METHOD FOR MEASURING SERVICEABILITY INDEX WITH THE MAYS ROAD METER

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The age-old problem of providing an objective tool for determining when a pavement has failed has yet to be solved completely. However, the development of the pavement serviceability performance concept by Carey and Irick (1) during the AASHO Road Test standardized a performance measurement procedure through which efforts toward solving this problem might better be directed. A high-speed road roughness measuring capability has been developed for the Texas Highway Department using this concept at the Center for Highway Research, where the surface dynamics profilometer (SDP) (2, 3, 4) is used for obtaining objective road profile measurements. Serviceability index (SI) is then computed from the power spectral estimates of these data. Use of the SDP for obtaining SI has several advantages, one being an internal calibration facility that ensures proper operation of the measuring equipment. It has proved to be an excellent device for obtaining accurate road profile information over selected bandwidths. However, there are some factors that limit its usefulness in obtaining routine SI measurements throughout the state. Among these are high equipment investment, operating cost, and the lack of an immediate SI measurement. (Technology is now such that an immediate SI for any given run can be obtained by the use of a small digital computer installed in the vehicle.) Because of the need for such routine SI information, a more economical device was sought. The availability, low cost, and favorable initial evaluations of the Mays road meter (MRM) by other agencies made this device an attractive candidate for providing such information needs. However, MRM roughness measurements are dependent on all factors that affect the vehicle's suspension system, and, because these factors vary from vehicle to vehicle, standard roughness measurement units are needed. For this reason, studies were directed toward correlating this device with the SDP-SI measurements. By using the SDP-SI measurements as a standard, a general set of calibration, operational, and control procedures were then developed for all MRM devices purchased by the Texas Highway Department. These procedures provide a means of measuring roughness in standard roughness units for all MRM devices, thus allowing 2 separate instruments, installed in separate vehicles, to get the same roughness readings for the same road section. Five MRM devices have been calibrated and are currently being used in accordance with these procedures. Following is a brief discussion of these procedures.

MAYS ROAD METER CALIBRATION, OPERATION, AND CONTROL

The procedures developed are divided into 3 areas: calibration, operation, and control. Calibration involves obtaining the necessary tables for converting MRM roughness readings in inches per mile to SI values. The operational procedures provide a standard method for measuring roughness. The control procedures provide a method of ensuring that the MRM is functioning properly. No measuring device ever gives exactly the same measurement each time it is used; that is, there are measurement errors. For the MRM device using SI, these errors can be divided into 3 types: actual

MRM measurement errors (equipment errors), errors due to the lack of nonhomogeneous roughness characteristics of roads, and model or regression errors between the actual and predicted SI measurements. The Rainhart meter (Mays road meter) seems to exhibit very insignificant errors of the first type, as compared to those of the second type, and the MRM-SI model development in the calibration procedures ensures that those of the third type are never statistically significant in relation to those of the first 2 types.

Calibration

MRM calibration consists of running 25 quarter-mile pavement sections of various roughness classes in accordance with the following specifications:

1. MRM vehicle—The MRM device must be calibrated in the vehicle in which the device is to operate. Physical characteristics that affect vehicle body motion, such as excess weight and vehicle shocks, should likewise be the same during calibration as in operations.
2. Calibration runs—Each ¼-mile section is run 5 times at 50 mph. (Vehicle speed was set at 50 mph because this was the speed used in developing the original SI models for the SDP.) The calibration procedure is performed on a typical day; that is, when no extreme weather conditions exist. Because the MRM provides a measurement of vehicle body movement, conditions that might affect this movement should be avoided.

The general calibration procedure is used to obtain a representative sample of roughness readings to derive an equation of the form

$$SI = 5e^{\left(\frac{\ln M}{\beta}\right)^5}$$

where

M = the MRM roughness reading, in inches per mile, and
β = the MRM instrument coefficient.

This equation was obtained by linearly regressing the MRM readings onto the SI values and then solving for SI. From this equation, an MRM-SI conversion table is generated that can easily be used during measurement operations for obtaining SI. Figure 1 shows a typical plot of this equation for one of the MRM devices calibrated (β = 5.697).

Operation

The MRM operations section is divided into 2 parts. The first part explains how SI readings are obtained from the MRM roughness record. Following this, the tentative operating procedures that should be followed for obtaining an accurate record are described.

SI Computation—The MRM device provides as output 6-in.-wide strip chart paper that contains 3 channels of information (Fig. 2). The purpose of each of these 3 channels is as follows:

1. Distance event channel (upper channel record in Fig. 2)—Distance traveled by the MRM vehicle is indicated by alternate up and down ⅛-in. pen movements (pen movements in the same directions occur every 0.1 mile). This event marker is driven by the speedometer drive cable of the vehicle. Because the strip chart paper drive is a function of the vehicle body movement, the distance between successive distance marks is proportional to the cumulative vehicle body movement and hence can be scaled to inches of body movement per unit distance traveled.
2. Roughness signature—The strip chart paper movement is proportional to the vehicle body movement. Vehicle body movement also drives a second pen (center channel record in Fig. 2) across the chart, depending on the direction and magnitude of the up or down vehicle body movements with respect to the differential. Thus, this record or channel is used to indicate the pattern of vehicle body movements.

Figure 1. Typical equation plot of MRM device.

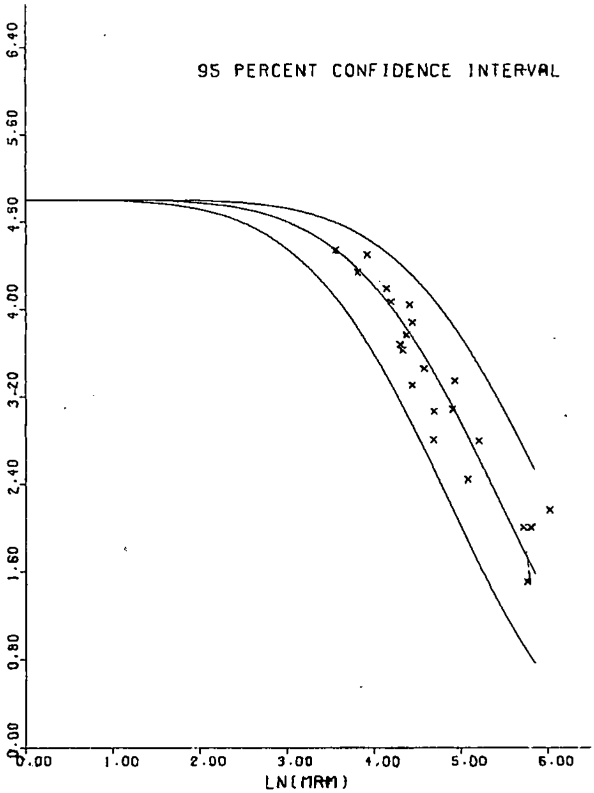

Figure 2. MRM output chart.

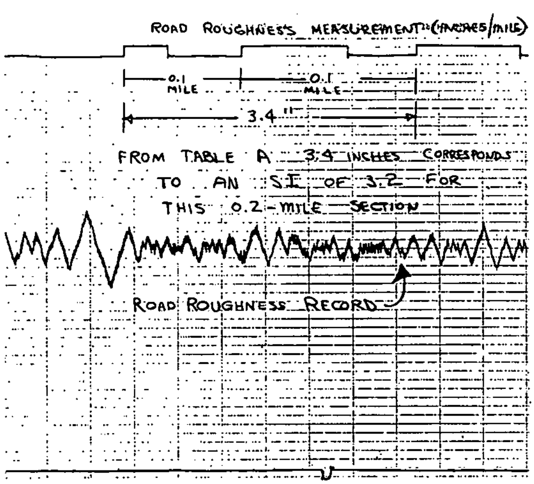

Table 1. MRM-SDP serviceability index correlations.

Mays Meter (in./0.2 mile)	Serviceability Index	Mays Meter (in./0.2 mile)	Serviceability Index
21.5	0.50	4.5	2.80
19.4	0.60	4.2	2.90
17.6	0.70	3.9	3.00
16.1	0.80	3.7	3.10
14.8	0.90	3.5	3.20
13.7	1.00	3.2	3.30
12.7	1.10	3.0	3.40
11.9	1.20	2.8	3.50
11.1	1.30	2.6	3.60
10.4	1.40	2.4	3.70
9.7	1.50	2.2	3.80
9.1	1.60	2.1	3.90
8.6	1.70	1.9	4.00
8.1	1.80	1.7	4.10
7.6	1.90	1.5	4.20
7.2	2.00	1.4	4.30
6.8	2.10	1.2	4.40
6.4	2.20	1.1	4.50
6.0	2.30	0.9	4.60
5.7	2.40	0.7	4.70
5.3	2.50	0.6	4.80
5.0	2.60	0.4	4.90
4.7	2.70	0.0	5.00

3. General event marker—The third channel (lower channel record in Fig. 2) provides an up or down pen displacement when a manual event marker located on the floorboard is depressed, thus providing a means of marking specific events of interest by the driver. For the Rainhart device, the operator may also mark specific events or write notes with pencil or pen directly on the chart paper.

The MRM-SI measurements are then made as follows:

1. The MRM device is activated and the roughness record for a desired road section obtained. Figure 2 shows a typical example of one such 0.2-mile section.
2. The roughness measurement in terms of SI is obtained by first measuring the length of paper (in inches) between 0.2-mile marks on the distance event channel (as shown in Fig. 2) and then using Table 1 to relate this measurement to SI. As shown in the figure, the length of paper between the 0.2-mile event markers was 3.4 in. (or 3.4 × 6.4 = 21.8 in. of body movement per 0.2 mile) of strip chart movement. Table 1 gives the relations between body movement and SI in terms of SI intervals of 0.5; for example, 3.4 in. of body movement corresponds to an SI of 3.2. Because of the accuracies involved, the SI readings need not be read beyond one decimal place, and the nearest distance interval value can be used for obtaining the appropriate SI.

Operating Procedures—The operating procedures briefly described are recommended for MRM operators to ensure accurate SI readings. Variations from these procedures, such as having a load of cement in the trunk, can significantly affect or bias the SI measurement:

1. SI measurements should be made only under normal driving conditions, especially with regard to weather. For instance, measurements should not be made during heavy rain, snow, extremely cold weather, or under gusty wind conditions.
2. Two operators are recommended, one for driving the vehicle and the second for operating the MRM. The average weights should be approximately those (e.g., ±50 lb) of the operators during MRM calibrations. The vehicle driver typically provides mileage information to the MRM operator and operates the event marker channel. The MRM operator monitors the roughness record, ensuring proper operation, and makes any necessary event marks or comments on the strip chart during operations.
3. Minimum section length has been established as 0.2 mile. This is the minimum length that can be measured without introducing excessive errors due to nonhomogeneity of roadway profiles. Note that this length of measurement can be obtained by repeating runs on shorter segments and summing the paper output; that is, a 0.1-mile section can be run twice and the total length resulting from both runs used as the roughness distance.

Control

Accurate SI measurements will depend on proper usage and operation of the MRM. Proper operation of the equipment can be ensured by development of a set of quality control procedures in which MRM results are continually monitored. Control procedures provide a means of detecting MRM out-of-calibration conditions and involve the use of replication runs or measurements over known test or control sections. The mean and range SI values from these are compared with control values. The general procedures developed provide a means for selecting MRM control sections, establishing control charts, and maintaining MRM control operations:

1. Selecting MRM control sections—A set of twenty 0.2-mile control sections is initially selected, convenient to the MRM base of operations. These sections are selected so as to provide a representative sample of smooth-to-rough sections for the area or district in which the MRM is to operate.
2. Establishing control charts—Two control charts are used for monitoring MRM measurement validity, one for checking the measurement mean (or average) from repeated SI measurements and the second for checking the variations from the mean of the replication measurements. The control limits for 2 control charts are established from initial measurements of the 20 control sections.

3. Maintaining MRM control operations—As previously indicated, MRM control is provided by comparing the mean and range values from periodic test runs with the control limits. When the values fall outside the limits, an out-of-calibration condition would be suspected.

SUMMARY

A set of calibration, operational, and control procedures has been developed for the MRM in order to provide a means of obtaining standard roughness measurements for Texas highways in terms of SI. These procedures involve correlating the MRM roughness readings in inches per mile to SI as measured by the SDP. Because of the SDP measurement characteristics, SI values computed from road profile data obtained with this instrument provide an accurate measurement standard.

Several MRM devices have been calibrated according to these procedures and are currently in use. Initial uses of this procedure for obtaining SI are quite promising, and, by providing standard roughness measurements for roads throughout Texas, invaluable information for aiding in solving the problems of pavement failure can be obtained.

ACKNOWLEDGMENT

The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This paper does not constitute a standard, specification, or regulation.

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