Preliminary Investigation (PI-0354)

Caltrans Division of Research, Innovation and System Information

Alternative Methods for Measuring Surface Smoothness of Bridge Decks

Requested by
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List of Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ANN	artificial neural network
ARAN	automated road analyzer network
ASTM	American Society for Testing and Materials
Caltrans	California Department of Transportation
CNN	convolution neural network
CTDOT	Connecticut Department of Transportation
DEM	digital elevation model
DFT	dynamic friction tester
DOT	department of transportation
DSM	digital surface model
DSV	digital survey vehicle
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FOV	field-of-view
GNSS	global navigation satellite system
GSI	GOMACO Smoothness Indicator
HMA	hot-mix asphalt
IDOT	Illinois Department of Transportation
IMU	inertial measurement unit
INDOT	Indiana Department of Transportation
IRI	International Roughness Index
IRSV	intelligent road survey vehicle
JRCP	jointed reinforced concrete pavement
LaDOTD	Louisiana Department of Transportation and Development
LiDAR	light detection and ranging
MCS&T	Materials Control, Soils and Testing Division (West Virginia)
Mean IRI	Mean International Roughness Index
ML	machine learning
MLS	mobile laser scanner
MRI	Mean Ride Index
NCHRP	National Cooperative Highway Research Program
NHS	National Highway System
ODOT	Ohio Department of Transportation
OSU	Oklahoma State University
PCCP	portland cement concrete pavement
PCI	Pavement Condition Index
PI	Profile Index

PMPC	Pavement and Materials Partnering Committee (Caltrans)
PMS	pavement management system
PPC	polyester polymer concrete
PRI	Profilograph Index
ProVAL	Profile Viewer and Analyzer (AASHTO software)
RCBA	reinforced concrete bridge approach
RMS	root mean square
RMSE	RMS error
RSP	road surface profiler
RTP	real-time profiler
RTS	real-time smoothness
SAG	stop-and-go
SfM	Structure from Motion
SHAP	Shapley Additive Explanations
SHRP2	Second Strategic Highway Research Program
TPE	Tree-structured Parzen Estimator
TxDOT	Texas Department of Transportation
UAS	uncrewed aircraft systems
UAV	unmanned aerial vehicle
VTI	Swedish National Road and Transport Research Institute
VTIRST	dedicated road surface measurement vehicle (Sweden)
XGBoost	Extreme Gradient Boosting

Executive Summary

Background

Since the 1960s, Caltrans Standard Specifications Section 51-1.01D(3)(b)(ii) has required that surface smoothness testing of concrete bridge decks be conducted using a bridge profilograph. California Test 547, revised in June 2016, specifies that the profilograph equipment must be one of two models that are both operated at “no greater than walking speed” to prevent “excessive spikes (chatter) that is difficult to evaluate.”

Some state transportation agencies are moving away from the use of a profilograph in favor of alternative methods to evaluate surface smoothness. These alternative methods typically require less time to gather and process data and may deliver results more quickly. Caltrans is seeking information about methods that might replace the two specified profilograph models in measuring surface smoothness of bridge decks for contract compliance. Of particular interest are the benefits and potential challenges of implementing a new evaluation practice within Caltrans.

CTC & Associates surveyed state departments of transportation (DOTs) to gather information about their methods for measuring the smoothness of concrete bridge decks. A literature search of domestic and international research supplemented survey findings with information on state practices, new measurement technologies and commercial measurement tools.

Summary of Findings

Survey of Practice

An online survey distributed to state DOT members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Bridges and Structures received 24 responses.

- Alaska
- Arizona
- Arkansas
- Colorado
- Connecticut
- Florida
- Idaho
- Indiana
- Iowa
- Michigan
- Mississippi
- Missouri
- New Hampshire
- New Mexico
- New York
- North Dakota
- Pennsylvania
- South Carolina
- South Dakota
- Tennessee
- Virginia
- Washington
- West Virginia
- Wisconsin

Survey results are presented in two topic areas:

- States employing a standard smoothness measurement practice.
- States not employing a standard smoothness measurement practice.

States Employing a Standard Smoothness Measurement Practice

Seventeen survey respondents provided information about their states’ guidelines, measurements, tools, processes and tolerances for concrete bridge deck construction.

Bridge Deck Smoothness Measurement Methods

The most common measurement instrument for bridge deck smoothness among respondents is the straightedge, used by 15 of the 17 responding states. This is followed by the profilograph used by five states, the rolling straightedge used by four states, and three states using the inertial profiler. While none of the responding agencies' specifications address the use of a walking profiler, the North Dakota DOT respondent described limited use of a walking profilograph on large bridges.

Three agencies (*Florida*, *South Carolina* and *Virginia*) differentiate specifications based on the length of the bridge. Florida and South Carolina DOTs use a straightedge or rolling straightedge for bridges with lengths of 100 feet or less; a profilograph is used for bridges longer than 100 feet. The Virginia DOT respondent did not specify lengths, instead reporting the use of profilers for "special, larger bridges."

Maximum Permissible Deviation

The most common maximum deviation for pavement smoothness measured with straightedges and rolling straightedges is 1/8 inch over 10 feet, established by nine agencies. The second most common maximum deviation is 3/16 inch over 10 feet, used by three agencies. For smoothness tolerances of specific agencies and the measurement equipment used, refer to the state specifications compiled in Appendix B.

Changes to Smoothness Measurement Methods

Twelve of the 17 responding agencies have had no changes to their smoothness measurements for bridges decks within the past 10 years. Five agencies have made changes:

- *North Dakota*. A walking profilograph is used on large bridges to determine ride quality.
- *Pennsylvania*. The agency moved away from application of International Roughness Index (IRI) and Mean Ride Index (MRI) after finding that contractors are willing to pay a penalty when work fails to meet tolerance requirements.
- *South Dakota*. IRI has been added in the last five years.
- *Tennessee*. The agency moved from Profilograph Index (PRI) to IRI in recognition of IRI's acceptance as the industry norm.
- *West Virginia*. Inertial profilers are now permitted to collect rolling straightedge data.

Testing Smoothness Measurement

Thirteen of the 17 agencies have not engaged in testing smoothness measurement methods or practices. Four agencies provided details of testing efforts:

- *Florida*. A laser profiler is used for pavements and has been used on bridge decks for research as needed, using IRI as the smoothness measure.
- *Indiana*. At the time of the survey, the agency was finalizing a pilot study of inertial profilers to update Indiana's smoothness specifications; see page 7 for additional information.
- *North Dakota*. A walking profilograph and ProVAL (Profile Viewer and Analyzer) software has been used on some larger bridges to enforce a ride special provision.
- *Washington*. The agency used IRI on a tunnel roadway deck.

Indiana's Pilot Study and Specification Change

Indiana DOT was completing a pilot on bridge deck smoothness measurement and drafting changes to agency specifications at the time the survey for this project was deployed. In 2024 and 2025, the DOT tested a road surface profiler (RSP) inertial profiler with IRI measurement for full bridge project limits plus 50 feet at each end. Existing specifications applied to the bridge deck and bridge approaches.

As part of the initiative to improve smoothness and rideability of bridges, there was also a proposal to change the specification so bridge decks and approaches would be continuously poured. The current specification for Indiana DOT, which takes effect on September 1, 2025, and is available in Appendix B, reflects the addition of the inertial profiler for full bridge project limits plus 50 feet at each end, but still stipulates that bridge decks and approaches be poured separately.

Accuracy of Measurement Method

The survey identified no consensus on respondents' assessment of the accuracy of their measurement methods. For example, respondents rating their agencies' smoothness measurement method as *extremely* or *very accurate* used different measurement methods. Four of the six respondents rating their smoothness measurement methods as *somewhat accurate* identified the straightedge as their sole measurement instrument (*Colorado*, *New Mexico*, *Virginia* and *Washington*). The straightedge is also the primary instrument for Arkansas (one of the six providing the *somewhat accurate* rating), but contractors in Arkansas may opt for the inertial profiler to pursue a smoothness incentive. Only one agency — Pennsylvania DOT — rated its current measurement method (straightedge used with IRI, MRI and ProVAL) as *not so accurate*.

Benefits of Current Measurement Method

Respondents described the benefits of their current smoothness measurement methods for bridge decks. Table ES1 provides a sampling of survey responses to allow for a comparison of methods and associated benefits.

Table ES1. Benefits of Current Measurement Method

Benefit	Agency, Measurement Method and Description
Cost	*Arkansas* describes its method as "low cost." The agency's specification describes use of a straightedge, but contractors may choose to use an inertial profiler when opting to obtain a bridge deck smoothness incentive.
Ease of Use	*South Carolina* described its profilograph's data printout as "easy to understand." *South Carolina* acknowledged that the rolling straightedge's portability makes it easier to use.
Reliability	*Colorado* uses the straightedge for bridge deck smoothness measurement and noted that "obvious discrepancies are caught" by this method. *South Carolina* described the profilograph as "very accurate, reliable and repeatable." *Tennessee* uses a road surface profiler with IRI, MRI and ProVAL, noting that the method "is efficient and as accurate as it can get." The agency still requires engineers to validate data when a dispute arises between DOT and contractor test results.
Safety	*Wisconsin*'s specifications address use of the straightedge, IRI, profilograph measurements and ProVAL software. The respondent noted that "high speed profilers keep the operators safe."

Benefit	Agency, Measurement Method and Description
Speed of Use	*Arkansas'* use of the straightedge allows for the identification of corrections while the surface is still workable. *South Carolina* noted the "quick data on a printout" provided by the profilograph. *South Dakota's* smoothness methods and measurements include the straightedge, rolling straightedge, IRI and MRI. The respondent noted that "IRI is fast."

Limitations of Current Measurement Method

A sampling of the limitations of respondents' current smoothness measurement methods for bridge decks are summarized in Table ES2.

Table ES2. Limitations of Current Measurement Method

Limitation	Agency, Measurement Method and Description
Access to Equipment	*Indiana* identified a need for the contracting industry to invest in inertial profiler equipment and operators when considering changes to the agency's specification. *South Carolina* has only one profilograph in its inventory, so its use must be scheduled in advance and the unit must be transported in a trailer. *Wisconsin*'s respondent noted, "Not all operators have zero stop machines yet."
Ease of Use	*Michigan*'s use of a straightedge makes it "complicated to mark areas" when the deck has "an excessive number of defects/bumps." *South Carolina* reported a concern with the length of its profilograph in connection with the agency's bridge deck paving sequence. With approach slabs recessed two inches to allow for subsequent asphalt pavement, the agency is unable to measure the 16 to 17 feet at each end of the bridge deck due to the central wheel placement of the 33-feet-long profilograph. *South Dakota's* respondent identified a similar issue, noting that the bridge and pavement, with approaches, must be completed to take the IRI measurement. *West Virginia*'s respondent commented that "sometimes the bridge deck is inaccessible for the high-speed inertial profiler."
Need for Oversight	*Tennessee* does not consider IRI and MRI data as "set in stone"; instead, the agency checks after grinding and has disregarded data in some cases.
Personnel Needs	*Arkansas*, which primarily uses a straightedge for smoothness measurement, raised the issues of personnel availability, since two people are needed for taking straightedge measurements. *Indiana's* specification change permitting the use of inertial profilers for bridge deck smoothness measurement will require training for DOT personnel on field use and software.
Time-Consuming	*North Dakota*'s specifications call for use of a straightedge and/or profilograph with ProVAL software. The North Dakota respondent noted that the methods are "still time-consuming" and "a high-speed profilograph would be better." *Washington*'s specifications indicate the use of a straightedge, which the respondent described as "time-consuming if required for more than spot checking."

Recommendations

Highlighted below is a sampling of the recommendations respondents provided for other agencies preparing to adopt their current method of measuring bridge deck smoothness:

Measurement Tools and Practices

- Consider use of the straightedge. It is simple, easy to use and has an immediate response time (*Colorado*).
- Evaluate limits of the bridge project to be included in the specification (*Indiana*).
- Investigate the smaller profilograph (CS8550) to allow more of the bridge deck to be measured (*South Carolina*).
- Use a high-speed profilograph (*Indiana*).
- Use the most current available version of the technology (*West Virginia*).

Pilot Studies

- Allow contractors and DOT field personnel to give input into the specification through pilot projects (*Indiana*, *Tennessee*).
- Give DOT staff and contractors the opportunity to build knowledge through pilot participation (*Indiana*).
- Pilot on large projects (*Pennsylvania*).

Tolerances, Incentives and Disincentives

- Consider the profile index that is needed to benefit the traveling public (*South Carolina*).
- Carefully evaluate smoothness and grinding thresholds when setting tolerances (*Indiana*).
- Ensure that incentives/disincentives are appropriate (*North Dakota*).
- Establish a limit for grinding and sealing at the contractor's expense (*Michigan*).
- Fund incentives so they are worth achieving (*Pennsylvania*).
- Set appropriate thresholds for corrective action (*North Dakota*).

Training

- Conduct training on equipment and software (*Indiana*).
- Equip DOT staff to field questions from contractors (*Tennessee*).
- Make the data visual for contractors to show the impact on their bottom line (*Tennessee*).

States Not Employing a Standard Smoothness Measurement Practice

Respondents not reporting experience with a standard smoothness measurement practice fell into two categories: states contemplating a new standard practice and states with no plans to do so.

States Contemplating a Standard Practice

Two state DOTs are contemplating implementing a standard measurement practice:

- *Connecticut* DOT has not constructed a new bridge with a concrete surface in 15 years. Any smoothness requirements are specified to employ the agency's automated road analyzer network (ARAN) vans to measure IRI. The agency is currently assessing the benefit of specifying smoothness on polyester polymer concrete (PPC) bonded overlays that will be ground or grooved.

- *Mississippi* DOT is considering development of a new specification for the transition between the road and bridge deck. The new specification and measurement practice may be implemented in late 2025/early 2026.

States Reporting No Interest in a Standard Practice

Four of the five respondents (*Alaska*, *Idaho*, *Missouri*, *New Hampshire* and *New York)* reporting no plans for or interest in establishing a standard measurement practice provided additional context:

- *Alaska*. The agency uses predominately precast decked bulb-tee girders with a waterproofing membrane and asphalt wearing surface, so the roughness of the deck is only relevant for application of membrane.
- *Missouri*. The agency requires diamond grinding for bridge wearing surfaces and smoothness acceptance is determined by a Missouri DOT engineer.
- *New Hampshire*. The respondent estimates that 98% of bridge decks in the state receive a barrier membrane and asphalt wearing course.
- *New York*. The agency has had "pretty good results for most situations based on screed machine setup. Any measuring is done with straightedges."

Related Research and Resources

A literature search of publicly available domestic and international research and related resources identified a sampling of publications that are organized in the following categories:

- National research and guidance.
- State research.
- Exploring new measurement technologies.
- Measurement tools.

Tables ES3 through ES6, which begin on page 12, summarize these publications, providing the publication or resource title, the year of publication, a category where appropriate, and a brief description of the resources. More information about each resource can be found in the **Detailed Findings** section of this report.

Appendix B provides specifications for smoothness measurement of bridge decks and concrete pavement construction from 28 state DOTs, including all 24 survey respondents.

Gaps in Findings

A 2022 National Cooperative Highway Research Program (NCHRP) synthesis (NCHRP Synthesis 580; see **Related Research and Resources**, page 35, for the citation) documented the procedures used by the 39 responding states. Although the 24 states that responded to the survey for this Preliminary Investigation provided information on current practices, input from other agencies would offer additional perspectives and data points for consideration. On some topics, such as simulated rolling straightedges, more recent research studies were lacking to present a full account of the attributes of different smoothness measurement methods. Also, the resources available on new technologies for pavement smoothness measurement methods did not specifically address their potential application to or effectiveness for concrete bridge deck construction.

Next Steps

Moving forward, Caltrans could consider:

- Consulting with Indiana DOT to learn more about the agency's pilot study of inertial profilers and revised specification for bridge decks and approaches.
- Engaging with Illinois and Texas DOTs, which have studies underway regarding the use of stop-and-go profiler technology.
- Checking in with other states using measurement tools other than the profilograph currently used by Caltrans to gather additional details of alternative equipment and practices.
- Reviewing in detail selected specifications appearing in Appendix B to gather further details of agency practices for those measurement tools and practices of particular interest to Caltrans.

Table ES3. National Research and Guidance

Publication or Resource (Year)	Excerpt from Abstract or Description of Resource
NCHRP Synthesis 580: Practices for Ensuring the Smoothness of Concrete Bridge Decks (2022)	
Evaluating the Smoothness of Newly Constructed Concrete Bridge Decks (2022)	Presents findings from the NCHRP Synthesis 580, cited above. The webinar describes the methods and equipment for measuring smoothness of newly constructed bridge decks, and presents the indices used to quantify smoothness and threshold limits established by DOTs for smoothness.
Development of IDOT's Proposed Smoothness Specification Based on the International Roughness Index (2020)	
Development of a Bridge Smoothness Specification for Illinois DOT (2001)	Presents the IDOT specification for bridges, including the smoothness limits for bridges and a correlation between IRI and Profile Index measurements. (Referenced in NCHRP Synthesis 580.)
Measuring and Specifying Pavement Smoothness (2016)	
Best Practices for Achieving and Measuring Pavement Smoothness: A Synthesis of State-of-Practice (2015)	Provides current data for IRI-based construction measurements and best practices for achieving quality as states transition from profilograph-based smoothness specifications to IRI-based specifications.

Table ES4. State Research

Publication or Resource (Year)	State	Excerpt from Abstract or Description of Resource
Implementation of a 3-D Sensing Technology for Automated Pavement Data Collection in Connecticut (2018)	Connecticut	Compares older automated ARAN equipment (2D Strobe cameras, ultrasonic rut bar and inertial profiler) with the newest 3D laser technology (Pavemetric LCMS and RoLine sensors) for accuracy and precision of pavement performance data. Results indicate the new 3D laser scanning technology produces greater resolution in both longitudinal and transverse directions.
Cross-Correlation Analysis of Line Laser High-Speed Inertial Profilers (2020)	Florida	Describes the testing program, data collection efforts, and subsequent analyses and findings resulting from testing of 13 different line-laser high-speed inertial profilers from four different manufacturers. Tests were conducted at the Florida DOT Inertial Profiler Test Track.
Research in Progress: Advancements in Profiler Certification (expected completion: July 2026)	Illinois	Will conduct research to validate inertial profilers and investigate improvements to IDOT's Certification and Research Track.
Research in Progress: SPR-4617: Demonstration of Zero Speed Inertial Profilers (expected completion: August 2025)	Indiana	Will test zero speed inertial profilers for their ability to collect accurate profiles in urban areas with low-speed zones that prevent the use of high-speed inertial profilers.
Performance Evaluation of Bridge Approach Slabs and Joints through Sub-mm 3D Laser Imaging System (2024)	Oklahoma	Surveys approach slabs for 377 bridges across Oklahoma with different designs and conditions. The Pave3D 8K system featuring sub-mm 3D laser technology and inertial profiler collected 2D/3D images and inertial data from these bridges to assess slab design and bump mitigation methods.
Research in Progress: Evaluation of Low-Speed Profiler for Network-Level Pavement Management (expected completion: August 2026)	Texas	Will explore the potential of low-speed profilers under stop-and-go conditions that compromise the accuracy of data from high-speed profilers the state typically uses to gather ride quality data.

Table ES5. Exploring New Measurement Technologies

Publication or Resource (Year)	Technology	Excerpt from Abstract or Description of Resource
Comparison of IRI from Connected Vehicles and IRI from Profilometer: Measurements Done in 2021 (2022)	Connected Vehicles	Evaluates the roughness measurements from connected vehicles equipped with software from Nira Dynamics to determine ride quality. Although the Nira-estimated IRI is not the same as the benchmarked road surface measurement vehicle, it may be a parallel roughness index.
Evaluation of Pavement Smoothness with a Digital Surface Model (DSM) (2024)	Digital Surface Model Measurement	Extracts profiles of a standard road section from the digital surface model (DSM) to be used for calculating the IRI with ProVAL software. Profiles obtained by a walking profiler were compared to confirm the method's validity for measuring smoothness.
Safety Evaluation of Pavement Surface Characteristics with 1mm 3D Laser Imaging (2019)	Laser	Documents the use of 1mm 3D laser imaging technology to perform safety evaluation of pavements. Several state-of-the-art data collection devices were used for data collection, including the Oklahoma State University 3D laser imaging technology (PaveVision3D Ultra) for 1mm 3D pavement surface data.
Assessing of the Road Pavement Roughness by Means of LiDAR Technology (2021)	LiDAR	Compares three different roughness measurement methods. The road subsections from the profilometer measure that were classified as critical coincided with those derived from light detection and ranging (LiDAR) surveys.
Roughness Analysis of Paved Road Using Drone LiDAR and Images (2021)	LiDAR	Compares road surface data from the latest 3D geospatial information construction technology: ground LiDAR, drone photogrammetry and drone LiDAR. Researchers analyzed the accuracy and roughness of each method.
A Machine Learning-Based Framework for Predicting Pavement Roughness and Aggregate Segregation During Construction (2024)	Machine Learning Models	Tests a method to predict pavement roughness using digital image analysis, image recognition and deep machine learning models. Researchers used 600 pavement surface images from the Louisiana Department of Transportation and Development's pavement management system.
Surrogate Modelling of Surface Roughness for Asphalt Pavements Using Artificial Neural Networks: A Mechanistic-Empirical Approach (2024)	Machine Learning Models	Uses an adaptive sampling technique for pavement simulations. Developed two machine learning models and compared them for accuracy in modeling IRI measurement.
Developing an Improved Extreme Gradient Boosting Model for Predicting the International Roughness Index of Rigid Pavement (2024)	Machine Learning Models	Uses the Extreme Gradient Boosting (XGBoost) method for an IRI prediction model, along with other machine learning techniques. The method provided improved accuracy when compared to other "ensemble learning models."

Publication or Resource (Year)	Technology	Excerpt from Abstract or Description of Resource
Low-Cost Portable Road Smoothness Testing Method Based on Pseudo-Vibration Velocity Range (2024)	Pseudo-Vibration Velocity Range Testing	Uses vehicle-mounted acceleration sensors to detect road smoothness, establishing a correlation between driving vibration acceleration data and IRI. Testing showed that the method is applicable to both sedans and SUV models.
Comparison of Smartphone-Based and Drone-Based Approaches for Assessing Road Roughness (2024)	Smartphones	Investigates use of the smartphone and drone as road roughness assessment devices. Results reveal a significant correlation (above 0.8) of both methods with the road surface profiler method, although the smartphone was more cost- and time-effective and also easy to use.
Pavement Roughness Evaluation Method Based on the Theoretical Relationship Between Acceleration Measured by Smartphone and IRI (2022)	Smartphones	Uses the integrated sensors of smartphones (e.g., GPS, acceleration sensor) to apply a theoretical algorithm that includes vehicle suspension parameters to calculate IRI.
Assessing the Feasibility of Utilizing a UAS-Based Point Cloud in Pavement Smoothness/Roughness Measurement (2022)	Uncrewed Aircraft Systems	Assesses the feasibility and data accuracy of the Structure from Motion (SfM) technique for conducting ground surveys and creating high-resolution images, including obtaining IRI measurement.
Determination of the Pavement Condition Index (PCI) and International Roughness Index (IRI) in Urban Roads Using Images Obtained by Unmanned Air Vehicles (UAV) (2019)	Uncrewed Aircraft System	Proposes the use of georeferenced images, obtained from an unmanned aerial vehicle, which are processed to generate an orthophoto high resolution and dense point cloud on the surface of the pavement.

Table ES6. Measurement Tools

Category	Device, Tool or Software
Measurement Tools	• Walking profiler • California profiler • Inertial profiler • Real-time smoothness measurement • ProVAL

Detailed Findings

Background

Since the 1960s, Caltrans Standard Specifications Section 51-1.01D(3)(b)(ii) has required that surface smoothness testing of concrete bridge decks be conducted using a bridge profilograph. As specified by California Test 547, revised in June 2016, the profilograph equipment must be one of the following:

a. 12-ft-long rigid beam frame supported on one wheel at each end with an outrigger wheel for balancing support (see Figure 1). Motive power for the beam frame profilograph is supplied manually from the push handle in the rear. Steering is accomplished by rotating the handle grip to move the front wheel.
b. 12-ft-long rigid truss frame supported on wheel assemblies (see Figure 2). Motive power for the truss frame profilograph is supplied manually from the steering wheel located midpoint of the frame.

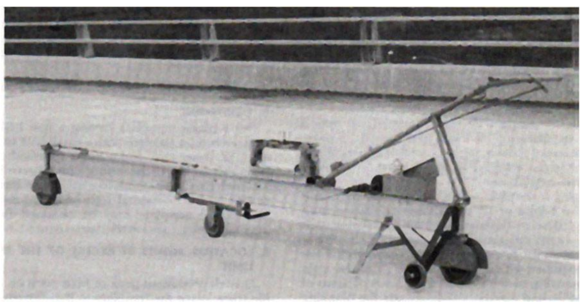

Figure 1. Rigid Beam Frame Bridge Profilograph
(*Source*: Caltrans.)

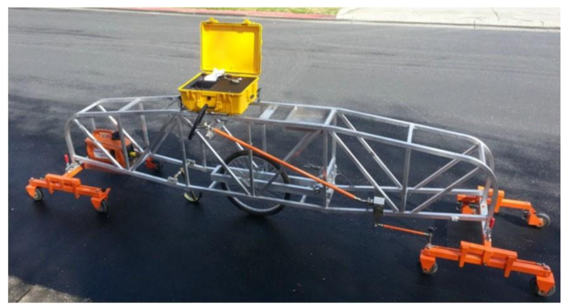

Figure 2. Rigid Truss Frame Bridge Profilograph
(*Source*: Caltrans.)

California Test 547 also describes operation of the profilograph:

1. The bridge profile is recorded from the vertical movement of a wheel attached at the midpoint of the frame. This wheel is linked to a pen-recording device on a paper reel, or an electronic recorder, that records the movement of the center wheel from the established datum to create a profilogram.
2. When operating the profilograph, move at a speed no greater than a walk. Moving too fast will result in a profilogram with excessive spikes (chatter) that is difficult to evaluate. Sweep the deck surface clean of any loose material. Keep the bridge profilograph wheels clean and free of particles which may become embedded in the tires.

Some state transportation agencies are moving away from the use of a profilograph in favor of alternative methods to evaluate surface smoothness. These alternative methods typically require less time to gather and process data and may deliver results more quickly.

For this Preliminary Investigation, CTC & Associates completed two information-gathering efforts:

- *Literature search*. A review of domestic and international published and in-progress research and related resources explored methods used to measure the surface smoothness of concrete bridge decks, including alternatives to the profilograph. Other research topics included new applications of existing technologies, commercial measurement products, and new technologies in development or experimental use.

- *Transportation agency survey.* Survey respondents from each of the state departments of transportation (DOTs) and the District of Columbia were asked to participate in a survey that examined current agency practices for measuring the surface smoothness of concrete bridge decks.

Survey of Practice

An online survey distributed to state DOT members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Bridges and Structures sought information about methods that might replace Caltrans' current use of the profilograph for measuring surface smoothness of new concrete bridge decks. Respondents were surveyed on their agencies' requirements and processes for bridge deck surface measurement, including current practices and tools for collecting data on surface smoothness, and any future plans to change measurement practices. Survey questions are provided in Appendix A.

Twenty-four state DOTs responded to the survey:

- Alaska
- Arizona
- Arkansas
- Colorado
- Connecticut
- Florida
- Idaho
- Indiana
- Iowa
- Michigan
- Mississippi
- Missouri
- New Hampshire
- New Mexico
- New York
- North Dakota
- Pennsylvania
- South Carolina
- South Dakota
- Tennessee
- Virginia
- Washington
- West Virginia
- Wisconsin

Survey results are presented below in two topic areas:

- States employing a standard smoothness measurement practice (immediately below).
- States not employing a standard smoothness measurement practice (see page 33).

States Employing a Standard Smoothness Measurement Practice

Survey respondents describing their agencies' standard smoothness measurement practice addressed the methods, processes, equipment and personnel associated with determining bridge deck smoothness.

Measurement Practices

Respondents described their agencies' measurement practices in seven topic areas:

- Bridge deck smoothness measurement methods.
- Measurement products: vendors and models.
- Maximum permissible deviation.
- Changes to smoothness measurement methods.
- Testing smoothness measurement.
- Responsibility for gathering smoothness measurements.
- Time frame and bridge elements subject to smoothness measurement.

Bridge Deck Smoothness Measurement Methods

Seventeen state DOTs reported experience with the surface smoothness measurement methods identified in Table 1. Almost 90% of these respondents use a straightedge as the only measurement tool or include it with other tools to measure smoothness.

Table 1. Respondents' Surface Smoothness Measurement Methods

State	Straightedge Only	Straightedge	Rolling Straightedge	Inertial Profiler Data Rolling Straightedge Simulation	Walking Profiler Data Rolling Straightedge Simulation
Arizona	X	X			
Arkansas	X			X[1]	
Colorado	X				
Florida		X			
Indiana[2]		X	X		
Iowa		X		X	
Michigan		X			
New Mexico	X				
North Dakota		X			
Pennsylvania		X			
South Carolina		X	X		
South Dakota		X	X		
Tennessee					
Virginia	X				
Washington		X			
West Virginia			X	X	
Wisconsin		X			
Total	**5**	**11**	**4**	**3**	**0**

1 An inertial profiler is only used if the contractor wishes to pursue a bridge deck smoothness incentive.

2 The agency is piloting the use of an inertial profiler using International Roughness Index.

Table 1. Respondents' Surface Smoothness Measurement Methods (Continued)

State	International Roughness Index (IRI)	Mean International Roughness Index (Mean IRI)	Profilograph Measurements	Profile Viewer and Analysis (ProVAL)
Arizona				
Arkansas				
Colorado				
Florida			X	
Indiana				
Iowa			X	X
Michigan				

State	International Roughness Index (IRI)	Mean International Roughness Index (Mean IRI)	Profilograph Measurements	Profile Viewer and Analysis (ProVAL)
New Mexico				
North Dakota			X	X
Pennsylvania	X	X		X
South Carolina			X	
South Dakota	X	X		
Tennessee	X	X		X
Virginia				X
Washington				
West Virginia				X
Wisconsin	X		X	X
Total	**4**	**3**	**5**	**7**

Fourteen of the 17 responding agencies have used the measurement methods identified in Table 1 for more than 10 years. North Dakota DOT has used a 10-foot straightedge on smaller bridges for more than 10 years. Within the last six to 10 years, North Dakota DOT has also used a walking profilograph and ProVAL (engineering software used to view and analyze pavement profiles) on some larger bridges to enforce a special provision on ride quality.

Tennessee DOT has used its current measurement process for the shortest amount of time among respondents — three to five years.

Several respondents provided additional information about agency practices:

- In *Colorado*, contractors have the option to use another agency-approved device.
- *Florida* DOT uses a straightedge for short bridges (100 feet or less) and a profilograph for long bridges (greater than 100 feet).
- *Michigan* DOT will also dimension the tining. If smoothness is called into question, the agency can use all other measurement methods identified in the survey.
- *South Carolina* DOT uses a longitudinal rolling straightedge for bridges 100 feet or less. A longitudinal profilograph is used for bridges greater than 100 feet in length. A straightedge is used for transverse measurement.
- *Virginia* DOT only uses profilers on "special, larger bridges."

Measurement Products: Vendors and Models

Three agencies identified a specific product in current use:

- *North Dakota*: SurPro 5000 walking profiler provided by International Cybernetics Company, LP.
- *South Carolina*: CS8500 California Profilograph provided by Surface Systems & Instruments, Inc.
- *Tennessee*: Road Surface Profiler MK III provided by Dynatest.

Comparing Traditional Walking Profilograph with Vehicle-Mounted Inertial Profiler

Of the three commercially available products for measuring bridge deck smoothness identified by survey respondents, two are operated manually and at walking speeds (SurPro 5000 and CS8500 California Profilograph) while the third (Road Surface Profiler MK III) is mounted to a vehicle and is designed to collect data at driving speeds. Through the use of laser technology, accelerometers and a Distance Measuring Instrument, this inertial profiler collects data on the pavement texture and transmits these data to proprietary software.

The Road Surface Profiler MK III inertial profiler used by Tennessee DOT — also referred to as a zero-speed profiler in an Indiana DOT research project in progress — has stop-and-go (SAG) functionality, allowing it to test the pavement surface at variable speeds. This represents an advancement in the functionality of the inertial profiler that previously required constant speeds to effectively evaluate pavement smoothness. The IRI and Ride Number can be calculated from collected data.

Related Resource:

"Development and Implementation of Stop-and-Go Inertial Profiler Certification Procedure in California," Biplab Bhattacharya, Nicholas Schaefer, Rahshaun Spears and Baron Colbert, *Transportation Research Record 2679*, Issue 3, pages 312-329, 2025.
Citation at https://doi.org/10.1177/03611981241277823
From the abstract: The ride quality of a road in California is often determined by evaluating pavement smoothness using an inertial profiler (IP). Conventional IP technology, per California Test (CT) 387, requires IP operators to maintain a minimum speed of 15 mph to collect pavement-smoothness data. However, maintaining a minimum speed of 15 mph in busy urban areas or on hilly terrains can be difficult and unsafe, often requiring traffic control. Caltrans and industry have identified a new technology, the "Stop-and-Go" (SAG) IP, for collecting pavement-smoothness data at low speeds (under 15 mph) without traffic control. The previous version of CT 387 did not allow for the use of SAG IPs. To address this issue, the Pavement and Materials Partnering Committee (PMPC) evaluated SAG IP and updated CT 387. A certification procedure for SAG IP was developed, and included in CT 387, based on a series of runs using speed profiles under various braking and acceleration conditions simulating urban traffic conditions. Any SAG profiler can be certified if it meets the requirements of AASHTO R 56 and CT 387. The certification procedure was validated using qualification runs at the Caltrans certification track, along with field testing, demonstrating that SAG IPs provide similar results to conventional IPs. Based on the validation, along with the subsequent update of CT 387, the PMPC approved the implementation of SAG IPs for optional use by Caltrans and industry. These developments helped California become one of the first states to develop and implement a certification procedure for SAG IPs.

Maximum Permissible Deviation

Tables 2 and 3 provide the maximum deviation permitted by each state using either a straightedge or rolling straightedge to measure bridge deck smoothness. Eight of 15 respondents reported the application of 1/8 inch over 10 feet as the agency standard. Indiana, South Dakota and South Carolina DOTs use both a straightedge and rolling straightedge, so their maximum permissible deviation is indicated in both tables.

Table 2. Maximum Permissible Deviation: Straightedge

Maximum Permissible Deviation	Agency
1/8 inch over 10 feet	Arizona, Arkansas, Colorado, Iowa, Michigan, North Dakota, South Dakota, Washington
3/16 inch over 10 feet	Florida (bridges ≤ 100 ft), New Mexico, Pennsylvania
1/4 inch over 16 feet	Indiana
1/8 inch over 10 feet longitudinally **0.20 inch over 10 feet transversely**	South Carolina
1/4 inch over 10 feet longitudinally **1/8 inch over 10 feet transversely**	Virginia

Table 3. Maximum Permissible Deviation: Rolling Straightedge

Maximum Permissible Deviation	Agency
1/8 inch over 10 feet	South Dakota, West Virginia
1/4 inch over 16 feet	Indiana
1/8 inch over 10 feet longitudinally **0.20 inch over 10 feet transversely**	South Carolina

Changes to Smoothness Measurement Methods

Twelve of the 17 responding agencies have had no change to their smoothness measurement method or practice within the last 10 years. Five agencies have changed their smoothness measurement methods in the following ways:

- *North Dakota*. A walking profilograph is used on large bridges to determine ride quality.
- *Pennsylvania*. The agency moved away from application of International Roughness Index (IRI) and Mean Ride Index (MRI) after finding that contractors are willing to pay a penalty when work fails to meet tolerance requirements.
- *South Dakota*. IRI has been added in the last five years.
- *Tennessee*. The agency moved from Profilograph Index (PRI) to IRI in recognition of IRI's acceptance as the industry norm.
- *West Virginia*. Inertial profilers are now permitted to collect rolling straightedge data.

NOTE: As noted in Table 1 and addressed in the case study on page 27, Indiana DOT was piloting the use of inertial profilers and IRI at the time of the survey and has since updated its specifications, which are available in Appendix B.

Testing Smoothness Measurement

Thirteen of the 17 responding agencies have not engaged in testing the smoothness measurement method or practice. Four respondents provided details of their agencies' testing efforts:

- *Florida*. A laser profiler is used for pavements and has been used on bridge decks for research as needed, using IRI as the smoothness measure.
- *Indiana*. At the time of the survey the agency was finalizing a pilot study of inertial profilers and an update to Indiana's smoothness specifications.
- *North Dakota*. A walking profilograph and ProVAL software has been used on some larger bridges to enforce a ride special provision (see Appendix B).
- *Washington*. The state has used IRI on a tunnel roadway deck.

Responsibility for Gathering Smoothness Measurements

Table 4 identifies the staff members responsible for gathering respondents' smoothness measurements. The 17 responding agencies are nearly equally divided, with six reporting that a state DOT staff member gathers measurements, six reporting contractor responsibility, and five reporting both.

Table 4. Responsibility for Gathering Smoothness Measurements

State	State DOT Staff	Contractor Staff	Comments
Arizona		X	
Arkansas	X		
Colorado		X	
Florida		X	
Indiana		X	
Iowa		X	
Michigan	X	X	
New Mexico		X	
North Dakota	X		
Pennsylvania	X		Third party if DOT staff not available.
South Carolina	X	X	Profilograph performed by DOT staff; responsibility for use of rolling straightedge varies.
South Dakota	X		
Tennessee	X		
Virginia	X		
Washington	X	X	Contractor performs quality control; state DOT provides quality assurance.
West Virginia	X	X	
Wisconsin	X	X	

Time Frame and Bridge Elements Subject to Smoothness Measurement

Respondents provided information on agency time frame guidelines for gathering smoothness measurements and the bridge elements that are subject to smoothness specifications.

Five of the 17 responding agencies only apply smoothness specifications to bridge decks, while eight currently include bridge decks and approach slabs. The remaining four agencies that also measure abutting roadway pavement vary in the amount of roadway assessed, from 50 feet to 150 feet. Tennessee DOT reported the longest stretch of abutting pavement, at 150 feet, with the caveat that the engineer may specify a shorter length. Wisconsin DOT, one of the four agencies measuring abutting pavement, does not indicate a numeric length, instead including the project length in its smoothness measurement.

Table 5 summarizes survey responses.

Table 5. Time Frame and Bridge Elements Subject to Smoothness Specifications

State	Specific Time Frame (Y/N)	Time Frame	Bridge Elements Subject to Smoothness Specifications
Arizona	Y	Plastic stage of concrete	Bridge deck only
Arkansas	Y	After deck finishing and the next day	Bridge deck and approach slabs
Colorado	Y	After concrete is set, but requirement is not clearly defined	Bridge deck and approach slabs
Florida	N	Not applicable	Bridge deck and approach slabs
Indiana	N	It is expected that contractors will do so in timely manner, as it may be disadvantageous to wait.	Bridge deck and approach slabs[1]
Iowa	N	Not applicable	Bridge deck and approach slabs
Michigan	Y	During finishing and after curing is complete	Bridge deck and approach slabs
New Mexico	N	Not applicable	Bridge deck, approach slabs and 50 ft. of abutting roadway
North Dakota	Y	Contractor required to schedule time, engineer will collect profile within 5 working days	Bridge deck only
Pennsylvania	N	Not applicable	Bridge deck and approach slabs
South Carolina	Y	Between curing and grooving	Bridge deck only
South Dakota	Y	Before open to traffic	Bridge deck, approach slabs and 100 ft. of abutting roadway
Tennessee	Y	After bridge deck, approach slabs and pavement tie-ins are done, and IRI and MRI rideability tests	Bridge deck, approach slabs and 150 ft. of abutting roadway unless engineer specifies shorter distance
Virginia	N	Not applicable	Bridge deck only
Washington	Y	During placement	Bridge deck and approach slabs
West Virginia	Y	After finishing when concrete has hardened, using a straightedge or certified inertial profiler	Bridge deck only
Wisconsin	N	Not applicable	Bridge deck, approach slabs and abutting roadway the project length; bridges are profiled but excluded

1 Indiana DOT's specification at the time of the survey indicated bridge deck and reinforced concrete bridge approach (RCBA) only; a recent revision includes full bridge project limits of +50 feet at each end.

Data Collection

Respondents addressed the acquisition and management of data in three topic areas:

- Extent of data collection.
- Time windows for data collection and analysis.
- Certification requirements.

Extent of Data Collection

Table 6 identifies the portion of the bridge deck subject to respondents' measurement practices. Almost half of the 17 responding agencies collect data on both wheel paths in each travel lane. The North Dakota DOT respondent did not address this survey question.

Table 6. Extent of Respondents' Measurement of the Bridge Deck Surface

Portion of Bridge Deck Subject to Data Collection	Agency and Description
Both wheel paths in each travel lane	Florida, Indiana, Iowa, Pennsylvania, South Carolina, South Dakota, Tennessee, Wisconsin ***Note**:* Indiana DOT's pilot of an inertial profiler collects data on both wheel paths.
Entire surface	Arizona, Arkansas, New Mexico, Virginia, Washington
No data collection	*Colorado*. No data collection but all areas visually observed for discrepancies. *Michigan*. Only considered when a ride issue is identified and further investigation is required.
Other	*West Virginia*. Collect straightedge data from the centerline and every 2 feet to the edge of the bridge marking, with all deviations greater than 1/8 inch.

Time Windows for Data Collection and Analysis

The typical time windows for collecting and analyzing smoothness data for a single lane (two wheel lines) along 100 feet of bridge deck varied widely among respondents. The South Dakota and Wisconsin respondents reported the shortest time requirements — under one minute. For South Dakota DOT, this short collection time is associated with IRI measurement; using the straightedge takes up to an hour. Respondents from Iowa, North Dakota and Tennessee describe typical collection times in the range of five to 10 minutes.

At the other end of the range are Colorado at one hour, Indiana at two to four hours, and New Mexico at four hours for data collection. As shown in Table 1 (see page 18), all three use a straightedge (Indiana also employs a rolling straightedge) and none reported current use of an inertial profiler or ProVAL software to manage the smoothness data.

Data analysis times also vary, from the shortest of 10 minutes reported by Iowa to the longest of two to four hours reported by West Virginia. Seven of the 10 agencies indicated an analysis time of less than one hour. Table 7 summarizes survey responses.

Table 7. Typical Time for Respondents to Collect and Analyze Data

State	Typical Time to Collect Data for Single Lane[1]	Typical Time to Analyze Data for Single Lane[2]
Arizona	15 minutes	15 minutes
Colorado	1 hour	Not provided
Florida	Walking speed	Little time since process is mostly automated
Indiana[3]	2 to 4 hours	30 minutes
Iowa	10 minutes	10 minutes
New Mexico	4 hours	2 hours
North Dakota	Approximately 5 minutes once the lane line is set up and the system is calibrated	30 minutes
South Carolina	Less than 1 hour	Less than 1 hour
South Dakota	Less than 1 minute with IRI; up to 1 hour with the straightedge	1 to 2 hours
Tennessee	Less than 10 minutes to set up and collect	Maximum of 30 minutes to create a report showing data
Virginia	Less than 1 hour	Less than 1 hour
Washington	Specific timing not provided. Smoothness is typically measured during deck placement and verified, as needed, after curing is complete.	Timing varies
West Virginia	2 hours	2 to 4 hours
Wisconsin	Few seconds to 1 minute	Varies depending on the data collector

1 The full text of this survey question: *If possible, please estimate the typical amount of time required to measure and collect data for a single lane (two wheel lines) along 100 feet of bridge deck.*

2 The full text of this survey question: *If possible, please estimate the typical amount of time required to analyze the collected data to determine the quantity and location of areas not in compliance with smoothness requirements for a single lane (two wheel lines) along 100 feet of bridge deck.*

3 These estimates are associated with the agency's pilot use of an inertial profiler. The time estimate includes equipment setup and checks. Joint locations are flagged and layout is completed prior to collecting data.

Certification Requirements

Respondents are more likely to require certification or approval of the measurement equipment used (nine agencies) than require certification of the operators using that equipment (seven agencies). Table 8 summarizes agency requirements for certification or approval of the measurement equipment before use and certification of the equipment operator.

Table 8. Certification of Measurement Equipment and Operator

State	Measurement Equipment Certification	No Measurement Equipment Certification	Operator Certification	No Operator Certification
Arizona		X		X
Arkansas		X		X
Colorado		X		X

State	Measurement Equipment Certification	No Measurement Equipment Certification	Operator Certification	No Operator Certification
Florida		X		X
Indiana	X			X
Iowa	X		X	
Michigan	X		X	
New Mexico		X		X
North Dakota	X		X	
Pennsylvania	X		X	
South Carolina	X			X
South Dakota		X	X	
Tennessee	X			X
Virginia		X		X
Washington		X		X
West Virginia	X		X	
Wisconsin	X		X	
Total	**9**	**8**	**7**	**10**

Treatment of Different Bridge Deck Types

Respondents described differences in practice based on certain bridge characteristics in four topic areas:

- Applying measurement practices.
- New versus existing bridge decks.
- Smoothness tolerances for new concrete bridge decks.
- Pedestrian and bicycle bridges.

Applying Measurement Practices

Eleven of the 17 responding agencies apply the same measurement practices to all concrete bridge decks, regardless of type, size, posted speed limit or other bridge characteristic. The remaining six agencies employ different measurement practices:

- *Arizona*. Measurement practice is dependent on the riding surface and waterproofing.
- *Florida*. A straightedge is used for short bridge decks of 100 feet or less; a profilograph is used for bridge decks greater than 100 feet.
- *North Dakota*. The agency is starting to use a walking profilograph on larger bridges where a straightedge is not practical.
- *Pennsylvania*. Other measurement practices may be used for major projects, interstates and special projects.
- *South Carolina*. Bridges of 100 feet or less are measured using a rolling straightedge or straightedge only. Bridges longer than 100 feet are measured longitudinally using a profilograph. Transverse tolerance for all bridge sizes is determined using a straightedge.
- *Tennessee.* Speed limit is a factor that changes the threshold for the selection of a measurement practice.

New Versus Existing Bridge Decks

Sixteen of 17 respondents reported no difference in smoothness tolerances for new and existing bridge decks. Indiana DOT applies a higher IRI allowance for rigid overlays "due to existing conditions."

Smoothness Tolerances for New Concrete Bridge Decks

Fourteen of the 17 respondents provided specifications or other relevant comments when asked to describe smoothness tolerances. Six states (*Arizona*, *Colorado*, *New Mexico*, *Virginia*, *Washington* and *West Virginia*) reported the same tolerances presented in Tables 2 and 3 (see page 21). See Appendix B for a compilation of specifications for the 24 responding agencies, plus additional specifications from other state DOTs.

Pedestrian and Bicycle Bridges

For eight of 17 responding agencies — Florida, Iowa, North Dakota, Pennsylvania, South Dakota, Tennessee, West Virginia and Wisconsin — bridges that are primarily for pedestrians and bicycles are not subject to the agency smoothness specifications. Respondents from eight of the nine agencies that do apply smoothness specifications to pedestrian and bicycle bridges noted that there is no distinction in the smoothness measurement specifications based on the type of bridge. In South Carolina, construction of pedestrian- or bicycle-only bridges is extremely rare so the issue may not have been considered. The respondent noted that the agency's "standard specification does not distinguish between these use types."

Indiana DOT's Pilot Study and Specification Change

Indiana DOT is the only responding agency that was actively evaluating a transition to a new surface smoothness measurement method for bridge construction at the time the survey was deployed. As indicated in the survey responses, in 2025 the agency continued its 2024 pilot of a road surface profiler (RSP) inertial profiler with IRI measurement for full bridge project limits plus 50 feet at each end. Indiana DOT was considering this transition given the current specification's applicability to only bridge decks and reinforced concrete bridge approaches.

Indiana DOT's highway smoothness program converted from use of a profilograph to inertial profilers in the past few years, and the agency anticipates the same benefits of accuracy and safety when applying the measurement method to bridges.

Related Resources:

> **Recurring Special Provision 704-R-794 Bridge Encounter Smoothness**, Division 700, Structures, Indiana Department of Transportation, revised February 21, 2025.
> https://www.in.gov/dot/div/contracts/standards/rsp/sep25/700/704-R-794%20250901.pdf
> This recently adopted special provision will be in effect for the September 1, 2025, letting date. *From the special provision*:
>
> > **Description**
> > This work shall consist of measuring and correcting the smoothness of bridge encounters, in accordance with 105.03 and as specified herein.

Construction Requirements

Longitudinal smoothness of the bridge encounter will be accepted by means of an inertial profiler or a 16 ft long straightedge as specified herein. Transverse smoothness of the bridge encounter will be accepted by means of a 10 ft long straightedge as specified herein. The smoothness of the bridge encounter mainline travel lanes shall be measured and corrected as required prior to the final longitudinal grooving surface finish.

The bridge encounter will be defined as 50 ft of existing entry pavement, the entry RCBA slab, the bridge concrete floor slab, the exit RCBA slab, and 50 ft of existing exit pavement including all joints. When the plans specify a rigid bridge deck overlay, the full extent of the rigid overlay material shall be included in the bridge encounter including bridge floor slab overlay, RCBA overlay, terminal joints overlay, and PCCP transition overlay. When the contract includes any of the following work: PCCP or HMA terminal joints, concrete lugs, JRCP [jointed reinforced concrete pavement] transition slabs, HMA pavement wedges, transition milling and transition overlays whether HMA or PCCP, the length of the bridge encounter shall be extended at each end to include all such components, and the bridge encounter shall extend an additional 50 ft into the entry and exit existing pavements.

Inertial Profilers, ITM No. 917-25, Division of Materials and Tests, Indiana Department of Transportation, Revised March 20, 2025.
https://www.in.gov/indot/doing-business-with-indot/files/917_testing_.pdf
This test method "covers the requirements for acceptance of smoothness with an inertial profiler, certification and operation of an inertial profiler to evaluate the smoothness of HMA and PCC pavements and Bridge encounters, and the operator approval process for use of the inertial profiler equipment."

Proposal to Standards Committee, Revision to 2024 Standard Specifications and Standard Drawings, Indiana Department of Transportation, November 2023.
https://www.in.gov/dot/div/contracts/standards/sc/2023/nov/SC_Addendum_1%20231117.pdf
Based on the work of a two-year pilot project, a proposed change in the specification would have bridge decks and approaches be poured continuously to promote a smoother ride, which is possible with advances in pavement construction. The method is also quicker and more cost-effective. This change would be the first of two phases to promote a smoother transition between the bridge deck and approaches. In spring 2024, the department planned to start phase two of the pilot, which would be a smoothness requirement specification to ensure rideability performance.

Current specifications require that bridge decks and bridge approaches be paved separately; see Appendix B for Indiana DOT's specifications.

"IRI Pilot Program Lessons Learned," Jacob Blanchard, *Road Profile Users' Group Webinar Series*, 2020.
https://rpug.sspa.us/wp-content/uploads/2020/10/3.23-Blanchard.pdf
A previous pilot program conducted in Indiana addressed the use of IRI as the smoothness measurement for multiple construction projects. Included in this pilot were incentives for contractors and the opportunity for contracting companies to provide feedback on the method, standards and equipment. Feedback topics included:

- Calibration of tolerance and comparing profilograph index to IRI.
- Need to communicate specification and incentives before construction.
- Different payment tables for different types of work.
- Guidance on the use of ProVAL for locating areas needing correction.

Assessment

Respondents assessed current agency practices and offered feedback in four topic areas:

- Accuracy of measurement method.
- Benefits of current measurement method.
- Limitations of current measurement method.
- Recommended practices.

Accuracy of Measurement Method

The survey identified no consensus regarding respondents' assessment of the accuracy of their measurement methods. For example, respondents rating their agencies' smoothness measurement method as *extremely* or *very accurate* used different measurement methods. Arizona, Indiana and Michigan use the straightedge or rolling straightedge; Florida, Iowa, South Carolina and Wisconsin use the profilograph in addition to the straightedge or rolling straightedge. South Dakota and Tennessee use IRI and MRI, while Iowa and West Virginia use inertial profilers along with a straightedge or rolling straightedge. Finally, four of the 10 agencies rating their methods as *extremely* or *very* accurate use ProVAL software.

Four of the six respondents rating their smoothness measurement methods as *somewhat accurate* identified the straightedge as their sole measurement instrument (*Colorado*, *New Mexico*, *Virginia* and *Washington*). The straightedge is also the primary instrument for Arkansas (one of the six), but contractors in Arkansas may opt for the inertial profiler to pursue a smoothness incentive. Two of the six use ProVAL software.

Only one agency — Pennsylvania DOT — rated its current measurement method (straightedge used with IRI, MRI and ProVAL) as *not so accurate*.

Table 9 presents survey responses by frequency and state.

Table 9. Rating the Accuracy of Measurement Data by Current Method

Accuracy Rating	Frequency	State
Extremely	2	Michigan, Wisconsin
Very	8	Arizona, Florida, Indiana, Iowa, South Carolina, South Dakota, Tennessee, West Virginia
Somewhat	6	Arkansas, Colorado, New Mexico, North Dakota, Virginia, Washington
Not So Accurate	1	Pennsylvania

Benefits of Current Measurement Method

Fourteen respondents described benefits of their agencies' current smoothness measurement methods. Table 10 summarizes survey responses.

Table 10. Benefits of Current Smoothness Measurement Method

Benefit	State and Description
Cost	*Arkansas*. The agency's use of a straightedge is a "low cost" solution.

Benefit	State and Description
Ease of Use	*South Carolina*. The profilograph provides quick data on a printout that is easy to understand. *South* Carolina. The rolling straightedge, while not as accurate, is much easier to use due to its portability. *Washington*. The agency's use of a straightedge with ProVAL offers "simplicity."
Oversight	*Tennessee*. The agency's engineers and technicians are available to validate the data if a dispute between the DOT and contractor occurs due to testing results. *West Virginia*. Agency practices allow for a hands-on approach to testing the bridge deck that can identify where other defects in the deck appear.
Reliability	*Colorado*. "Obvious discrepancies are caught" by the agency's use of a straightedge. *Florida*. The straightedge and profilograph measurements provide "reasonable smoothness measurement, well-known technology." *South Carolina*. The profilograph is very accurate, reliable and repeatable. *Tennessee*. The agency's current method — road surface profiler used with IRI, MRI and ProVAL — is "efficient and as accurate as it can get."
Safety	*Wisconsin*. High-speed profilers keep the operators safe.
Speed of Use	*Arkansas*. The straightedge identifies areas for correction while the surface is still workable. *South Carolina*. The profilograph provides quick data on a printout. *South Dakota*. IRI is fast. (The agency also uses a straightedge and rolling straightedge.) *Virginia*. The agency's use of a straightedge is "quick."
Other	*Indiana*. The agency's revised practices will align with its highway smoothness program for full bridge project limits, not just bridge deck and RCBA. *North Dakota*. The respondent noted that agency practices are "still a work in progress." While the walking profilograph is faster than a straightedge, the agency has had difficulty obtaining desired results using a ride specification in connection with the walking profilograph. *Pennsylvania*. Though the agency has moved away from its use of IRI/MRI measurement practices, the respondent commented, "It was a great metric to show improvement." *South Dakota*. The agency's IRI incentive/disincentive places the burden on the contractor to build a smooth approach.

Limitations of Current Measurement Method

Table 11 summarizes feedback from the 15 respondents who described the most significant limitations of their current measurement method.

Table 11. Limitations of Current Smoothness Measurement Method

Limitation	State and Description
Access to Equipment	*Indiana*. Industry investment in inertial profiler equipment and operators is needed. *South Carolina*. With only one profilograph in its inventory, the equipment's use must be scheduled in advance and it must be transported in a trailer. *Wisconsin*. Not all operators have zero stop machines yet.
Ease of Use	*Michigan*. It can be complicated to mark areas to be addressed if the deck has an excessive number of defects/bumps. *South Carolina*. The respondent reported a concern with the length of its profilograph in connection with the agency's bridge deck paving sequence. With approach slabs recessed two inches to allow for subsequent asphalt pavement, the agency is unable to measure the 16 to 17 feet at each end of the bridge deck due to the central wheel placement of the 33-feet-long profilograph. *South Dakota*. With IRI, the bridge and pavement with approaches must be completed. *West Virginia*. Sometimes the bridge deck is inaccessible for the high-speed inertial profiler.
Oversight	*Tennessee*. As the respondent noted, "All equipment has limitations. The data we collect is not set in stone; we go out and check after grinding if needed and have gone against the data in some cases."
Personnel Needs	*Arkansas*. Availability of sufficient personnel. Generally, two people are required to use the straightedge. *Florida*. Measurement is a manual practice with decreasing department experience for thorough verification. *Indiana*. The agency's specification change permitting the use of inertial profilers for bridge deck smoothness measurement will require training for DOT personnel on field use and software.
Time-Consuming	*North Dakota*. Agency specifications call for use of a straightedge and/or profilograph with ProVAL software. The North Dakota respondent noted that the methods are "still time-consuming" and "a high-speed profilograph would be better." *Washington*. The agency's use of a straightedge is "time-consuming if required for more than spot checking."
Other	*Colorado*. A straightedge is "usually just used on significant/obvious discrepancies." *New Mexico*. While the agency's specification indicates to measure/test "parallel" to centerline of roadway, there have been instances where the area perpendicular to centerline is the issue. *Pennsylvania*. The agency has moved away from IRI/MRI measurement practices. The respondent said, "[W]e have found the contractor will gladly eat the 'penalty'; it was a reward for doing good work." The respondent also noted that "the reward was way too small; contractors were not willing to put in the effort for such a small gain." *Virginia*. The agency's current method — straightedge used with ProVAL— is "not comprehensive."

Recommended Practices

Nine respondents provided at least one recommendation intended for other agencies preparing to adopt their current method of measuring bridge deck smoothness. Table 12 presents their recommendations. (Agency measurement methods are taken from Table 1; see page 18.)

Table 12. Recommendations for Other Agencies

State	Measurement Method*	Recommendation
Colorado	Straightedge	Beneficial characteristics of this measurement method: • Simple. • Easy to use. • Immediate response time.
Indiana	Straightedge Rolling Straightedge	• Consider piloting a new measurement practices. Piloting inertial profilers on bridge encounters allows industry and DOT field personnel input into the specification and builds knowledge. • Prepare to offer training on the equipment and software for field personnel when transitioning to a new measurement method. • Carefully evaluate smoothness thresholds, diamond grinding options, and limits of the bridge project and types of work involved.
Michigan	Straightedge	Establish a limit when grinding and sealing a large portion of the deck is required at the contractor's expense.
North Dakota	Straightedge Profilograph Measurement ProVAL	• Use a high-speed profilograph. • Ensure the incentive/disincentive is appropriate. • Establish appropriate thresholds for corrective action.
Pennsylvania	Straightedge IRI MRI ProVAL	• Fund the improvement in pavement smoothness; if it is an incentive, it has to be worth achieving. • Pilot on large projects. • Use third-party surveys until the agency is comfortable the specification "will stick."
South Carolina	Straightedge Rolling Straightedge Profilograph Measurement	• Carefully consider the Profile Index that is needed. Almost every bridge deck requires corrective grinding to approach the profile index of 10 inches per mile. This amounts to loss of concrete cover that may not make any noticeable difference to the traveling public. Such a discussion is currently underway at the agency. • Investigate the smaller profilograph (CS8550) as it may be a suitable option to allow more of the bridge deck to be measured.
South Dakota	Straightedge Rolling Straightedge IRI MRI	• Apply incentives or disincentive for smoothness. • Grind for smoothness if necessary. • Use IRI for everything.

State	Measurement Method*	Recommendation

Tennessee	IRI
	MRI
	ProVAL
		• Involve the contractors impacted by any possible change:
		  ○ Maintain an open line of communication and listen.
		  ○ Make the thresholds realistic and attainable.
		(The agency has added items at contractor request, such as a higher threshold along the joint.)
		• Make the data visual. Contractors do not like to be presented with endless research; they want to see what is impacting their bottom line.
		• Expect and prepare for contractor queries while their crews adapt to a new method. Train DOT staff and make them available to answer questions after revisions are made.

West Virginia	Rolling Straightedge Inertial Profiler ProVAL	Use the most recent version of the technology available.

* Measurement methods identified in Table 12 are taken from Table 1; see page 18.

States Not Employing a Standard Smoothness Measurement Practice

Respondents not reporting experience with a standard smoothness measurement practice fell into two categories: states contemplating a new standard practice and states with no plans to do so.

States Contemplating a Standard Practice

Two agencies — Connecticut and Mississippi DOTs — are contemplating establishing a formalized measurement practice.

Connecticut Department of Transportation
Connecticut DOT has not constructed a new bridge with a concrete surface in 15 years. For that large bridge, the agency specified the use of a California profilograph to measure smoothness. At that time, the agency's automated profilograph vans used a small laser footprint that had issues with diamond-ground surfaces; optical footprint lasers are now used.

The agency has started to replace some asphalt membrane bridge deck surfaces with polyester polymer concrete (PPC) surfaces that will be diamond-grooved, and is considering specifying smoothness measurements as part of these bonded overlays. As the respondent reported, "We expect a lot more rehabs on larger bridges that will replace the existing membrane and asphalt overlay system with a bonded concrete overlay — with primarily PPC."

For any new larger concrete-surfaced bridges, the respondent expects the agency to "specify some smoothness requirements utilizing our current ability to measure IRI with our ARAN (automated road analyzer network) vans." While Connecticut DOT is currently assessing the benefit of specifying smoothness on PPC rehabilitation projects that will be ground or grooved, the respondent commented that "it may be overkill," further noting:

A decent level of smoothness is almost guaranteed if the PPC overlay placed is typically around 1-2" on an existing bridge deck, and then ground or grooved.

We will be grinding or grooving any new or bonded rehab concrete surfaces. For new surfaces, we will specify smoothness via our smoothness spec. We would have to verify that the current laser footprint will work. For rehabilitated concrete decks with thin bonded concrete overlays, we will be assessing whether we need to measure smoothness for payment. We are currently in that decision process for [three] major bridge rehab projects. The first bridge may not specify measuring smoothness to see how we make out. And then go from there.

Mississippi Department of Transportation

Mississippi DOT is considering development of a new specification for the transition between the road and bridge deck. As the respondent noted, this transition "normally has an MRI bump around 350 in/mile." The new specification and measurement practice, which is expected to help ease the transition between the surface of the road and the bridge deck, may be implemented in late 2025/early 2026.

The respondent noted that the agency has collected data for several bridges of varying age using the agency's high-speed inertial profiler.

States Reporting No Interest in a Standard Practice

Five state DOTs have no plans for or interest in establishing a smoothness measurement practice (*Alaska*, *Idaho*, *Missouri*, *New Hampshire* and *New York*). Four of these respondents provided additional context:

- *Alaska*. The agency uses predominately precast decked bulb-tee girders with a waterproofing membrane and asphalt wearing surface, so the roughness of the deck is only relevant for application of membrane.
- *Missouri*. The agency requires diamond grinding for bridge wearing surfaces and smoothness acceptance is determined by a Missouri DOT engineer.
- *New Hampshire*. The respondent estimates that 98% of bridge decks in the state receive a barrier membrane and asphalt wearing course.
- *New York*. The agency has had "pretty good results for most situations based on screed machine setup. Any measuring is done with straightedges."

Related Research and Resources

Results of a literature search of in-progress and published domestic and international research are presented below in the following categories:

- National research and guidance.
- State research.
- International research.
- Measurement tools.

Domestic and international resources are reflected together under the final two categories of research.

Appendix B contains specifications for smoothness measurement of concrete pavement construction from 28 state DOTs (including all 24 survey respondents):

Alaska	Indiana	New Mexico	South Dakota
Arizona	Iowa	New Jersey	Tennessee
Arkansas	Kentucky	New York	Utah
Colorado	Michigan	North Dakota	Virginia
Connecticut	Mississippi	Ohio	Washington
Florida	Missouri	Pennsylvania	West Virginia
Idaho	New Hampshire	South Carolina	Wisconsin

National Research and Guidance

NCHRP Synthesis 580: Practices for Ensuring the Smoothness of Concrete Bridge Decks, Rohan W. Perera, 2022.
Publication available at https://nap.nationalacademies.org/download/26562
From the summary:

> The objectives of this synthesis were to document the procedures used by state DOTs to evaluate the smoothness of concrete bridge decks when constructed, procedures used to keep track of the roughness of concrete bridge decks over time, and procedures used to maintain the smoothness of concrete bridge decks over their life.
>
> ….
>
> A variety of methods are used by state DOTs to evaluate the smoothness of newly constructed concrete bridge decks. The methods used by the DOTs include the following:
>
> - Smoothness not evaluated (two state DOTs, 5% of respondents).
> - Using only a straightedge (17 state DOTs, 43% of respondents).
> - Based on a rolling straightedge (six state DOTs, 15% of respondents).
> - Based on a straightedge or a rolling straightedge (one state DOT, 2% of respondents).
> - Based on International Roughness Index (IRI) (six state DOTs, 15% of respondents).
> - Based on profilograph measurements (eight state DOTs, 20% of respondents).

Figure 3 below, taken from page 27 of the report (page 36 of the PDF), identifies the evaluation methods used and the agencies using them. Six case examples presented in Chapter 4 of the report provide details of the measurement practices employed by Florida, Mississippi, Nevada, New Jersey, Ohio and Utah DOTs.

Method Used to Evaluate Smoothness	State DOTs Using the Method	Number of State DOTs	Percentage of Responding State DOTs (%)
Smoothness not evaluated	Indiana, New Hampshire	2	5
Only a straightedge used[a]	Alabama, Alaska, Arkansas, Colorado, Connecticut, Louisiana, Maine, Maryland, Massachusetts, Montana, New Mexico, New York, Pennsylvania, Texas, Vermont, Washington, Wyoming	17	44
Rolling straightedge	Kansas, Kentucky, Missouri	3	7
Straightedge or rolling straightedge	Delaware	1	3
Rolling straightedge simulation on inertial profiler data	Rhode Island	1	3
Rolling straightedge simulation on walking profiler data	New Jersey	1	3
IRI[b]	Michigan, Minnesota, Nevada, Ohio, Tennessee, Utah	6	15
Profilograph measurements[c]	Florida, Georgia, Hawaii, Illinois, Iowa, Mississippi, Nebraska, South Carolina	8	20
Total		39	100

[a] Some state DOTs that use IRI or profilograph measurements also have a straightedge-based requirement. Such state DOTs are not included in this category.

[b] Some state DOTs indicated that if an IRI-based specification is not used for a bridge, a straightedge-based specification is used.

[c] Some state DOTs indicated that if a PI-based specification is not used for a bridge, a straightedge-based specification is used.

Figure 3. State DOT Practices for Evaluating the Smoothness of New Concrete Bridge Decks
(*Source*: NCHRP Synthesis 580.)

From Chapter 4, Case Examples (page 39 of the report, page 48 of the PDF):

> Three of the selected state DOTs (Nevada DOT, Ohio DOT and Utah DOT) use a smoothness specification that is based on the IRI, two of the selected state DOTs (Florida DOT and Mississippi DOT) use a smoothness specification that is based on profilograph measurements, and the other state DOT (New Jersey DOT) uses a specification that is based on a rolling straightedge simulation performed on the data collected with a walking profiler.

From the Nevada DOT case example (page 41 of the report, page 50 of the PDF):

> Nevada DOT uses an IRI-based smoothness specification for concrete bridge decks. This specification only has a localized roughness criterion and does not have an overall MIRI [Mean IRI] criterion. Nevada DOT adopted this IRI-based criterion in 2016.
>
> Before 2016, the Nevada DOT smoothness specification for bridge decks was based on a profilograph criterion. This criterion indicated that bumps/dips above 0.3 in. over a 25-ft. chord length should be corrected. This specification did not have an overall PI [Profile Index]-based criterion. When the DOT adopted the IRI-based criterion, the profilograph bump criterion was replaced with a localized IRI criterion.

Related Resource:

Evaluating the Smoothness of Newly Constructed Concrete Bridge Decks*,* TRB Webinar, Transportation Research Board, February 2022.
https://onlinepubs.trb.org/onlinepubs/webinars/230206.pdf
The learning objectives for this webinar presenting findings from the NCHRP synthesis cited above include:

- Describe the methods used by state DOTs to evaluate the smoothness of newly constructed concrete bridge decks.
- Identify the various equipment and methods that are used to measure smoothness of newly constructed concrete bridge decks.
- Understand the indices used to quantify smoothness and the threshold limits established by DOTs for smoothness.

Illinois DOT completed a research project in May 2001 that established recommendations for pavement corrections using a lightweight profiler for data collection and IRI specifications. IRI specifications adopted in 2022 (moving away from PI) call for bridge decks being placed 1/4 inch thicker to accommodate grinding, and the final surface must have a continuous MRI below 200 in./mi. over 25 ft. (see slides 36-38).

Ohio DOT (ODOT) historically used PI computed from California profilograph measurements to evaluate smoothness, but in 2007 it transitioned from PI to IRI (see slides 41-54). A research project conducted during the period 2008 through 2011 evaluated ride quality improvements at the interface of pavement and bridge decks. It established an overall mean IRI of lane < 130 in/mile to avoid the need for correction. In January 2021, Supplement 1112 was rewritten to address costs of corrective action and provide guidelines for ProVAL software for measuring IRI for bridge encounters. Among Ohio DOT's lessons learned:

- Educate agency construction staff and place specialists in all parts of your state. ODOT's IRI Smoothness Specification and ProVAL Software User's Group is an example.
- Educate and work with contractors. ODOT has contractors involved in the specification process and user groups.
- Prepare a supplement for approval for equipment and operators.
- Prepare a supplement that provides clear direction on how to perform IRI and provide information for non-ProVAL users.
- Positive and negative adjustments have value for a long-term specification, providing a consistent path for project administration and maintenance of quality standards for bridge structures.
- Smooth bridges have value — lower maintenance cost, improved user cost and safety, and improved user satisfaction.

Related Resources:

Development of IDOT's Proposed Smoothness Specification Based on the International Roughness Index, Hyung Lee, William Vavrik and Hesham Abdualla, Illinois Department of Transportation, September 2020.
https://doi.org/10.36501/0197-9191/20-015
From the abstract: The existing smoothness specification implemented by the Illinois Department of Transportation (IDOT) was based on profile-index measurement, which was

also widely used by other agencies. There is a national and international trend, however, toward using the international roughness index (IRI) as a standard smoothness index for pavement management as well as construction acceptance. Therefore, the primary objective of this study was to develop an IRI-based smoothness specification for IDOT. It was desired that IRI thresholds be developed objectively by quantifying the benefit of pavement smoothness. The benefits quantified within the framework of life cycle cost analysis and benefit-cost analysis generally revealed that smoother pavements are anticipated to exhibit increased service life, reduced life cycle cost (including agency and user costs), and improved safety. IRI is also a crucial component of user comfort, especially for high-speed facilities. IDOT's new IRI-based specification was developed while considering these benefits along with the increased cost quantified as the incentive payments to be made for smoother pavements. In addition, several aspects of IRI thresholds and the smoothness assessment schedule were investigated for achievability and risk. Although the risk of moving from a profile-index-based specification to an IRI-based specification was found to be relatively low (i.e., 4.4% and 6.6% risk assessed for high-speed and low-speed facilities, respectively), it indicated that IDOT and IDOT's contractors may need to work together to adapt to the new specification and continue to refine the IRI-based specification as more experience is gained.

Development of a Bridge Smoothness Specification for Illinois DOT, Dulce Rufino, Kenyatta BaRaKa and Michael Darter, Illinois Department of Transportation, May 2001.
https://www.ideals.illinois.edu/items/46361
From the abstract: Smoothness is considered to be the most important ride quality by the highway user. Although bridges are much rougher than pavements, most of the studies conducted to improve pavement smoothness have been focused solely on pavements. This report describes the effort of the University of Illinois to develop a preliminary bridge smoothness specification for the Illinois Department of Transportation (IDOT). The preliminary specification presented in this research report is based on the testing and analysis conducted under this study and reflects the views and experience of the authors. It is emphasized that this draft specification is not intended for use in construction without significant additional development and field testing. The most suitable index and equipment are recommended based on a literature review of smoothness indices and different pieces of equipment.
In addition, International Roughness Inde x (IRI) and Profile Index (PI) values were computed from testing 20 recently constructed or rehabilitated IDOT bridges in Illinois using a lightweight profilometer. These data were analyzed in order to set up smoothness limits for bridges, and a correlation between IRI and PI was established.

Measuring and Specifying Pavement Smoothness, Kurt Smith and Prashant Ram, Technical Brief, Federal Highway Administration, June 2016.
https://rosap.ntl.bts.gov/view/dot/38480/dot_38480_DS1.pdf
From the summary: As an important indicator of pavement performance, smoothness is used interchangeably with roughness as an expression of the deviation of a surface from a true planar surface (as defined by ASTM E867) and is often cited as the most important indicator of user satisfaction. However, smoothness also imparts a number of other benefits, including improved pavement performance and service life, improved safety, and reduced fuel and vehicle maintenance cost. The purpose of this Tech Brief is to describe the tools and techniques used to measure and express pavement smoothness.

Best Practices for Achieving and Measuring Pavement Smoothness: A Synthesis of State-of-Practice, David Merritt, George Chang and Jennifer Rutledge, Louisiana Transportation Research Center, March 2015.
https://rosap.ntl.bts.gov/view/dot/28837
From the abstract: Pavement smoothness specifications have evolved significantly over the past decade. More and more states are moving away from profilograph-based smoothness specifications to IRI-based specifications. Unfortunately, a limited history with the usage of IRI-based specifications has led to some confusion over how best to structure a specification in terms of test methods and profiling equipment, thresholds for full pay/incentive/disincentive, and requirements for localized roughness or "must correct" areas. This limited history has also led to contractors who were used to profilograph-based specifications struggling to achieve the same level of quality under IRI-based specifications. This synthesis summarizes the current state-of-the-practice for IRI-based pavement smoothness specifications in the US. It highlights recent and current research related the pavement smoothness and provides general best practices for construction to help achieve requirements for IRI-based specifications.

State Research

Presented below are research studies conducted by or in conjunction with six state DOTs: Connecticut, Florida, Illinois, Indiana, Oklahoma and Texas.

Connecticut

Implementation of a 3-D Sensing Technology for Automated Pavement Data Collection in Connecticut, Iliya Yut, James Mahoney and Donald Larsen, Connecticut Department of Transportation, June 2018.
http://hdl.handle.net/11134/30002:720241882
From the abstract: This report summarizes research on the impact of replacing older ARAN equipment (2D Strobe cameras, ultrasonic rut bar and inertial profiler) by the newest 3D laser technology (Pavemetric LCMS and RoLine sensors) on the accuracy and precision of pavement performance data collected by the Connecticut Department of Transportation (CTDOT). The main goal of the project was to develop transfer functions and/or correction factors relating cracking, rutting, and roughness values reported by the older and newer systems. In addition, precision and accuracy of the new technology was evaluated by comparison of data collected by two identical 3D systems. … Overall, this project revealed the new 3D laser scanning technology produces a much larger dataset and ultimately a much greater degree of resolution on the profiles due to an increase in the number of data points measured in both longitudinal and transverse directions.

Florida

"Cross-Correlation Analysis of Line Laser High-Speed Inertial Profilers," Noah Borelli, Bouzid Choubane, James Greene, Charles Holzschuher and James Fletcher, *Transportation Research Record 2674*, Issue 5, pages 626-636, 2020.
Citation at https://doi.org/10.1177/0361198120917371
From the abstract: Thirteen different line-laser high-speed inertial profilers from four different manufacturers were recently tested at the Florida Department of Transportation (FDOT) Inertial Profiler Test Track. … A cross-correlation analysis was performed on the resulting ride data. The accuracy comparison was performed using a SurPro reference profiler. The profilers as a group met the AASHTO R 56 cross-correlation criteria on each section except on a smooth, open-graded section. The profilers as a group met the repeatability cross-correlation on this section, but did not meet the accuracy cross-

correlation requirement. This paper presents a description of the testing program, data collection efforts and subsequent analyses and findings.

Illinois

Research in Progress: Advancements in Profiler Certification, Illinois Department of Transportation, start date: August 2024; expected completion: July 2026.
Project description at https://trid.trb.org/View/2410637
From the project description: Building smooth roads extends the life of pavements while lowering fuel consumption and vehicle maintenance costs. This project's aim is to help the Illinois Department of Transportation (IDOT) implement the latest technology in collecting ride-quality data or measuring road smoothness. Researchers will validate proposed tests for inertial profilers, a device that measures pavement's smoothness, and investigate improvements to IDOT's Illinois Certification and Research Track. Successfully implementing the latest technology will allow IDOT to make better decisions on what roads need to be addressed as well as provide data for underserved areas.

Indiana

Research in Progress: SPR-4617: Demonstration of Zero Speed Inertial Profilers, Purdue University/ Indiana Department of Transportation Joint Transportation Research Program, start date: March 2022; expected completion: August 2025.
Project description at https://trid.trb.org/View/1896769
From the project description: Indiana Department of Transportation (INDOT) pavement smoothness specifications utilize inertial profilers and IRI to evaluate newly constructed concrete pavement. The utilization of current inertial profilers is limited in low-speed zones that include stop signs and traffic lights. Currently, one vendor is producing a "Zero Speed" inertial profiler, and the two other major players in inertial profilers are developing Zero speed inertial profilers. The "Zero Speed" inertial profilers include additional hardware and updated software to better model the motion of the vehicle. This allows collecting more accurate profiles in urban areas that include stop signs and traffic lights. The purpose of this study is to demonstrate the utility of "Zero Speed" inertial profiler in urban areas.

Oklahoma

"Performance Evaluation of Bridge Approach Slabs and Joints Through Sub-mm 3D Laser Imaging System," Guolong Wang, Kelvin Wang, Guangwei Yang and Joshua Qiang, *International Conference on Transportation and Development*, pages 742-754, June 2024.
Citation at https://doi.org/10.1061/9780784485514.065
From the abstract: In this study, a total of 377 bridges located across Oklahoma with different designs and conditions of approach slabs were surveyed. The recent Pave3D 8K system featuring sub-mm 3D laser technology and inertial profiler was used to collect the 2D/3D images and inertial data from these bridges for evaluating approach bump and distress. Based on the bump levels of all approach slabs, the performance of the slab design, including slab length and skew angle, and bump mitigation method via asphalt overlay were evaluated.

Texas

Research in Progress: Evaluation of Low-Speed Profiler for Network-Level Pavement Management, Texas Department of Transportation, start date: September 2024; expected completion: August 2026.
Project description available at https://library.ctr.utexas.edu/Presto/project=0-7210
From the project summary: For pavement management and to understand the condition of its network, TxDOT [Texas DOT] relies on high-speed inertial profilers to gather ride quality. However, a persistent

challenge arises when assessing pavement smoothness at low speeds or under stop-and-go conditions (i.e., signalized intersection, stop-control intersections, high driveway density producing turning traffic, and congested roadways during peak-hour traffic) that compromises the accuracy of data collected by conventional profilers. … The research team will explore the potential of low-speed profilers to enhance data collection accuracy in such scenarios. The research team will evaluate the effectiveness of low-speed profilers in providing accurate pavement profile data, particularly in areas prone to low-speed or acceleration and deceleration operations. The research team will validate the capabilities of low-speed profilers and recommend strategies for their integration into TxDOT's pavement management practices, ultimately leading to a more accurate condition assessment.

Exploring New Measurement Technologies

The sampling of publications cited below, many that are the product of international research teams, explore the application of new measurement technologies to determine pavement smoothness. While the methods examined are not specifically described in the context of evaluating the smoothness of bridge decks, their potential application to more targeted smoothness measurements may be of interest to Caltrans. Presented below are publications in eight topic areas:

- Connected vehicles.
- Digital surface model measurement.
- Laser.
- LiDAR.
- Machine learning models.
- Pseudo-vibration velocity range testing.
- Smartphones.
- Uncrewed aircraft systems.

Connected Vehicles

"Comparison of IRI from Connected Vehicles and IRI from Profilometer: Measurements Done in 2021," Olle Eriksson, Peter Andrén and Thomas Lundberg, *VTI Rapport*, Issue 1135A, 2022.
http://vti.diva-portal.org/smash/get/diva2:1678028/FULLTEXT01
From the abstract: The purpose of the present study is to perform an objective evaluation of the roughness measurements from connected vehicles equipped with software from Nira Dynamics AB (Nira). The focus of the study is to determine the quality of the estimated IRI from the connected vehicles, regarding both daily and aggregated long-term data. The quality will be determined by comparing with a dedicated road surface measurement vehicle (VTIRST) from the Swedish National Road and Transport Research Institute (VTI) which is approved according to the Swedish Transport Administration's "Technical approval for road surface measurement." The study shows that the Nira estimated IRI is not quite the same as the IRI from the VTIRST. Nira's estimated IRI may, however, be seen as a different index of road roughness, that may well be used in parallel with the standardized IRI. Also, the algorithms used by Nira can most likely be improved and produce a result closer to IRI from the VTIRST.

Digital Surface Model Measurement

"Evaluation of Pavement Smoothness with a Digital Surface Model (DSM)," Jia-Ruey Chang, Jyun-Ping Jhan, Kun-Hu Lin, Chun-Chieh Tseng, Po-Sen Yang, Chih-De Wang and Hsun Chiao Yu, *13th International Conference on Road and Airfield Pavement Technology*, pages 321-337, January 2024.
Citation at https://doi.org/10.1061/9780784485255.026

From the abstract: This study reviewed smoothness measurement and digital surface models (DSM), and developed an intelligent road survey vehicle (IRSV). Firstly, a 100-m standard section was established by road and level. Then, the developed IRSV was driven to obtain images of the overall pavement within the three-lane width range including the left and right lanes of the vehicle's lane. After dense point-cloud matching of the images, a DSM was obtained. Three survey profiles of the standard section were extracted from the DSM, and ProVAL 3.60 was used to calculate the international roughness index (IRI) of these three survey profiles. Then, an institution accredited by Taiwan Accreditation Foundation used a walking profiler to obtain the profiles and IRIs for the three survey profiles for comparison purposes. The findings show that the ability of the IRSV to obtain the pavement profile is successfully verified.

Laser

Safety Evaluation of Pavement Surface Characteristics with 1mm 3D Laser Imaging, Kelvin Wang and Joshua Li, Southern Plains Transportation Center, 2019.
https://rosap.ntl.bts.gov/view/dot/41983
From the abstract: This report documents the applications of 1mm 3D laser imaging technology to perform safety evaluation of pavements. Several state-of-the-art data collection devices were used for data collection, including the Oklahoma State University (OSU) 3D laser imaging technology (named as PaveVision3D Ultra) for 1mm 3D pavement surface data, the Inertial Measurement Unit (IMU), Grip Tester for continuous surface friction, dynamic friction tester (DFT) for dynamic friction coefficients, AMES high speed profiler for pavement roughness and macro-texture, and the portable LS-40 3D Surface Analyzer for ultra-high resolution pavement texture. … This study with field pavement applications has shown that the 1mm 3D Ultra technology is promising in real-time pavement surface characterization and evaluation for both pavement and safety management at network and project level surveys.

NOTE: Publications examining the application of laser imaging to smoothness measurement also appear under **State Research** beginning on page 39; see the **Connecticut** and **Oklahoma** citations.

LiDAR

"Assessing of the Road Pavement Roughness by Means of LiDAR Technology," Maria Rosaria De Blasiis, Alessandro Di Benedetto, Margherita Fiani and Marco Garozzo, *Coatings,* Vol. 11, No. 17, 2021.
https://www.mdpi.com/2079-6412/11/1/17/pdf
From the abstract: In this work, the authors compared the roughness index (International Roughness Index, IRI) derived from high speed inertial profilometer with two other roughness indices, one dynamic and one geometric computed on a digital elevation model (DEM) built by using mobile laser scanner (MLS) data. The MLS data were acquired on an extra-urban road section and interpolated on the nodes of a DEM with a curvilinear abscissa, coinciding with the global navigation satellite system (GNSS) track of the profilometer. … The roughness values computed on the surface of the DEM showed a similar trend and a high correlation with those acquired by the profilometer, higher for the dynamic index than for the geometric index. The differences between the IRI values by profilometer and those computed on the DEM were small enough not to significantly affect the judgments on the analyzed sections. Moreover, the road sub-sections derived from profilometer measure that were classified as critical coincided with those derived from light detection and ranging (LiDAR) surveys. The proposed method can be used to perform a network-level analysis.

"Roughness Analysis of Paved Road Using Drone LiDAR and Images," Kap Yong Jung and Joon Kyu Park, *Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography,* Vol. 39, No. 1, pages 55-63, February 2021.
https://doi.org/10.7848/ksgpc.2021.39.1.55
From the abstract: In this study, data on the road surface were acquired using the latest 3D geospatial information construction technology of ground LiDAR, drone photogrammetry, and drone LiDAR, and the accuracy and roughness of each method were analyzed. … As a result of roughness analysis, the ground LiDAR showed the same slope as the design value, and the drone photogrammetry and drone LiDAR showed a slight difference from the design value. Research is needed to improve the accuracy of drone photogrammetry and drone LiDAR in measurement fields such as road roughness analysis. If the usability through improved accuracy can be presented in the future, the time required for acquisition can be greatly reduced by utilizing drone photogrammetry and drone LiDAR, so it will be possible to improve related work efficiency.

Machine Learning Models

"A Machine Learning-Based Framework for Predicting Pavement Roughness and Aggregate Segregation During Construction," Mostafa Elseifi, Md Tanvir Ahmed Sarkar, Ramchandra Paudel, Hossam Abohamer and Momen Mousa, *Journal of Transportation Engineering, Part B: Pavements*, Vol. 150, Issue 3, September 2024.
Citation at https://doi.org/10.1061/JPEODX.PVENG-1411
From the abstract: The key objective of this study was to develop a quality assurance decision-making tool that can predict pavement roughness, in terms of the International Roughness Index (IRI), and aggregate segregation based on digital image analysis, image recognition, and deep machine learning models. The developed models were trained, tested, and validated using 600 pavement surface images extracted from the Louisiana Department of Transportation and Development (LaDOTD) Pavement Management System (PMS). Furthermore, the effectiveness of the convolution neural network (CNN) model was validated using pavement surface images collected at construction sites in Louisiana a few days after paving. The roughness model predicted the International Roughness Index values with a coefficient of determination R^2 of 0.98 and a RMS error (RMSE) of 3.5%. To support the implementation of these results, the models were incorporated into a computer application that can be used by site engineers for quality assurance without the need for coding software on their device.

"Surrogate Modelling of Surface Roughness for Asphalt Pavements Using Artificial Neural Networks: A Mechanistic-Empirical Approach," Haoran Li, Hessam Azarijafari, Randolph Kirchain, João Santos and Lev Khazanovich, *International Journal of Pavement Engineering*, Vol. 25, Issue 1, 2024.
Citation at https://doi.org/10.1080/10298436.2024.2434909
From the abstract: Previous studies have used field measurement data or AASHTOWare Pavement ME Design simulations for the development of machine learning (ML) models to streamline the IRI modelling. However, these models frequently lack the accuracy and robustness of the measurement data or high-fidelity computational simulations they are intended to surrogate. To address this issue, the authors employed a new adaptive sampling technique to generate an informative yet efficient pavement damage database from Pavement ME simulations. Utilising Artificial Neural Networks (ANNs), the authors engineered two types of surrogate ML models: (a) Model I, an ANN-based IRI predictive model, and (b) Model II, a hybrid model combining ANN-based predictions of rutting, fatigue damage, and thermal cracking with closed-form relationships between these indicators and IRI. The authors' findings show that Model II outperforms Model I in IRI modelling accuracy both globally and locally. Moreover, Model II matches IRI simulations of Pavement ME while providing enhanced efficiency and adaptability to a broader spectrum of design considerations.

"Developing an Improved Extreme Gradient Boosting Model for Predicting the International Roughness Index of Rigid Pavement," Changbai Wang, Wei Xiao and Jimin Liu, *Construction and Building Materials*, Vol. 408, December 2023.
Citation at https://doi.org/10.1016/j.conbuildmat.2023.133523
From the abstract: The International Roughness Index (IRI) is a crucial indicator for evaluating pavement performance. However, existing prediction models for IRI in rigid pavements primarily rely on linear regression or simple machine learning techniques, which necessitates improvements in both training efficiency and interpretability. In addressing this issue, a proposed IRI prediction model combines the Extreme Gradient Boosting (XGBoost) method with advanced hyperparameter optimization utilizing the Tree-structured Parzen Estimator (TPE) technique. Furthermore, the model incorporates the Shapley Additive Explanations (SHAP) interpretability framework. …Results demonstrated that after TPE hyperparameter optimization, the XGBoost model achieved an R^2 value of 0.896, and an RMSE value of 0.187. Surpassing performance compared to other ensemble learning models.

Pseudo-Vibration Velocity Range Testing

"Low-Cost Portable Road Smoothness Testing Method Based on Pseudo-Vibration Velocity Range," Hongwei Jiang, Xinlong Tong, Yanhong Zhang, Zhoujing Ye, Junqing Li, Yu Wang and Yinghao Miao, *Advances in Civil Engineering*, Issue 1, pages 1-13, January 2024.
https://doi.org/10.1155/2024/6314144
From the abstract: This study uses vehicle-mounted acceleration sensors to detect road smoothness, establishing a correlation between driving vibration acceleration data and the international roughness index (IRI). For this research, a driving vibration acceleration data acquisition device was developed, and the driving acceleration data from the test sections were denoised and their feature values extracted. The pseudo-vibration velocity range was used as the characteristic index representing the road surface smoothness IRI value. Testing with different vehicle types showed that the method is applicable to both sedans and SUV models, yielding a relative error of 8.9% for the sedan smoothness test model and 6.7% for the SUV smoothness test model.

Smartphones

"Comparison of Smartphone-Based and Drone-Based Approaches for Assessing Road Roughness," Hamed Afsharnia and Seyed Morsal Ghavami, *Transportation Research Record 2678,* Issue 2, pages 24-34, 2024.
Citation at https://doi.org/10.1177/03611981231172968
From the abstract: The study aims to investigate the merits of using two different types of device for assessing road roughness: the smartphone as a response-type and the drone as a non-contact-type device. To this end, firstly, linear vertical acceleration data is collected by using a smartphone that is mounted on a car dashboard. Then, the collected data is used for calculating vertical displacement data using a fast Fourier transform. The displacement data is used for calculating international roughness index (IRI) as a measure of road roughness. Secondly, a drone flies over the studied road to construct a 3D model, extract the longitudinal profile, and eventually calculate the accurate IRI values of the road. Finally, the results of the approaches above will be compared with the results of a road surface profiler (RSP) as a reference method. Although the results reveal a significant correlation (above 0.8) of both methods with the RSP method, from an operational point of view, the smartphone was more cost and time effective, and also an easy-to-use approach for the purpose.

"Pavement Roughness Evaluation Method Based on the Theoretical Relationship Between Acceleration Measured by Smartphone and IRI," Zhen Zhang, Hongliang Zhang, Song Xu and Wenjiang Lv, *International Journal of Pavement Engineering*, Vol. 23, No. 9, pages 3082-3098, August 2022.
Citation at https://doi.org/10.1080/10298436.2021.1881783
From the abstract: Smartphones have integrated various sensors (e.g., GPS, acceleration sensor) and can be used to evaluate road roughness. In this study the theoretical algorithm, in which the vehicle suspension parameters were included, would be established to calculate International Roughness Index (IRI) from acceleration using smartphones. … The validation experimental results on three asphalt pavement segments indicated that the collected acceleration data utilizing smartphone were basically consistent with that by accelerometers. Meanwhile, IRI calculated by the proposed theoretical methodology was close to that obtained by digital survey vehicle (DSV) and the maximum relative error between them was below 10%. Overall, due to the consideration of vehicle dynamic characteristics, the proposed method could improve the measurement accuracy and enable various vehicles to be used for road roughness evaluation.

Uncrewed Aircraft Systems

Assessing the Feasibility of Utilizing a UAS-Based Point Cloud in Pavement Smoothness/Roughness Measurement, Erzhuo Che, Chase Simpson and Fatih Sen, U.S. Department of Transportation, December 2022.
https://digital.lib.washington.edu/server/api/core/bitstreams/2badf9b7-de9e-4e7d-abf5-b59e88db211f/content
From the abstract: The metric derived from the longitudinal profile IRI (international Roughness Index) is a substantial input for the majority transportation agencies' highway monitoring systems used to improve road safety, increase road quality, and reduce fuel consumption. Traditionally, authorities have used data collected by inertial profilers to evaluate IRI; however, these instruments are usually unfeasible for data collection in smaller areas, and their narrow field-of-view (FOV) produces inadequate context for the scene. Meanwhile, uncrewed aircraft systems (UAS) have been widely used in a variety of transportation applications because of their efficiency and affordability in acquiring high-quality data. Especially for smaller areas, through the Structure from Motion (SfM) technique, UASs are a promising complementary tool for conducting ground surveys because they can provide good 3D context with high-resolution images. However, the SfM approach has some limitations for predicting the accuracy and quality of produced point clouds because of some factors such as surface texture, lighting conditions, processing algorithms/software etc. Our study aimed to assess the feasibility and data accuracy of the SfM technique for evaluating IRI by considering its limitations. This study also sought to build a framework for obtaining IRI metrics from an SfM-derived point cloud and to provide recommendations for collecting and processing UAS data with the goal of extracting pavement information.

Determination of the Pavement Condition Index (PCI) and International Roughness Index (IRI) in Urban Roads Using Images Obtained by Unmanned Air Vehicles (UAV), J. Cruz Toribio and W. Gutierrez Lazares, *26th World Road Congress*, 2019.
Citation at: https://trid.trb.org/View/1743830
From the abstract: This research proposes an alternative methodology to obtain the Pavement Condition Index (PCI) and the International Roughness Index (IRI) using georeferenced images, obtained from an unmanned aerial vehicle (UAV), which are processed to generate an orthophoto high resolution and a dense point cloud on the surface of the pavement. The processing of the images and the analysis of the products allow the total visual inspection of the road in a safe way, identifying the type of existing deterioration, its severity and the damaged density, as parameters and inputs to use the PCI method. In addition, the profiles of the pavement circulation tracks are obtained for the calculation of the IRI in

each one of them. The innovation of the procedure to evaluate pavements and determine the PCI and IRI, periodically with the purpose of conservation of the urban roads, optimizing the scarce resources of the local governments with the benefit of the users.

Measurement Tools

Presented below is information on selected measurement tools that may be employed when measuring concrete bridge deck smoothness:

- Walking profiler.
- California profilograph.
- Inertial profiler.
- Real-time smoothness measurement.
- ProVAL.

NOTE: See page 20 of this report for a discussion of profiling equipment: *Comparing Traditional Walking Profilograph with Vehicle-Mounted Inertial Profiler*.

Walking Profiler

SurPro, International Cybernetics Company, LP, 2024.
https://icc-ims.com/equipment/reference-devices/surpro/
This is the model used by North Dakota DOT.

California Profilograph

CS8500 California Profilograph, Surface Systems & Instruments, Inc., 2025.
https://www.smoothroad.com/equipment/profilographs/cs8500-california-profilograph/
This is the model used by South Carolina DOT.

Inertial Profiler

8300 High Speed Inertial Road Profiler, Ames Engineering LLC, 2025.
https://www.amesengineering.com/products/8300-high-speed-profiler
This unit is "designed as a portable inertial profiling system that can be used on multiple vehicles. It can be front or rear mounted and can easily install onto any vehicle using a standard 2" receiver hitch."

Road Surface Profilometer MK III, Dynatest, 2025.
https://dynatest.com/equipment/road-surface-profiler-3/
This is the model used by Tennessee DOT.

SSI CS9500 Full Lane Survey Profiler, Surface Systems & Instruments, Inc., 2025.
https://www.smoothroad.com/equipment/inertial-profilers/cs9500-full-lane-survey-profiler/
From the website: Collect data quickly for wheelpath smoothness (IRI, MRI), rutting or point clouds for surveying and machine control. The CS9500 only requires one pass per lane to stitch together the entire pavement surface.

Zero-Speed Inertial Profiler, Surface Systems & Instruments, Inc., 2025.
https://www.smoothroad.com/equipment/inertial-profilers/zero-speed-inertial-profiler/
This unit may be used at high speeds or in stop-and-go environments.

Real-Time Smoothness Measurement

Real-Time Profiler, Ames Engineering LLC, 2025.
https://www.amesengineering.com/products/real-time-profiler
From the website: The Ames Real-Time Profiler is a laser enabled smoothness measurement system that monitors profile and calculates smoothness indices directly behind the paver and displays profile as concrete is placed.

- Quality Control: In-process profiling locates problem areas and informs fast and appropriate responses.
- Easy to Use: Mounts directly onto the back of a slipform paver.
- Instant Information: Rugged Panasonic Toughbook mounts to paver, creating a real-time scoreboard for monitoring smoothness values.

GSI GOMACO Smoothness Indicator, GOMACO Corporation, 2025.
https://www.gomaco.com/resources/gsi.html
From the website:

What is the GSI?

- A noncontact surface smoothness instrument that is so versatile it provides multiapplication usage.
- The GSI includes: GSI computer assembly, real-time graphic display, media storage card, two sonic sensors, slope sensor, distance counter wheel assembly and cables.

How is it done?
Three different sensors, two sonic and one slope, read the smoothness data in the wheel tracks (or anywhere on the surface of the slab) on up to eight traces or four lanes in one pass. The readings are from a six inch (152 mm) footprint to simulate the true picture of the tire contact area on the pavement. The information gathered by the sensors in each trace establishes a measurement of the slab.

Related Resource:

"Real-Time Smoothness Measurements for Portland Cement Concrete Pavements," Gary Fick, *Moving Advancements into Practice (MAP) Brief*, August 2016.
https://www.intrans.iastate.edu/wp-content/uploads/2019/11/MAPbriefAugust2016.pdf
From the brief:

Real-Time Smoothness (RTS) Systems
There are currently two systems commercially available for measuring PCCP [portland cement concrete pavement] (smoothness in real-time: Ames Real-Time Profiler (RTP), and Gomaco Smoothness Indicator (GSI). The Ames unit is a laser-based sensor combined with a ruggedized laptop (figure 2). The Gomaco unit uses sonic sensors and a dedicated computer (figure 3). Both are configured similarly with sensors mounted to the back of the paver to measure the pavement profile and send it to the data collection hardware and software for processing and display in real-time (figure 1).

The primary difference between the systems is the sensor technology used, the GSI uses acoustic (ultrasonic) sensors and the RTP uses lasers. When mounted to the back of the paver, both systems capture profile data by measuring the height of the sensor relative to the fresh pavement directly behind the paver (typically 6 in. to 12 in. behind the pan or trailing pan).

Benefits of Using Real-Time Smoothness Systems
When properly implemented into the contractor's paving operation, real-time smoothness systems provide valuable feedback that allows the contractor to adjust their processes to improve the initial smoothness characteristics (overall smoothness and localized roughness) of the new PCCP.

While profilographs and lightweight inertial profilers have traditionally been used for quality control and quality assurance (acceptance level) smoothness measurements, the pavement must have adequate strength and all sawing must be completed before they can be operated on the pavement surface, resulting in a minimum 12- to 24-hour delay in the feedback on smoothness numbers. Real-time smoothness systems provide the same profile information as the profilograph and inertial profiler, but in real-time during paving. It should be noted that these systems are not intended for, and should not be used for, acceptance measurements. (See Real-Time IRI vs. Hardened IRI page 4 for further details.)

ProVAL

Pavement Profile Viewer and Analyzer, Pavements and Materials Program, Federal Highway Administration, updated September 2018.
https://www.fhwa.dot.gov/pavement/proval/
From the website: The Profile Viewer and Analyzer (ProVAL) is a software that was initially developed to provide a means to view and analyze pavement profiles efficiently and robustly, as part of the Federal Highway Administration (FHWA) smoothness initiative. ProVAL imports, displays and analyzes the characteristics of pavement profiles from many different sources. ProVAL can analyze pavement profiles using several methods, including International Roughness Index (IRI), Ride Number, Profile Index, California profilograph, and rolling straightedge, and other more complex filters such as Butterworth band pass filters and power spectral density. Version 1.0 of the ProVAL software could import several popular profile data formats, such as ERD1, TxDOT2 and KJ Law3. A new standard profile format (PPF) was also created as a native ProVAL file specification, which proved to be stable, efficient, portable, and upgradeable. The PPF has since been recommended as the basis for the American Society for Testing and Materials (ASTM) draft profile data standard. Workshop material was also developed along with the ProVAL software to provide training in profiling fundamentals and the application of ProVAL.

ProVAL Applications
ProVAL can help State highway engineers, contractors and quality control managers improve the quality of pavement construction by analyzing a given profile quickly and providing results in a number of formats. In addition, researchers can use ProVAL to analyze large numbers of profiles of virtually any length, frequency of data collection and number of longitudinal traces.

Current Status
ProVAL is kept current under a Transportation Pooled Fund Project TPF-5(354), *Improving the Quality of Highway Profile Measurement*.

Download the current version of ProVAL from the following web site:
http://www.roadprofile.com/proval-software/current-version/

Contacts

CTC engaged with the individuals below to gather information for this investigation.

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Appendix A: Survey Questions

The online survey represented below was distributed via email to members of the American Association of State Highway and Transportation Officials Committee on Bridges and Structures.

Caltrans Survey on Methods for Measuring Surface Smoothness of Concrete Bridge Decks
The California Department of Transportation (Caltrans) is gathering information about the equipment and evaluation methods used by state departments of transportation to measure the surface smoothness of new concrete bridge decks. Caltrans is considering revising its current practice to apply profilograph measurements to evaluate surface smoothness with another method that will deliver the same degree of accuracy more quickly and with the use of less cumbersome equipment.

Caltrans is familiar with survey conducted for the 2022 *NCHRP Synthesis 580: Practices for Ensuring the Smoothness of Concrete Bridge Decks*. The survey below seeks to build on findings from NCHRP Synthesis 580 and identify agencies considering transition to a new smoothness evaluation method.

We estimate the survey below will take 20 minutes to complete. We would appreciate receiving your responses by **February 21**.

If someone else in your agency would be more appropriate to address questions related to this issue, please forward this survey to that person.

The final report for this project, which will include a summary of the responses received from all survey participants, will be available on the Caltrans website.

If you have questions about completing the survey, please contact Chris Kline at chris.kline@ctcandassociates.com. If you have questions about Caltrans' interest in this issue, please contact Tori Kanzler at tori.kanzler@dot.ca.gov.

Thank you in advance for your participation!

(Required) Please provide your contact information.

Name:
Agency:
Division/Title:
Email Address:
Phone Number:

NOTE: Responses to the question below determined how respondents are directed through the survey.

(Required) Does your agency employ a standard practice for measuring the surface smoothness of new concrete bridge decks?

- Yes (Skipped the respondent to **Measurement Method and Equipment**, **Measurement Practices**, **Data Collection and Analysis**, **Assessment** and **Wrap-Up.**)

- No, but we are contemplating establishing one. (Skipped the respondent to **Interest in Establishing a New Smoothness Measurement Practice** and **Wrap-Up**).
- No, and we have no plans for or interest in establishing such a practice. (Skipped the respondent to **Wrap-Up**.)

Measurement Method and Equipment

1. Please indicate below the measurement methods and tools your agency uses to evaluate the surface smoothness of a new concrete bridge deck. Select all that apply.
    - Straightedge only
    - Straightedge
    - Rolling straightedge
    - Inertial profiler data used with rolling straightedge simulation
    - Walking profiler data used with rolling straightedge simulation
    - International Roughness Index (IRI)
    - Mean International Roughness Index (Mean IRI)
    - Profilograph measurements
    - Profile Viewer and Analysis (ProVAL) (engineering software used to view and analyze pavement profiles)
    - Other (Please describe.)
2. How long has your agency used its current measurement method?
    - Less than one year
    - One to two years
    - Three to five years
    - Six to 10 years
    - More than 10 years
3. If applicable, please identify the vendor and model of the equipment used to measure surface smoothness.
    Vendor:
    Model:
4. If your agency uses a straightedge (including rolling and simulated), please describe aspects of the equipment and its use below.
    - Length of straightedge (feet):
    - Maximum permissible deviation between the bottom of the straightedge and the top of the bridge deck when the straightedge is placed on the bridge deck (inches):
    - Maximum permissible deviation at the center of the rolling straightedge with respect to the datum established by the wheels at the ends (inches):
5. Does your agency specify that data collection occur for both wheel paths in each travel lane of a new concrete bridge?
    - Yes
    - No (Please describe what portion of the bridge deck is subject to data collection.)
6. Does your agency require certification or approval of the **measurement equipment** before use?
    - Yes
    - No
7. Does your agency require certification of the **measurement equipment operator**?
    - Yes
    - No

8. Has your agency changed its smoothness measurement method or practice within the last 10 years?
   - No
   - Yes (Please briefly describe the previous measurement method or practice and why it is no longer used.)
9. Has your agency tested or experimented with other methods for measuring surface smoothness?
   - No
   - Yes (Please describe the other methods your agency has tested.)

Measurement Practices

1. Who gathers the smoothness measurements? Select all that apply.
   - State DOT staff
   - Contractor staff
   - Other (Please describe.)
2. Do the same measurement practices apply to all new concrete bridge decks, regardless of type, size, posted speed limit or other bridge characteristic?
   - Yes
   - No (Please describe the differences in measurement practice that are based on bridge characteristics.)
3. Is there a specific time frame during which smoothness measurements must be taken?
   - No
   - Yes (Please describe this time frame.)
4. Please identify the bridge elements that are subject to your agency's smoothness specification.
   - Bridge deck only
   - Bridge deck and approach slabs
   - Bridge deck, approach slabs and a specified length of roadway abutting the approach slab (Please identify the length of the roadway abutting the approach slab that is subject to the smoothness specification.)
5. Are bridge structures used primarily for pedestrians and bicycles subject to your agency's smoothness specification?
   - No
   - Yes (Please describe differences in measurement practices for these bridge structures, if any.)

Data Collection and Analysis

1. If possible, please estimate the **typical amount of time** required to **measure and collect data** for a single lane (two wheel lines) along 100 feet of bridge deck.
2. How is the collected data analyzed?
3. If possible, please estimate the **typical amount of time** required to **analyze the collected data** to determine the quantity and location of areas not in compliance with smoothness requirements for a single lane (two wheel lines) along 100 feet of bridge deck.
4. What are your agency's acceptable smoothness tolerances for new concrete bridge decks?
5. Has your agency established different smoothness tolerances for new and existing concrete bridge decks?
   - No
   - Yes (Please describe the differences in tolerances.)

Assessment

1. In your experience, how accurate is the data collected using your agency's current measurement method?
    - Extremely accurate
    - Very accurate
    - Somewhat accurate
    - Not so accurate
    - Not at all accurate
2. Please describe the benefits of your agency's current measurement method.
3. Please describe the most significant limitations of this measurement method.
4. Please identify your agency's top three recommendations for another agency preparing to adopt your measurement method.
    Recommendation 1:
    Recommendation 2:
    Recommendation 3:
5. Has your agency developed a specification or other documents that describe smoothness measurement requirements?
    - No
    - Yes (Please provides a link to the specification or links to other documents. Send any files not available online to chris.kline@ctcandassociates.com.)
6. (Required) Is your agency considering transitioning to a new surface smoothness measurement method?
    - Yes (Skips the respondent to **Interest in Other Smoothness Measurement Practices**.)
    - No (Skips the respondent to **Wrap-Up**.)

Interest in Other Smoothness Measurement Practices

1. Please identify the smoothness measurement practice(s) your agency is considering.
2. Why is your agency considering this change?
3. What does your agency need to implement the new measurement practice?
4. When do you anticipate beginning implementation?

Interest in Establishing a New Smoothness Measurement Practice

1. Please briefly describe your agency's interest in establishing a new smoothness measurement practice for new concrete bridge decks.
2. Why is your agency considering implementing this measurement practice?
3. What does your agency need to implement this measurement practice?
4. When do you anticipate beginning implementation?

Wrap-Up

Please use this space to provide any comments or additional information about your previous responses.

Appendix B: State Specifications for Smoothness Measurement

Specifications describing surface smoothness measurement guidelines are presented below for 28 state transportation agencies:

Alaska	Indiana	New Mexico	South Dakota
Arizona	Iowa	New Jersey	Tennessee
Arkansas	Kentucky	New York	Utah
Colorado	Michigan	North Dakota	Virginia
Connecticut	Mississippi	Ohio	Washington
Florida	Missouri	Pennsylvania	West Virginia
Idaho	New Hampshire	South Carolina	Wisconsin

Twenty of these agencies refer to bridge construction and/or bridge decks in their specifications:

Arizona	Iowa	New Jersey	South Dakota
Arkansas	Kentucky	New York	Tennessee
Colorado	Mississippi	North Dakota	Utah
Connecticut	New Hampshire	Ohio	Virginia
Florida	New Mexico	South Carolina	West Virginia

Specifications for the remaining eight agencies provide general guidelines for concrete pavements and construction.

Alaska

Section 501, Concrete for Structures, Standard Specifications for Highway Construction, Alaska Department of Transportation and Public Facilities, 2020.
https://dot.alaska.gov/stwddes/dcsspecs/assets/pdf/hwyspecs/sshc2020.pdf
From Section 501-3.10.4, Concrete for Structures > Tolerances, beginning on page 174 of the specifications, page 202 of the PDF:

4. Surface Irregularities (deviation from a 10-foot straight edge):
   a. For surfaces receiving a topping or are buried: ± 1/4 inch.
   b. For surfaces not receiving a topping or are visible in the completed work: ± 1/8 inch.

Arizona

Section 401-4.02 Pavement Smoothness, Standard Specifications for Road and Bridge Construction, Arizona Department of Transportation, 2021.
https://azdot.gov/sites/default/files/media/2021/04/2021_Standard_Specifications_for_Road_and_Bridge_Construction_PC.pdf
See page 268 of the specifications, page 274 of the PDF, for the specification, which indicates use of a profilograph for testing smoothness in accordance with Arizona Test Method 801. Selected elements of the specification:

- Two profilograph readings are to be taken in each lane, 3 feet from each lane edge of traffic lanes or 18 inches from the lane edge or pavement edge of distress lanes.
- The Profile Index for a lane will be the average of the two Profile Indexes obtained for that lane.
- The tested profile will include bridge approaches and 50 feet of any pavement which abuts the new pavement.

- All mainline traffic lanes, distress lanes, ramp lanes, and tapers shall have a Profile Index of 9 inches or less per mile in any 0.1-mile section.
- The contractor must correct high areas or depressions with deviations greater than 0.3 inches in 25 feet or less.
- The pavement will also be tested with a 10-foot straightedge, checking for pavement deviations greater than 1.8 inch, or ¼ inch across any longitudinal or transverse joint.

Related Resource:

> **Section 801b Evaluation of Profiles (A Modification of California Test 526)**, Materials Testing Manual, Arizona Department of Transportation, September 2019.
> https://apps.azdot.gov/files/materials-manuals/materials-testing/ariz-801b.pdf
> *From the scope on page 1 of the PDF*: This method describes the procedure for determining the Profile Index (PI) from profilograms of pavements made with a California type profilograph. Also described is the procedure used to locate individual high areas in excess of 0.3 inches when their reduction is required by the contract documents.

Arkansas

Standard Specifications for Highway Construction, Arkansas State Highway and Transportation Department, 2014.
https://ardot.gov/wp-content/uploads/2020/10/2014SpecBook.pdf
From Section 802.06(d) Quality Control, Acceptance and Adjustments in Payments > Incentives, beginning on page 675 of the specifications, page 697 of the PDF:

> If the Contractor elects, on bridges over 150' (50 m) in length, an incentive payment for exceptional smoothness will be included in the pay schedule for Class S(AE) concrete if:
>
> - the bridge deck smoothness criteria below are met, and
> - no corrective grinding is required to achieve the incentive profile index values.
>
> The Contractor shall furnish a California-style profilograph complying with ASTM E 1274 or an automated lightweight profilometer complying with ASTM E 950, Class 1 and calibrated to the California-style profilograph scale and take a profile near the center of all continuous traffic lanes, including auxiliary lanes and ramps. The Engineer will verify the calibration of the profilograph as frequently as necessary to assure proper operation. In order to position the profilograph, the profile record may exclude 12.5' (4 m) of the deck at each end of the bridge if using a California-style profilograph. If using an automated lightweight profilometer, the profile record shall start and stop at the ends of the bridges at the joints. A blanking band of ±0.1" (±2.5 mm) will be used in the determination of the profile index.

From Section 802.20 Bridge Roadway Surface Construction, beginning on page 706 of the specifications, page 728 of the PDF:

> **(c) Initial Surface Test.** As soon as the surface has set sufficiently to withstand damage when walking on it, and not later than the morning following the placing of the concrete, it shall be straightedged in both directions with the 10' (3 m) straightedge and any variations exceeding 1/8" (3 mm) shall be plainly marked. In addition, profiles shall be taken at 10' (3 m) intervals along the centerline of bridge, centerline of each lane, and each gutter line.

When the bridge roadway surface profiles exhibit surface deviations in excess of 1/4" (6 mm) in 20' (6 m), the Contractor shall make appropriate changes to either equipment or methods prior to proceeding with the next bridge deck placement.

After the initial placement, the straightedge and profile requirements shall extend onto the adjacent placements.

(d) Final Surface Test. Upon completion of the entire bridge superstructure, the bridge roadway surface shall be checked as specified above.

All marked areas shall be corrected by grinding until such deviations have been reduced to meet the tolerances of 1/8" (3 mm) in 10' (3 m) and 1/4" (6 mm) in 20' (6 m) at no cost to the Department. The grinding equipment shall be power driven and specifically designed to smooth and texture portland cement concrete by means of diamond blades.

All areas that have been ground shall be re-grooved according to Subsection 802.19, Class 7.

Colorado

Section 105, Control of Work, Standard Specifications for Road and Bridge Construction, Colorado Department of Transportation, 2025.
https://www.codot.gov/business/designsupport/cdot-construction-specifications/2025-construction-specifications/2023-specs-book/2025-cdot-specs-book.pdf
From page 105-23 of the specifications, page 71 of the PDF:

105.7(a)2 Conformity to Roadway Smoothness Criteria

2. The finished transverse and longitudinal surface elevation of the pavement shall be measured using a 10-foot straightedge. Areas to be measured will be directed by the Engineer. The Contractor shall furnish an approved 10-foot straightedge, depth gauge, and operator to aid the Engineer in testing the pavement surface. Areas showing high spots of more than 3/16 inch in 10 feet shall be marked and diamond ground until the high spot does not exceed 3/16 inch in 10 feet.

Connecticut

Section 6.01.03.II Requirements for New Construction, Standard Specifications for Roads, Bridges, Facilities and Incidental Construction, Connecticut Department of Transportation, 2024.
https://portal.ct.gov/dot/-/media/dot/aec/form-819_2024.pdf?rev=cac5c8b2283e41b1aa28abebe40cd311
From Section 6.01.03.II.7b Surface Testing and Correction, beginning on page 261 of the PDF:

The entire surface shall be checked by the Contractor in the presence of the Engineer, with an acceptable 10 foot straightedge.

1. The surface shall not vary more than +/- 1/8 inch over 10 feet for decks which will not be covered with an overlay.
2. The surface shall not vary more than +/- ¼ inch over 10 feet for decks which will be covered with an overlay.

Variances greater than these, which, in the judgment of the Engineer, may adversely affect the riding qualities of the surface shall be corrected, and this shall be done at the expense of the Contractor.

Florida

Chapter 400 Concrete Structures, Standard Specifications for Road and Bridge Construction**,** Florida Department of Transportation, 2024-25.
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/specifications/by-year/fy-2024-25/ebook/fy2024-25ebookfinalcomp-revised3-4-24.pdf?sfvrsn=16ab03d_1
See page 410 of the specifications, page 418 of the PDF, for guidance on smoothness measurements, excerpted in part below:

> **Section 400-15.2.5.4 Smoothness Requirements for Short Bridges and Miscellaneous Bridges (including approach slabs)**. Perform a final straightedge check with a 10 foot straightedge, positioning and half-lapping the straightedge parallel to the centerline, approximately 5 feet apart to cover the entire surface. Correct all irregularities greater than 3/16 inch measured as an ordinate to the straightedge, by grinding. Perform grinding by the abrasive method using hand or power tools or by machine, to leave a smooth surface within a 1/8 inch tolerance.
>
> **Section 400-15.2.5.5 Smoothness Evaluation and Concrete Surface Planing, Long Bridges (including approach slabs)**. Prior to planing, provide a smoothness evaluation of the completed bridge deck and exposed concrete surfaces of approach slabs by a computerized California-type profilograph in accordance with the criteria herein and FM 5-558. Furnish this evaluation through an independent provider approved by the Engineer, using equipment calibrated by the Engineer. All bridge deck and concrete approach slab surfaces within 2 feet of gutter lines are subject to this smoothness evaluation.

Idaho

Section 409.03 Construction Requirements, Standard Specifications for Highway Construction, Idaho Transportation Department, 2023.
https://apps.itd.idaho.gov/Apps/manuals/SpecBook/SpecBook23.pdf
See Section 409.3.K Surface Test, beginning on page 257 of the specifications, page 293 of the PDF, excerpted in part below:

> **K. Surface Test.**
>
> Test the finished pavement the next working day after placement as follows:
>
> 1. Use a 10-foot straightedge on the surface at locations determined by the Engineer. When the straightedge is laid on finished pavement in a direction parallel with centerline or perpendicular to centerline, locate surface areas that vary more than 1/4 inch from the lower edge. Remove high points that cause the surface to exceed these tolerances by grinding.
> 2. Furnish and operate the profiler. Operate the profiler at the manufacturer's recommended speed. Calibrate at the beginning of the work and as needed thereafter. Supply a profiler, calibrated, in good working condition, and ready for operation before work of any concrete paving begins. Provide a competent and experienced operator to operate the equipment.
>
>   Profile the surface in IRI.
>
>   Make 2 profiles 3 feet from and parallel to the edge of each driving lane.
>
>   Surface smoothness testing must be verified by the Engineer. The profile run must be witnessed by the Engineer and an electronic copy of the results submitted immediately after the end of the run.

> Testing will not be accepted unless witnessed by the Engineer. At the Engineer's request, submit the profile data in a format suitable for evaluation using ProVAL or other acceptable software.
>
> The Engineer may elect to perform additional testing as verification. If the results vary from the Contractor's IRI results by more than 10 percent when profiled under the same environmental conditions, the Engineer will use the Department's IRI results for acceptance.

Section 409.05.B Basis of Payment > Profile Incentive, beginning on page 263 of the specification, page 299 of the PDF, specifies incentive payments to the pavement contractor based on IRI measurements indicating pavement smoothness.

Indiana

Division 500 Concrete Pavement, Standard Specifications, Indiana Department of Transportation, 2026 (effective September 1, 2025).
https://www.in.gov/dot/div/contracts/standards/book/sep25/500-2026.pdf
From Section 501.25 Pavement Smoothness, beginning on page 416 of the specifications, page 10 of the PDF:

> **501.25 Pavement Smoothness**
> Pavement smoothness will be accepted by means of an inertial profiler, a 16 ft straightedge, or a 10 ft straightedge as described below.

From Section 502.20 Pavement Smoothness, beginning on page 435 of the specifications, page 29 of the PDF:

> Pavement smoothness will be in accordance with 501.25 except inertial profiler requirements will not apply.

Iowa

Determining Pavement Ride Quality, Materials Instructional Memorandum 341, Iowa Department of Transportation, April 2025.
https://ia.iowadot.gov/erl/current/IM/content/341.htm
This memorandum "describes procedures used to perform smoothness testing on pavement and bridge surfaces. A certified person is required to perform the testing, evaluation and reporting. An approved apparatus must be used to test and evaluate all surfaces."

Below is a list of the apparatus that may be employed in the smoothness testing:

- Inertial profiler meeting the requirements of AASHTO M328 (this requires an auto start/stop) and currently certified on the Iowa DOT test strips or other state test strips approved by the Iowa DOT. For all surfaces other than dense graded HMA [hot-mix asphalt], a large footprint laser is required.
- California or Ames Engineering type 25-foot profilograph. [The memorandum notes that the profilograph "may only be used for internal information or for testing and evaluation under Section 2428, Smoothness of Bridge Decks and Bridge Deck Overlays."]
- Ten-foot straightedge or a 10-foot straightedge software simulation.
- Distance measuring wheel or tape.
- Latest version of ProVAL software.

- Latest version of the Iowa DOT Spreadsheet, Profile Summary Sheet and the current ProVAL template.

Related Resource:

> **Section 2428, Smoothness of Bridge Decks and Bridge Deck Overlays**, Standard Specifications, Iowa Department of Transportation, April 2025.
> https://ia.iowadot.gov/erl/current/gs/content/2428.htm
> This specification describes the use of "an Ames type or California profilograph or an inertial profile to produce a profilogram (profile trace) of the surface tested according to Materials I.M. 341."

Kentucky

Standard Specifications for Road and Bridge Construction, Kentucky Transportation Cabinet, June 2019.
https://transportation.ky.gov/Construction/StdSpecsWSupplSpecs/2019%20Standard%20Spec%20with%20Supplemental%20Spec%20July%202019.pdf
From Section 501.02.23 JPC Pavement, PCC Base, and JPC Shoulders > Materials and Equipment > Profiler, beginning on page 238 of the PDF:

> The Department will measure the longitudinal profile of the surface with an ASTM E 950, Class 1 device.

From Section 608.03.16 Concrete Bridges > Construction > Permissible Finish Variations, beginning on page 374 of the PDF:

> Do not allow lines of the finished concrete, except bridge slabs and precast piles, to vary more than 1/4 inch per 10 feet or vary from plan lines more than 0.1 percent of the distance between extremities of the unit considered.

Michigan

Special Provision for Pavement Ride Quality (Mean Roughness Index Acceptance Criteria), 20SP-501K-01, Michigan Department of Transportation, March 2020.
https://mdotjboss.state.mi.us/SpecProv/getSSSPDocumentById.htm?projNum=704577&fileName=20SP-501K-01.pdf
From the description on page 1:

> This work consists of providing a pavement surface with acceptable ride quality for all pavements covered by this special provision. Furnish, operate and maintain a profiler, in proper calibration, to measure ride quality for quality control purposes. Prepare and submit a Ride Quality Plan and, if required, a corrective action plan, to the Engineer for approval. Complete all corrective action as required by this special provision.
>
> Ensure that the pavement on which ride quality measurements are taken, including acceptance runs conducted by the Engineer, is clean prior to ride quality measurements.
>
> The following subsections of the Standard Specifications for Construction apply only to areas excluded from pavement ride quality in Class II, III and IV sections:
>
> > Subsection 501.03.H (10 foot straightedge on Hot Mix Asphalt (HMA) pavements)
> > Subsection 602.03.I (10 foot straightedge on concrete pavements)

Related Resources:

> **Manual for the Michigan Test Methods***,* Michigan Department of Transportation, January 2025.
> https://www.michigan.gov/mdot/-/media/Project/Websites/MDOT/Business/Construction/Standard-Specifications-Construction/CFS-Manuals/Manual-Michigan-Test-Methods.pdf
> Relevant test methods:
>
> - 726.1.1 Michigan Test Method for Determining Ride Quality Using an Inertial Profiling System (page 302 of PDF)
> - 727.1.1 Michigan Test Method for Manual Analysis for California Type Profilograms (page 304 of PDF)
> - 729 Michigan Test Method for Certification of California Type Profilographs (page 314 of PDF)
> - 730 Michigan Test Method for Certification of Inertial Profilers (page 317 of PDF)
>
> **Section 602 Concrete Pavement Construction**, 2020 Standard Specifications for Construction, Michigan Department of Transportation, 2020.
> https://www.michigan.gov/mdot/-/media/Project/Websites/MDOT/Business/Construction/Standard-Specifications-Construction/2020-Standard-Specifications-Construction.pdf
> See Section 602.03.I, Concrete Pavement Construction > Construction > Straightedge Testing, Surface Correction and Edging, beginning on page 6-13 of the Standard Specifications, page 335 of the PDF.

Mississippi

Section 501 Concrete Pavement, Mississippi Standard Specifications for Road and Bridge Construction, Mississippi Transportation Commission, 2017.
https://mdot.ms.gov/documents/Construction/Specifications/2017%20Standard%20Specifications.pdf
See Section 501.03.19, Surface Test, beginning on page 352 of the specification, page 376 of the PDF, excerpted in part below:

> **501.03.19—Surface Test.** It is the intent of these specifications that the finished surface will have good riding qualities.
>
> The smoothness of the surface will be determined by using an Inertial Profiling System (IPS) that meets the requirements of Subsection 401.02.6.9 to measure and record roughness data in each designated location. Roughness data for each longitudinal profile will be reported as a mean roughness index (MRI). MRI is calculated by averaging the international roughness index (IRI) values from the two wheelpath profiles. The surface shall be tested and corrected to a smoothness index as described herein with the exception of those locations or specific projects that are excluded from smoothness testing with an IPS.
>
> ….
>
> The smoothness of the surface will be determined for traffic lanes, auxiliary lanes, climbing lane and two-way turn lanes. Areas excluded from a smoothness test with the IPS are acceleration and deceleration lanes, tapered sections, transition sections for width, shoulders, crossovers, ramps, side street returns, etc. The roadway pavement on bridge replacement projects having 1,000 feet or less of pavement on each side of the structure will be excluded from a smoothness test. Pavement on horizontal curves having a radius of less than 1,000 feet at the centerline and pavement within

the super elevation transition of such curves are excluded from smoothness testing. Smoothness testing shall terminate 15 feet from each transverse joint that separates the pavement from a bridge deck, bridge approach slab or existing pavement not constructed under the contract.

Missouri

Section 610 Pavement Smoothness, Missouri Standard Specifications for Highway Construction, Missouri Department of Transportation, 2025.
https://www.modot.org/sites/default/files/documents/2025%20Missouri%20Standard%20Specific%20-%20MHTC%20%28July%202025%29_Signed.pdf
From Section 610 Pavement Smoothness, beginning on page 323 of the specifications, page 324 of the PDF:

610.1 Description. This work shall consist of measuring the smoothness of the final pavement surface. Smoothness shall be measured using the International Roughness Index (IRI). The following pavement types shall comply with this specification:

(a) Multi-lift asphalt construction greater than 3 inches contained in Secs 401 and 403.
(b) Concrete pavement construction contained in Secs 502 and 506.
(c) Combination of surface planing, such as diamond grinding or milling, and single lift asphalt construction or multi-lift asphalt construction less than or equal to 3 inches contained in Secs 401 and 403.
(d) Single lift asphalt construction contained in Secs 401 and 403.

610.2 Material Requirements.

610.2.1 Inertial Profiler. IRI shall be computed from profile data collected with an inertial profiler (IP) that meets the requirements of AASHTO M 328

610.2.2 ProVAL Software. The ProVAL software program shall be used to compute IRI smoothness and locate areas of localized roughness (ALR) in accordance with MoDOT TM-59.

610.2.3 Straightedge. A rolling 10-foot straightedge shall be used for checking longitudinal elevation changes.

A 4-foot straightedge shall be used for checking transverse elevation changes.

Related Resource:

Section 106.3.2.59 TM-59, Determination of the International Roughness Index, Engineering Policy Guide, Missouri Department of Transportation, April 2025.
https://epg.modot.org/index.php/106.3.2.59_TM-59,_Determination_of_the_International_Roughness_Index
From the website: This method describes the procedure for determining the International roughness index (IRI) of pavement surfaces in English units.

New Hampshire

Section 520 Portland Cement Concrete, Standard Specifications for Road and Bridge Construction, State of New Hampshire Department of Transportation, March 2016.
https://www.dot.nh.gov/sites/g/files/ehbemt811/files/inline-documents/2016-nhdot-spec-book.pdf
From Section 520.3.9.2.5 Concrete Decks and Approach Slabs (at grade), beginning on page 5-46 of the specifications, page 210 of the PDF:

Section 520.3.9.2.5 The finished concrete shall have the required crown and grade and the surface shall not vary from either by more than 1/8" in 10 ft. The surface shall have a concrete surface profile (CSP) of 5 or less in accordance with the International Concrete Repair Institute (ICRI) technical guideline for "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays" Guideline No. 03732. As soon as the bleeding has stopped or the sheen has started to disappear, the concrete shall be given a final surface finish by scraping or dragging with an approved float at least 3 ft. in length. The float shall be placed on the outer edge of the finished concrete and moved transversely the full width of the deck. The finished edge shall be parallel to centerline. Each subsequent pass shall lap the preceding pass by at least 1/2 the length of the float. Concrete decks that will be the final wearing surface shall receive a pan drag without a float finish. This shall be followed by a broom finish utilizing a broom specifically made for this purpose. Fabric impressions in the surface caused by the texture of water-retaining materials shall not be cause for rejection. Objectionable defects, such as sharp edges caused by cement cream lines or fabric creases, shall be removed by the Contractor.

New Jersey

Section 507.03.02 Concrete Bridge Deck, New Jersey Standard Specifications for Road and Bridge Construction, New Jersey Department of Transportation, 2019.
https://www.nj.gov/transportation/eng/specs/2019/pdf/Standard%20Specifications%20for%20Road%20and%20Bridge%20Construction%202019%20ORIGINAL.pdf
See Section 507.03.02.N., Concrete Bridge Deck > Concrete Deck Surface Requirements, beginning on page 250 of the specifications, page 284 of the PDF, excerpted in part below:

N. Concrete Deck Surface Requirements

1. **Acceptance Testing**. Construct deck slabs so that less than 9 percent of the measured length of the lot exceeds 1/8 inch tolerance in 10 feet. The ME will test the surface of concrete bridge deck slabs with a Class I Walking Profiler. The ME will calculate the percent defective using a rolling straight edge simulator analysis of the profiler data.

   The RE will determine conformance to the surface tolerance for concrete deck slabs in lots, each lot being equal to the number of cubic yards of deck concrete placed in the designated lanes of traffic from joint assembly to joint assembly. The RE will calculate such lot quantity using the specified nominal deck thickness, excluding the quantity of concrete placed in haunches, end dams, and diaphragms.

   The RE will base acceptance on the percentage of the total length of the lot having surface variation exceeding 1/8 inch in 10 feet, this percent noncompliance being defined as the Lot Percent Defective Length. To compute the lot percent defective length, add the lengths of individual surface defects exceeding the specified tolerance, and divide this sum by the total length tested, then multiply by 100 to convert to percent.

   ….

Table 507.03.02-2 Reduction Per Lot of Deck Slab Concrete Due to Nonconformance with Surface Requirements	
Lot Percent Defective Length	**Reduction Per Lot, Percent**
0 – 8.9	none
9.0 – 13.9	1.0
14.0 – 24.9	7.0
25.0 – 34.9 (manually finished deck)	12.0

Figure 4. Table 507.03.02 Reduction Per Lot of Deck Slab Concrete Due to Nonconformance with Surface Requirements
(*Source*: New Jersey Standard Specifications for Road and Bridge Construction, 2019.)

New Mexico

Standard Specifications for Highway and Bridge Construction, New Mexico Department of Transportation, 2019.
Specifications available at https://www.dot.nm.gov/infrastructure/plans-specifications-estimates-pse-bureau/standards/
See Section 512.3.10.2 Acceptance Criteria, beginning on page 380 of the specifications, page 388 of the PDF, excerpted in part below:

> **512.3.10.2 Acceptance Criteria**
> The Contractor shall test the smoothness of the completed Roadway surfaces of Bridge decks, approach slabs, and the adjoining 50 ft of approach pavement. After the concrete of Bridge decks, approach slabs, and pavement hardens, the Contractor shall check the entire surface areas with a ten (10) foot straightedge. The Contractor shall hold the straightedge in successive positions parallel to the centerline of the Roadway and in contact with the slab. The Contractor shall advance the straightedge longitudinally along the slab in successive stages no greater than half the length of the straightedge.

New York

Section 557 Superstructure Slabs, Sidewalks on Bridges and Structural Approach Slabs, Standard Specifications, Volume 2: Construction and Materials, New York State Department of Transportation, May 1, 2025.
https://www.dot.ny.gov/main/business-center/engineering/specifications/english-spec-repository/2025_5_specs_usc_tc_vol2.pdf
See 557-3.09, beginning on page 305 of the specifications, page 308 of the PDF, excerpted in part below:

> **557-3.09 Finishing Surfaces to be Overlaid with Portland Cement or Asphalt Concrete.**
> ....
> Surfaces shall be finished to a surface tolerance of 3/8 inch in 10 feet. The surface tolerance shall be verified by the Engineer with an approved straightedge not less than 10 feet long. The straightedge shall be furnished by the Contractor who shall maintain it in good condition at the paving site at all times.
>
> Hand finishing shall be allowed only in areas inaccessible to finishing machines or manually driven vibratory-equipped power screeds. Hand finishing shall be performed in the same sequence and manner as machine finishing, unless otherwise permitted by the Engineer. Hand finishing shall be performed in such a manner as to produce a concrete surface with quality and uniformity identical to that produced by the finishing machine. Hand screeds or bullfloats shall be magnesium and 10

inches, or more, in width. Care shall be taken not to overwork the concrete surface during any finishing operation.

Upon completion of screeding, surfaces which will be overlaid with portland cement concrete shall be textured to conform to §557-3.07.

North Dakota

Section 602.04 Construction Requirements, Standard Specifications for Road and Bridge Construction, North Dakota Department of Transportation, July 2024.
https://www.dot.nd.gov/sites/www/files/documents/Standard%20Specifications/%602024%20NDDOT%20Standard%20Specifications%20for%20Road%20and%20Bridge%20Construction.pdf
From Section 602.04.E Construction Requirements > Surface Tolerances, beginning on page 259 of the specifications, page 276 of the PDF:

E. Surface Tolerances.
After the concrete has cured, the Engineer will test the bridge deck, approach slabs, and adjacent pavement, if applicable, for surface irregularities with a 10 foot straightedge.

The Engineer will check the profile using a 10 foot straightedge oriented in the longitudinal direction and starting at one end of the deck, move the straightedge transversely across the deck to the other edge with constant contact with the deck. Repeat this process in 5 foot intervals from one end of the deck to the other. Check the cross slope using the 10 foot straightedge oriented in the transverse direction and starting at one end of the deck, move the straightedge longitudinally from one end of the deck to the other end with constant contact with the deck. Repeat this process in 5 foot intervals from one side of the deck to the other.

Grind areas with a deviation greater than 1/8 inch, but less than or equal to 1/2 inch, until the deviation is 1/8 inch or less. The Engineer will apply a contract price reduction as specified in Section 602.06 B, “Surface Tolerance.”

The Engineer will make a serviceability determination as specified in Section 105.07, “Conformance with the Contract Requirements” for any deviations greater than 1/2 inch.

Ohio

Construction and Material Specifications, Ohio Department of Transportation, January 1, 2023.
https://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Specifications/2023CMS/2023_CMS_01172025_for_web_Letter%20size.pdf
From Section 341.13 Surface Smoothness, beginning on page 272 of the PDF:

451.13 Surface Smoothness. After final concrete curing and cleaning the pavement surface, test the pavement surface for smoothness using a 10-foot (3 m) rolling straightedge. Provide a two or four-wheeled device with an indicator wheel at the center that detects high and low areas in the pavement surface. Provide equipment that actuates a pointer scale, issues an audio alert, or marks the pavement with paint or dye when encountering any high or low areas in excess of a preset tolerance. Tow or walk the rolling straightedge over the completed pavement. Test all wheel paths in the presence of the Engineer. Locate wheel paths parallel to the pavement centerline and approximately 3 feet (1 m) measured transversely from the center of the lane. Maintain alignment of the rolling straightedge with reference to the pavement edge at all times. Other devices such as approved profilers conforming to Supplement 1058 and using ProVAL software may be used with approval of the Engineer.

Correct all surface variations so indicated to within the specified tolerance and in a manner that provides a surface texture conforming to 451.10. For corrective grinding provide equipment conforming to 451.14. Ensure pavement surface variations do not exceed 1/8 inch in a 10 foot (3 mm in a 3 m) length of pavement. For ramp pavements and for those pavements with curvature greater than 8 degrees, or with grades exceeding 6 percent, ensure the surface variations do not exceed 1/4 inch in 10 feet (6 mm in 3 m).

Repair or replace sections of pavement containing depressions that cannot be corrected by grinding as directed by the Engineer.

Related Resources:

Proposal Note 555: Surface Smoothness for Bridges and Approaches, Construction Administration, Ohio Department of Transportation, January 2021.
https://www.dot.state.oh.us/Divisions/ConstructionMgt/Specification%20Files/PN555_01152021_for_2019.pdf
From the description on page 1:

> For projects with new full depth cast-in-place decks and slab superstructures, the surface smoothness requirements of C&MS 451.13 are modified as follows for bridge encounters defined as 25 feet of entry pavement, entry approach slab, bridge deck, exit approach slab and 25 feet of exit pavement including all joints.

From mandatory corrective action on page 2:

> The Department will require corrective action where the Localized Roughness IRI (Refer to Supplement 1112 Appendix D for Definition) in any 25 feet segment of the bridge encounter exceeds 250 inches per mile, except on structures that include a steel armored expansion joint system where corrective action is required when the IRI exceeds 300 inches per mile.

Supplement 1112: Submittal and Application Requirements for ProVAL Highway Smoothness Software for Bridge Encounters, Construction Administration, Ohio Department of Transportation, January 15, 2021.
https://www.dot.state.oh.us/Divisions/ConstructionMgt/Specification%20Files/1112_01152021_for_2023.pdf
From the scope: This supplement provides guidelines for use of ProVAL software for measuring and evaluating IRI based bridge encounter smoothness and development of corrective action plan as required.

Supplement 1058: Surface Smoothness Equipment and Operator Requirements, Construction Administration, Ohio Department of Transportation, April 18, 2014.
https://www.dot.state.oh.us/Divisions/ConstructionMgt/Specification%20Files/1058_04182014_for_2019.PDF
From the scope: This Supplement defines the requirements for calibration of equipment measuring smoothness on asphalt and concrete pavements and the approval of operators running the smoothness equipment. This supplement also defines the verification process for the output data at the project site.

Pennsylvania

Section 501 Plain or Reinforced Cement Concrete Pavements, Specifications, Publication 408/2020, Pennsylvania Department of Transportation, Change 11, Effective October 10, 2025.

https://www.pa.gov/content/dam/copapwp-pagov/en/penndot/documents/public/pubsforms/publications/pub_408/408_2020/408_2020_11/408_2020_11.pdf
From Section 501.3.(o).1 Surface Tolerance > Longitudinal Joints, beginning on page 501-14 of the specifications, page 366 of the PDF:

> **(o) Surface Tolerance.** After the concrete has hardened, test the surface of pavement again as specified in Section 501.3(k)3. The pavement surface will be accepted when the surface does not vary more than:
>
> - 3/16 inch when the straightedge is laid parallel with the centerline
> - 3/16 inch when the straightedge is laid perpendicular to the centerline and within a traffic lane.
>
> Remove high points by means of grinding or cutting tools, as directed.
>
> **1. Longitudinal Joints.** Test the surface of pavement at all longitudinal joints, including the joint between the pavement and shoulder, again for the following tolerance requirements:
>
> - Where there is no change in the design cross slope across a joint, the tolerance will not be greater than 1/4 inch as measured by holding a 12-foot straightedge centered across and perpendicular to the joint.
> - Where there is a change in the design cross slope across a joint, the tolerance will not be greater than 1/4 inch as measured by holding a 4-foot straightedge perpendicular to and on each side of the joint.
> - Remove high points in excess of 1/4 inch by means of grinding or with cutting tools, as directed.
>
> Pavement containing depressions of 3/16 inch or more between adjacent lanes will be considered defective.
>
> Retest corrected areas of the pavement surface. Corrected areas must be within 3/16 inch as tested above.

South Carolina

Section 702.3.15 Bridge Deck Rideability, Standard Specifications for Highway Construction, South Carolina Department of Transportation, 2025.
https://www.scdot.org/content/dam/scdot-legacy/business/pdf/2025_SCDOT_Standard_Specifications.pdf
From page 700-59 of the specifications, page 654 of the PDF:

> **702.3.15 Bridge Deck Rideability**
>
> Provide stakes, lines, and grades according to Subsection 105.8. With the RCE present, check the slab for smoothness using a rolling straightedge immediately after the curing operation is complete. Provide a rolling straightedge equipped with devices for marking irregularities in the slab surface of ⅛ in. or more in a length of 10 ft for removal. For temporary detour bridges, ¼ in. or more in a length of 10 ft is acceptable. Details of an acceptable rolling straightedge are available from the BCE office and will be furnished on request. When the bridge length is longer than 100 ft, provide a surface smoothness that conforms to SC-M-701.

In addition to the longitudinal rolling straightedge check, ensure that the deck surface meets a 0.20 in. in 10 ft straightedge check made transversely across the slab at a spacing determined by the RCE. Perform the longitudinal rolling straightedge tests first.

Payment for the above work is according to Subsection 105.8.

Related Resources:

Supplemental Technical Specification for Surface Smoothness of Bridge Decks and Approach Slabs, SC-M-701, South Carolina Department of Transportation, April 2008.
https://www.scdot.org/content/dam/scdot-legacy/business/technicalpdfs/suptechspecs/SC-M-701.pdf
From the scope: This standard describes the smoothness requirements for bridge decks. The riding surfaces subject to this standard include all traffic lanes, all full-width acceleration and deceleration lanes, and lanes planned for future use on both bridge decks and approach slabs.

Operation of the Cox Model CS8500 Electronic Profilograph for Surface Measurement, SC-T-124, South Carolina Department of Transportation, April 2012.
https://www.scdot.org/content/dam/scdot-legacy/business/pdf/materials-research/testprocedure/misc/SCT124.pdf
I: This method describes the operation of a 25-foot wheelbase California-type profilograph with computerized data collection used to measure surface deviations on bridges and pavements. The minimum section length for this procedure is 300 feet.

South Dakota

Section 380 Portland Cement Concrete Pavement, Standard Specifications for Roads and Bridges, South Dakota Department of Transportations, 2015.
https://dot.sd.gov/media/a2ff7bcb/2015_SDDOT_SpecBook.pdf
From Section 308.3.B.8 Equipment, Profilograph, beginning on page 199 of the specifications, page 209 of the PDF:

When specified in the Contract, the Contractor shall furnish and operate an approved 25 foot California style profilograph.

From Section 308.3.O Surface Test, beginning on page 214 specifications, page 224 of the PDF:

The pavement surface shall be checked for deviations using either a 10 foot straightedge or a profilograph (when specified). When the use of a profilograph is specified, the 10 foot straightedge check may also be required in locations determined by the Engineer.

Tennessee

Section 604 Concrete Structures, Standard Specifications for Road and Bridge Construction, Tennessee Department of Transportation, January 2021.
https://www.tn.gov/content/dam/tn/tdot/construction/2021-standard-specifications/January_1_2021_Standard_Specifications.pdf
Section 604.27, Rideability of New or Resurfaced Bridge Decks and Roadway Approaches, includes a subsection on rideability testing. *From page 550 of the specifications, page 559 of the PDF:*

B. Rideability Testing
After the bridge deck, approach slabs, and roadway pavement tie-ins are completed, the Department will conduct rideability tests using a roadway profiler to provide an International

Roughness Index (IRI) for each wheel path and Mean IRI (MRI) for overall roughness. A lot is considered each lane for the length of the bridge and 150 feet before and 150 feet after each end of the bridge, unless a shorter distance is specified by the Engineer or shown on the Plans. Each lot shall be tested.

Schedule rideability testing at least seven days prior to need. Clean and clear the area to be tested of all obstructions. Wheel paths will be located 3 feet each side of the centerline of each traffic lane.

To determine pavement rideability, the Department will evaluate the pavement using Mean IRI for the lot and IRI for individual continuous 25-foot sections for localized roughness in each wheel path. Mean IRI shall be the average of each wheel path. IRI data shall be calculated per ASTM E1926. Each lot shall have a maximum Mean IRI value of 130 inches per mile.

For bridges with a posted speed limit of 45 mph or greater no individual continuous 25-foot section shall exceed an IRI of 190 inches per mile in either wheel path, except sections which include an expansion joint.

For bridges with a posted speed limit of 40 mph or less, no individual continuous 25-foot section shall exceed an IRI of 250 inches per mile in either wheel path, except sections which include an expansion joint.

For sections with an expansion joint, no individual continuous 25-foot section shall exceed an IRI of 350 inches per mile in either wheel path.

Utah

Section 02701, Pavement Smoothness, 2025 Standard Specifications for Road and Bridge Construction, Utah Department of Transportation, latest revision: December 8, 2022.
https://drive.google.com/file/d/1Cc2VtZkcgXhgS9ZvJlSJFOjjiDUSIrYq/view?usp=drive_link
This section of Utah DOT's specifications begins on page 409 of the PDF and addresses longitudinal profile collection and "[d]etermination of International Roughness Index (IRI) using the Profile Viewer and Analysis (ProVAL) software and Incentives/Disincentives for smoothness."

From 1.6 Acceptance, pages 411-417 of the PDF:

- 1.6.B: Limit transverse pavement deviations to less than 3/16 inch from the lower edge of a 10-foot straightedge.
- 1.6.C: Localized Roughness greater than 15 ft. in length is calculated with IRI on 25 ft. segments.

Localized Roughness Limits (inch/mile)	
Interstate including ramps	≤ 190
Bridge decks, approach slabs & transitions, manholes and valves	≤ 250
Non-interstate	≤ 190
Urban roadways with speed limits less than 45 mph	≤ 190
Shoulders and Bike Lanes	≤ 250 (single profile)

Figure 5. Table Showing Localized Roughness Limits
(*Source*: Utah DOT.)

- 1.6.D: The Department applies Incentives and Disincentives based on the pavement's MRI, as outlined in tables 2 through 10 on pages 413-417 of the PDF.

Virginia

Section 404.04 Bridge Deck Construction, Road and Bridge Specifications, Virginia Department of Transportation, 2020.
https://www.vdot.virginia.gov/media/vdotvirginiagov/doing-business/technical-guidance-and-support/technical-guidance-documents/construction/VDOT_2020_RB_Specs_acc071522.pdf
From the bottom of page 472 of the specifications, page 500 of the PDF:

> The deck surface shall be tested with a 10-foot straightedge and rescreeded as many times as is necessary to ensure a smooth riding surface. The straightedge shall be held in successive positions at the edges and quarter points and on the centerline, parallel thereto and in contact with the surface. Advancement along the deck shall be in successive stages of not more than the length of the straightedge. The surface shall also be checked transversely at the ends, quarter points, and center of the span. Areas showing high spots or depressions of more than 1/8 inch in 10 feet in the longitudinal direction and ¼ inch in 10 feet in the transverse direction shall be struck off or filled with freshly mixed concrete.

Washington

Division 5, Surface Treatments and Pavements, 2025 Standard Specifications, M 41-10, Washington State Department of Transportation.
https://wsdot.wa.gov/publications/manuals/fulltext/m41-10/division5.pdf
From Section 5-05.3(12), Surface Smoothness, beginning on page 5-66 of the specifications, page 66 of the PDF:

> Pavement surface smoothness for this project will include International Roughness Index (IRI) testing. The Contractor shall perform IRI testing on each through lane, climbing lane, and passing lane, greater than 0.25 mile in length and these lanes will be subject to incentive/disincentive adjustments. Ride quality will be evaluated using the Mean Roughness Index (MRI) calculated by averaging the IRI data for the left and right wheel path within the section.
>
> …
>
> Operate the inertial profiler in accordance with AASHTO R 57. Collect two longitudinal traces, one in each wheel path.
>
> …
>
> Surface smoothness of travel lanes not subject to MRI testing will be measured with a 10-foot straightedge no later than 5:00 p.m. of the day following the placing of the concrete. The completed surface of the wearing course shall not vary more than 1/8 inch from the lower edge of a 10-foot straightedge placed on the surface parallel to the centerline.
>
> Smoothness perpendicular to the centerline will be measured with a 10-foot straightedge across all lanes with the same cross slope, including shoulders when composed of cement concrete pavement. … The completed surface of the wearing course shall not vary more than ¼ inch from the lower edge of a 10-foot straightedge placed on the surface perpendicular to the centerline. Deviations in excess of the above tolerances shall be corrected.

Section 5-05.5 Payment, beginning on page 5-72 of the specifications, page 72 of the PDF, presents Smoothness Compliance Adjustments and a Price Adjustment Schedule calculated according to MRI measurement.

West Virginia

Standard Specifications Roads and Bridges, West Virginia Department of Transportation Division of Highways, 2023.
https://transportation.wv.gov/highways/TechnicalSupport/specifications/Documents/2023_Standard_%2812-16-22%29.pdf
From Section 601.11.4.3 Straightedge Testing of Hardened Bridge Decks, beginning on page 341 of the specifications, page 361 of the PDF, excerpted in part below:

- When using a rolling straight edge, areas showing high spots of more than 1/8 inch shall be marked by the Engineer.
- When an inertial profiler is used, the data ProVal be analyzed by using the rolling straight edge simulation on the most recent version of ProVal Software.
- Where the initial deviation from the straightedge is 1/2 inch or more, the Contractor will be required to remove and replace the complete pour in which the areas not meeting the required tolerance are located.

From Section 679.5.1 Final Bridge Deck Finish > Straightedge Test, beginning on page 741 of the specifications, page 761 of the PDF:

> After defective or damaged concrete has been repaired and cured in accordance with 679.4.9 and before opening to traffic, the bridge deck shall be grooved as set forth in 679.5.2. Prior to grooving, the entire deck shall be checked with an approved ten (10) foot rolling straightedge or approved inertial profiler and inertial profile operator as outlined in section 720.2.

Related Resource:

Chapter 720 Smoothness Testing, Supplemental Specifications, West Virginia Department of Transportation Division of Highways, 2022.
https://transportation.wv.gov/highways/TechnicalSupport/specifications/Documents/2022_Supplemental_2022-1-6(redline).pdf
From Section 720.2.1 beginning on page 303 of the specifications, page 315 of the PDF:

> **High-Speed or Low Speed Inertial Profiler**: Provide a high-speed or low speed inertial profiler for measuring and evaluating the ride quality of pavement surfaces. The inertial profiler shall be certified at a facility approved by the Materials Control, Soils and Testing Division (MCS&T).

From Section 720.4.1 Ride Quality Analysis on page 305 of the specifications, page 317 of the PDF:

> The average IRI number used in ride quality analysis shall be the mean roughness index (MRI) which is the average IRI of both the left and right wheel path.

From Section 720.5.2.1 Corrective Action for Schedule 1 NHS [National Highway System] Pavement Projects on page 306 of the specifications, page 318 of the PDF:

> Corrective action shall be required for Schedule 1 NHS Pavement Projects having an IRI greater than 95.1 in/mi. Corrective action shall be performed using diamond grinding, micro milling, or other work methods approved by the Engineer.

Wisconsin

Section 740 Quality Management Program (QMP) Ride, Standard Specifications for Highway and Structure Construction, Wisconsin Department of Transportation, 2025.
https://wisconsindot.gov/rdwy/stndspec/ss-07-40.pdf
Selected relevant excerpts from this section of the specifications:

- From Section 740.1.1 General, page 542 of the specifications, page 1 of the PDF:

  This section describes profiling with a non-contact profiler, locating areas of localized roughness, and determining the International Roughness Index (IRI) for each wheel path.

- From Section 740.1.2.4 Documentation, page 542 of the specifications, page 1 of the PDF:

  After profiling, compute the segment IRI for each segment and analyze areas of localized roughness using the ProVAL software…

- From Section 740.3.4.2 Corrective Action for Localized Roughness, page 544 of the specifications, page 3 of the PDF:

  The engineer will assess each wheel path for areas of localized roughness within 5 business days of being notified that ProVAL reports are uploaded. For each area that exceeds 200 in/mile, the engineer will do one of the following: …

- From Section 740.3.4.3 Corrective Action for Excessive Segment IRI, page 544 of the specifications, page 3 of the PDF:

  If an individual segment IRI exceeds 140 in/mile for HMA I, HMA II, and PCC II pavements after correction for localized roughness, the engineer may require the contractor to correct that segment's final surface as follows: …

Related Resource:

Section 415 Concrete Pavement, Standard Specifications for Highway and Structure Construction, Wisconsin Department of Transportation, 2025.
https://wisconsindot.gov/rdwy/stndspec/ss-04-15.pdf
From page 151 of the specifications, page 5 of the PDF:

415.3.10.1 Smoothness
Test the pavement surface at engineer-selected locations with a 10-foot straightedge or other engineer-specified device. The engineer may direct the contractor to mark and grind down areas showing high spots greater than 1/8 inch but not exceeding 1/2 inch in 10 feet. Grind until there are no deviations greater than 1/8 inch when retested with the straightedge. The engineer may direct the contractor to remove and replace areas with deviations greater than 1/2 inch in 10 feet.

Perform grinding as specified in 415.3.11.

If the engineer directs removal, remove an area at least 6 feet long and extending across the full lane width. Also remove adjacent pavement less than 6 feet from a transverse joint.