Smoothness Criteria for Construction and In-Service Conditions for LTPP SPS WIM Sites

Background Material for the Presentation by John Weaver, Indiana DOT

The Long-Term Pavement Performance Program (LTPP) has intensified its efforts to obtain sufficient quantities of research quality loading data at a number of Specific Pavement Studies (SPS) sites. Recognizing that pavement smoothness has a significant impact on the variability of the data obtained, the FHWA has consulted with the Transportation Research Board LTPP Traffic Expert Task Group and the Distress and Profile Expert Task Group on the development of a pavement smoothness specification for WIM installations. The smoothness specifications apply to both newly constructed and in-service pavements. Newly constructed pavements are evaluated using both longitudinal and transverse profile measurements. In-service pavements are evaluated based on longitudinal profile measurements to eliminate the need to close lanes. Both short wave and long wave measurements are considered in evaluating the possible vehicle dynamic effects at the WIM scale.

The long wave length specifications are still in the preliminary stages of development.

Individuals wishing to provide comments or obtain updates and any revisions with respect to this smoothness protocol should contact Larry Wiser, Traffic Lead for the FHWA LTPP Team, at 202-493-3079 or via e-mail at larry.wiser@fhwa.dot.gov.

Pavement Smoothness Specifications for LTPP SPS WIM Locations

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U.S. Department of Transportation
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Long-Term Pavement Performance
Serving your need for durable pavements

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Pavement Smoothness Specifications for LTPP SPS WIM Locations

1.0 Introduction

The Long Term Pavement Performance (LTPP) Program is a study of pavement performance at approximately 2,400 in-service pavement sections throughout North America. The specific objectives of the LTPP program are to:

- Evaluate existing design methods;
- Develop improved design methods and strategies for the rehabilitation of existing pavements;
- Develop improved design equations for new and reconstructed pavements;
- Determine the effect on pavement distress and performance of loading, environment, material properties, construction quality, and maintenance levels;
- Determine the effects of specific design features on pavement performance, and
- Establish a national long-term pavement performance database.

The LTPP program will collect data on in-service pavement sections over a twenty year period. The data collected at the test sections are stored in the LTPP Information Management System (IMS) database. These data will be used to achieve the objectives of the LTPP program. Traffic data is an important parameter that is required for the analysis of pavement performance. A major data collection effort of the LTPP program is the collection of traffic load data using Weigh-In-Motion (WIM) scales located prior to LTPP test sections. Accurate recording of truck axle weights are required at the WIM sites in order to provide accurate data for pavement performance analysis. The accuracy of load data collected by the WIM scales is affected by the dynamic motions of trucks. The load applied to the surface of a road by a tire of a truck, called the dynamic load, is the sum of the static load carried by the tire and a continuously varying load. This continuously varying load is related to the dynamic motions induced in the vehicle due to road roughness. The dynamic load applied by a tire to the pavement can be either greater or less than the static load carried by that tire. Truck dynamic motions are affected by pavement roughness, which is caused by both short and long wavelengths present in the pavement. The short wavelength roughness affects the axle motions, while the long wavelength roughness contributes to the body bounce of the vehicle.

As truck dynamic motions affect the accuracy of the load data recorded at WIM scales, the usual practice is to provide a smooth pavement section prior to the WIM scale in order to minimize those motions. As the vehicle traverses the WIM scale, the motion of the front of the vehicle can affect the dynamic motions at the back of the vehicle. Therefore, a smooth pavement section is also provided for at least one truck length past the WIM scale. Maintaining a smooth pavement in front of and beyond the WIM scale (at least one truck length) can minimize the dynamic motions that are induced in the truck due to roughness caused by short wavelengths. However, dynamic motions may still be induced on the truck if the pavement sections contain long wavelengths that affect the body bounce of the vehicle.

In order to obtain accurate axle load data at WIM scales, the pavement section must meet smoothness specifications that will limit the effect of dynamic vehicle motions induced by short wavelengths. In addition, an assessment of the dynamic loads that are caused by long wavelengths in the pavement is needed to verify the accuracy of the load data collected at the WIM scales.

This document describes smoothness specifications that must be met at selected LTPP SPS WIM sites. Adherence to these specifications will help ensure that accurate data are being collected at LTPP WIM sites.

This document describes smoothness specifications that are applicable to the following three cases:

1. Verification of existing WIM sites
2. Acceptance of new WIM sites
3. Annual check of existing WIM sites accepted into the LTPP program.

2.0 Weigh-In-Motion (WIM) Sections

A Weigh-In-Motion (WIM) section is defined as a section of pavement that is 152.4 m long, with the distance from the centerline of the WIM scale to the beginning of the test section being 122 m, and the distance from the centerline of the WIM scale to the end of the test section being 30.4 m.

The surface type of the pavement within the 152.4 m long WIM section can fall into one of the following three categories:

1. Portland Cement Concrete (PCC)
2. Asphalt Concrete (AC)
3. AC lead in followed by PCC pavement followed by AC pavement.

The last category occurs at sites where a portion of the existing AC pavement was replaced by a PCC pavement for the purposes of installing WIM sensors.

3.0 Smoothness Specifications for WIM Sites

In the LTPP program, smoothness evaluation of WIM sites can fall into one of the following categories:

1. Verification of existing WIM sites: These WIM sites are already in operation, but they will be evaluated to determine if they satisfy the specified smoothness criteria.
2. Acceptance of newly constructed WIM sites: Newly constructed WIM sites will be evaluated to determine if they satisfy the specified smoothness criteria.
3. Annual check of WIM sites: Newly constructed WIM sites that are accepted into the LTPP program, as well as existing WIM sites that have been verified and accepted into the LTPP program, will be monitored once a year to determine if they satisfy the specified smoothness criteria.

Table 1 provides an overview of the smoothness specifications that must be satisfied for each of the above three WIM site categories. This table presents the applicable specifications and the equipment used to obtain measurements for each specification.

The following is a detailed description of the specifications that need to be satisfied at the WIM sites, presented separately for each category.

3.1 Verification of Existing WIM Sites

Three options are available for verification of existing WIM sites. Parties responsible for verification may follow any of the following options to verify an existing WIM site.

Option 1

- Short Wavelength Smoothness Specification – Profiler: An inertial profiler is used to evaluate pavement. Data collection and evaluation shall be performed in accordance with specifications presented in Attachment D - Short Wavelength Smoothness Specification - Profiler. Lane closure is not required.
- Long Wavelength Specification: An inertial profiler is used to evaluate pavement. Data collection and evaluation shall be performed in accordance with specifications presented in Attachment C - Long Wavelength Smoothness Specification. Lane closure is not required.

Option 2

- Short Wavelength Smoothness Specification – Profiler: An inertial profiler is used to evaluate pavement. Data collection and evaluation shall be done in accordance with specifications presented in Attachment D - Short Wavelength Smoothness Specification - Profiler. Lane closure is not required.
- Long Wavelength Specification: An inertial profiler is used to evaluate pavement. Data collection and evaluation shall be done in accordance with specifications presented in Attachment C - Long Wavelength Smoothness Specification. Lane closure is not required.
- Transverse Profile Specification – Straightedge: A straightedge is used to evaluate transverse profile of pavement. Data collection and evaluation shall be done in accordance with specifications presented in Attachment B - Transverse Profile Specification – Straightedge. Lane closure is required.

Table 1. Overview of Smoothness Specifications

Test Condition	Specifications	Equipment	Location of Specification In This Document
Acceptance of New WIM Sites	1. Short Wavelength Smoothness Specification	Straightedge	Attachment A
	2. Transverse Profile Specification	Straightedge	Attachment B
	3. Long Wavelength Specification	Profiler or Dipstick	Attachment C
Verification of Existing WIM Sites	1. Short Wavelength Smoothness Specification	Profiler	Attachment D
	2. Long Wavelength Specification	Profiler	Attachment C
	3. Optional: Transverse Profile Specification	Straightedge	Attachment B
	4. Optional: Short Wavelength Smoothness Specification (Note 1)	Straightedge	Attachment A
Annual Check of WIM Sites	1. Short Wavelength Smoothness Specification	Profiler	Attachment D

Note 1: If short wavelength smoothness specification for the straightedge is used (Attachment A), the short wavelength smoothness specification for the profiler (Attachment D) need not be performed. However, the long wavelength smoothness
specification (Attachment C) should be evaluated using data collected by a profiler or Dipstick

Option 3

- Short Wavelength Smoothness Specification - Straightedge: A straightedge is used to evaluate pavement. Data collection and evaluation shall be done in accordance with specifications presented in Attachment A - Short Wavelength Smoothness Specification – Straightedge. Lane closure is required.
- Transverse Profile Specification – Straightedge: A straightedge is used to evaluate transverse profile of pavement. Data collection and evaluation shall be done in accordance with specifications presented in Attachment B - Transverse Profile Specification – Straightedge. Lane closure is required.
- Long Wavelength Specification: Either the Dipstick® or an inertial profiler is used to collect data. Data collection and evaluation shall be done in accordance with specifications presented in Attachment C - Long Wavelength Specification. Lane closure is required if data collection is performed with Dipstick®.

3.2 Acceptance of Newly Constructed WIM Sites

- Short Wavelength Smoothness Specification - Straightedge: A straightedge is used to evaluate pavement. Data collection and evaluation shall be done in accordance to the specification presented in Attachment A - Short Wavelength Smoothness Specification – Straightedge. Lane closure is required.
- Transverse Profile Specification – Straightedge: A straightedge is used to evaluate transverse profile of pavement. Data collection and evaluation shall be done in accordance with specifications presented in Attachment B - Transverse Profile Specification – Straightedge. Testing shall be performed at same time pavement is tested for short wavelength smoothness.
- Long Wavelength Specification: Either the Dipstick® or an inertial profiler is used to collect data. Data collection and evaluation shall be done in accordance with specifications presented in Attachment C - Long Wavelength Specification. Lane closure is required if data collection is performed with Dipstick®.

3.3 Annual Check of WIM Sites

An annual check of WIM sites accepted into the LTPP program shall be done to verify that those sites satisfy the short wavelength smoothness specifications. The procedures presented in Attachment D - Short Wavelength Smoothness Specification – Profiler shall be used to perform the annual site checks. The LTPP profiler shall be used to collect the profile data required for these annual checks.

Note: Evaluation of pavement long wavelengths is performed after a WIM site has just been constructed (i.e., new WIM site) or during the initial verification of an existing WIM site. Long wavelengths at a WIM site that affect vehicle motions are not generally expected to change over time and therefore, an annual verification of the long wavelength specifications shall not be performed.

4.0 Pavement Markings

WIM sites shall be marked in accordance with the specifications provided in Attachment F - Site Marking at WIM Locations.

5.0 Data Storage

Data collected at WIM sites for purposes of evaluating pavement smoothness specifications fall into the following categories:

1. Short wavelength smoothness specification – Straightedge: Data collected for evaluation of short wavelength smoothness specifications are recorded in Form A-1 (see Attachment A).
2. Transverse profile specification – Straightedge: Data collected for evaluation of transverse profile specifications are recorded in Form B-1 (see Attachment B).
3. Longitudinal profile data for long wavelength evaluation – Dipstick®: Data collected for evaluation of long wavelength specifications using the Dipstick® are recorded in standard forms included in Appendix II of the LTPP Manual for Profile Measurements, Operational Field Guidelines, Version 3.1.
4. Longitudinal profile data for short and long wavelength specification – Profiler: Data collected for evaluation of short and long wavelength specifications using an inertial profilers are recorded in electronic data files.

Party(ies) responsible for data collection shall maintain an organized filing system for storage of data forms collected under data categories 1 through 3. A copy of all data forms collected at a WIM site shall be forwarded to the appropriate LTPP Regional Coordination Office within three (3) months of data collection.

Party(ies) collecting longitudinal profile elevation data (data category 4) shall keep original data files collected at WIM sites as well as a backup copy of those data files in their office. A copy of the data files shall be forwarded to the appropriate LTPP Regional Coordination Office within three (3) months of data collection. Also, a log shall be maintained that describes the data file names, associated WIM site, and position of testing (i.e., wheel path, left of wheel path, right of wheel path, etc).

Profile data collected for evaluation of pavement smoothness specifications will not be stored in the LTPP IMS database. However, an IMS data summary sheet shall be prepared to store key summary information for each WIM location evaluated. The data summary sheet shall, as a minimum, contain the following information items:

1. State Code
2. SHRP ID associated with WIM location
3. Date tested
4. Test reason (i.e., verification, acceptance testing, annual check)
5. Method used to collect long wavelength data (i.e., profile or Dipstick)

6. Did WIM location pass long wavelength criteria, if evaluation required on date tested? If not, report deviations from criteria.
7. Method used to collect short wavelength data (i.e., straightedge or profile)
8. Did WIM location pass short wavelength criteria? If criteria was not met, report percentage of locations where failure occurred.
9. Did WIM location pass transverse profile criteria, if evaluation required on date tested? If criteria was not met, report percentage of locations where failure occurred.

6.0 Response to Failures

The following smoothness specifications were described in this document:

1. Short wavelength smoothness specification - Straightedge
2. Transverse profile specification - Straightedge
3. Short wavelength smoothness specification - Profiler
4. Long wavelength smoothness specification

Each specification lists requirements that must be satisfied in order for the WIM location to be acceptable. If a WIM site fails any of the specified requirements, the results obtained shall be evaluated by an group of knowledgeable persons identified by the Federal Highway Administration LTPP team and specifically chosen for this task.

A variety of pavement and environmental conditions at the time of testing can influence the results obtained for the short wavelength smoothness specifications. These conditions include:

1. Temperature and moisture effects on PCC pavements that lead to slab curling or warping
2. Crack sealing and joint sealing within WIM section
3. Localized distresses (e.g., spalling for PCC pavements)

In the event the short wavelength smoothness specifications fail (either straightedge or profiler), the effect of the above factors as well as other factors that could have had on impact on the test results shall be evaluated. Based on the results of this evaluation, an appropriate corrective response to the failure shall be formulated. Possible actions that will be considered include:

1. Pavement remediation measures to achieve required smoothness level, such as diamond grinding of pavement surface.
2. Removal of existing WIM scale, reconstruction of pavement and re-installation of WIM scale.
3. Discontinuing collection of WIM data at location and collecting only vehicle classification data.
4. Discontinuing both WIM and vehicle classification data collection at the site.

In deciding on the final resolution, the age of the equipment as well as the anticipated life of the pavement in which the WIM is installed shall be considered.

In the event the long wavelength specifications fail, further analysis of the profile data shall be performed to evaluate the impact on the loads recorded by the WIM scale, and an appropriate resolution to the failure shall be formulated.

Attachment A
Short Wavelength Smoothness Specification - Straightedge

Attachment A
Short Wavelength Smoothness Specification - Straightedge

A.1 Introduction

This specification describes a procedure to determine if short wavelengths that affect dynamic motions of vehicles are present on a roadway by using a straightedge as the measuring device. Lane closure is required to perform the measurements.

This procedure consists of:

1. Marking wheel paths on pavement using a chalk line.
2. Placing a 3.66 m straightedge at specified locations along wheel path and at an offsets from wheel path.
3. Determining if a circular plate, 3 mm thick and 150 mm in diameter, can be passed below straightedge at locations where straightedge is placed.

This specification describes procedures for laying out the site, specifies the locations to place the straightedge, and requirements to evaluate if the site satisfies the smoothness criteria.

A.2 Measuring Equipment

A straightedge that is 3.66 m in length and has a mark at the center of the straightedge and a circular plate that is 3 mm in height and 150 mm in diameter are needed to perform this test. The bottom rectangular surface of the straightedge shall be at least 19 mm but not more than 75 mm wide in the measurement plane. The maximum out-of-trueness of the bottom surface of the straightedge in the measurement plane and along the width shall be less than $\pm$ 0.40 mm/m.

A.3 Site Layout

The site layout consists of identifying the wheel paths, and then marking the wheel paths using a chalk line. The pavement must be clean of any debris before the site layout is performed.

The wheel paths at a site are defined to be at a distance of 0.826 m from the center of the travel lane. Use following procedure to locate the center of the travel lane:

Case I: Where wheel paths are easily identified, midway point between two wheel paths shall be used as center of lane. In a newly diamond ground pavement it will not be possible to identify the wheel paths, and either Case II or Case III shall be used to identify the center of the travel lane.

Case II: If wheel paths are not clearly identifiable, but two lane edges are well defined, center of travel lane is considered to be midway between the two lane edges.

Case III: Where wheel paths are not apparent and only one lane edge can be clearly distinguished, center of lane should be established at 1.83 m from that edge.

Once the center of travel lane has been identified, use the following procedure to layout the site:

1. Determine location of start of WIM section.

   (a) If site is marked according to procedures described in Attachment F, station 0+00 for the site is located at the leave edge of the white stripe at the beginning of the WIM section.

   (b) If site is not marked, the beginning of WIM section shall be determined. The beginning of the WIM section is located 122 m from the centerline of the WIM scale. This length of 122 m shall be accurately measured using a tape measure (measurement wheels are not acceptable).

2. Identify location of two longitudinal elevation survey lines 0.826 m from center of lane. Mark these locations at intervals equal to length of chalk line used for marking. Use chalk line to mark a straight line between previously established points. The chalk lines shall be marked till the end of the section, which is 152.4 m from the beginning of the section.

A.4 Measurement Procedure

The measurement procedure consists of laying down the 3.66 m long straightedge on the pavement at locations that are described in this section, and determining if a circular plate that is 3 mm thick and 150 mm in diameter can be passed below the straightedge (i.e., between the straightedge and the pavement surface) at any location within the limits of the straightedge.

The following procedure shall be followed in obtaining measurements within the WIM section.

1. Go to start of section (Station 0+00) and lay down straightedge on left wheel path on top of the chalk line, with one end of the straightedge (back end) at Station 0+00 and the other end (front end) extending into the WIM section. The position of the straightedge is shown as Position 1 in Figure A1. Mark location of front end of the straightedge on the chalk line using a lumber crayon. Determine if the specified disk can be passed below the straightedge, and note the result of the test in Form A1.

2. Pick up straightedge and place it so that it is parallel to the wheel path but offset 0.3 m to the right of the wheel path, and with the center of the straightedge being in line with the mark that was placed on the pavement with lumber crayon in the previous step. The location of the straightedge shall correspond to Position 2 in Figure A1. At this position, 1.83 m of the straightedge overlaps into the previously measured portion of the

pavement. Use lumber crayon to put a mark in the wheel path that is in line with the front end of the straightedge. Determine if the specified disk can be passed below the straightedge, and note the result in Form A1.

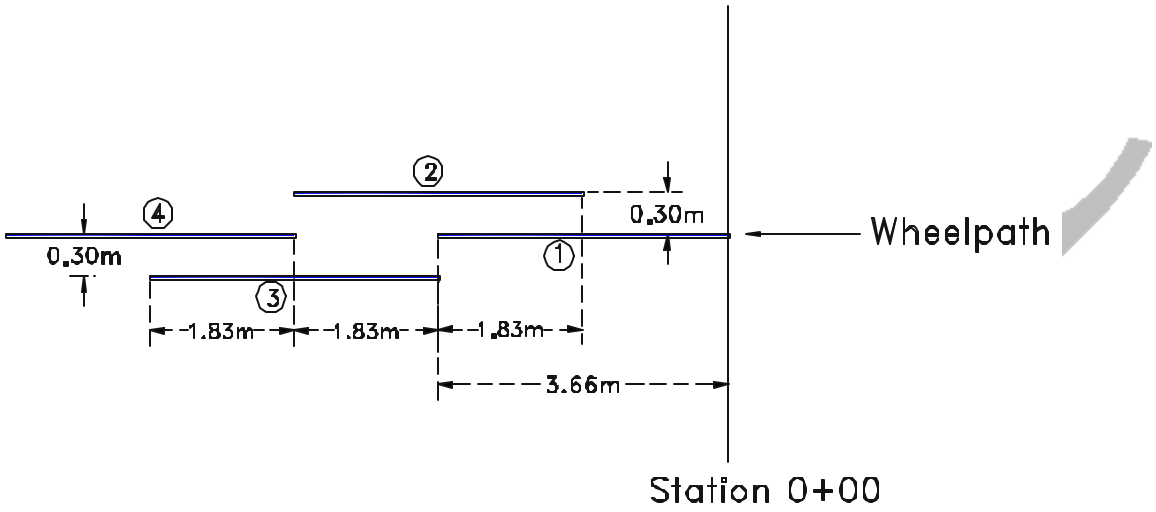

Figure A-1. Measurement Procedure Using a Straight Edge

3. Pick up straightedge and place it so that it is parallel to the wheel path but offset 0.3 m left of the wheel path, with the center of the straightedge being in line with the mark on the pavement that was made with lumber crayon in the previous step. The location of the straightedge shall correspond to Position 3 in Figure A1. In this position, 1.83 m of the straightedge overlaps into the previously measured length of the pavement. Use lumber crayon to put a mark in the wheel path that is in line with the front end of the straightedge. Determine if the specified disk can be passed below the straightedge, and note the result in Form A1.

4. Pick up straightedge and place it on the wheel path, such that the center of the straightedge is in line with the mark on the pavement that was made with lumber crayon in the previous step. The location of the straightedge shall correspond to Position 4 in Figure A1. In this position, 1.83 m of the straightedge overlaps into the previously measured length of the pavement. Use lumber crayon to put a mark in the wheel path that is in line with the front end of the straightedge. Determine if the specified disk can be passed below the straightedge, and note the result in Form A1.

5. Repeat steps 2, 3 and 4 in sequence until the end of the WIM section is reached.

6. Repeat steps 1 through 5 for the right wheel path.

If during diamond grinding, multiple measurements are performed on the test section, submit the data form (Form A-1) for the final measurements that are performed at the WIM section.

A.5 Smoothness Criteria

The smoothness of the pavement at each position of the straightedge is evaluated by determining if a circular plate that is 3 mm thick and 150 mm in diameter can be passed below the straightedge (i.e., between the straightedge and the pavement surface) at any position within the limits of the straightedge. If the specified plate can be passed below the straightedge, the smoothness requirement is considered to have failed at that location.

In order for a WIM section to satisfy the short wavelength smoothness criteria, the specified smoothness criteria shall not fail at any location within the WIM section. If the specified criteria fails at any location within the WIM section, the WIM section is considered to have failed the "Short Wavelength Smoothness Specification – Straightedge".

FORM A-1: Straightedge Measurements - Longitudinal Direction

State Code: Date:
LTPP WIM Section:
Route:

Station for Back End of Straightedge	Location of Straightedge	Can Disk be Passed (Y/N) ?	Station for Back End of Straightedge	Location of Straightedge	Can Disk be Passed (Y/N) ?
0.00	Wheel Path		75.03	0.3 m Left	
1.83	0.3 m Right		76.86	Wheel Path	
3.66	0.3 m Left		78.69	0.3 m Right	
5.49	Wheel Path		80.52	0.3 m Left	
7.32	0.3 m Right		82.35	Wheel Path	
9.15	0.3 m Left		84.18	0.3 m Right	
10.98	Wheel Path		86.01	0.3 m Left	
12.81	0.3 m Right		87.84	Wheel Path	
14.64	0.3 m Left		89.67	0.3 m Right	
16.47	Wheel Path		91.50	0.3 m Left	
18.30	0.3 m Right		93.33	Wheel Path	
20.13	0.3 m Left		95.16	0.3 m Right	
21.96	Wheel Path		96.99	0.3 m Left	
23.79	0.3 m Right		98.82	Wheel Path	
25.62	0.3 m Left		100.65	0.3 m Right	
27.45	Wheel Path		102.48	0.3 m Left	
29.28	0.3 m Right		104.31	Wheel Path	
31.11	0.3 m Left		106.14	0.3 m Right	
32.94	Wheel Path		107.97	0.3 m Left	
34.77	0.3 m Right		109.80	Wheel Path	
36.60	0.3 m Left		111.63	0.3 m Right	
38.43	Wheel Path		113.46	0.3 m Left	
40.26	0.3 m Right		115.29	Wheel Path	
42.09	0.3 m Left		117.12	0.3 m Right	
43.92	Wheel Path		118.95	0.3 m Left	
45.75	0.3 m Right		120.78	Wheel Path	
47.58	0.3 m Left		122.61	0.3 m Right	
49.41	Wheel Path		124.44	0.3 m Left	
51.24	0.3 m Right		126.27	Wheel Path	
53.07	0.3 m Left		128.10	0.3 m Right	
54.90	Wheel Path		129.93	0.3 m Left	
56.73	0.3 m Right		131.76	Wheel Path	
58.56	0.3 m Left		133.59	0.3 m Right	
60.39	Wheel Path		135.42	0.3 m Left	
62.22	0.3 m Right		137.25	Wheel Path	
64.05	0.3 m Left		139.08	0.3 m Right	
65.88	Wheel Path		140.91	0.3 m Left	
67.71	0.3 m Right		142.74	Wheel Path	
69.54	0.3 m Left		144.57	0.3 m Right	
71.37	Wheel Path		146.40	0.3 m Left	
73.20	0.3 m Right		148.23	Wheel Path	

Note: Station 0+00 is at the beginning of the test section

Attachment B
Transverse Profile Specification – Straightedge

Attachment B
Transverse Profile Specification – Straightedge

B.1 Introduction

Variations in the transverse profile within a WIM section may induce dynamic motions in the vehicle that can affect the weight that is measured at the WIM scale. This specification describes a procedure for checking the transverse profile at WIM sections using a straightedge to check if it meets a specified profile criteria. Lane closure is required for performing this test. The measurements for this test shall be performed at the same time the section is being evaluated for "Short Wavelength Smoothness Specification - Straightedge".

This procedure consists of:

1. Marking specified longitudinal distances from the centerline of the WIM scale.
2. Placing a 3.66 m long straightedge transversely across the lane at each of the specified longitudinal locations, in a direction that is perpendicular to the direction of travel.
3. Determining if a circular plate that is 150 mm in diameter and 3 mm thick can be passed below the straightedge (i.e., between the straightedge and the pavement) at any location within the limits of the straightedge.

This specification describes procedures for laying out the site, specifies the locations where the straightedge is to be placed to obtain measurements, and the requirements that have to be met in order to pass the transverse profile criteria.

B.2 Measuring Equipment

A straightedge that is 3.66 m in length and a circular plate that is 3 mm in thickness and 150 mm in diameter is required for this test. The bottom rectangular surface of the straightedge shall be at least 19 mm but not more than 75 mm wide in the measurement plane. The maximum out-of-trueness of the bottom surface of the straightedge in the measurement plane and along the width shall be less than $\pm$ 0.40 mm/m.

B.3 Site Layout

The site layout consists of marking off specified distances from the centerline of the WIM scale. The pavement must be clear of any debris before the site layout is performed.

Lumber crayon should be used to place marks on the pavement surface along the inside and outside lane edges at the following distances from the center line of the WIM scale in the direction upstream of the WIM (i.e., towards the beginning of the WIM section): 0 (centerline of the WIM scale), 5, 10, 15,

20, 25, 50, 75 and 100 m. The specified distances shall be measured using a measuring tape (measuring wheel not acceptable).

B.4 Measurement Procedure

The following procedure shall be used to check the transverse profile of the pavement.

1. At first longitudinal location that was marked on the pavement (station 0, centerline of the WIM scale), place one end of the straightedge at the inner edge of the lane and the other end of the straightedge on the outer edge of the lane, such that left face of the straightedge is flush with the lumber crayon markings on the inner and outer lane edges. At this position, the straightedge will be perpendicular to the traffic direction of the lane.

2. Determine if circular plate that is 3 mm in height and 150 mm in diameter can be passed below the straightedge (i.e., between the straightedge and the pavement surface) at any location within the limits of the straightedge. Note the result of this test in Form B1.

3. Repeat procedure described in step 2 at all other locations marked on the pavement surface (i.e., 5, 10 , 15 , 20 , 25, 50 , 75, and 100 m). Note results of this test in Form B-1.

B.5 Profile Requirements

The transverse profile at each position of the straightedge is evaluated by determining if a circular plate that is 3 mm thick and 150 mm in diameter can be passed below the straightedge (i.e., between the straightedge and the pavement surface), at any position within the limits of the straightedge. If the specified plate can be passed below the straightedge, the transverse profile requirement is considered to have failed at that location.

In order for a WIM section to satisfy the transverse profile criteria, the specified transverse profile criteria shall not fail at all test locations. If the specified transverse profile criteria fails at any test location, the WIM section is considered to have failed the specification “Transverse Profile Specification – Straightedge”.

Form B-1
Straightedge Measurements - Transverse Direction

State Code:

WIM LTPP Section:

Route:

Date:

Distance From Centerline of WIM (m)	Can Disk Be Passed Below Straightedge (Y/N) ?
0.0	
5.0	
10.0	
15.0	
20.0	
25.0	
50.0	
75.0	
100.0	

Attachment C
Long Wavelength Specification

Attachment C
Long Wavelength Specification

C.1 Introduction

Long wavelengths in the pavement induce body bounce of trucks (1.5 to 4 Hz), which induce dynamic loads on pavements. The presence of long wavelengths in the pavement prior to the WIM scale that affects the body bounce of the vehicle can affect the loads that are recorded by the WIM scale. In this specification, an evaluation of the dynamic loads that are applied by trucks at the WIM scale location is made.

This procedure consists of:

1. Collecting longitudinal profile data within test section using an inertial profiler. A Dipstick may be used to collect longitudinal profile data if an inertial profiler is not available.
2. Analyzing the profile collected versus the long wave length index which reflects the distribution of wavelengths that are considered not to significantly impact the precision of the WIM sensor response.

C.2 Equipment Used

The preferred equipment for collecting longitudinal profile data is an inertial profiler. The profiler shall meet the requirements outlined in Section D.2 (Measuring Equipment) in Attachment D - Short Wavelength Smoothness Specification - Profiler. If a Dipstick is used to collect profile data, it shall meet the requirements outlined in Section 1.2 (Measuring Equipment) in Attachment E - Procedure for Longitudinal Data Collection Using Dipstick.

C.3 Measurement Procedure

If profile data is collected at the site to evaluate Specification D - Short Wavelength Smoothness Specification Profiler, no additional data collection is required. If the site is being profiled specifically to evaluate the long wavelength specification, collect profile data along the wheel paths using the procedures outlined in Section D.3 (Profile Data Collection) in Attachment D - Short Wavelength Smoothness Specification - Profiler. If the Dipstick is used, collect data according to procedures outlined in Attachment E - Procedure for Longitudinal Data Collection Using Dipstick.

C.4 Data Analysis

The data analysis will utilize software developed for LTPP following multiple truck simulations using Class 9 vehicles with various dynamic properties and loadings on a variety of pavement profiles. The

analysis is intended to provide an indication of the characteristics of a profile which preclude a WIM scale from meeting the performance criteria in the equipment specifications. (See Table C-1.)

Table C-1. Tolerance Limits

Case	Tolerance for 95% Probability of Conformity
Loaded Single Axle	+/- 20 percent
Loaded Tandem Axle	+/- 15 percent
Gross Vehicle Weights	+/- 10 percent

Note: Values obtained from ASTM Standard E 1318

C.5 Long Wavelength Criteria

TO BE DETERMINED

Attachment D
Short Wavelength Smoothness Specification – Profiler

Attachment D
Short Wavelength Smoothness Specification – Profiler

D.1 Introduction

This specification presents a method to determine, using data collected by an inertial profiler, if short wavelengths that can induce dynamic motions on vehicles are present at a WIM site. The presence of such short wavelengths will be investigated by simulating the placement of a 3.66 m straightedge on the profile data at specified locations and determining if a simulated circular plate, 3 mm thick and 150 mm in diameter, can be passed below the straightedge. If the circular plate cannot be passed, it is considered that such short wavelengths are not located within the limits of the straightedge.

The longitudinal profile data collected during initial verification testing of existing WIM sites and during annual WIM visits will be used to check the requirements specified in this specification.

Profile data collected at three lateral positions are used to evaluate the presence of short wavelengths within the WIM section. The three lateral positions along which the profiler shall be driven to collect the data are: along the wheel paths, close to the shoulder (right of the wheel path), and close to the inner edge of the lane (left of the wheel path).

The equipment requirements for the profiler, measuring procedures, data analysis procedure, and smoothness criteria are described in this specification.

D.2 Measuring Equipment

An inertial profiler meeting the Class I standards as specified in ASTM Standard E950-98 shall be used to collect longitudinal profile data. In addition to the requirements specified in E950, the profile equipment shall specifically meet the following requirements.

1. Sensors: Profiler shall be equipped with either laser or infra-red sensors.
2. Number of Sensors: Profiler shall be equipped with two sensors located on either side of the center of the vehicle, equidistant from the center of the vehicle. The center to center distance between the two sensors shall be 1,676 mm. The profiler may have an additional sensor that is located at the center of the vehicle.
3. Photocell: Profiler shall be equipped with either a horizontal or a vertical photocell that can automatically trigger profile data collection using a mark on the pavement (for vertical photocell) or a target placed on the shoulder of the pavement (for horizontal photocell).
4. Sampling Interval: Profiler shall be capable of recording profile data at 25 mm intervals. A moving average shall not be performed on the data that is recorded.
5. Distance Measuring System: Profiler shall be equipped with a distance measuring system.

D.3 Profile Data Collection

Profile data within the LTPP program are currently collected using K.J. Law Model T6600 profilers. Detailed procedures used for collecting profile data for the LTPP program are described in the "LTPP Manual for Profile Measurements, Operational Field Guidelines, Version 3.1." This document describes procedures to be followed for calibration of equipment, daily checks on the equipment, and data collection procedures. Updates on profile data collection activities are described in LTPP profile directives that are issued by the FHWA. Although some of the procedures described in the LTPP Profile Manual are only applicable to K.J. Law Model T6600 profilers, many of the general procedures are applicable to any inertial profiler.

The profile data collection at WIM sites shall be performed following the procedures outlined in the LTPP Manual for Profile Measurements and applicable LTPP Profile Directives, except that the procedure for profiling a site and the number of acceptable runs that are required at a WIM site are different from the procedures described in the manual. Detailed procedures for profiling a WIM site, and the number of profile runs that are required at a WIM site are presented later in this section.

The following procedures shall be followed by all profilers that collect profile data at WIM sites.

1. Displacement sensors, accelerometers, and distance measuring system shall be calibrated.
2. Any applicable daily checks shall have been performed on the equipment (e.g., bounce test) prior to data collection.
3. Highway agency procedures relating to safety issues shall be strictly followed (i.e., flashing signal bar on etc.).
4. Operating speed for collecting profile data shall be 80 km/h.
5. Data collection at the WIM site shall be initiated using photocell.
6. Termination of data collection at a WIM site shall be made by specifying the distance of data collection to be 152.4 m from initiation of data collection.

The following procedure shall be used to obtain an acceptable set of profile runs at a WIM site:

1. Obtain three profile runs by driving the profiler along the wheel paths.
2. Perform data collection by aligning the vehicle such that the right tire of the vehicle is approximately 0.5 m from the white stripe along the edge of the lane. Obtain three runs following this procedure. Every effort shall be made to obtain all three runs along a consistent path.
3. Perform data collection by following a path that is left of the wheel path, and close as much as possible to the left edge of the traffic lane. The driver of the profiler shall judge the path to be followed based on the site conditions, such that the path followed does not cause any safety concerns. Obtain three runs following this procedure, making every effort to obtain all three runs along a consistent path.

4. After completing data collection, compare the three profile runs that were collected at each specific path. Evaluate the profiles for equipment related spikes following the procedures outlined in the LTPP Manual for Profile Measurements. If the operator is confident that at least one error free run has been obtained at the site, terminate data collection. Maintain a log of the runs that the operator considers to be error free.
5. If the operator believes that at least one error free run has not been obtained for given path, repeat data collection along that path and evaluate the profile data using the procedures described in Step 4.
6. Prepare a log indicating file names and paths followed (i.e., wheel path, left of wheel path, right of wheel path). Note the runs that are considered to be error free. For profile runs performed left of the wheel path, indicate the approximate offset from the wheel path. Back up the data to disks prior to leaving the site.

D.4 Data Analysis

Profile data collected along each longitudinal path will be analyzed to determine if short wavelengths that affect the dynamic motion of vehicles are present in the pavement. The procedure that will be used to determine the presence of short wavelengths is to simulate the placement of a straightedge that is 3.66 m in length on the profile data at specific positions, and then determining if a disk that is 3 mm in height and 150 mm in diameter can be passed below the straightedge. If the disk can be passed below the straightedge, the short wavelength criteria is considered to have failed at that specific position.

Data collection along the three paths described in the previous section will result in six longitudinal profiles for a profiler with two sensors (one along each wheel path) and nine longitudinal profiles for a profiler with three sensors (a sensor along each wheel path and a sensor along the center of the vehicle).

The following procedure shall be used to simulate the straightedge along each longitudinal path.

1. For a specific longitudinal path, data collected for three profile runs are available. Select a path to be analyzed, and for that path select profile data corresponding to first error free profile run for use in analysis.
2. Simulate placement of a 3.66 m long straightedge on the profile data with one edge of the straightedge (back end) at the start of the section (station 0+00) and the other end (front end) extending into the WIM section. The simulation of the straightedge shall be performed using a computer program. The computer program shall be capable of determining the stable position at which the straightedge will rest on the profile data.
3. Determine if a circular plate that is 3 mm thick and 150 mm in diameter can be passed below simulated straightedge (i.e., between the straightedge and the pavement) at any location within the limits of the straightedge. If the disk can be passed, the short wavelength criteria is considered to have failed at this placement of the simulated straightedge.

4. Thereafter, simulate the placement of the straightedge such that the edge of the straightedge that was at the beginning of the WIM section (back end) is now at 1.88 m from the start of the section. At this position, half of the straightedge (1.88 m) will overlap into a portion that was covered by the straightedge previously.
5. At this position of straightedge, follow procedure described in Step 3.
6. Computer program shall keep moving straightedge along section. At each position, the straightedge shall overlap 1.88 m into the previous position of the straightedge. At each simulated position, the procedure described in Step 3 shall be performed.
7. Once the front end of the straightedge reaches the end of the section, the program shall terminate, and it shall output the stations at which the specified criteria (step 3) failed. These reported stations shall correspond to the station at which the back end of the straightedge was located.
8. For the specific profile path that was analyzed, two outcomes are possible:
   (a) If specified criteria did not fail at any position, the analyzed path is considered to have passed the short wavelength specification.
   (b) If specified criteria failed at one or more locations, and additional error free profile runs are not available for that path, the analyzed path is considered to have failed the short wavelength specification.
   (c) If specified criteria failed at one or more locations, and additional error free runs are available for that path, repeat steps 2 through 7 using data from the second error free run that was collected along the same path. If data from second run does not fail specified criteria at any location, then the analyzed path is considered to have passed the short wavelength criteria. If data for second run fails the specified criteria at one or more locations, and a third error free run is not available for that path, the analyzed path is considered to have failed the short wavelength specification. If data for second run fails criteria at one or more locations, but data for a third error free run are available for that path, repeat steps 2 through 7 using data from the third error free run. If data for third run does not fail the specified criteria at any location, then the analyzed path is considered to have passed the short wavelength smoothness specification for the analyzed path. If the data for the third error free run fails the specified criteria at one or more locations, that path is considered to have failed the smoothness specification.
9. Repeat analysis (Steps 1 through 8) for the other paths for which profile data was collected. For data collected with a profiler having two sensors, there will be a total of six paths, while for data collected with a profiler having three sensors, data for a total of nine paths are available.

D.5 Data Reporting

1. For each profiled path, indicate if profile passed or failed specified smoothness criteria.
2. If smoothness criteria failed for a specific path, indicate stations where criteria failed (give station for back end of straightedge) for all three runs that were analyzed.

D.6 Smoothness Criteria

If the smoothness criteria passes for all paths surveyed (six for a profiler with two sensors, and nine for a profiler with three sensors), the WIM section is considered to have passed the short wavelength smoothness specification.

If the smoothness criteria failed for any of the analyzed paths, the WIM section is considered to have failed the short wavelength smoothness specification.

Attachment E
Procedure for Longitudinal Data Collection Using the Dipstick®

Attachment E
Procedure for Longitudinal Data Collection Using the Dipstick®

E.1 Introduction

Long wavelengths at WIM sites may induce dynamic vehicle motions that can cause errors in the weights that are measured at WIM scales. The longitudinal profile of the WIM section is required in order to assess the potential impact of long wavelengths on dynamic motions of the vehicle. This analysis is performed when newly constructed WIM sites are evaluated and, if possible, also when verification of existing WIM sites are performed. The preferred method for collecting the longitudinal profile elevation data for analysis is to use an inertial profiler. However, a Dipstick® may be used to collect longitudinal profile data at a WIM section if an inertial profiler is not available.

E.2 Equipment Used

Data collection shall be performed using Face Technologies Dipstick®. Automated Dipsticks® that collect data by recording the data values in the computer shall not be used to collect the data. If automated Dipsticks® are used, they shall be used in the manual mode (i.e., computer shall not be connected and data should be read off from display and recorded on data sheets). The distance between the two feet of the Dipstick® shall be set to 305.8 mm.

E.3 Data Collection Procedure

Detailed procedures for collecting longitudinal profile data using the Dipstick® are described in Section 3.3 of the LTPP Manual for Profile Measurements, Operational Field Guidelines, Version 3.1. The following items are covered in the manual:

- General Background (Section 3.3.1)
- Site Inspection and Layout – Longitudinal Profile Measurements (Section 3.3.2)
- Pre-operational checks on Dipstick® (Section 3.3.1.1)
- Longitudinal Profile Measurement (Section 3.3.3.2)
- Post Data Collection Check (Section 3.3.3.3)

The longitudinal elevation data for the site shall be collected using the procedures outlined in Section 3.3 of the LTPP Manual for Profile Measurements, Operational Field Guidelines, Version 3.1.

E.4 Data Reporting

Dipstick® data shall be recorded in the data sheets that are provided in Appendix II of the LTPP Profile Manual. The data shall be organized and filed. A copy of the data sheets shall be forwarded to the appropriate LTPP Regional Coordination Office.

E.5 Profile Requirements

Dipstick® data that is collected will be used to assess the impact of long wavelengths on vehicle dynamics, and its effect on the loads that are recorded at WIM scales. The analysis of the Dipstick® data will be performed using the procedures described in Attachment C - Long Wavelength Specification.

Attachment F
Site Markings at WIM Locations

Attachment F
Site Markings at WIM Locations

WIM sites shall be marked as shown in Figure F-1. The test section shall be marked by two white stripes, nominally 150 mm wide, across the test lane. The stripe at the beginning of the test section shall be located 122 m from the centerline of the WIM scale. The stripe at the end of the test section shall be located 30.4 m from the centerline of the WIM scale.

At the beginning of the test section, the letters WIM shall be painted near the outside shoulder. Monuments (in the form of nails, spikes, or rebars) shall be installed in the shoulders, exactly at the beginning and end of the test section, as shown in Figure F-1. These monuments will serve as a section marker in case of pavement paint wear. Also a delineator with two blue reflector shall be installed at the end of each test section.

Marking of sites not included in the national SPS program or undergoing initial evaluation - TO BE DETERMINED

NOT TO SCALE

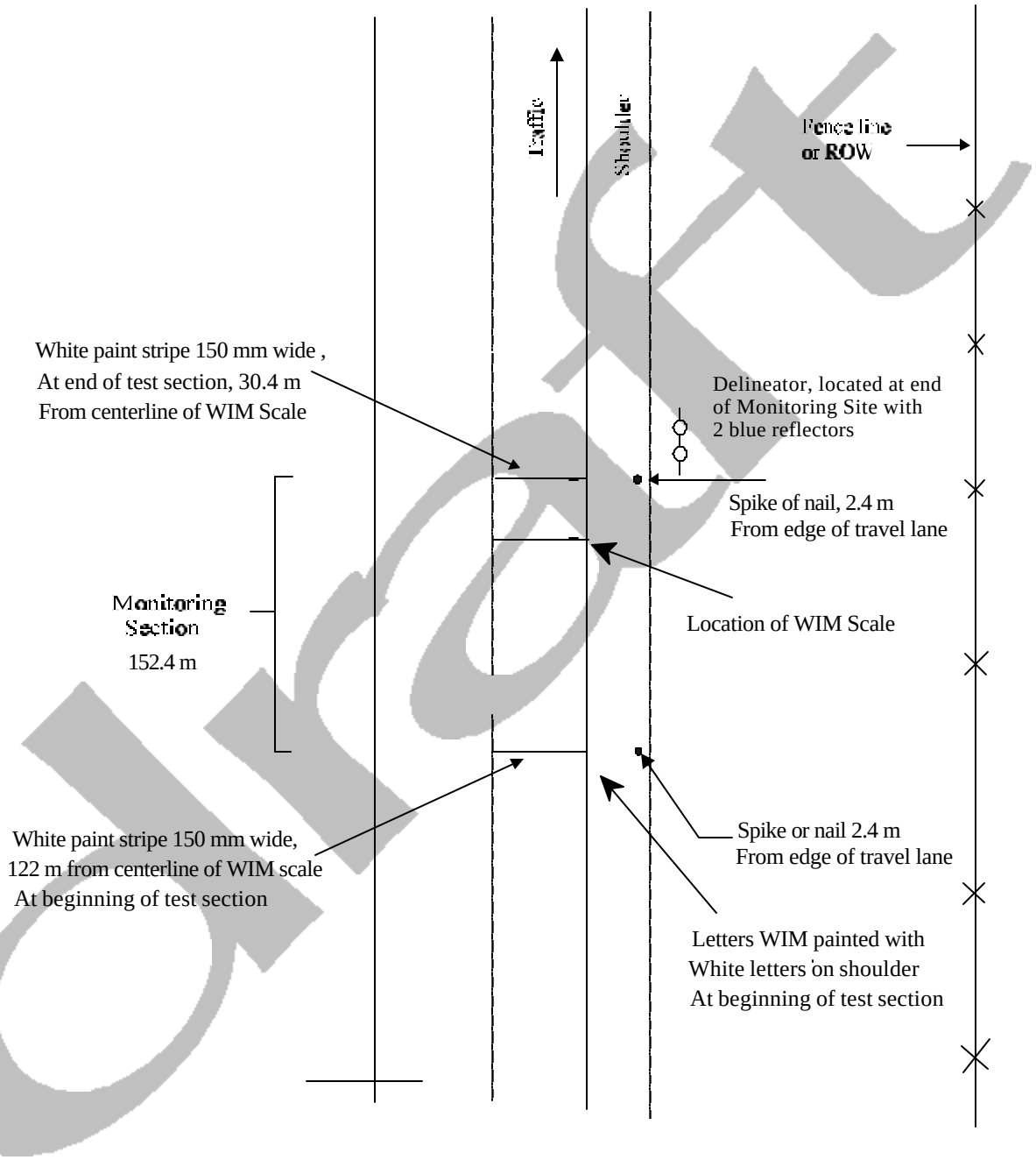

Figure F-1. Site markings at WIM site