1. **SCOPE**

1.1 **Description of Test**

The High Speed Profilograph (HSP) is a motorized vehicle that is specially equipped to measure and record the longitudinal profile of a road surface. This equipment can collect data at speeds of up to 80 km/h while providing the results in a variety of formats, including the same format that is produced by the push type profilograph.

1.2 **Application of Test**

The HSP is used to measure the profile of a roadway. Smoothness is then calculated from the profile data. Smoothness is a Pay Adjustment consideration in the Department's Specification for Asphalt Concrete Pavements.

1.3 **Units of Measure**

The HSP has the ability to measure the profile of a roadway. The following are the HSP indices that can be calculated:

The Profile Ride Index (PrI) using any null band, as specified in the contract, and
The International Roughness Index (IRI).

The magnitude of bumps and dips are also computed from the profile plot.

The respective profile index stated in the construction contract will be the basis for calculating the smoothness.

1.3.1 **Profile Ride Index (PrI)**

The Profile Ride Index, PrI, is the sum of the vertical deviations outside a specified null band in millimetres that a roadway deviates from a perfectly flat surface over a horizontal distance of 100 m. This is a rolling straight edge calculation from the profile data.
1.3.2 The International Roughness Index

The International Roughness Index (IRI) is a standardized measure of the response of a standard vehicle to roadway profile and roadway roughness. The index is computed from the longitudinal profile measurements using a quarter car simulation at a simulation speed of 80 km/h. It is an internationally accepted scale for ride quality. The IRI is determined in millimetres per 100 m or in millimetres per kilometre.

1.3.3 Bumps or Dips

The bump or dip magnitude is the vertical difference, in millimetres, measured over a 7.6 m section or as indicated in the construction contract. The 7.6 m length is equivalent to the length of the standard push type profilograph.

2. APPARATUS AND MATERIALS

2.1 Equipment Required

A vehicle equipped with sensors and profile computing and recording equipment. The sensors are used to measure vertical acceleration, displacement and the distance travelled. The computer is used to process the sensors’ output to produce the computed profile of the travelled surface.

2.2 Materials Required

Measuring chain, spray paint and adhesive reflective tape.

2.3 Section to be tested

The definition or the size of the section to be tested will be as defined in the construction contract.

2.4 Data Required

The location of the area to be tested and the location of an unacceptable area (bumps and dips) determined after measurement in accordance with the requirements of the construction contract.
3. **PROCEDURE**

3.1 **Description of Equipment and Preparation**

Before the test section is driven, ensure that the current safety regulations are followed as outlined in the Traffic Control Devices Manual For Work Zones and the Safety Manual. This includes the correct placement of signs, the wearing of hard hats or high visibility hats, vests, overalls and all other safety requirements.

The operator will discuss the particularities of the project with the project manager or designate before commencement of the test. After the test section is identified, drive over the section and become familiar with the section to be measured including the beginning, end and any other features that should be noted such as curves, hills, bridges, culverts and potentially unsafe areas.

3.2 **Sample Preparation**

Mark the beginning location of the section to be tested with spray paint, keel, reflective tape or a pylon. Also mark and document all reference points and end points.

3.3 **Documenting Reference Points (Location Markers)**

Use markers or spray paint to locate a reference point such as pavement joints, bridges and railway tracks. A separate output will produce a list of the reference points. Indicate on the output the item that is being referenced.

3.4 **Omitting Bridges from Profile data**

The beginning and end of the bridge shall be marked and recorded as a reference point. The report will omit the profile values for the bridge and the length of each terminal section before and after the bridge. The length of each terminal section will be as specified in the construction contract.

3.5 **Test Procedure for determining the Profile Index**

Drive the HSP vehicle at the appropriate speed recommended by the vehicle’s manufacturer. The operating speed is normally 40 to 80 km/h.
The Profile Index is normally measured in the approximate Outer Wheel Path (OWP), in millimetres per 100 m. The Department has the option of testing anywhere within the driving lanes.

The Department will make one pass in each driving lane.

The Profile Index measurement is conducted at 100 m intervals on the section to be tested. If the starting station is not on an even 100 m station (e.g. 17+250), the next reading will be on an even 100 m (e.g. 17+300) and so on. If the roadway or construction project is divided into a number of separate sections, each section will be profiled and analyzed independently.

4. RESULTS AND CALCULATIONS

4.1 Collection of Test Results

Ensure the data file is filed and backed up before leaving site.

4.2 Calculations

The Profile Index is normally measured in the approximate OWP, in millimetres per 100 m in excess of the designated null band. The following examples demonstrate the calculation procedure for determining the profile index.

Example 1: Determining the PrI with a 5 mm null band
The PrI for the above 100 m section from station 2+100 to station 2+200 is calculated as follows:
PrI = the summation of the PrI numbers at each point outside the 5 mm null band

PrI = 0.16+0.35+0.51+0.09+0.14+0.08+0.13+0.37+0.33+0.33 = 3.12 cm/100 m or 31.2 cm/km (31.2 mm/100m) as shown on Figure 1 above.

Example 2 determining the PrI for the same section using a zero null band

FIGURE 2  PrI using zero Null Band

The PrI for the above 100 m, section from station 2+100 to station 2+200 is calculated as follows:
PrI = the summation of the PrI numbers at each point above the horizontal axis or outside the zero mm null band.

PrI = 0.28+ 0.98+ 0.63+ 0.22+ 0.26+ 0.09+ 0.08+ 0.21+ 0.15+ 0.09+ 0.16+ 0.25+ 0.26+
0.15+ 0.09+ 0.11+ 0.14+ 0.10+ 0.49+ 0.10+ 0.10+ 0.16+ 0.16+ 0.46+ 0.46 = 6.36
cm/100 m or 63.6 cm/km (63.6 mm/100m) as shown on Figure 2 above.

Example 3 describing the International Roughness Index (IRI) value, for the above 100 m section from station 2+100 to station 2+200, in comparison with the PrI values using different null bands.
Table 1 - IRI values in comparison to PrI with different null bands

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>PrI, 5 mm Null Band (mm/100m)</th>
<th>PrI, zero Null Band (mm/100m)</th>
<th>IRI (mm/100m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2+100</td>
<td>2+200</td>
<td>31.20</td>
<td>63.60</td>
<td>184</td>
</tr>
</tbody>
</table>

If the profile index is not on an even 100 m station, the index value will be mathematically prorated over the 100 m section as shown in Table 2 below.

Table 2- Index Calculation when the starting/end station is not on an even 100 m

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Distance (m)</th>
<th>Index (mm)</th>
<th>Manually prorated Index value over 100 meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1+625</td>
<td>1+600</td>
<td>25</td>
<td>8</td>
<td>32 ( = 8x100/25)</td>
</tr>
</tbody>
</table>

Bumps and Dips

Bumps and dips are calculated separately based on the specified height along a specified length. Normally the height is greater than 8 mm over a 7.6 m length, unless other dimensions are stated in the construction contract.

4.3 Reporting Results

Report test results using the profile index designated in the contract. The field report for each test section will include the following items:

- Date and time of day,
- Operator, driver and vehicle identification,
- Weather conditions; mainly temperature and wind,
- Location, beginning, end, reference points and description of each section,
- Surface description; type of pavement and condition,
- Run number,
- Measuring speed,
- Direction measured,
- Lane measured,
- Profile data, and
- Other system specific measurement options such as filter wavelength and resolution.
5. **CALIBRATIONS, CORRECTIONS, REPEATABILITY**

5.1 **Equipment Calibration**

The following three types of calibrations are required:

- linear distance sensor,
- vertical height sensor, and
- vertical position accelerometer.

The calibrations are to be repeated at least once per week and as many times as deemed necessary if the test results are not repeatable within the prescribed tolerances. The calibration procedures will be in accordance with the HSP manufacturer’s manual.

Maintain an ongoing record for the values established during each calibration procedure.

5.1.2 **Odometer (Horizontal) Calibration**

Drive the vehicle over a prescribed measured course. The prescribed measured course has to conform to the control section chainage.

Choose a paved stretch of road 3000 m in length. Ensure the test section is relatively flat with good visibility for oncoming traffic from both directions.

Ensure that the current safety regulations are followed. This includes the correct placement of signs and the wearing of hard hats, vests and overalls.

Use spray paint or keel to mark the starting point on the pavement. Place a pylon beside the mark as a reference while chaining.

Mark the end point with spray paint or keel and place a pylon beside the mark.

The chainage has to match the highway’s chainage within +/- 1%; otherwise the unit must be recalibrated.

5.1.3 **Sensor Height (Vertical) Calibration**

The vehicle is equipped with a height sensor on the front bumper of the vehicle and is calibrated using calibration blocks.

The sensor height calibration will be done on a levelled area such as the garage floor before operating the vehicle on the road.
5.1.4 Accelerometer

Each sensor has an accelerometer located directly above it. The accelerometer measures the vertical acceleration and the displacement expected from the bounce motions of the vehicle, in response to the profile of the road.

The acceleration calibration should be done every day after the system has been warmed up for at least 15 minutes. The vehicle should be on a levelled section of pavement. Those who will be travelling in the vehicle during data collection must be in the same seat in the vehicle during calibration.

5.2 Tolerances and Repeatability

Repeatability is achieved by re-testing the section in question.

5.3 Equipment Care and Maintenance

Regular maintenance and calibration procedures must be performed in accordance with the manufacturer’s manual.

6. ADDED INFORMATION

ASTM E950