METHODS OF SAMPLING AND TESTING
MT-422
METHOD OF TEST FOR SURFACE SMOOTHNESS AND PROFILE

1. SCOPE

1.1. This method covers the testing of a finished flexible pavement surface for smoothness and profile. The surface smoothness is expressed in International Roughness Index (IRI) in units of inches per mile. The surface profile is generated to locate variations in profile (e.g., bumps or dips). This method is not intended to be used with rigid pavement or gravel surfacing.

2. REFERENCE DOCUMENTS

2.1. MDR 4080/4097 Mobile Data Recorder (MDR) Operation Manual, International Cybernetics Corporation.

2.2. Profiler Operations Manual (POM) for MDT Profilers (most recent version).

2.3. MDT QC/QA Plan (most recent version).

3. TERMINOLOGY

3.1. International Roughness Index (IRI) – An index resulting from a mathematical simulation of vehicular response to the longitudinal profile of a pavement using a 'quarter-car' simulation model as described in NCHRP Report 228.

4. APPARATUS

4.1. Class I laser road profiler as defined in ASTM E950. The road profiling system is mounted on a vehicle, usually a van or truck. It consists of the following components:

4.1.1. A vertical non-contact height measurement system (i.e., laser) capable of measuring the height from the mounted sensor face to the surface of the pavement.

4.1.2. A linear distance measuring system (i.e., DMI) capable of measuring distance traveled.

4.1.3. An inertial referencing system (i.e., accelerometers) capable of measuring the movement of the vehicle as it traverses the pavement.

5. SOFTWARE

5.1. The software must activate the testing using parameters (i.e., data collection initiation) that are stored by the control setup.

5.2. The software must receive, display, and store raw data received from the profiler.

5.3. The software must be able to accumulating desired output and printing results.

6. CALIBRATION

6.1. A comprehensive calibration and sensor check should be performed at an interval of thirty (30) days during construction season.

6.2. Calibration is used to establish and adjust the operating characteristics of the MDR system. There are four items that will either be calibrated or checked: laser sensors, accelerometers, bounce test, and DMI.

6.3. Laser Sensor Check

6.3.1. The laser sensors have been calibrated in the factory and the operator cannot truly calibrate these sensors.

6.3.2. A calibration check of the laser sensors is performed prior to data collection.

6.3.3. A full calibration check of the laser sensors must also be performed whenever problems are suspected on the laser sensors, or when a sensor is repaired or replaced.

6.3.4. Facility

6.3.4.1. Each MDT District should have a facility available (e.g., enclosed garage at District).

6.3.4.2. Facility should have level surface and be free of any vibration.

6.3.5. Procedures

6.3.5.1. Calibration check should be performed following the procedures discussed in the latest version of the MDT Profiler Operations Manual.

6.3.5.2. Check Sensor Height: Make sure the laser sensors are powered off. Remove sensor covers. Measure distance from floor to glass face of the laser sensor. This distance should be within 13 in ± 0.5 in (330 mm ± 10 mm). The distance from ground to face of the sensor should not change between calibration checks that are performed monthly, unless sensors have been moved or replaced since the previous calibration check. Adjust sensor if required so that height from glass face of sensor to ground is 13 in ± 0.5 in (330 mm ± 10 mm).

6.3.5.3. The operator should be outside of the profiler when the calibration check is performed. Adjust the computer monitor so that it can be seen from outside the vehicle, and the keyboard should be placed on the seat of the profiler. Do not enter the profiler, bounce or bump the profiler, or lean on the profiler during the calibration check.

6.3.5.4. Record the actual ¼", ½", and 1" calibration block thicknesses (in English Units) in the Profiler Calibration Record Sheet.

6.3.5.5. Verify that no blocks, objects, or debris are directly under the laser sensors. From the Sensor Calibration Screen, record the left laser (sensor 1) Height value for the floor height measurement in the appropriate space on line 2 (Height: Floor) in the Profiler Calibration Record Sheet.

6.3.5.6. Place the ¼" calibration block on the floor under the left laser sensor, and position the block so that the laser will reflect approximately at the center of the block. From the Sensor Calibration Screen, record the left laser (sensor 1) Height value for the block height measurement in the appropriate space on line 3 (Height: Block) in the Profiler Calibration Record Sheet.

6.3.5.7. Remove the calibration block from under the left laser sensor and verify the Height value on the Sensor Calibration Screen is the same as the value recorded in step 6.3.5.5.

6.3.5.8. Repeat steps 6.3.5.6 and 6.3.5.7 using the ½" and 1" calibration block.

6.3.5.9. Using the Height values recorded in the Profiler Calibration Record Sheet, compute the "Height: Floor - Block" values for each of the ¼", ½", and 1" calibration blocks by subtracting the "Height: Block" value from the "Height: Floor" value.

6.3.5.10. Using the "Height: Floor - Block" values recorded in the Profiler Calibration Record Sheet, compute the "Difference: Actual - Height" values for each of the ¼", ½", and 1" calibration blocks by subtracting the "Height: Floor - Block" value from the "Actual Block Thickness" value.

The computed value should be less than or equal to 0.002 ft for the laser sensor to be considered working properly. If the value is greater than 0.002 ft, the trouble shooting procedure below is a suggested guide to verify and resolve any issues with the laser sensor.

6.3.5.11. Repeat previous steps to perform the laser sensor calibration check on the right laser (i.e., sensor 2).

6.3.5.12. If any of the "Difference: Actual – Height" values computed for the left and right sensors are greater than 0.002 ft, the following items are suggested to verify that there is an actual problem with the laser sensor. If these procedures do not successfully rule out a problem with the laser sensor(s), ICC should be contacted to assist and resolve sensor problems.

Verify that all recorded values and computations are accurate.

Repeat the laser sensor calibration check for the block(s) and laser that produced an unacceptable difference greater than 0.002 ft. It is possible that the block was not positioned under the laser sensor properly, or that the block was not sitting squarely on the floor. It is not necessary to repeat the calibration check for any blocks that satisfy the acceptable criteria.

If the laser sensor calibration check was performed with the engine running, attempt to perform the calibration check (in its entirety) with the engine switched off and the profiling system plugged into house power (if possible).

Move the profiler to another location and redo the laser sensor calibration check in its entirety.

6.4. Accelerometers

6.4.1. Accelerometers in the profiler should be calibrated if the accelerometer check indicates accelerometer calibration factor(s) are outside the allowable range. The accelerometers should be calibrated when repairs are performed on the accelerometer(s) or on computer cards associated with the accelerometer(s). The accelerometers should be calibrated at the time a full calibration check is performed on the laser sensors.

6.4.2. Facility

6.4.2.1. Each MDT District should have a facility available (e.g., enclosed garage at District).

6.4.2.2. Facility should have level surface and be free of any vibration.

6.4.3. Procedures

6.4.3.1. Calibration should be performed following the procedures discussed in the latest version of the MDT Profiler Operations Manual.

6.4.3.2. Calibration of accelerometers should not be performed when the engine of the profiler is running.

6.4.3.3. Operator should be outside of vehicle when calibration is performed.

6.4.3.4. Operator should adjust computer monitor so that it can be seen from outside vehicle and keyboard should be placed on seat of profiler.

6.4.3.5. Do not enter vehicle, bounce or bump vehicle, or lean on vehicle during calibration.

6.4.3.6. The power to the system should have been turned on for about 15 minutes for the system to warm up prior to calibrating the accelerometers.

6.4.3.7. Proceed to Accelerometer Calibration Menu and begin collecting data. After approximately 2000 samples, end calibration.

6.4.3.8. System will prompt the operator if the new Accelerometer Calibration Factor (ACF) values should be accepted. The accelerometers are considered to be working properly if the ACF values are within the range 512 ± 10. If test appears to be valid, accept the values. If test was not valid, repeat the calibration procedure.

6.5. Bounce Test

6.5.1. The bounce test is a controlled-conditions procedure that uses the profiler's built in simulation capabilities to test that the profiling system is operating properly.

6.5.2. Facility

6.5.2.1. Each MDT District should have a facility available (e.g., enclosed garage at District).

6.5.2.2. Facility should have level surface and be free of any vibration.

6.5.3. Procedures

6.5.3.1. Place a brown wooden clipboard on the ground directly under the right and left laser sensors so that the lasers spots are near the center of the clipboards. Metal, plastic, or colored clipboards are not recommended as the intent of the clipboards is to have the laser sensor take height measurements off a flat neutral colored surface.

6.5.3.2. Verify that the "Reference Post Display Mode" is set to "Mile".

6.5.3.3. Set the "Asc/Dsc Ref Point" to "+".

6.5.3.4. Highlight the "DMI Simulator" option and press 'Enter' key to toggle the distance simulator to "On".

6.5.3.5. Begin simulation and verify that the "Speed" indicates a reasonable simulated speed. If the indicated speed is zero, exit the run screen and verify that the distance simulator is turned on.

6.5.3.6. Initiate the reference reset. The profiler should remain settled for the static portion of the bounce test for a minimum of 0.5 miles (0.80 km) indicated on the "Reference Post."

6.5.3.7. After the "Reference Post" indicates a minimum of 0.5 mi (0.80 km), the operator should begin to apply a vertical up and down motion to the center of the sensor bar on the front of the profiler. The pitching motion on the sensor bar should impart a displacement of approximately 1 in total. All efforts should be attempted to avoid any side to side or rolling motions. This dynamic portion of the bounce test should continue, without interruption, for a minimum of 30 seconds.

6.5.3.8. At the conclusion of the dynamic portion, mark the section end of the simulated profile and then stop the simulated profile.

6.5.3.9. Save the profile data file to the hard disk drive.

6.5.3.10. Create IRI report with interval of 100 ft (30.48 m).

6.5.3.11. Review the IRI report for Reasonableness.

The first 0.5 mi (0.80 km) of intervals on the report should contain IRI values reflecting the profiler in a static condition. The resulting static IRI values should be less than or equal to 5 in/mi (0.08 m/km) for the profiler to be considered functioning properly under static conditions. As long as no more than two static intervals have IRI values greater than 5 in/mi (0.08 m/km) in either the left or right channels the profiler is considered to have satisfied the static bounce test criteria.

If more than two static intervals have IRI values greater than 5 in/mi (0.08 m/km), the bounce test should be repeated to make sure that the profiler remained completely motionless (was not bumped, moved, or otherwise disturbed) during the static portion of the bounce test. The profiler can also be moved to a new location and the bounce test repeated if the static IRI values are not improved.

The intervals following the static portion represent the profiler in a dynamic condition and typically have IRI values much larger than the static condition IRI values. The dynamic IRI values would typically be in the range of 20 to 45 in/mi (0.32-0.71 m/km) for the amount of motion imparted following this bounce test procedure. If more than three intervals of dynamic IRI values are less than 20 in/mi (0.32 m/km), the bounce test should be repeated with emphasis to make sure that a displacement of 1 inch (25.4 mm) is applied at the sensor bar during the dynamic portion of the bounce test.

If a majority of intervals of dynamic IRI values are significantly more than 50 in/mi (0.79 m/km), the bounce test should be repeated with emphasis to make sure that a displacement of 1 inch (25.4 mm) is applied at the sensor bar during the dynamic portion of the bounce test. The profiler can also be moved to a new

location and the bounce test repeated if the dynamic IRI intervals are not improved.

Select one interval from the static portion of the bounce test and record the resulting IRI values for the right and left sensors in the appropriate blocks in the Profiler Calibration Record Sheet.

Select one interval from the dynamic portion of the bounce test and record the resulting IRI values for the right and left sensors in the appropriate blocks in the Profiler Calibration Record Sheet.

6.6. Distance Measuring Instrument (DMI)

6.6.1. DMI should be calibrated whenever problems are suspected. The DMI should also be calibrated when tires are replaced, suspension repairs are performed or when wheels are rotated or aligned. The DMI should be calibrated when repairs are performed on the DMI or to computer cards associated with the DMI.

6.6.2. Calibration Site

6.6.2.1. Each MDT District should have a calibration site established.

6.6.2.2. This site should be located on a straight portion of roadway that is reasonably level and has low traffic volume.

6.6.2.3. Speed limit at the site should be at least 50 mph (80 km/h).

6.6.2.4. This site should be in an area where the vehicle can be driven at a constant speed without interruptions.

6.6.2.5. The site should be measured with a standard surveying tape using standard surveying procedures, or laid out using an electronic distance measuring system.

6.6.3. Procedures

6.6.3.1. Calibration should be performed following the procedures discussed in the latest version of the MDT Profiler Operations Manual.

6.6.3.2. The DMI is calibrated by driving the vehicle over a known distance to calculate the Distance Calibration Factor (DCF).

6.6.3.3. A total of six calibration runs are performed.

6.6.3.4. Acceptability of the DMI Calibration

This is determined by comparing the six “PULSE COUNT” values resulting from the six calibration attempts to the “PULSE COUNT” value in the “AV” row. All six calibration attempts should have values that are within ± 10 of the average pulse count. For example: If the average pulse count is 14047, then all six pulse counts from the six calibration attempts must be within 14037 and 14057.

If any of the six calibration attempts is outside the acceptable limits, then the unacceptable runs should be highlighted and deleted. Following the deletion of the unacceptable runs, new calibration attempts should be made for each run that was

deleted. The intention is to only delete the poor runs and replace with new runs, and NOT re-run a complete set of 6 runs.

6.6.3.5. Save the new DCF value that was computed during DMI calibration.

6.7. Record Keeping

6.7.1. All calibration activities must be documented. Instruction and forms are provided in latest version of reference documents.

7. PROJECT TESTING

7.1. Preparation of Surface

7.1.1. MDT will test the roadway only when it is free of moisture and any deleterious material that would not provide accurate test results.

7.1.2. The Contractor is responsible for all work to prepare the roadway for testing, such as, but not limited to sweeping off of debris.

7.1.3. Testing will not be conducted while it is raining or under other weather conditions determined inclement by the Engineering Project Manager (EPM).

7.2. Project Setup

7.2.1. Meet with the Engineering Project Manager (EPM) or one of his/her representatives and identify the Beginning-of-Project (BOP), the End-of-Project (EOP), and all excluded areas (e.g., all bridges that were not paved as part of the project).

7.2.2. If possible, project should be marked for testing using reflective tape or reflective traffic cones. These markers are used to initiate and stop data collection.

7.2.3. If it is not feasible to use the photocell to initiate and stop data collection, data collection can be initiated and stopped manually. When manually initiating and stopping profile data collection, cones should be placed at the beginning and end of the project to be used as reference points by the operator.

7.2.4. Example project layout is provided in attached figure 1.

7.3. Profiler Operations

7.3.1. Operation of profiler should be consistent with guidelines discussed in the latest version of the MDT Profiler Operations Manual. This includes but is not limited to the following:

7.3.1.1. Establish one unit system.

7.3.1.2. If possible, initiate data collection via reflective surface and photocell.

7.3.1.3. Use approved file naming convention.

7.3.1.4. Document any issues that occurred during testing.

7.3.1.5. Process data with software.

7.3.1.6. Properly backup data.

7.3.1.7. Provide report to EPM or one of his/her representatives.

7.3.2. MDT collects two error free runs.

7.3.2.1. Once the operator is confident that a minimum of two error free runs have been obtained, the Quality Control Review and Bump Reports are used to evaluate their acceptability. Profiler runs should satisfy the following criteria:

7.3.2.1.1. The average IRI values at each 1 mi (1.61 km) interval for each of the two runs are within ± 5.7% of the mean IRI of both runs.

7.3.2.1.2. If spikes (e.g., unusually high IRI) are present in the data, the operator should determine if spikes are pavement related or the result of equipment or operator error. The operator should examine the profile bump reports for discrepancies and features that cannot be explained by observed pavement features.

7.4. Testing Results

7.4.1. Results shall be provided to EPM or one of his/her representatives and shall be processed into desired segments (e.g., 0.2 miles) as described in most recent Ride Specification.

7.4.2. A Roughness Report will be generated for the first profile run deemed to be error free for each lane profiled. This report will contain the IRI values for the left and right wheel paths. These IRI values will be applied to the most recent pay incentives/disincentives as described in Ride Specification.

7.4.3. A Bump Report will be generated for the first profile run deemed to be error free for each lane profiled. The Bump Report will indicate the locations of potential defects. These will be reviewed with the EPM. Location should be physically examined to determine if, at the EPM's discretion, the location should be considered a defect.

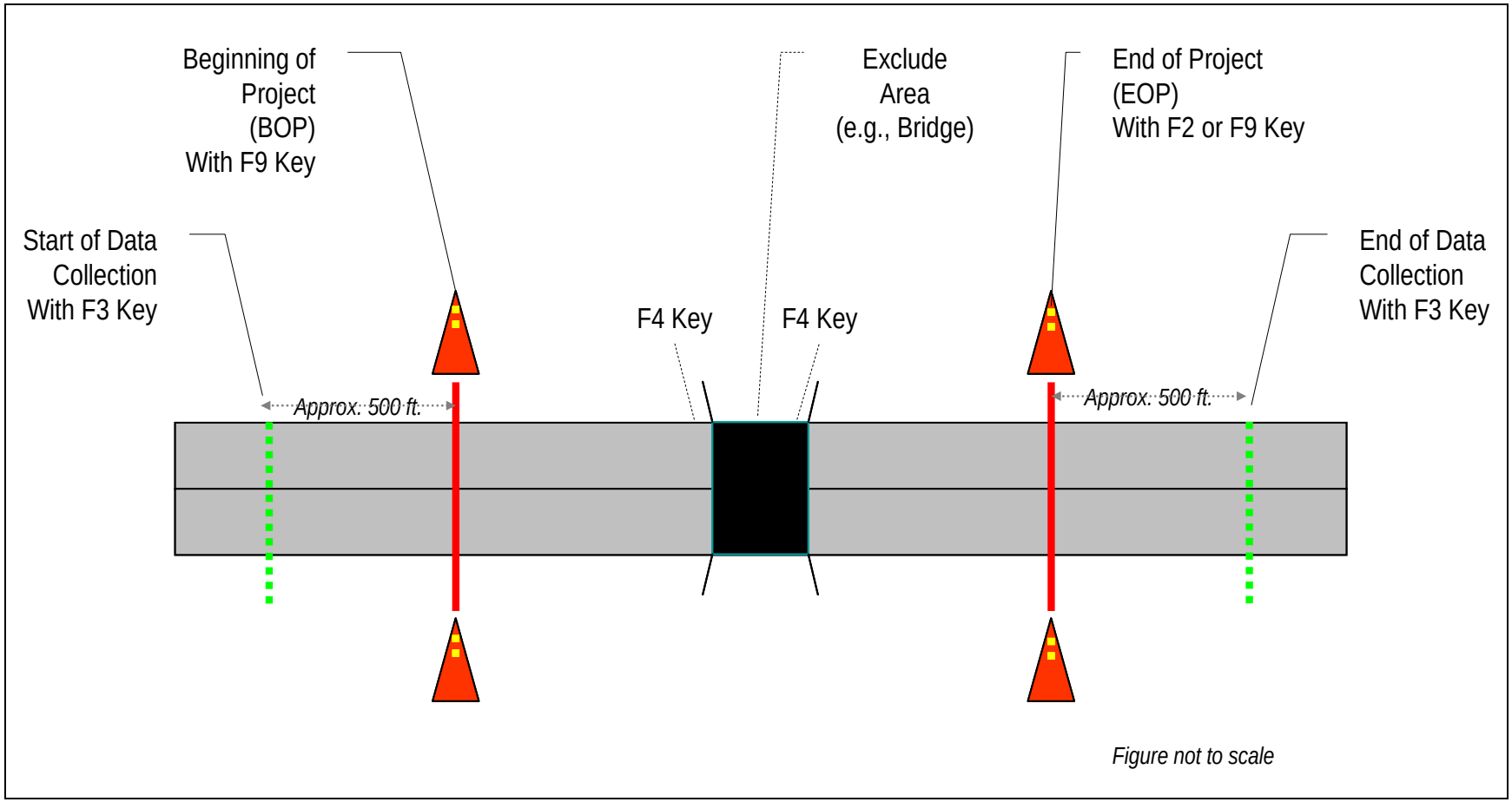

Figure 1. Example of Project Layout.