile Index, mm/km per 0.1 km section**	**Profile Index, in/mile per 0.1 mile section**	**Adjustment, % of payment of Unit Bid Price**
Flexible	---	---	---	---	---	---	---

NORTH DAKOTA

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Profile Index, mm/km per 0.16 km section**	**Profile Index, in/mile per 0.1 mile section**	**Adjustment**
Rigid	California-style profilograph	PI = 81.25 mm/km (5 in/mile)	0.16 km (0.1 mile)	---	<50	<3	Bonus
					50.00-81.25	3-5	Full Pay
					87.5-143.75	5.1-9.0	Penalty
					>143.75	>9.0	Corrective Work Required

OHIO

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Profile Index, mm/km per 0.1 km section**	**Profile Index, in/mile per 0.1 mile section**	**Adjustment, % of payment of Unit Bid Price**
Flexible	California-style profilograph	PI = 7 in/mile	0.1 mile	same day	---	1 or less	105
					---	Over 1 to 2	103
					---	Over 2 to 3	102
					---	Over 3 to 4	101
					---	Over 4 to 7	100
					---	Over 7 to 8	98
					---	Over 8 to 9	96
					---	Over 9 to 10	94
					---	Over 10 to 11	92
					---	Over 11 to 12	90
					---	Over 12	Corrective Work Required

OHIO

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km per 160 m section	Profile Index, in/mile per 0.1 mile section	Adjustment, % of payment of Unit Bid Price
Rigid	California-style profilograph	PI = 7 in/mile	0.1 mile	same day	---	3 or less	105
					---	Over 3 to 4	104
					---	Over 4 to 5	102
					---	Over 5 to 7	100
					---	Over 7 to 8	98
					---	Over 8 to 9	96
					---	Over 9 to 10	94
					---	Over 10 to 11	92
					---	Over 11 to 12	90
					---	Over 12	Corrective Work Required

OKLAHOMA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Class I Price Adjustments*		
					Profile Index, mm/km	**Profile Index, in/mile**	**Pay Factor**
Flexible	California-style profilograph or Lightweight Inertial Profiler	PI = 110 mm/km (7.0 in/mile)	528 feet (161 meters)	same day	<47	<3	1.03
					47-62	3.0-3.9	1.02
					63-77	4.0-4.9	1.01
					78-110	5.0-7.0	1.00
					111-134	7.1-8.5	0.99
					135-158	8.6-10.0	98
					159-189	10.1-12.0	96
					190-221	12.1-14.0	94
					222-252	14.1-16.0	92
					>252	>16.0	Corrective Work Required
					Class II Price Adjustments*		
					Profile Index, mm/km	**Profile Index, in/mile**	**Pay Factor**
					<78	<5.0	1.03
					78-94	5.0-5.9	1.02
					95-109	6.0-6.9	1.01
					110-142	7.0-9.0	1.00
					143-166	9.1-10.5	0.99
					167-189	10.6-12.0	98
					190-221	12.1-14.0	96
					222-252	14.1-16.0	94
					253-284	16.1-18.0	92
					>284	>18.0	Corrective Work Required
					Class III Price Adjustments*		
					Profile Index, mm/km	**Profile Index, in/mile**	**Pay Factor**
					<110	<7.0	1.03
					110-125	7.0-7.9	1.02
					126-140	8.0-8.9	1.01
					141-174	9.0-11.0	1.00
					175-197	11.1-12.5	0.99
					198-221	12.6-14.0	98
					222-252	14.1-16.0	96
					253-284	16.1-18.0	94
					285-316	18.1-20.0	92
					>316	>20.0	Corrective Work Required

OKLAHOMA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Class I Price Adjustments*		
					Profile Index, mm/km	Profile Index, in/mile	Pay Factor
Rigid	California-style profilograph or Lightweight Inertial Profiler	PI = 110 mm/km (7.0 in/mile)	528 feet (161 meters)	same day	<47	<3	1.03
					47-62	3.0-3.9	1.02
					63-77	4.0-4.9	1.01
					78-110	5.0-7.0	1.00
					111-134	7.1-8.5	0.99
					135-158	8.6-10.0	98
					159-189	10.1-12.0	96
					190-221	12.1-14.0	94
					222-252	14.1-16.0	92
					>252	>16.0	Corrective Work Required
					Class II Price Adjustments*		
					Profile Index, mm/km	Profile Index, in/mile	Pay Factor
					<78	<5.0	1.03
					78-94	5.0-5.9	1.02
					95-109	6.0-6.9	1.01
					110-142	7.0-9.0	1.00
					143-166	9.1-10.5	0.99
					167-189	10.6-12.0	98
					190-221	12.1-14.0	96
					222-252	14.1-16.0	94
					253-284	16.1-18.0	92
					>284	>18.0	Corrective Work Required
					Class III Price Adjustments*		
					Profile Index, mm/km	Profile Index, in/mile	Pay Factor
					<110	<7.0	1.03
					110-125	7.0-7.9	1.02
					126-140	8.0-8.9	1.01
					141-174	9.0-11.0	1.00
					175-197	11.1-12.5	0.99
					198-221	12.6-14.0	98
					222-252	14.1-16.0	96
					253-284	16.1-18.0	94
					285-316	18.1-20.0	92
					>316	>20.0	Corrective Work Required

*CLASS I roads are rural in nature and/or have few, if any, intersecting roads, drainage inlets, or other features which significantly increase the difficulty in obtaining a smooth road surface.

*CLASS II and CLASS III roads are urban in nature and/or do have these features which significantly increase the difficulty.

OREGON

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments PI, mm/km	PI, in/mile	Adjustment
Flexible	California-style profilograph	PI = 110 mm/km (7 in/mile)	0.16 km (0.1 mile)	---	<=80	<=5	Bonus
					81-110	5.1-7.0	Full Pay
					111-155	7.1-10.0	Penalty
					>155	>10	Corrective Work Required

OREGON

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments PI, mm/km	PI, in/mile	Adjustment
Rigid	California-style profilograph	PI = 110 mm/km (7 in/mile)	0.16 km (0.1 mile)	---	<=80	<=5	Bonus
					81-110	5.1-7.0	Full Pay
					---	---	Penalty
					>110	>7	Corrective Work Required

PENNSYLVANIA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments Average IRI (mm/km per lot)	Average IRI (in/mile per lot)	Payment, $/lot
Flexible	Lightweight Inertial Profiler	Average IRI = 1105 mm/km (70 in/mile)	lot length =161 meters (528 feet)	---	< 553	< 35.0	+300
					< 790	≤ 50.0	+150
					≤ 948	≤ 60.0	+75
					≤ 1105	≤ 70.0	+0
					> 1105	> 70.0	correct to 1500 mm/km (70 in/mile) or less

PENNSYLVANIA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Average IRI (mm/km per lot)	Price Adjustments: Average IRI (in/mile per lot)	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Rigid	Lightweight Inertial Profiler		lot length =161 meters (528 feet)	---	<=632	<=40	106
					<=948	<=60	104
					<=1105	<=70	102
					<=1500	<=95	100
					>1500	>95	Corrective Work Required

PENNSYLVANIA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Average IRI (mm/km per lot)	Price Adjustments: Average IRI (in/mile per lot)	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Rigid	High Speed Inertial Profiler	Average IRI = 1105 mm/km (70 in/mile)	lot length =161 meters (528 feet)	---	<=553	<=35	106
					<=790	<=50	104
					<=948	<=60	102
					<=1105	<=70	100
					>1105	>70	Corrective Work Required

RHODE ISLAND

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Flexible	--	--	--	---	--	---	--

RHODE ISLAND

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Rigid	--	--	---	---	--	--	--

SOUTH CAROLINA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Roughness (in/mile)	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Flexible	Mays Ride Meter	Roughness = 40 in/mile	1.0 mile	--	<24	105
					25-29	103
					30-34	101
					35-40	100
					41-45	95
					46-50	90
					51-55	80
					>=56	Corrective Work Required

SOUTH CAROLINA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Roughness (in/mile)	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Rigid	Mays Ride Meter	Roughness = 55 in/mile	1.0 mile	---	<=55	Full Pay
					>55	Corrective Work Required

SOUTH DAKOTA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: IRI, mm/km	Price Adjustments: IRI, in/mile	Price Adjustments: Adjustment
Flexible	Inertial Profiler	IRI = 1105 mm/km (70 in/mile)	0.16 km (0.1 mile)	---	<=868	<=55	Bonus
					869-1105	55.1-70.0	Full Pay
					1106-1262	70.1-80.0	Penalty
					>1262	>80.0	Corrective Work Required

SOUTH DAKOTA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment
Rigid	California-style profilograph	PI = 550 mm/km (35 in/mile)	0.1 km (0.1 mile)	---	<=395	<=25	Bonus
					396-550	25.1-35	Full Pay
					551-630	35.1-40	Penalty
					>630	>40	Corrective Work Required

TENNESSEE

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Mays Ride Number, mm/km	Price Adjustments: Mays Ride Number, in/mile	Price Adjustments: Adjustment
Flexible	Mays Ride Meter	MRN = 475 mm/km (30 in/mile)	0.16 km (0.1 mile)	---	<=315	<=20	Bonus
					316-475	20.1-30	Full Pay
					476-950	30.1-60	Penalty
					>950	>60	Corrective Work Required

TENNESSEE

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km per 0.1 km section	Price Adjustments: Profile Index, in/mile per 0.1 mile section	Price Adjustments: Adjustment
Rigid	Rainhart profilograph	PI = 160 mm/km (10 in/mile)	0.1 km (0.1 mile)	---	---	---	Bonus
					<=160	<=10	Full Pay
					161-235	10.1-15.0	Penalty
					>235	>15.0	Corrective Work Required

TEXAS

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Flexible	California-style profilograph	PI = 315 mm/km (20 in/mile)	0.16 km (0.1 mile)	--	<=237	<=15	Bonus
					238-315	15.1-20.0	Full Pay
					316-630	20.1-40.0	Penalty
					>630	>40.0	Corrective Work Required

TEXAS

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Rigid	California-style profilograph	PI = 315 mm/km (20 in/mile)	0.16 km (0.1 mile)	--	<=237	<=15	Bonus
					238-315	15.1-20.0	Full Pay
					316-630	20.1-40.0	Penalty
					>630	>40.0	Corrective Work Required

UTAH

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Flexible	California-style profilograph	PI = 110 mm/km (7 in/mile)	0.2 km (0.12 mile)	--	--	--	Bonus
					<=110	<=7	Full Pay
					--	--	Penalty
					>110	>7	Corrective Work Required

UTAH

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Rigid	California-style profilograph	PI = 110 mm/km (7 in/mile)	0.2 km (0.12 mile)	--	--	--	Bonus
					<=110	<=7	Full Pay
					--	--	Penalty
					>110	>7	Corrective Work Required

VERMONT

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments	
					IRI, in/mile	Pay Factor
Flexible	Inertial Profiler	IRI = 65 in/mile	--	--	<=42	1.050
					43-53	1.025
					54-65	1.000
					66-82	0.975
					>=83	0.950

VERMONT

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					Profile Index, mm/km	Profile Index, in/mile	Adjustment
Rigid	--	--	--	--	--	--	--

VIRGINIA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					IRI, mm/km	IRI, in/mile	Adjustment
Flexible	South Dakota Type Profiler	IRI = 1105 mm/km (70 in/mile)	0.16 km (0.1 mile)	---	<=868	<=55	Bonus
					869-1105	55.1-70.0	Full Pay
					1106-1578	70.1-100.0	Penalty
					>1578	>100.0	Corrective Work Required

VIRGINIA

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments		
					IRI, mm/km	IRI, in/mile	Adjustment
Rigid	South Dakota Type Profiler	IRI = 1262 mm/km (80 in/mile)	0.16 km (0.1 mile)	---	<=946	<=60	Bonus
					947-1262	60.1-80.0	Full Pay
					1263-1578	80.1-100.0	Penalty
					>1578	>100.0	Corrective Work Required

WASHINGTON

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**IRI, mm/km**	**IRI, in/mile**	**Adjustment**
Flexible	Lightweight Inertial Profiler	IRI = 1500 mm/km (95.0 in/mile)	0.1 km (0.1 mile)	---	<=946	<=60	Bonus
					947-1500	60.1-95.0	Full Pay
					1501-1815	95.1-115	Penalty
					>1815	>115	Corrective Work Required

WASHINGTON

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Profile Index, mm/km**	**Profile Index, in/mile**	**Adjustment**
Rigid	California-style profilograph	PI = 100 mm/km (6.3 in/mile)	0.1 km (0.1 mile)	---	<=60	<=3.8	Bonus
					61-100	3.9-6.3	Full Pay
					>100	>6.3	Penalty
					---	---	Corrective Work Required

WEST VIRGINIA

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Mays Ride Number, mm/km**	**Mays Ride Number, in/mile**	**Adjustment**
Flexible	Mays Ride Meter	MRN = 1000 mm/km (65 in/mile)	0.16 km (0.1 mile)	---	---	---	Bonus
					<=1000	<=65	Full Pay
					1001-1500	66-97.5	Penalty
					>1500	>97.5	Corrective Work Required

WEST VIRGINIA

					Price Adjustments		
Pavement Type	**Equipment**	**Acceptance Limits**	**Section Length**	**Time of Testing**	**Profile Index, mm/km per 0.1 km section**	**Profile Index, in/mile per 0.1 mile section**	**Adjustment**
Rigid	Mays Ride Meter	MRN = 1000 mm/km (65 in/mile)	0.16 km (0.1 mile)	---	---	---	Bonus
					<=1000	<=65	Full Pay
					1001-1500	66-97.5	Penalty
					>1500	>97.5	Corrective Work Required

WISCONSIN

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Pay Adjustment, $ per section
Flexible	California-style profilograph	PI =316 mm/km (20 in/mile)	0.16 km (0.1 mile)	---	<=158	<=10	+250
					158-316	10-20	0
					>316	>20	-400
					---	---	Corrective Work Required

WISCONSIN

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment
Rigid	California-style profilograph	PI = 700 mm/km (44.3 in/mile)	0.16 km (0.1 mile)	---	<=400	<=25.3	Bonus
					401-700	25.4-44.3	Full Pay
					701-800	44.4-50.7	Penalty
					>800	>50.7	Corrective Work Required

WYOMING

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: IRI, mm/km	Price Adjustments: IRI, in/mile	Price Adjustments: Pay Adjustment, $ per section
Flexible	Inertial Profiler	IRI = 1105 mm/km (70 in/mile)	0.16 km (0.1 mile)	---	---	---	Bonus
					868-1105	55-70	Full Pay
					---	---	Penalty
					---	---	Corrective Work Required

WYOMING

Pavement Type	Equipment	Acceptance Limits	Section Length	Time of Testing	Price Adjustments: Profile Index, mm/km	Price Adjustments: Profile Index, in/mile	Price Adjustments: Adjustment, % of payment of Unit Bid Price
Rigid	California-style profilograph	PI = 80 mm/km	0.16 km (0.1 mile)	---	0-5	---	5.0
					41-48	---	4.0
					49-56	---	3.0
					57-64	---	2.0
					65-72	---	1.0
					73-80	---	0.0

Table A-2. Summary of Flexible Pavement Smoothness Specifications in the U.S.

State	Testing Device	Specs Found	Incentives Found	Disincentives Found
Alabama	California Profilograph	yes	yes	yes
Alaska	Straightedge	no	no	no
Arizona	General Motors Profilometer	yes	yes	yes
Arkansas	California Profilograph	yes	yes	yes
California	California Profilograph	yes	no	no
Colorado	California Profilograph	yes	yes	yes
Connecticut	ARAN Inertial Profiler	yes	yes	yes
Delaware	---	no	no	no
Florida	Laser Profiler	yes	yes	no
Georgia	Laser Profiler	yes	no	no
Hawaii	California Profilograph	yes	yes	yes
Idaho	California Profilograph	yes	no	no
Illinois	California Profilograph	yes	yes	yes
Indiana	California Profilograph	yes	yes	yes
Iowa	California Profilograph	yes	yes	no
Kansas	California Profilograph	yes	yes	no
Kentucky	Inertial Profiler	yes	yes	yes
Louisiana	California Profilograph	yes	no	yes
Maine	Inertial Profiler	yes	yes	yes
Maryland	California Profilograph	yes	yes	yes
Massachusetts	Inertial Profiler	yes	no	no
Michigan	California profilograph or General Motors Profilometer	yes	yes	no
Minnesota	California profilograph or Lightweight Inertial Profiler	yes	yes	yes
Mississippi	California Profilograph	yes	yes	yes
Missouri	California Profilograph	yes	yes	yes
Montana	Laser Profiler	yes	yes	yes
Nebraska	California Profilograph	yes	yes	yes
Nevada	California Profilograph	yes	no	no
New Hampshire	General Motors Inertial Profiler	no	no	no
New Jersey	Rolling Straightedge	no	no	no
New Mexico	California Profilograph	yes	yes	yes
New York	---	no	no	no
North Carolina	Hearne Straightedge	yes	yes	yes
North Dakota	---	no	no	no
Ohio	California Profilograph	yes	yes	yes
Oklahoma	California profilograph or Lightweight Inertial Profiler	yes	yes	yes
Oregon	California Profilograph	yes	yes	yes
Pennsylvania	Lightweight Inertial Profiler	yes	yes	no
Rhode Island	---	no	no	no
South Carolina	Mays Ride Meter	yes	yes	yes
South Dakota	Inertial Profiler	yes	yes	yes
Tennessee	Mays Ride Meter	yes	yes	yes
Texas	California Profilograph	yes	yes	yes
Utah	California Profilograph	yes	no	no
Vermont	Inertial Profiler	yes	yes	yes
Virginia	South Dakota Type Profiler	yes	yes	yes
Washington	Lightweight Inertial Profiler	yes	yes	yes
West Virginia	Mays Ride Meter	yes	no	yes
Wisconsin	California Profilograph	yes	yes	yes
Wyoming	Inertial Profiler	yes	no	no

Table A-3. Summary of Rigid Pavement Smoothness Specifications in the U.S.

State	Testing Device	Specs Found	Incentives Found	Disincentives Found
Alabama	California Profilograph	yes	yes	yes
Alaska	---	no	no	no
Arizona	California Profilograph	yes	yes	yes
Arkansas	California Profilograph	yes	yes	yes
California	California Profilograph	yes	no	no
Colorado	California Profilograph	yes	yes	yes
Connecticut	California Profilograph	yes	yes	yes
Delaware	California Profilograph	yes	yes	yes
Florida	California Profilograph	yes	yes	yes
Georgia	California Profilograph	yes	no	no
Hawaii	California Profilograph	yes	no	yes
Idaho	California Profilograph	yes	no	no
Illinois	California Profilograph	yes	yes	yes
Indiana	California Profilograph	yes	no	yes
Iowa	California Profilograph	yes	yes	no
Kansas	California Profilograph	yes	yes	no
Kentucky	California Profilograph	yes	yes	yes
Louisiana	California Profilograph	yes	no	yes
Maine	Inertial Profiler	yes	yes	yes
Maryland	California Profilograph	yes	yes	yes
Massachusetts	---	no	no	no
Michigan	California profilograph or General Motors Profilometer	yes	yes	no
Minnesota	California Profilograph	yes	yes	yes
Mississippi	California Profilograph	yes	no	yes
Missouri	California Profilograph	yes	yes	yes
Montana	California Profilograph	yes	yes	yes
Nebraska	California Profilograph	yes	yes	yes
Nevada	California Profilograph	yes	no	no
New Hampshire	---	no	no	no
New Jersey	Rolling Straightedge	no	no	no
New Mexico	California Profilograph	yes	yes	yes
New York	California Profilograph	yes	yes	no
North Carolina	California Profilograph	yes	no	no
North Dakota	California Profilograph	yes	yes	yes
Ohio	California Profilograph	yes	yes	yes
Oklahoma	California profilograph or Lightweight Inertial Profiler	yes	yes	yes
Oregon	California Profilograph	yes	yes	no
Pennsylvania	Lightweight Inertial Profiler	yes	yes	no
Rhode Island	---	no	no	no
South Carolina	Mays Ride Meter	yes	no	no
South Dakota	California Profilograph	yes	yes	yes
Tennessee	California Profilograph	yes	no	yes
Texas	California Profilograph	yes	yes	yes
Utah	California Profilograph	yes	no	no
Vermont	---	no	no	no
Virginia	South Dakota Type Profiler	yes	yes	yes
Washington	California Profilograph	yes	yes	yes
West Virginia	Mays Ride Meter	yes	no	yes
Wisconsin	California Profilograph	yes	yes	yes
Wyoming	California Profilograph	yes	yes	no

APPENDIX B

Table B-1. Raw Data collected with ARRB Profiler

North Tangent Inside Lane					
Sample					
1		2		3	
Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)
0.7917	-0.0413	0.7917	-0.0764	0.7917	-0.0572
1.5833	-0.0711	1.5833	-0.0935	1.5833	-0.0991
2.3750	-0.1352	2.3750	-0.1735	2.3750	-0.1689
3.1667	-0.1907	3.1667	-0.2439	3.1667	-0.2183
3.9583	-0.1961	3.9583	-0.2662	3.9583	-0.2383
4.7500	-0.1951	4.7500	-0.2729	4.7500	-0.2443
5.5417	-0.2019	5.5417	-0.2922	5.5417	-0.2596
6.3333	-0.2322	6.3333	-0.3302	6.3333	-0.2935
7.1250	-0.2750	7.1250	-0.3792	7.1250	-0.3393
7.9167	-0.3215	7.9167	-0.4318	7.9167	-0.3882
8.7083	-0.3572	8.7083	-0.4692	8.7083	-0.4290
9.5000	-0.3781	9.5000	-0.4962	9.5000	-0.4526

Table B-2. Raw Data collected with ARRB Profiler

South Tangent Inside Lane					
Sample					
1		2		3	
Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)
0.7917	-0.1074	0.7917	-0.0878	0.7917	-0.0941
1.5833	-0.2057	1.5833	-0.0297	1.5833	-0.1165
2.3750	-0.1319	2.3750	-0.0317	2.3750	-0.1054
3.1667	-0.1357	3.1667	-0.0703	3.1667	-0.1260
3.9583	-0.1820	3.9583	-0.1148	3.9583	-0.1468
4.7500	-0.2313	4.7500	-0.1095	4.7500	-0.1999
5.5417	-0.1467	5.5417	-0.1390	5.5417	-0.2019
6.3333	-0.1714	6.3333	-0.1657	6.3333	-0.2329
7.1250	-0.2083	7.1250	-0.1996	7.1250	-0.2671
7.9167	-0.2432	7.9167	-0.2357	7.9167	-0.3041
8.7083	-0.2746	8.7083	-0.2676	8.7083	-0.3408
9.5000	-0.2984	9.5000	-0.2906	9.5000	-0.3787

Table B-3. Raw Data collected with ARRB Profiler

North Tangent, Reconstructed Lane: Subgrade					
Sample					
1		2		3	
Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)
0.7917	0.0276	N/A	N/A	N/A	N/A
1.5833	-0.0173	N/A	N/A	N/A	N/A
2.3750	-0.0016	N/A	N/A	N/A	N/A
3.1667	-0.0243	N/A	N/A	N/A	N/A
3.9583	-0.0368	N/A	N/A	N/A	N/A
4.7500	-0.0849	N/A	N/A	N/A	N/A
5.5417	-0.0789	N/A	N/A	N/A	N/A
6.3333	-0.0569	N/A	N/A	N/A	N/A
7.1250	0.0159	N/A	N/A	N/A	N/A
7.9167	-0.0015	N/A	N/A	N/A	N/A
8.7083	0.0756	N/A	N/A	N/A	N/A
9.5000	0.0528	N/A	N/A	N/A	N/A

Table B-4. Raw Data collected with ARRB Profiler

North Tangent, Reconstructed Lane: Granular Base					
Sample					
1		2		3	
Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)
0.7917	-0.0756	0.7917	-0.0860	0.7917	-0.0769
1.5833	-0.1650	1.5833	-0.1553	1.5833	-0.1579
2.3750	-0.2278	2.3750	-0.2619	2.3750	-0.2685
3.1667	-0.2624	3.1667	-0.2922	3.1667	-0.3167
3.9583	-0.2687	3.9583	-0.2624	3.9583	-0.3392
4.7500	-0.2931	4.7500	-0.2621	4.7500	-0.3509
5.5417	-0.3581	5.5417	-0.2995	5.5417	-0.4224
6.3333	-0.3991	6.3333	-0.3240	6.3333	-0.4675
7.1250	-0.4309	7.1250	-0.3709	7.1250	-0.4928
7.9167	-0.4493	7.9167	-0.3691	7.9167	-0.5061
8.7083	-0.4804	8.7083	-0.4207	8.7083	-0.5488
9.5000	-0.4992	9.5000	-0.4520	9.5000	-0.5792

Table B-5. Raw Data collected with ARRB Profiler

North Tangent, Reconstructed Lane: HMA Layer 2					
Sample					
1		2		3	
Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)
0.7917	-0.0437	0.7917	-0.0384	0.7917	-0.0378
1.5833	-0.0686	1.5833	-0.0565	1.5833	-0.0595
2.3750	-0.1032	2.3750	-0.0853	2.3750	-0.0876
3.1667	-0.1469	3.1667	-0.1333	3.1667	-0.1313
3.9583	-0.1950	3.9583	-0.1856	3.9583	-0.1767
4.7500	-0.2432	4.7500	-0.2357	4.7500	-0.2224
5.5417	-0.3034	5.5417	-0.2897	5.5417	-0.2856
6.3333	-0.3433	6.3333	-0.3339	6.3333	-0.3265
7.1250	-0.3916	7.1250	-0.3820	7.1250	-0.3709
7.9167	-0.4521	7.9167	-0.4402	7.9167	-0.4126
8.7083	-0.5027	8.7083	-0.4925	8.7083	-0.4689
9.5000	-0.5667	9.5000	-0.5442	9.5000	-0.5284

Table B-6. Raw Data collected with ARRB Profiler

North Tangent, Reconstructed Lane: HMA Layer 1					
Sample					
1		2		3	
Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)
0.7917	-0.0367	0.7917	-0.0261	0.7917	-0.0379
1.5833	-0.0600	1.5833	-0.0548	1.5833	-0.0632
2.3750	-0.0985	2.3750	-0.0953	2.3750	-0.0926
3.1667	-0.1350	3.1667	-0.1387	3.1667	-0.1232
3.9583	-0.1686	3.9583	-0.1789	3.9583	-0.1546
4.7500	-0.2015	4.7500	-0.2121	4.7500	-0.1894
5.5417	-0.2356	5.5417	-0.2463	5.5417	-0.2241
6.3333	-0.2656	6.3333	-0.2811	6.3333	-0.2454
7.1250	-0.3088	7.1250	-0.3321	7.1250	-0.3009
7.9167	-0.3588	7.9167	-0.3796	7.9167	-0.3550
8.7083	-0.3972	8.7083	-0.4186	8.7083	-0.4008
9.5000	-0.4415	9.5000	-0.4693	9.5000	-0.4486

Table B-7. Raw Data collected with ARRB Profiler

North Tangent, Reconstructed Lane: Wearing					
Sample					
1		2		3	
Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)	Distance (ft)	Profile Height (in)
0.7917	-0.0383	0.7917	-0.0292	0.7917	-0.0403
1.5833	-0.0727	1.5833	-0.0795	1.5833	-0.0785
2.3750	-0.1166	2.3750	-0.1189	2.3750	-0.1222
3.1667	-0.1626	3.1667	-0.1685	3.1667	-0.1601
3.9583	-0.1964	3.9583	-0.2033	3.9583	-0.1984
4.7500	-0.2395	4.7500	-0.2455	4.7500	-0.2425
5.5417	-0.2850	5.5417	-0.2926	5.5417	-0.2841
6.3333	-0.3224	6.3333	-0.3339	6.3333	-0.3261
7.1250	-0.3726	7.1250	-0.3763	7.1250	-0.3769
7.9167	-0.4240	7.9167	-0.4307	7.9167	-0.4266
8.7083	-0.4796	8.7083	-0.4852	8.7083	-0.4817
9.5000	-0.5470	9.5000	-0.5511	9.5000	-0.5520

APPENDIX C

Table C-1. IRI obtained using ARRB with 25 ft interval

North Tangent Inside Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
25	107.00	25	98.70	25	114.50
50	87.90	50	102.50	50	98.10
75	58.60	75	85.30	75	80.00
100	45.30	100	47.70	100	48.70
125	48.90	125	68.00	125	72.20
150	66.90	150	45.30	150	28.50
175	58.00	175	64.40	175	57.50
200	67.10	200	85.60	200	75.70
225	178.10	225	181.50	225	164.10
250	137.50	250	138.80	250	111.90
275	87.40	275	90.80	275	80.40
300	50.80	300	52.00	300	45.10
325	20.20	325	27.80	325	37.60
350	58.70	350	59.60	350	44.50
375	47.00	375	43.10	375	38.10
400	55.70	400	83.00	400	55.40
425	119.70	425	84.40	425	107.80
450	31.50	450	53.50	450	37.20
475	80.80	475	44.70	475	77.70
500	26.20	500	41.00	500	41.40
525	30.00	525	49.70	525	39.30
550	27.10	550	36.90	550	43.80
575	41.30	575	33.40	575	35.00
600	98.10	600	110.70	600	90.70
625	101.50	625	65.30	625	81.30
650	38.80	650	46.20	650	27.60
675	37.40	675	59.50	675	48.20
700	46.10	700	62.30	700	33.00
725	21.30	725	41.20	725	23.30
750	27.10	750	47.20	750	30.80
775	37.10	775	53.10	775	37.90
800	74.70	800	94.10	800	68.70
825	103.60	825	68.20	825	73.40
850	90.10	850	38.60	850	67.90
875	44.00	875	62.30	875	47.50
900	40.60	900	51.10	900	38.00
925	26.10	925	33.80	925	27.40
950	36.40	950	36.90	950	24.20
975	34.20	975	104.30	975	30.30
1000	101.90	1000	161.00	1000	107.10
1025	165.70	1025	117.50	1025	166.00
1050	130.80	1050	87.90	1050	108.60

1075	96.20	1075	51.50	1075	94.30
1100	81.00	1100	54.80	1100	45.60
1125	50.20	1125	57.80	1125	37.80
1150	51.20	1150	95.40	1150	31.30
1175	47.70	1175	314.70	1175	36.90
1200	98.90	1200	67.30	1200	105.10
1225	89.00	1225	36.60	1225	115.90
1250	29.90	1250	55.00	1250	45.60
1275	60.50	1275	42.20	1275	52.30
1300	53.20	1300	45.70	1300	84.30
1325	47.60	1325	38.40	1325	105.90
1350	50.20	1350	45.70	1350	50.40
1375	49.40	1375	70.70	1375	44.10
1400	85.00	1400	113.90	1400	80.80
1425	84.30	1425	104.90	1425	95.40
1450	108.30	1450	52.50	1450	91.30
1475	83.50	1475	63.10	1475	57.30
1500	64.90	1500	39.10	1500	85.60
1525	52.40	1525	39.40	1525	43.60
1550	140.20	1550	62.90	1550	38.50
1575	92.00	1575	98.20	1575	63.70
1600	109.40	1600	135.90	1600	100.50
1625	99.30	1625	76.90	1625	72.80
1650	49.60	1650	62.90	1650	74.80
1675	59.50	1675	39.30	1675	63.20
1700	44.70	1700	42.90	1700	46.20
1725	43.60	1725	32.20	1725	35.80
1750	54.20	1750	46.60	1750	52.30
1775	54.40	1775	119.70	1775	36.90
1800	124.60	1800	51.40	1800	128.30
1825	60.40	1825	81.00	1825	52.70
1850	66.60	1850	60.20	1850	62.80
1875	57.30	1875	60.10	1875	77.50
1900	34.00	1900	54.00	1900	42.40
1925	39.10	1925	45.00	1925	38.00
1950	35.20	1950	50.80	1950	45.20
1975	44.70	1975	142.00	1975	34.90
2000	136.80	2000	95.90	2000	127.90
2025	117.50	2025	70.30	2025	93.80
2050	75.20	2050	53.00	2050	82.60
2075	56.40	2075	88.80	2075	49.00
2100	54.80	2100	55.00	2100	55.90
2125	73.40	2125	197.70	2125	46.10
2150	206.20	2150	97.10	2150	156.00
2175	115.80	2175	143.70	2175	112.50
2200	121.50	2200	117.60	2200	156.70
2225	140.40	2225	54.30	2225	121.90

2250	73.80	2250	46.00	2250	54.20
2275	51.10	2275	56.60	2275	56.20
2300	65.00	2300	73.70	2300	53.60
2325	101.60	2325	57.30	2325	59.30
2350	111.20	2350	76.40	2350	60.40
2375	135.30	2375	176.70	2375	82.50
2400	151.10	2400	186.20	2400	180.80
2425	194.30	2425	133.60	2425	176.30
2450	124.90	2450	55.80	2450	129.30
2475	63.40	2475	91.90	2475	56.30
2500	68.60	2500	56.20	2500	60.70
2525	35.00	2525	55.00	2525	45.10
2561	72.20	2538	1208.90	2546	41.20

Table C-2. IRI obtained using ARRB with 25 ft interval

South Tangent Inside Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
25	102.00	25	111.70	25	94.80
50	93.10	50	85.70	50	92.50
75	66.90	75	57.00	75	70.30
100	53.40	100	60.10	100	53.70
125	72.40	125	80.90	125	74.90
150	30.80	150	33.20	150	35.60
175	32.50	175	32.40	175	40.70
200	122.80	200	106.70	200	109.70
225	139.60	225	142.20	225	142.40
250	97.90	250	77.00	250	100.50
275	41.60	275	41.90	275	29.60
300	34.70	300	34.40	300	63.30
325	56.90	325	48.40	325	60.50
350	33.00	350	65.70	350	67.70
375	57.20	375	49.70	375	62.50
400	96.30	400	75.70	400	70.20
425	52.40	425	68.80	425	63.70
450	57.20	450	55.30	450	47.50
475	42.20	475	32.50	475	29.60
500	40.80	500	39.50	500	39.40
525	39.90	525	39.10	525	33.20
550	41.00	550	30.60	550	34.70
575	63.00	575	34.20	575	33.60
600	128.50	600	125.30	600	113.80
625	41.20	625	65.00	625	72.10
650	35.80	650	38.90	650	34.90
675	28.10	675	34.50	675	18.90

700	25.40	700	25.80	700	30.50
725	40.60	725	29.00	725	30.30
750	49.70	750	34.70	750	20.10
775	45.80	775	41.10	775	33.70
800	170.40	800	133.50	800	110.80
825	73.90	825	95.10	825	106.50
850	135.80	850	127.90	850	130.30
875	66.20	875	131.40	875	121.90
900	43.10	900	63.60	900	85.60
925	35.10	925	30.80	925	57.00
950	24.00	950	35.50	950	20.20
975	85.30	975	65.70	975	61.70
1000	250.20	1000	271.90	1000	242.20
1025	120.00	1025	87.60	1025	103.20
1050	121.70	1050	131.00	1050	138.60
1075	56.50	1075	59.90	1075	96.70
1100	87.20	1100	67.00	1100	87.40
1125	66.80	1125	29.10	1125	40.10
1150	74.90	1150	58.60	1150	64.90
1175	117.30	1175	79.20	1175	55.80
1200	89.40	1200	106.60	1200	114.00
1225	57.30	1225	96.50	1225	80.00
1250	47.20	1250	46.30	1250	24.30
1275	39.30	1275	44.70	1275	38.00
1300	33.50	1300	22.00	1300	28.30
1325	31.80	1325	32.60	1325	23.00
1350	83.10	1350	56.20	1350	48.20
1375	165.20	1375	107.40	1375	88.90
1400	85.30	1400	117.50	1400	139.10
1425	58.10	1425	82.10	1425	78.20
1450	49.90	1450	68.20	1450	43.30
1475	39.70	1475	53.00	1475	38.80
1500	36.40	1500	25.00	1500	25.60
1525	51.20	1525	47.00	1525	47.90
1550	29.40	1550	29.60	1550	36.10
1575	241.30	1575	116.60	1575	40.50
1600	61.00	1600	196.00	1600	224.10
1625	34.90	1625	50.40	1625	58.80
1650	51.50	1650	33.90	1650	52.80
1675	42.40	1675	27.00	1675	23.60
1700	64.60	1700	38.40	1700	42.90
1725	49.00	1725	30.60	1725	42.00
1750	90.20	1750	32.40	1750	22.60
1775	199.60	1775	114.20	1775	61.30
1800	96.60	1800	154.70	1800	175.70
1825	37.20	1825	94.20	1825	87.80
1850	34.20	1850	37.70	1850	35.50

1875	38.80	1875	28.40	1875	28.20
1900	33.40	1900	31.20	1900	26.90
1925	31.70	1925	36.10	1925	17.20
1950	125.30	1950	28.50	1950	31.30
1975	239.10	1975	132.10	1975	109.40
2000	163.30	2000	214.20	2000	228.50
2025	96.10	2025	151.50	2025	128.60
2050	69.10	2050	105.40	2050	80.70
2075	37.20	2075	31.90	2075	47.80
2100	34.10	2100	46.60	2100	43.60
2125	55.20	2125	43.60	2125	33.50
2150	60.90	2150	40.10	2150	37.20
2175	64.60	2175	70.80	2175	61.30
2200	73.80	2200	41.20	2200	58.10
2225	27.70	2225	47.00	2225	38.80
2250	51.40	2250	77.70	2250	73.90
2275	57.00	2275	73.60	2275	42.90
2300	43.90	2300	62.30	2300	68.60
2325	52.50	2325	66.40	2325	57.40
2350	100.40	2350	47.00	2350	48.50
2375	89.90	2375	69.80	2375	92.40
2400	101.80	2400	100.20	2400	113.80
2425	84.60	2425	112.10	2425	113.10
2450	64.20	2450	109.20	2450	90.20
2475	46.50	2475	77.60	2475	76.10
2500	26.50	2500	52.40	2500	48.90
2536	40.30	2529	20.20	2535	32.00

Table C-3. IRI obtained using ARRB with 25 ft interval

North Tangent Subgrade Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
25	263.90	N/A	N/A	N/A	N/A
50	125.50	N/A	N/A	N/A	N/A
75	162.60	N/A	N/A	N/A	N/A
100	140.40	N/A	N/A	N/A	N/A
125	260.30	N/A	N/A	N/A	N/A
150	399.50	N/A	N/A	N/A	N/A
175	248.20	N/A	N/A	N/A	N/A
200	133.50	N/A	N/A	N/A	N/A
225	97.30	N/A	N/A	N/A	N/A
250	97.10	N/A	N/A	N/A	N/A
275	237.30	N/A	N/A	N/A	N/A
300	153.30	N/A	N/A	N/A	N/A
325	200.60	N/A	N/A	N/A	N/A

350	255.40	N/A	N/A	N/A	N/A
375	1944.90	N/A	N/A	N/A	N/A
400	491.30	N/A	N/A	N/A	N/A
425	315.10	N/A	N/A	N/A	N/A
450	207.90	N/A	N/A	N/A	N/A
475	158.90	N/A	N/A	N/A	N/A
500	97.40	N/A	N/A	N/A	N/A
525	152.40	N/A	N/A	N/A	N/A
550	156.00	N/A	N/A	N/A	N/A
575	91.80	N/A	N/A	N/A	N/A
600	112.70	N/A	N/A	N/A	N/A
625	165.20	N/A	N/A	N/A	N/A
650	177.40	N/A	N/A	N/A	N/A
675	164.30	N/A	N/A	N/A	N/A
700	201.30	N/A	N/A	N/A	N/A
725	218.90	N/A	N/A	N/A	N/A
750	1311.50	N/A	N/A	N/A	N/A
775	307.30	N/A	N/A	N/A	N/A
800	190.60	N/A	N/A	N/A	N/A
825	328.90	N/A	N/A	N/A	N/A
850	245.00	N/A	N/A	N/A	N/A
875	379.00	N/A	N/A	N/A	N/A
900	271.90	N/A	N/A	N/A	N/A
925	279.10	N/A	N/A	N/A	N/A
950	230.30	N/A	N/A	N/A	N/A
975	261.20	N/A	N/A	N/A	N/A
1000	184.50	N/A	N/A	N/A	N/A
1025	175.50	N/A	N/A	N/A	N/A
1050	268.10	N/A	N/A	N/A	N/A
1075	148.70	N/A	N/A	N/A	N/A
1100	86.70	N/A	N/A	N/A	N/A
1125	264.90	N/A	N/A	N/A	N/A
1150	234.50	N/A	N/A	N/A	N/A
1175	181.00	N/A	N/A	N/A	N/A
1200	362.90	N/A	N/A	N/A	N/A
1225	146.90	N/A	N/A	N/A	N/A
1250	142.00	N/A	N/A	N/A	N/A
1275	435.90	N/A	N/A	N/A	N/A
1300	172.10	N/A	N/A	N/A	N/A
1325	152.90	N/A	N/A	N/A	N/A
1350	225.50	N/A	N/A	N/A	N/A
1375	275.60	N/A	N/A	N/A	N/A
1400	371.70	N/A	N/A	N/A	N/A
1425	245.30	N/A	N/A	N/A	N/A
1450	127.70	N/A	N/A	N/A	N/A
1475	162.90	N/A	N/A	N/A	N/A
1500	360.90	N/A	N/A	N/A	N/A

1525	375.00	N/A	N/A	N/A	N/A
1550	457.30	N/A	N/A	N/A	N/A
1575	1369.70	N/A	N/A	N/A	N/A

Table C-4. IRI obtained using ARRB with 25 ft interval

North Tangent Granular Base Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
25	95.50	25	121.10	25	126.70
50	80.50	50	89.70	50	100.20
75	127.00	75	142.60	75	167.60
100	167.30	100	171.30	100	208.40
125	162.30	125	140.20	125	133.00
150	107.60	150	113.30	150	118.60
175	63.40	175	57.00	175	60.80
200	88.60	200	97.60	200	109.00
225	144.30	225	115.20	225	119.50
250	105.60	250	93.80	250	100.70
275	105.50	275	93.30	275	100.60
300	79.10	300	79.10	300	65.90
325	138.90	325	171.30	325	130.90
350	436.10	350	4842.10	350	8415.10
375	18706.50	375	14795.00	375	11524.40
400	3776.70	400	3961.40	400	3893.60
425	1352.70	425	1312.40	425	1305.80
450	639.90	450	714.20	450	701.00
475	572.10	475	403.90	475	465.30
500	322.30	500	362.10	500	282.80
525	202.00	525	142.80	525	166.00
550	174.10	550	167.50	550	165.70
575	126.60	575	134.90	575	93.40
600	127.60	600	83.00	600	120.00
625	131.20	625	149.20	625	141.10
650	122.80	650	124.30	650	120.80
675	189.90	675	174.70	675	219.20
700	122.80	700	113.20	700	128.80
725	201.90	725	197.20	725	192.20
750	1436.40	750	1516.50	750	1569.60
775	603.00	775	450.20	775	525.10
800	424.90	800	344.90	800	286.70
825	154.00	825	166.00	825	234.40
850	266.60	850	250.70	850	204.60
875	253.90	875	270.50	875	250.80

900	185.20	900	161.60	900	198.40
925	177.90	925	204.80	925	209.10
950	232.20	950	217.80	950	192.00
975	307.40	975	256.30	975	278.10
1000	243.10	1000	220.90	1000	153.80
1025	107.30	1025	136.40	1025	129.80
1050	179.70	1050	286.20	1050	240.20
1075	257.50	1075	148.80	1075	143.70
1100	176.40	1100	173.80	1100	204.50
1125	165.90	1125	145.90	1125	155.70
1150	223.40	1150	211.20	1150	173.50
1175	221.20	1175	215.20	1175	216.50
1200	97.50	1200	119.80	1200	117.20
1225	144.60	1225	173.20	1225	181.20
1250	289.00	1250	306.20	1250	294.30
1275	234.20	1275	233.30	1275	189.00
1300	169.90	1300	179.10	1300	142.10
1325	154.40	1325	128.70	1325	191.60
1350	252.50	1350	171.10	1350	163.60
1375	181.60	1375	158.50	1375	135.70
1400	179.20	1400	181.50	1400	122.10
1425	173.90	1425	130.50	1425	59.80
1450	114.90	1450	150.60	1450	204.50
1475	179.70	1475	140.30	1475	257.20
1500	250.90	1500	168.10	1500	129.10
1525	134.60	1525	187.10	1525	146.10
1545	319.70	1542	541.80	1559	840.00

Table C-5. IRI obtained using ARRB with 25 ft interval

North Tangent HMA Layer 2 Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
25	65.20	25	70.10	25	64.50
50	68.40	50	57.70	50	63.80
75	78.40	75	59.40	75	77.50
100	57.40	100	58.50	100	75.60
125	62.70	125	68.90	125	75.00
150	62.30	150	52.80	150	63.20
175	89.30	175	76.90	175	83.70
200	82.10	200	77.70	200	67.50
225	98.70	225	94.10	225	99.70
250	54.50	250	47.90	250	81.00
275	77.60	275	76.50	275	69.00
300	42.40	300	92.70	300	51.50
325	37.20	325	43.80	325	38.00

350	84.50	350	104.80	350	103.40
375	65.60	375	84.80	375	81.00
400	47.50	400	58.10	400	51.60
425	112.80	425	133.20	425	134.20
450	82.20	450	82.10	450	83.10
475	65.00	475	62.30	475	62.30
500	36.30	500	28.80	500	24.20
525	87.60	525	110.00	525	122.00
550	132.60	550	154.80	550	195.80
575	220.80	575	218.00	575	177.50
600	121.70	600	111.30	600	114.90
625	45.90	625	53.80	625	36.80
650	36.50	650	39.50	650	39.80
675	42.50	675	35.90	675	37.70
700	53.00	700	54.40	700	58.60
725	54.60	725	52.80	725	58.10
750	87.70	750	87.30	750	72.40
775	74.60	775	64.60	775	67.60
792	405.10	792	321.80	788	598.40

Table C-6. IRI obtained using ARRB with 25 ft interval

North Tangent HMA Layer 1 Reconstructed Lane					
Sample 1		**Sample 2**		**Sample 3**	
Distance (ft)	**IRI (in/mi)**	**Distance (ft)**	**IRI (in/mi)**	**Distance (ft)**	**IRI (in/mi)**
25	32.00	25	54.90	25	44.60
50	49.60	50	35.00	50	54.80
75	60.60	75	52.50	75	54.40
100	53.10	100	86.30	100	40.30
125	37.10	125	57.10	125	37.90
150	57.90	150	52.10	150	51.50
175	128.40	175	117.90	175	118.40
200	101.80	200	89.10	200	102.20
225	133.40	225	132.80	225	130.20
250	86.40	250	72.10	250	75.70
275	74.30	275	74.80	275	70.20
300	63.70	300	71.70	300	67.20
325	66.10	325	60.60	325	49.80
350	55.40	350	48.70	350	54.70
375	79.20	375	62.50	375	65.60
400	47.50	400	41.70	400	55.90
425	45.10	425	53.50	425	60.30
450	67.70	450	66.80	450	65.30
475	64.10	475	76.60	475	73.30
500	46.00	500	45.20	500	36.90
525	69.80	525	88.80	525	44.90

550	50.20	550	63.60	550	37.50
575	144.70	575	140.90	575	134.30
600	131.10	600	103.00	600	135.90
625	61.10	625	47.10	625	53.10
650	63.00	650	37.60	650	39.50
675	50.30	675	57.40	675	47.90
700	35.70	700	28.20	700	34.00
725	29.10	725	33.00	725	37.70
750	50.20	750	37.90	750	48.50
775	64.60	775	71.70	775	68.00
800	77.60	800	68.30	800	57.30
825	48.20	825	52.50	825	41.90
850	68.40	850	53.80	850	58.10
875	72.40	875	71.10	875	75.70
900	73.10	900	87.30	900	72.00
925	60.20	925	78.90	925	60.80
950	114.50	950	130.40	950	124.50
975	154.90	975	145.30	975	162.00
1000	113.00	1000	107.30	1000	115.20
1025	67.10	1025	102.70	1025	72.80
1050	57.80	1050	60.70	1050	54.60
1075	67.50	1075	64.00	1075	57.00
1100	78.90	1100	63.40	1100	84.70
1125	69.90	1125	72.30	1125	66.50
1150	83.00	1150	61.70	1150	56.30
1175	61.20	1175	57.20	1175	96.90
1200	114.70	1200	126.40	1200	101.00
1225	111.60	1225	115.30	1225	89.00
1250	61.00	1250	68.30	1250	80.80
1275	83.90	1275	91.50	1275	95.70
1300	64.20	1300	81.00	1300	105.10
1325	78.60	1325	86.10	1325	109.60
1350	101.50	1350	102.60	1350	101.10
1375	71.10	1375	74.80	1375	68.40
1400	48.30	1400	48.00	1400	37.50
1425	65.40	1425	42.90	1425	80.50
1450	79.10	1450	58.40	1450	75.20
1475	39.10	1475	67.60	1475	58.00
1500	59.00	1500	36.40	1500	73.40
1525	95.00	1525	82.80	1525	79.80
1550	65.70	1550	56.60	1550	64.10
1564	817.20	1564	793.80	1564	970.80

Table C-7. IRI obtained using ARRB with 25 ft interval

North Tangent Wearing Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
25	53.00	25	55.00	25	39.90
50	37.30	50	37.40	50	35.50
75	70.70	75	76.20	75	77.30
100	53.20	100	52.00	100	61.00
125	31.50	125	37.20	125	36.70
150	26.90	150	28.80	150	41.20
175	69.00	175	70.70	175	70.00
200	56.80	200	73.10	200	49.80
225	68.50	225	75.00	225	75.40
250	57.90	250	63.80	250	48.10
275	47.00	275	38.30	275	50.30
300	63.00	300	67.90	300	76.30
325	44.90	325	56.50	325	43.50
350	39.70	350	25.80	350	46.40
375	67.10	375	52.50	375	64.10
398	192.60	398	190.00	398	206.00

Table C-8. IRI obtained using ARRB with 52.8 ft interval

North Tangent Inside Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
52.8	94.60	52.8	100.10	52.8	105.70
105.6	54.30	105.6	66.00	105.6	65.40
158.4	55.80	158.4	56.00	158.4	44.20
211.2	88.40	211.2	91.10	211.2	94.70
264.0	131.40	264.0	144.10	264.0	115.00
316.8	56.50	316.8	57.20	316.8	53.10
369.6	44.00	369.6	46.70	369.6	39.80
422.4	84.70	422.4	82.50	422.4	74.30
475.2	57.60	475.2	50.30	475.2	61.70
528.0	31.20	528.0	44.10	528.0	41.10
580.8	33.20	580.8	34.60	580.8	38.10
633.6	96.20	633.6	86.70	633.6	83.20
686.4	43.60	686.4	57.20	686.4	38.20
739.2	28.30	739.2	49.10	739.2	27.80
792.0	36.40	792.0	61.40	792.0	37.00
844.8	108.60	844.8	65.10	844.8	82.10
897.6	46.00	897.6	52.60	897.6	42.80
950.4	28.50	950.4	35.40	950.4	28.80
1003.2	61.00	1003.2	118.50	1003.2	58.60

1056.0	148.00	1056.0	111.60	1056.0	139.00
1108.8	87.00	1108.8	51.50	1108.8	69.60
1161.6	50.70	1161.6	78.50	1161.6	33.60
1214.4	75.00	1214.4	183.50	1214.4	84.10
1267.2	56.40	1267.2	47.00	1267.2	68.70
1320.0	53.80	1320.0	40.80	1320.0	89.60
1372.8	49.20	1372.8	39.50	1372.8	52.30
1425.6	75.90	1425.6	100.90	1425.6	70.20
1478.4	94.30	1478.4	75.70	1478.4	85.10
1531.2	69.00	1531.2	43.20	1531.2	64.60
1584.0	107.30	1584.0	72.00	1584.0	50.50
1636.8	98.30	1636.8	110.40	1636.8	86.40
1689.6	61.90	1689.6	50.60	1689.6	68.40
1742.4	44.20	1742.4	39.90	1742.4	40.10
1795.2	70.40	1795.2	80.70	1795.2	52.00
1848.0	81.20	1848.0	68.90	1848.0	88.80
1900.8	50.20	1900.8	57.60	1900.8	66.60
1953.6	37.00	1953.6	46.70	1953.6	38.10
2006.4	71.20	2006.4	111.20	2006.4	60.50
2059.2	109.90	2059.2	66.50	2059.2	99.30
2112.0	54.70	2112.0	71.50	2112.0	55.20
2164.8	119.90	2164.8	136.50	2164.8	91.30
2217.6	126.60	2217.6	132.60	2217.6	138.80
2270.4	109.50	2270.4	51.10	2270.4	86.60
2323.2	60.40	2323.2	62.30	2323.2	54.90
2376.0	110.90	2376.0	92.10	2376.0	61.60
2428.8	161.20	2428.8	160.40	2428.8	133.60
2481.6	120.80	2481.6	93.00	2481.6	146.00
2534.4	61.40	2534.4	65.50	2534.4	52.80
2582.7	311.60	2559.7	648.90	2593.8	53.80

Table C-9. IRI obtained using ARRB with 52.8 ft interval

South Tangent Inside Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
52.8	96.10	52.8	97.00	52.8	93.40
105.6	64.90	105.6	66.50	105.6	67.00
158.4	43.10	158.4	44.30	158.4	47.00
211.2	110.50	211.2	96.90	211.2	101.20
264.0	81.40	264.0	81.60	264.0	90.20
316.8	46.40	316.8	41.10	316.8	56.50
369.6	45.00	369.6	53.60	369.6	58.40
422.4	74.10	422.4	77.10	422.4	71.60
475.2	47.10	475.2	41.50	475.2	38.50
528.0	40.80	528.0	38.80	528.0	35.30

580.8	52.30	580.8	32.90	580.8	34.90
633.6	83.20	633.6	90.80	633.6	89.10
686.4	30.20	686.4	37.70	686.4	30.00
739.2	32.80	739.2	26.70	739.2	26.30
792.0	85.50	792.0	38.50	792.0	27.70
844.8	105.90	844.8	134.70	844.8	125.30
897.6	79.30	897.6	111.60	897.6	111.10
950.4	28.60	950.4	36.00	950.4	57.40
1003.2	157.50	1003.2	129.90	1003.2	111.60
1056.0	116.60	1056.0	131.30	1056.0	148.30
1108.8	73.40	1108.8	70.50	1108.8	91.80
1161.6	70.00	1161.6	44.20	1161.6	51.60
1214.4	104.20	1214.4	95.40	1214.4	87.20
1267.2	47.10	1267.2	68.00	1267.2	46.10
1320.0	33.00	1320.0	31.00	1320.0	34.00
1372.8	77.40	1372.8	53.50	1372.8	44.60
1425.6	112.10	1425.6	111.60	1425.6	117.00
1478.4	49.00	1478.4	62.70	1478.4	39.50
1531.2	42.40	1531.2	40.60	1531.2	44.40
1584.0	119.30	1584.0	37.30	1584.0	32.50
1636.8	58.70	1636.8	154.90	1636.8	139.80
1689.6	45.90	1689.6	29.90	1689.6	38.70
1742.4	55.40	1742.4	35.10	1742.4	41.20
1795.2	146.80	1795.2	93.80	1795.2	64.30
1848.0	58.70	1848.0	97.10	1848.0	107.60
1900.8	37.10	1900.8	33.90	1900.8	26.70
1953.6	37.90	1953.6	32.20	1953.6	22.10
2006.4	198.50	2006.4	147.50	2006.4	132.20
2059.2	111.90	2059.2	128.10	2059.2	129.80
2112.0	34.90	2112.0	54.10	2112.0	50.30
2164.8	54.00	2164.8	40.60	2164.8	34.90
2217.6	70.80	2217.6	55.30	2217.6	56.60
2270.4	42.90	2270.4	60.60	2270.4	56.90
2323.2	51.20	2323.2	70.30	2323.2	57.20
2376.0	77.90	2376.0	57.50	2376.0	50.20
2428.8	86.40	2428.8	91.70	2428.8	105.90
2481.6	73.10	2481.6	105.50	2481.6	96.90
2534.4	38.10	2534.4	47.50	2534.4	55.90
2557.4	1028.50	2575.6	549.10	2581.9	523.70

Table C-10. IRI obtained using ARRB with 52.8 ft interval

North Tangent Subgrade Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
52.8	194.50	N/A	N/A	N/A	N/A
105.6	144.80	N/A	N/A	N/A	N/A
158.4	348.50	N/A	N/A	N/A	N/A
211.2	157.90	N/A	N/A	N/A	N/A
264.0	144.70	N/A	N/A	N/A	N/A
316.8	183.90	N/A	N/A	N/A	N/A
369.6	959.70	N/A	N/A	N/A	N/A
422.4	475.30	N/A	N/A	N/A	N/A
475.2	191.60	N/A	N/A	N/A	N/A
528.0	131.10	N/A	N/A	N/A	N/A
580.8	121.50	N/A	N/A	N/A	N/A
633.6	138.60	N/A	N/A	N/A	N/A
686.4	168.60	N/A	N/A	N/A	N/A
739.2	286.30	N/A	N/A	N/A	N/A
792.0	704.90	N/A	N/A	N/A	N/A
844.8	282.20	N/A	N/A	N/A	N/A
897.6	291.30	N/A	N/A	N/A	N/A
950.4	291.00	N/A	N/A	N/A	N/A
1003.2	224.30	N/A	N/A	N/A	N/A
1056.0	204.50	N/A	N/A	N/A	N/A
1108.8	131.10	N/A	N/A	N/A	N/A
1161.6	244.90	N/A	N/A	N/A	N/A
1214.4	271.70	N/A	N/A	N/A	N/A
1267.2	132.50	N/A	N/A	N/A	N/A
1320.0	307.40	N/A	N/A	N/A	N/A
1372.8	221.10	N/A	N/A	N/A	N/A
1425.6	325.90	N/A	N/A	N/A	N/A
1478.4	135.00	N/A	N/A	N/A	N/A
1531.2	303.40	N/A	N/A	N/A	N/A
1588.2	674.10	N/A	N/A	N/A	N/A

Table C-11. IRI obtained using ARRB with 52.8 ft interval

North Tangent Granular Base Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
52.8	91.30	52.8	108.60	52.8	113.70
105.6	153.80	105.6	161.70	105.6	198.20
158.4	117.40	158.4	110.50	158.4	103.90
211.2	81.50	211.2	93.60	211.2	109.20
264.0	128.00	264.0	95.70	264.0	93.50

316.8	90.70	316.8	100.90	316.8	91.90
369.6	8371.10	369.6	8967.80	369.6	9208.20
422.4	3052.90	422.4	2789.80	422.4	2677.30
475.2	727.20	475.2	679.00	475.2	661.30
528.0	305.90	528.0	269.70	528.0	255.60
580.8	146.20	580.8	149.90	580.8	126.30
633.6	130.70	633.6	113.90	633.6	136.60
686.4	147.00	686.4	152.30	686.4	168.20
739.2	173.10	739.2	235.60	739.2	295.10
792.0	1036.50	792.0	935.70	792.0	902.40
844.8	271.00	844.8	216.60	844.8	247.10
897.6	225.10	897.6	224.40	897.6	210.30
950.4	192.60	950.4	202.40	950.4	207.10
1003.2	285.80	1003.2	253.80	1003.2	226.10
1056.0	129.40	1056.0	163.90	1056.0	178.30
1108.8	226.20	1108.8	195.30	1108.8	164.80
1161.6	189.80	1161.6	176.60	1161.6	166.00
1214.4	155.70	1214.4	170.50	1214.4	176.00
1267.2	222.40	1267.2	237.40	1267.2	237.20
1320.0	189.30	1320.0	187.70	1320.0	156.50
1372.8	196.50	1372.8	154.50	1372.8	170.90
1425.6	204.80	1425.6	181.70	1425.6	111.50
1478.4	153.10	1478.4	136.90	1478.4	194.20
1531.2	181.90	1531.2	163.40	1531.2	147.70
1583.5	1248.50	1580.3	1311.10	1572.4	1585.30

Table C-12. IRI obtained using ARRB with 52.8 ft interval

North Tangent HMA Layer 2 Reconstructed Lane					
Sample 1		**Sample 2**		**Sample 3**	
Distance (ft)	**IRI (in/mi)**	**Distance (ft)**	**IRI (in/mi)**	**Distance (ft)**	**IRI (in/mi)**
52.8	71.10	52.8	69.80	52.8	69.00
105.6	61.60	105.6	51.70	105.6	70.50
158.4	72.20	158.4	69.60	158.4	75.10
211.2	75.10	211.2	66.00	211.2	67.80
264.0	79.40	264.0	73.50	264.0	90.60
316.8	53.80	316.8	82.50	316.8	56.60
369.6	67.90	369.6	87.20	369.6	86.10
422.4	67.60	422.4	80.00	422.4	74.90
475.2	81.50	475.2	83.60	475.2	83.90
528.0	64.60	528.0	69.90	528.0	75.10
580.8	172.60	580.8	183.30	580.8	181.40
633.6	79.30	633.6	78.60	633.6	72.50
686.4	41.30	686.4	39.00	686.4	40.40
739.2	61.60	739.2	60.70	739.2	61.30
798.6	73.30	798.6	69.10	794.6	65.40

Table C-13. IRI obtained using ARRB with 52.8 ft interval

North Tangent HMA Layer 1 Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
52.8	41.70	52.8	44.60	52.8	50.30
105.6	54.40	105.6	70.30	105.6	45.60
158.4	51.80	158.4	57.40	158.4	49.70
211.2	114.60	211.2	106.90	211.2	112.30
264.0	111.10	264.0	94.60	264.0	99.80
316.8	63.30	316.8	74.20	316.8	61.40
369.6	70.10	369.6	54.70	369.6	60.50
422.4	45.90	422.4	44.60	422.4	55.00
475.2	67.20	475.2	72.70	475.2	71.20
528.0	55.30	528.0	65.50	528.0	40.50
580.8	96.30	580.8	101.20	580.8	84.00
633.6	94.50	633.6	72.40	633.6	90.20
686.4	54.10	686.4	48.00	686.4	45.80
739.2	37.50	739.2	30.90	739.2	37.50
792.0	60.90	792.0	61.10	792.0	61.80
844.8	62.90	844.8	58.60	844.8	49.10
897.6	69.50	897.6	73.30	897.6	70.00
950.4	51.40	950.4	74.10	950.4	51.80
1003.2	167.70	1003.2	151.80	1003.2	174.10
1056.0	62.90	1056.0	79.00	1056.0	66.10
1108.8	73.00	1108.8	67.00	1108.8	68.30
1161.6	77.00	1161.6	65.80	1161.6	62.20
1214.4	91.90	1214.4	100.10	1214.4	99.20
1267.2	86.00	1267.2	93.70	1267.2	93.00
1320.0	64.30	1320.0	73.60	1320.0	97.50
1372.8	92.70	1372.8	91.30	1372.8	94.30
1425.6	51.90	1425.6	56.20	1425.6	63.50
1478.4	70.80	1478.4	62.50	1478.4	65.00
1531.2	73.60	1531.2	58.00	1531.2	77.60
1577.9	300.90	1577.9	289.40	1577.9	347.50

Table C-14. IRI obtained using ARRB with 52.8 ft interval

North Tangent Wearing Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
52.8	45.30	52.8	46.10	52.8	38.2
105.6	59.00	105.6	64.50	105.6	67.9
158.4	39.30	158.4	39.50	158.4	46.5
211.2	51.40	211.2	61.00	211.2	51.6
264.0	64.40	264.0	70.60	264.0	63

316.8	60.30	316.8	60.30	316.8	63
369.6	44.60	369.6	38.80	369.6	50.3
401.3	159.50	401.3	149.10	402.1	166.3

Table C-15. IRI obtained using ARRB with 528 ft interval

North Tangent Inside Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
528	70.10	528	73.90	528	69.70
1056	62.20	1056	67.20	1056	57.00
1584	72.80	1584	73.10	1584	67.30
2112	67.40	2112	70.70	2112	65.50
2594	128.70	2571	129.60	2605	115.80

Table C-16. IRI obtained using ARRB with 528 ft interval

South Tangent Inside Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
528	65	528	63.90	528	66.00
1056	76.7	1056	76.70	1056	76.20
1584	66.1	1584	62.10	1584	59.20
2112	86.4	2112	80.50	2112	75.20
2569	111.4	2587	108.60	2594	110.10

Table C-17. IRI obtained using ARRB with 528 ft interval

North Tangent Subgrade Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
528	294.00	N/A	N/A	N/A	N/A
1056	269.60	N/A	N/A	N/A	N/A
1595	265.20	N/A	N/A	N/A	N/A

Table C-18. IRI obtained using ARRB with 528 ft interval

North Tangent Granular Base Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
528	1316.90	528	1342.60	528	1356.50
1056	273.70	1056	264.50	1056	267.30
1591	223.70	1587	214.20	1579	285.80

Table C-19. IRI obtained using ARRB with 528 ft interval

North Tangent HMA Layer 2 Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
528	69.70	528	73.30	528	74.80
802	106.40	802	102.00	798	111.30

Table C-20. IRI obtained using ARRB with 528 ft interval

North Tangent HMA Layer 1 Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
528	67.50	528	68.50	528	64.90
1056	76.30	1056	75.40	1056	73.00
1585	76.10	1585	74.70	1585	82.50

Table C-21. IRI obtained using ARRB with 528 ft interval

North Tangent Wearing Reconstructed Lane					
Sample 1		Sample 2		Sample 3	
Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)	Distance (ft)	IRI (in/mi)
403	60.70	403	62.00	404	63.60

Table C-22. Profile Index obtained with ARRB Profiler

0.0 in. Blanking Band						
	Sample 1		Sample 2		Sample 3	
Layer Profiled	*Segment	ProfiIe Index, in/mile	*Segment	ProfiIe Index, in/mile	*Segment	ProfiIe Index, in/mile
North Tangent	1	27.92	1	29.47	1	27.92
	2	26.54	2	28.04	2	27.04
	3	26.54	3	31.54	3	28.54
	4	28.04	4	31.54	4	28.04
	5	44.24	5	38.78	5	34.34
South Tangent	1	25.33	1	24.82	1	22.23
	2	28.04	2	28.54	2	25.54
	3	27.04	3	27.54	3	21.53
	4	32.05	4	34.55	4	26.04
	5	19.79	5	20.73	5	22.16
Wearing	1	17.85	1	21.42	1	20.66
HMA Base Layer 1	1	24.30	1	24.30	1	25.85
	2	29.04	2	28.54	2	26.04
	3	26.29	3	27.32	3	28.35
HMA Base Layer 2	1	23.27	1	25.33	1	24.30
	2	31.81	2	26.68	2	32.31
Granular Base	1	471.52	1	483.93	1	493.75
	2	84.12	2	83.12	2	81.12
	3	82.09	3	75.93	3	80.24
Subgrade	1	115.29	1	N/A	1	N/A
	2	100.14	2	N/A	2	N/A
	3	92.97	3	N/A	3	N/A

***Segment = 0.1 mile interval (528 ft)**

Table C-23. Profile Index obtained with ARRB Profiler

0.1 in. Blanking Band						
	Sample 1		Sample 2		Sample 3	
Layer Profiled	*Segment	ProfiIe Index, in/mile	*Segment	ProfiIe Index, in/mile	*Segment	ProfiIe Index, in/mile
North Tangent	1	14.99	1	14.48	1	15.51
	2	17.52	2	18.53	2	16.52
	3	13.52	3	19.03	3	11.52
	4	15.02	4	18.03	4	15.02
	5	30.63	5	25.06	5	23.82
South Tangent	1	12.41	1	11.37	1	14.48
	2	16.02	2	19.03	2	20.03
	3	12.02	3	11.52	3	8.01
	4	17.52	4	20.03	4	17.52
	5	7.80	5	9.22	5	9.66
Wearing	1	6.43	1	8.57	1	9.26
HMA Base Layer 1	1	12.93	1	14.99	1	10.86
	2	18.53	2	18.53	2	16.52
	3	12.37	3	12.37	3	15.46
HMA Base Layer 2	1	12.93	1	14.48	1	11.89
	2	16.42	2	17.44	2	18.76
Granular Base	1	458.59	1	466.35	1	477.72
	2	67.10	2	66.09	2	60.09
	3	70.37	3	66.18	3	74.51
Subgrade	1	99.78	1	N/A	1	N/A
	2	87.62	2	N/A	2	N/A
	3	82.36	3	N/A	3	N/A

***Segment = 0.1 mile interval (528 ft)**

Table C-24. Profile Index obtained with ARRB Profiler

0.2 in. Blanking Band						
	Sample 1		Sample 2		Sample 3	
Layer Profiled	*Segment	ProfiIe Index, in/mile	*Segment	ProfiIe Index, in/mile	*Segment	ProfiIe Index, in/mile
North Tangent	1	6.72	1	7.24	1	7.24
	2	10.51	2	9.51	2	8.51
	3	5.01	3	10.51	3	3.50
	4	7.51	4	8.51	4	6.51
	5	22.12	5	17.30	5	14.96
South Tangent	1	5.69	1	5.17	1	5.69
	2	10.51	2	12.02	2	12.02
	3	4.51	3	4.01	3	4.01
	4	12.52	4	13.02	4	12.02
	5	3.00	5	2.88	5	2.84
Wearing	1	1.43	1	2.14	1	3.56
HMA Base Layer 1	1	4.65	1	5.17	1	3.62
	2	10.01	2	10.01	2	9.51
	3	3.61	3	4.64	3	6.19
HMA Base Layer 2	1	4.65	1	5.69	1	7.24
	2	10.26	2	12.31	2	11.46
Granular Base	1	449.29	1	453.42	1	459.11
	2	49.57	2	51.07	2	43.56
	3	55.58	3	52.84	3	57.32
Subgrade	1	80.14	1	N/A	1	N/A
	2	72.60	2	N/A	2	N/A
	3	68.72	3	N/A	3	N/A

***Segment = 0.1 mile interval (528 ft)**

APPENDIX D

Table D-1. Raw Data Collected with ARAN Van

North Tangent 45 MPH					
Sample 1		Sample 2		Sample 3	
Distance	Profile Height	Distance	Profile Height	Distance	Profile Height
ft	in	ft	in	ft	in
0.0000	-0.3350	0.0000	-0.2429	0.0000	-0.0421
0.3374	-0.3445	0.3374	-0.2508	0.3374	-0.0508
0.6748	-0.3535	0.6748	-0.2610	0.6748	-0.0587
1.0122	-0.3634	1.0122	-0.2713	1.0122	-0.0665
1.3496	-0.3713	1.3496	-0.2831	1.3496	-0.0744
1.6870	-0.3787	1.6870	-0.2898	1.6870	-0.0807
2.0244	-0.3925	2.0244	-0.2914	2.0244	-0.0878
2.3618	-0.3965	2.3618	-0.2925	2.3618	-0.0870
2.6992	-0.3925	2.6992	-0.2925	2.6992	-0.0843
3.0366	-0.3976	3.0366	-0.2945	3.0366	-0.0854
3.3740	-0.4063	3.3740	-0.2976	3.3740	-0.0890
3.7114	-0.4161	3.7114	-0.2996	3.7114	-0.1008

Table D-2. Raw Data Collected with ARAN Van

South Tangent 45 MPH					
Sample 1		Sample 2		Sample 3	
Distance	Profile Height	Distance	Profile Height	Distance	Profile Height
ft	in	ft	in	ft	in
0.0000	-0.3095	0.0000	-0.3095	0.0000	-0.3004
0.3374	-0.3150	0.3374	-0.3063	0.3374	-0.3225
0.6748	-0.3201	0.6748	-0.3059	0.6748	-0.3402
1.0122	-0.3209	1.0122	-0.3158	1.0122	-0.3394
1.3496	-0.3197	1.3496	-0.3256	1.3496	-0.3315
1.6870	-0.3252	1.6870	-0.3299	1.6870	-0.3339
2.0244	-0.3362	2.0244	-0.3339	2.0244	-0.3449
2.3618	-0.3378	2.3618	-0.3433	2.3618	-0.3622
2.6992	-0.3394	2.6992	-0.3461	2.6992	-0.3673
3.0366	-0.3520	3.0366	-0.3457	3.0366	-0.3662
3.3740	-0.3579	3.3740	-0.3504	3.3740	-0.3776
3.7114	-0.3488	3.7114	-0.3508	3.7114	-0.3862

Table D-3. Raw Data Collected with ARAN Van

North Tangent 15 MPH					
Sample 1		Sample 2		Sample 3	
Distance	Profile Height	Distance	Profile Height	Distance	Profile Height
ft	in	ft	in	ft	in
0.0000	-1.58584	0.0000	-0.15277	0.0000	0.67952
0.3374	-1.58269	0.3374	-0.15001	0.3374	0.67243
0.6748	-1.58623	0.6748	-0.14450	0.6748	0.66495
1.0122	-1.58938	1.0122	-0.13702	1.0122	0.65904
1.3496	-1.58899	1.3496	-0.13663	1.3496	0.65156
1.6870	-1.58820	1.6870	-0.14292	1.6870	0.64172
2.0244	-1.59175	2.0244	-0.14450	2.0244	0.63345
2.3618	-1.59647	2.3618	-0.14135	2.3618	0.62834
2.6992	-1.59726	2.6992	-0.14096	2.6992	0.62440
3.0366	-1.59411	3.0366	-0.14332	3.0366	0.62046
3.3740	-1.59253	3.3740	-0.14804	3.3740	0.61613
3.7114	-1.59214	3.7114	-0.15395	3.7114	0.61180

Table D-4. Raw Data Collected with ARAN Van

South Tangent 15 MPH					
Sample 1		Sample 2		Sample 3	
Distance	Profile Height	Distance	Profile Height	Distance	Profile Height
ft	in	ft	in	ft	in
0.0000	0.83345	0.0000	0.22597	0.0000	0.93267
0.3374	0.83621	0.3374	0.21416	0.3374	0.91810
0.6748	0.83424	0.6748	0.21967	0.6748	0.92401
1.0122	0.83385	1.0122	0.23778	1.0122	0.91613
1.3496	0.80904	1.3496	0.24999	1.3496	0.87597
1.6870	0.77597	1.6870	0.25668	1.6870	0.83385
2.0244	0.77282	2.0244	0.26416	2.0244	0.80314
2.3618	0.77991	2.3618	0.27361	2.3618	0.78149
2.6992	0.76259	2.6992	0.28148	2.6992	0.77991
3.0366	0.72322	3.0366	0.28896	3.0366	0.77440
3.3740	0.68660	3.3740	0.29959	3.3740	0.74960
3.7114	0.65668	3.7114	0.30786	3.7114	0.73306

APPENDIX E

Table E-1. IRI Obtained with ARAN Van with 52.8 ft Interval

North Tangent @ 45 MPH					
Sample 1		Sample 2		Sample 3	
Distance	IRI	Distance	IRI	Distance	IRI
ft.	in/mile	ft.	in/mile	ft.	in/mile
52.8	67.40	52.8	75.40	52.8	67.20
105.6	51.90	105.6	58.30	105.6	58.50
158.4	57.40	158.4	60.70	158.4	62.70
211.2	145.20	211.2	140.50	211.2	144.00
264.0	72.50	264.0	73.50	264.0	66.10
316.8	40.60	316.8	40.00	316.8	37.00
369.6	60.40	369.6	59.40	369.6	56.50
422.4	73.30	422.4	71.80	422.4	65.90
475.2	49.10	475.2	43.20	475.2	47.60
528.0	30.50	528.0	26.20	528.0	36.00
580.8	82.70	580.8	78.20	580.8	75.60
633.6	42.30	633.6	46.00	633.6	44.20
686.4	36.90	686.4	34.80	686.4	29.10
739.2	40.90	739.2	35.60	739.2	29.50
792.0	79.90	792.0	81.80	792.0	79.60
844.8	79.00	844.8	72.60	844.8	69.70
897.6	37.60	897.6	36.50	897.6	36.60
950.4	34.50	950.4	30.90	950.4	30.50
1003.2	130.40	1003.2	125.20	1003.2	133.90
1056.0	94.30	1056.0	97.40	1056.0	94.10
1108.8	50.00	1108.8	47.60	1108.8	46.50
1161.6	40.30	1161.6	38.30	1161.6	38.20
1214.4	88.40	1214.4	86.10	1214.4	90.00
1267.2	46.30	1267.2	45.40	1267.2	50.30
1320.0	39.30	1320.0	37.90	1320.0	38.90
1372.8	55.30	1372.8	47.20	1372.8	56.10
1425.6	89.60	1425.6	79.90	1425.6	92.80
1478.4	57.50	1478.4	52.30	1478.4	60.70
1531.2	36.00	1531.2	34.00	1531.2	36.10
1584.0	73.50	1584.0	69.80	1584.0	70.10
1636.8	73.70	1636.8	77.00	1636.8	75.90
1689.6	49.70	1689.6	51.80	1689.6	54.90
1742.4	39.80	1742.4	42.70	1742.4	46.20
1795.2	79.60	1795.2	76.10	1795.2	83.10
1848.0	61.30	1848.0	62.30	1848.0	63.30
1900.8	38.90	1900.8	34.90	1900.8	35.30
1953.6	34.50	1953.6	44.20	1953.6	48.00
2006.4	105.90	2006.4	102.40	2006.4	105.70
2059.2	68.90	2059.2	73.70	2059.2	70.10
2112.0	53.40	2112.0	52.90	2112.0	56.90
2164.8	138.20	2164.8	135.00	2164.8	135.30

2217.6	133.00	2217.6	130.70	2217.6	132.90
2270.4	48.30	2270.4	45.80	2270.4	59.10
2323.2	61.10	2323.2	63.60	2323.2	66.90
2376.0	80.90	2376.0	78.10	2376.0	82.00
2428.8	153.70	2428.8	156.20	2428.8	160.40
2481.6	86.70	2481.6	85.20	2481.6	89.60
2534.4	44.50	2534.4	51.80	2534.4	47.90
2587.2	128.00	2587.2	130.60	2587.2	131.20
2640.0	153.80	2640.0	156.00	2640.0	154.70

Table E-2. IRI Obtained with ARAN Van with 52.8 ft Interval

North Tangent @ 15 MPH					
Sample 1		**Sample 2**		**Sample 3**	
Distance	**IRI**	**Distance**	**IRI**	**Distance**	**IRI**
ft.	**in/mile**	**ft.**	**in/mile**	**ft.**	**in/mile**
52.8	68.70	52.8	112.60	52.8	66.00
105.6	65.60	105.6	76.90	105.6	54.40
158.4	112.10	158.4	37.70	158.4	62.40
211.2	77.70	211.2	59.80	211.2	148.60
264.0	61.70	264.0	141.10	264.0	74.00
316.8	61.00	316.8	66.80	316.8	46.60
369.6	94.50	369.6	34.60	369.6	62.00
422.4	97.80	422.4	53.90	422.4	70.10
475.2	81.50	475.2	69.80	475.2	60.50
528.0	60.60	528.0	43.90	528.0	49.80
580.8	126.20	580.8	25.90	580.8	81.50
633.6	72.50	633.6	79.30	633.6	48.20
686.4	90.30	686.4	51.00	686.4	28.90
739.2	75.90	739.2	52.90	739.2	37.80
792.0	81.30	792.0	40.50	792.0	80.70
844.8	60.90	844.8	83.40	844.8	88.50
897.6	63.90	897.6	75.80	897.6	32.30
950.4	50.90	950.4	35.20	950.4	26.80
1003.2	136.80	1003.2	38.10	1003.2	133.50
1056.0	67.00	1056.0	138.00	1056.0	97.70
1108.8	55.00	1108.8	100.90	1108.8	44.90
1161.6	75.50	1161.6	49.60	1161.6	46.60
1214.4	71.40	1214.4	42.60	1214.4	94.60
1267.2	63.30	1267.2	91.40	1267.2	51.00
1320.0	58.30	1320.0	49.40	1320.0	35.90
1372.8	77.80	1372.8	38.50	1372.8	59.00
1425.6	70.20	1425.6	52.70	1425.6	90.40
1478.4	61.60	1478.4	87.90	1478.4	57.70
1531.2	67.10	1531.2	56.30	1531.2	32.20
1584.0	100.30	1584.0	41.40	1584.0	90.90

1636.8	89.40	1636.8	101.40	1636.8	75.30
1689.6	76.40	1689.6	75.50	1689.6	51.30
1742.4	83.80	1742.4	53.20	1742.4	46.60
1795.2	118.20	1795.2	45.80	1795.2	82.30
1848.0	81.50	1848.0	87.40	1848.0	73.50
1900.8	63.60	1900.8	60.20	1900.8	39.00
1953.6	60.40	1953.6	36.70	1953.6	46.80
2006.4	173.40	2006.4	37.80	2006.4	122.20
2059.2	88.60	2059.2	130.00	2059.2	76.90
2112.0	85.50	2112.0	79.40	2112.0	69.20
2164.8	163.30	2164.8	54.50	2164.8	137.60
2217.6	127.70	2217.6	134.80	2217.6	152.20
2270.4	92.50	2270.4	131.00	2270.4	66.30
2323.2	96.20	2323.2	52.60	2323.2	77.10
2376.0	154.50	2376.0	67.70	2376.0	64.60
2428.8	147.40	2428.8	103.30	2428.8	173.90
2481.6	98.10	2481.6	153.40	2481.6	97.30
2534.4	107.30	2534.4	93.70	2534.4	65.10
2587.2	138.60	2587.2	62.10	2587.2	141.50
2640.0	128.50	2640.0	142.10	2640.0	161.30

Table E-3. IRI Obtained with ARAN Van with 52.8 ft Interval

South Tangent @ 45 MPH					
Sample 1		**Sample 2**		**Sample 3**	
Distance	**IRI**	**Distance**	**IRI**	**Distance**	**IRI**
ft.	**in/mile**	**ft.**	**in/mile**	**ft.**	**in/mile**
52.8	35.60	52.8	38.50	52.8	45.40
105.6	45.60	105.6	35.20	105.6	33.20
158.4	76.40	158.4	73.90	158.4	80.10
211.2	40.60	211.2	45.00	211.2	47.40
264.0	27.00	264.0	29.60	264.0	30.40
316.8	31.90	316.8	27.60	316.8	28.80
369.6	104.10	369.6	79.20	369.6	78.50
422.4	31.90	422.4	57.40	422.4	58.00
475.2	24.40	475.2	24.20	475.2	36.10
528.0	18.90	528.0	21.20	528.0	18.40
580.8	89.70	580.8	92.90	580.8	88.20
633.6	112.90	633.6	116.70	633.6	105.00
686.4	42.50	686.4	45.20	686.4	42.60
739.2	38.90	739.2	32.70	739.2	35.90
792.0	170.00	792.0	157.70	792.0	147.50
844.8	88.30	844.8	98.30	844.8	100.80
897.6	58.10	897.6	56.70	897.6	54.20
950.4	72.40	950.4	61.30	950.4	61.10
1003.2	69.10	1003.2	67.00	1003.2	76.30

1056.0	40.80	1056.0	39.70	1056.0	40.00
1108.8	25.00	1108.8	21.10	1108.8	15.30
1161.6	119.10	1161.6	111.20	1161.6	100.20
1214.4	59.70	1214.4	73.70	1214.4	68.50
1267.2	39.70	1267.2	35.10	1267.2	40.80
1320.0	35.30	1320.0	35.50	1320.0	37.10
1372.8	154.80	1372.8	151.90	1372.8	150.10
1425.6	60.40	1425.6	48.80	1425.6	47.90
1478.4	27.60	1478.4	29.80	1478.4	30.00
1531.2	28.00	1531.2	28.10	1531.2	27.80
1584.0	132.00	1584.0	114.80	1584.0	109.30
1636.8	42.70	1636.8	53.10	1636.8	57.80
1689.6	23.70	1689.6	27.30	1689.6	19.90
1742.4	42.50	1742.4	39.80	1742.4	33.30
1795.2	192.90	1795.2	189.20	1795.2	178.00
1848.0	81.20	1848.0	93.10	1848.0	94.00
1900.8	31.90	1900.8	37.00	1900.8	36.50
1953.6	51.90	1953.6	45.00	1953.6	43.90
2006.4	48.90	2006.4	43.00	2006.4	56.90
2059.2	28.20	2059.2	34.90	2059.2	41.10
2112.0	51.80	2112.0	36.00	2112.0	47.10
2164.8	64.20	2164.8	64.70	2164.8	62.10
2217.6	93.50	2217.6	84.00	2217.6	87.80
2270.4	82.40	2270.4	80.80	2270.4	78.30
2323.2	46.00	2323.2	41.70	2323.2	43.10
2376.0	64.10	2376.0	46.50	2376.0	43.60
2428.8	58.50	2428.8	58.20	2428.8	63.90
2481.6	64.70	2481.6	62.10	2481.6	61.60
2534.4	43.60	2534.4	38.30	2534.4	45.20
2587.2	90.70	2587.2	87.80	2587.2	91.10
2640.0	35.20	2640.0	40.20	2640.0	37.80

Table E-4. IRI Obtained with ARAN Van with 52.8 ft Interval

South Tangent @ 15 MPH					
Sample 1		**Sample 2**		**Sample 3**	
Distance	**IRI**	**Distance**	**IRI**	**Distance**	**IRI**
ft.	**in/mile**	**ft.**	**in/mile**	**ft.**	**in/mile**
52.8	96.70	52.8	138.30	52.8	107.70
105.6	49.10	105.6	84.50	105.6	58.00
158.4	58.10	158.4	55.00	158.4	50.00
211.2	93.80	211.2	60.00	211.2	73.90
264.0	99.10	264.0	82.60	264.0	98.10
316.8	53.40	316.8	30.60	316.8	25.90
369.6	62.30	369.6	37.00	369.6	38.70
422.4	107.50	422.4	72.50	422.4	71.10

475.2	50.80	475.2	46.20	475.2	37.50
528.0	55.70	528.0	31.40	528.0	27.80
580.8	49.40	580.8	29.50	580.8	31.90
633.6	98.50	633.6	82.50	633.6	89.70
686.4	65.50	686.4	53.50	686.4	43.80
739.2	54.30	739.2	31.30	739.2	26.00
792.0	45.20	792.0	27.30	792.0	21.00
844.8	121.80	844.8	87.60	844.8	90.50
897.6	49.10	897.6	112.50	897.6	110.90
950.4	56.00	950.4	44.80	950.4	38.90
1003.2	51.30	1003.2	33.00	1003.2	37.50
1056.0	159.60	1056.0	173.70	1056.0	182.80
1108.8	65.40	1108.8	108.10	1108.8	80.60
1161.6	70.90	1161.6	61.50	1161.6	51.20
1214.4	116.10	1214.4	70.00	1214.4	72.50
1267.2	108.70	1267.2	81.80	1267.2	62.60
1320.0	59.00	1320.0	51.00	1320.0	31.90
1372.8	55.00	1372.8	36.90	1372.8	30.80
1425.6	156.90	1425.6	118.80	1425.6	115.50
1478.4	75.90	1478.4	78.50	1478.4	64.00
1531.2	59.10	1531.2	66.70	1531.2	30.90
1584.0	58.10	1584.0	57.10	1584.0	30.50
1636.8	232.70	1636.8	159.60	1636.8	147.90
1689.6	60.90	1689.6	54.60	1689.6	56.70
1742.4	119.80	1742.4	48.80	1742.4	32.00
1795.2	105.10	1795.2	49.40	1795.2	36.20
1848.0	272.10	1848.0	112.50	1848.0	163.10
1900.8	56.00	1900.8	79.80	1900.8	46.90
1953.6	46.80	1953.6	79.40	1953.6	27.50
2006.4	172.10	2006.4	56.70	2006.4	48.10
2059.2	127.10	2059.2	188.10	2059.2	195.10
2112.0	47.90	2112.0	94.90	2112.0	79.70
2164.8	46.30	2164.8	33.60	2164.8	34.70
2217.6	104.60	2217.6	55.30	2217.6	52.60
2270.4	67.30	2270.4	53.40	2270.4	47.40
2323.2	58.90	2323.2	47.00	2323.2	37.30
2376.0	64.30	2376.0	61.10	2376.0	47.30
2428.8	103.70	2428.8	69.70	2428.8	55.00
2481.6	64.50	2481.6	99.90	2481.6	93.10
2534.4	53.00	2534.4	83.50	2534.4	80.50
2587.2	51.30	2587.2	61.90	2587.2	31.80
2640.0	98.40	2640.0	76.40	2640.0	51.40

Table E-5. IRI Obtained with ARAN Van with 528 ft Interval

North Tangent @ 45 MPH					
Sample 1		**Sample 2**		**Sample 3**	
Distance	**IRI**	**Distance**	**IRI**	**Distance**	**IRI**
ft.	**in/mile**	**ft.**	**in/mile**	**ft.**	**in/mile**
528	64.70	528	64.70	528	64.10
1056	65.80	1056	63.80	1056	62.10
1584	57.80	1584	54.10	1584	58.10
2112	60.60	2112	61.70	2112	64.00
2640	102.60	2640	103.40	2640	106.10

Table E-6. IRI Obtained with ARAN Van with 528 ft Interval

North Tangent @ 15 MPH					
Sample 1		**Sample 2**		**Sample 3**	
Distance	**IRI**	**Distance**	**IRI**	**Distance**	**IRI**
ft.	**in/mile**	**ft.**	**in/mile**	**ft.**	**in/mile**
528	78.00	528	69.50	528	69.30
1056	82.70	1056	62.40	1056	65.60
1584	70.40	1584	61.10	1584	61.10
2112	93.80	2112	70.90	2112	67.80
2640	123.30	2640	103.00	2640	114.30

Table E-7. IRI Obtained with ARAN Van with 528 ft Interval

South Tangent @ 45 MPH					
Sample 1		**Sample 2**		**Sample 3**	
Distance	**IRI**	**Distance**	**IRI**	**Distance**	**IRI**
ft.	**in/mile**	**ft.**	**in/mile**	**ft.**	**in/mile**
528	43.50	528	43.20	528	45.60
1056	78.10	1056	76.50	1056	74.90
1584	68.60	1584	66.30	1584	64.20
2112	59.30	2112	59.10	2112	59.90
2640	63.80	2640	59.80	2640	60.70

Table E-8. IRI Obtained with ARAN Van with 528 ft Interval

South Tangent @ 15 MPH					
Sample 1		**Sample 2**		**Sample 3**	
Distance	**IRI**	**Distance**	**IRI**	**Distance**	**IRI**
ft.	**in/mile**	**ft.**	**in/mile**	**ft.**	**in/mile**
528	72.60	528	63.70	528	58.90
1056	74.90	1056	68.10	1056	68.20
1584	82.50	1584	72.40	1584	56.00
2112	123.60	2112	92.60	2112	83.20
2640	71.60	2640	64.70	2640	53.00