TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-86/20+187-11		

4. Title and Subtitle	5. Report Date
The SIometer	January, 1985
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Kenneth D. Hankins	187-11
9. Performing Organization Name and Address Texas State Department of Highways and Public Transportation D-10 Research P.O. Box 5051, Austin, Texas 78763	10. Work Unit No. 11. Contract or Grant No. HPR 1-10-77-187
12. Sponsoring Agency Name and Address Texas State Department of Highways and Public Transportation D-10 Research P.O. Box 5051, Austin, Texas 78763	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

Research study No. 1-10-77-187 "Demonstration and Special Projects"
Study done in cooperation with DOT, FHWA.

16. Abstract

The SIometer is a self calibrating roughness measuring device originally conceived by Dr. Roger Walker while at the University of Texas at Arlington. Later McClelland Engineers, Inc. in Houston, fabricated a prototype automated version of the device, designed to collect data for Texas' "Pavement Evaluation System". This report describes the post evaluation tests performed on the prototype "SIometer" by the Department. Tests indicate the device provides reproducable values through changes in vehicle weight, tire pressure and tire balance. However, variations in values were found when changing the device into different types of vehicles. The vehicles used were, a Ford Galaxy, a Dodge Aires and a Chevrolet Pickup.

17. Key Words	18. Distribution Statement
SIometer, Surface Dynamics Profilometer serviceability index, road roughness, road profile.	No restrictions. This document is available to the public through the National Technical Information Service Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassification	Unclassification		

Form DOT F 1700.7 (8-69)

The "SIometer"

By

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Research Report Number 187-11

Research Study No. 1-10-187-11
Demonstration and Field Test Support

Conducted by

Transportation Planning Division
Research Section
The Texas Department of Highways and Public Transportation

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

January 1985

The contents of this report reflect the views of the author, who is 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 report does not constitute a standard, specification, or regulation.

The research reported herein was conducted under the supervision of Mr. Jon P. Underwood, Engineer of Research and Development, and the general supervision of Mr. Phillip L. Wilson, State Transportation Planning Engineer.

Acknowledgement is given to:

Mr. Brad Hubbard who performed much of the testing for this study and assisted in report preparation.

Mr. Curtis Goss, Mr. James Wyatt, Mr. Bob Cannaday, and personnel is the Field Test Support group for equipment preparation and testing performed. Mr. Goss has maintained close contact with both Dr. Walker and personnel from McClelland throughout the course of development of the equipment.

Dr. Roger Walker for assistance in debugging, problem solving and for enduring the many questions during the development and testing period.

SUMMARY

Most roughness devices which produce a relatively accurate profile are either costly or collect data slowly. An automated device capable of producing a profile at the highway speeds in the $20,000 to $40,000, (1984) range is needed. In addition, this State needs a roughness measuring device with automation specifically designed to produce data in a format which would fit existing software presently used in a Pavement Evaluation System. At present roughness measurements are obtained with semiautomated MRM units. Dr. Walker had been involved with a research project in the 1960's which introduced the K. J. Law Surface Dynamics Profilometer to Texas. Therefore, when the Department was approached with the idea of a self-calibrating, roughness measuring device with the probability of conforming to the above need, a research project was initiated and Dr. Walker produced a device for the study. The device produced a roughnes value which the Department called a Serviceability Index or SI so Dr. Walker coined the term "SIometer" for a name. Additional development was performed and studies indicated the SIometer was capable of producing relatively repeatable values with a self calibrating feature which worked when changes in vehicle dynamics were applied. Later McCelland Engineers, Inc. produced an automated version. This report contains test information of the McClelland equipment.

IMPLEMENTATION STATEMENT

It is recommended this equipment be made available to the Maintenance Operations Division (D-18) so that this group may become familiar with the operation and use of the equipment. The equipment should be maintained in a larger automoblie such as the Ford Galaxy for future use. A smaller more compact, and more versatile unit is being developed by Dr. Walker. It is suggested that additional study be performed using the new unit especially in the development of filters which might permit the use of equipment in a variety of types of vehicles. The present unit should not replace the MRM and be used as the primary data collection unit for the roughness input to the Pavment Evaluation System. Additional modifications to the SIometer will first be needed.

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I. Introduction

The Slometer is a self calibrating roughness measuring device that uses an accelerometer which is normally mounted in the trunk of a passenger automobile. The device is a system that uses three principle components: the accelerometer, a micro or mini computer, and a software program that implements the process. In testing, the vertical acceleration, along with the vehicle speed, is used to predict the road profile. The micro computer processes the information, removes the vehicle suspension characteristics, and provides an estimate of the roadway profile. In order to remove the vehicle characteristics, a dynamic calibration is performed before testing. This calibration involves obtaining values with the vertical accelerometer at normal test speeds of 50 mph over a "typical" class of roadway. The microcomputer performs the computations that provide a statistical indentification of the vehicle's suspension system for that period in time. The effects of the vehicle's suspension system characteristics on various road profile frequencies are used to obtain an autoregressive model for the vehicle. The calibration procedure determines the coefficients used in the autoregressive process. When the coefficients are obtained, the measurement process discards the predictable components due to the vehicle suspension and produces the road profile. The above technique, process, and equipment was developed by Dr. Roger Walker.

Dr. Walker approached the Department, explained the process, and with the aid of the Federal Highway Administration a research project was initiated. During the research project some development and testing was accomplished as reported in Research Report 279-1 "A Self-Calibrating Roughness-Measuring Process."

At the time the SIometer project was being considered, the Department had initiated a "Maintenance Management System" which incorporated a "Pavement Evaluation System" (PES). The PES used roughness data as a part of the data input into the system. The Mays Road Meter (MRM) data collection units had recently been "overhauled" to produce a digital readout of roughness at the required 0.2 mile intervals. However, the data was recorded on code sheets and key punched before being processed by a program that produced the desired documentation for the Maintenance Management System. Therefore, the Department needed fully automated roughness measuring devices. McClelland Engineers, Inc. contacted the Department and, with the aid of the FHWA, a research contract was developed to fabricate a fully automated SIometer. The new unit featured thumbwheel switch data input to record such items as location and date. A distance and velocity measuring unit was incorporated in such a manner that values were obtained at 0.2 mile intervals. The data was displayed, printed, and recorded on a cassette. The display was hand held and contained "start/stop" test buttons so that one man data collection could be accomplished. At the close of the project, the prototype equipment was in reasonable working order but only a small amount of testing, equipment check out, and operational theory had been accomplished. The FHWA approved the completion of the project but insisted on additional testing. This report is in response to the FHWA request.

II. Test Procedure

The post-acceptance testing included: (1)debugging, (2)repeatability, (3)effects of temperature on the equipment and test values, and, (4)checks on the self-calibration theory by testing while using controlled changes of factors affecting the vehicle suspension. Finally, the equipment was placed into three different types of vehicles to provide additional information on the self calibration.

Debugging - Post acceptance testing was done by first "debugging" (checking for any abnormal operational behavior) of the unit. The SIometer had a built-in "self diagnostic" software routine, which was used quite frequently. Normal observance of equipment operation was made to ascertain if any peculiar or unusual symptoms appeared. The post acceptance testing indicated a few minor problems, which were corrected by McClelland.

Repeatability - The repeatability measurements were obtained by running ten repeat tests over the same 0.2 mile section one after the other. The series of tests was performed on five different sections with varying roughness. The following results were obtained:

General Range = 0.2 SI to 0.3 SI
Average Standard Deviation = 0.06 SI

A small amount of testing for day-to-day variation was performed with the original prototypes. This testing included repeat testing on five selected sections with varying roughness at several time periods. The day-to-day variance was found to be slightly larger than the repeatability as follows:

General Range = 0.3 SI to 0.4 SI
Average Standard Deviation = 0.19 SI

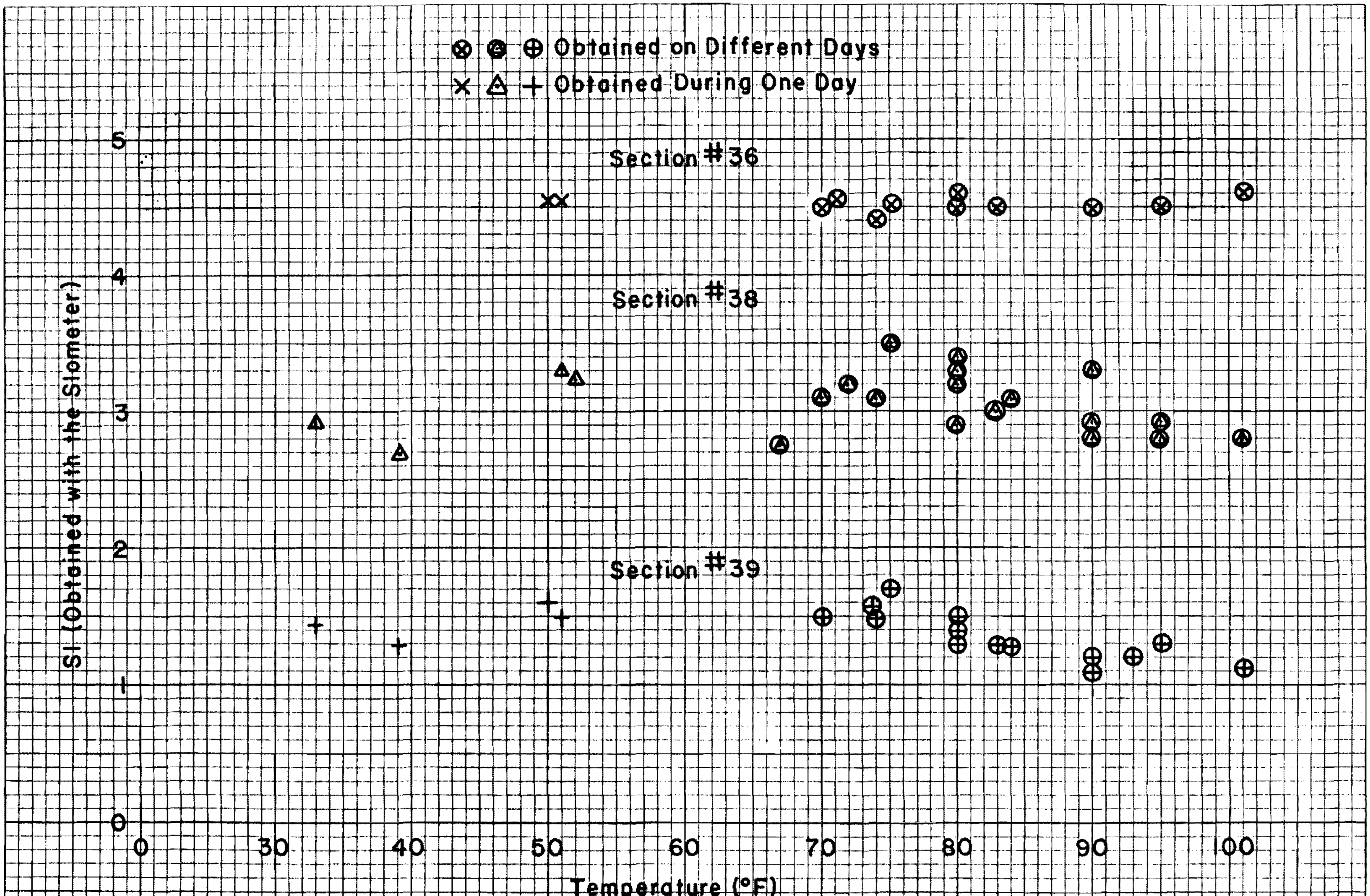

Figure I—Effect of Air Temperature on Slometer Values

Temperature Effects - The effects of ambient air temperature was studied by performing tests on three different test sections and recording the air temperature just prior to testing. The results are shown in Figure 1. Note the values from 32°F to 52°F were obtained during a one day period.

Controlled Factors - Tests of the self calibration feature were performed by obtaining two repeat runs while varying the weight in the vehicle, tire pressure, and tire balance as shown following (2^3 Factorial):

- Weight (a) Vehicle plus driver.
  (b) Vehicle plus 140 pounds of weight in the trunk, driver and passenger in left rear.
- Tire Pressure (a) 20 psi.
  (b) 30 psi.
- Tire balance (a) Using all wheel/tires balanced.
  (b) Adding a 5 ounce wheel weight to the left rear and right front.

This procedure was performed on three different 0.2 mile roadway sections of varying roughness. The results are found in Table I.

TABLE I

SIOMETER VARIABLE STUDY

Tire Condition	Weight in Vehicle	Tire 30	30	Pressure 20	20	Average 30	30	Section Number
BAL	140 WT	3.4	3.3	3.4	3.5	3.35	3.45	35
	NO WT	3.2	3.1	3.0	3.2	3.15	3.1	
UN BAL	140 WT	3.3	3.3	3.3	3.3	3.4	3.35	
	NO WT	3.3	3.0	3.1	3.1	3.15	3.1	
BAL	140 WT	4.6	4.6	4.6	4.5	4.6	4.55	36
	NO WT	4.4	4.3	4.5	4.6	4.35	4.55	
UN BAL	140 WT	4.6	4.6	4.6	4.6	4.6	4.6	
	NO WT	4.5	4.5	4.5	4.5	4.5	4.5	
BAL	140 WT	3.3	3.3	3.3	3.5	3.3	3.4	38
	NO WT	3.0	2.9	2.9	2.7	2.95	2.8	
UN NAL	140 WT	3.3	3.6	3.0	3.1	3.45	3.05	
	NO WT	3.1	3.0	2.7	3.0	3.05	2.85	

<u>Tests in Different Vehicles</u> - Finally additional tests of the self calibration feature were made by obtaining repeat runs on five different 0.2 mile tests sections while using the SIometer in three different vehicle types. The vehicles selected were (1) a Ford Galaxy, (2) a Dodge Aries, and (3) a Chevrolet Pickup. The results of the tests may be found on Table II.

TABLE II

STUDIES OF THE SIOMETER

IN DIFFERENT VEHICLES

	Chev. Pickup	Aries	Ford Galaxy
Section 35			
1	2.3	2.8	3.0
2	2.0	2.8	3.1
3	1.3	2.8	3.0
4	1.6	2.7	3.0
5	2.2	2.8	3.1
Section 36			
1	3.1	4.2	4.6
2	3.4	4.1	4.6
3	2.7	4.1	4.5
4	0.7	4.2	4.5
5	2.0	4.1	4.5
Section 38			
1	1.6	2.3	3.1
2	1.0	2.0	3.1
3	1.2	2.3	3.3
4	1.2	2.1	3.2
5	0.7	2.0	3.2
Section 39			
1	0.4	0.0	1.1
2	0.4	0.0	1.2
3	0.3	0.0	1.1
4	0.2	0.1	1.1
5	0.4	0.1	1.1
Section 40			
1	3.3	3.8	4.4
2	3.0	3.6	4.4
3	2.1	3.8	4.3
4	1.6	3.7	4.3
5	2.5	3.8	4.4

III. Data Analysis and Discussion

The system developed by McClelland included data entry features specifically designed to input data in a format needed by the Department. After receipt of the equipment, debugging consumed a considerable amount of time; however, some of the time consumed was devoted to becoming familiar with the equipment and data input features.

The variance in repeatability is assumed to be normally distributed and results obtained are self explanatory. The values do not seem excessive. The general range of 0.2 to 0.3 SI and a standard deviation of 0.06 SI form the basis for comparing the remaining test.

Figure 1 shows a horizontal string of data points indicating air temperature has little effect on values produced by the SIometer. Considering the data scatter, the tests for temperature on any one day seem to be about the same as the tests values collected on different days. It is concluded that <u>temperature does not have an effect on the equipment or values and correction is not necessary</u>.

The self calibrating feature envisioned by Dr. Walker is very interesting and can be very helpful in eliminating some of the measurement error to be expected in roughness equipment. In fact, no other calibration would be necessary. A change in vehicle weight could cause a change in suspension characteristics and would normally occur as gasoline is used from the tank of the test vehicle or as drivers or passengers are changed. Changes in tire pressures occur as the tires warm with running from a cold start condition. Wheel unbalance sometimes occurs as wheel balance weights are lost, front end allignment changes, tire wear occurs, or new tires are mounted. The three variables studied, and the values used, were the worst condition or the extremes to be expected. In observing the results found in Table I, the effects of changing the tire pressure from 30 psi to 20 psi appear to be small or non-existant. At times larger values are found for 30 psi and at other times 20 psi produces larger values. Except for one test series, the difference is less than that expected in repeat runs. A similar result is found in the comparison of the balanced tire and the unbalanced tire with the five ounce wheel weight added. For the same tire pressure and vehicle weight, the largest difference is 0.35 SI but differences are normally less than those expected in repeat tests. Adding or loosing weight in the vehicle seems to have the greatest effect with differences as much as 0.4 SI found. However, this error is slightly greater than the repeatability but within the range of day-to-day variation. It is concluded that variables studied has little effect on the self calibration feature of the equipment and program does correct for changes in vehicle suspension.

The results of placing and testing the equipment in different vehicles, as found in Table II, does not appear as promising. Larger differences were found in values obtained on the same test sections when different vehicles were used. The differences seem to be greater for the rougher sections. For example, several runs resulted in a value of zero on Section #39 when the Dodge Aries was used, whereas the Ford Galaxie provided a 1.1 SI. On the same section tests in the pickup produced values from 0.2 to 0.4 SI. It is concluded that major changes in vehicle suspension characteristics do affect the values produced by the SIometer in its present state, and could result in erroneous data.

IV. Recommendations

Dr. Walker has indicated that additional changes to the Slometer would permit the equipment to be calibrated and used in different vehicles. It is recommended that this work be accomplished. Also equipment with less size and weight is needed. It is not recommended that the present unit replace the MRM as the primary data collection unit for roughness input to the Pavement Evaluation System at this time. The changes mentioned above will be needed and verified before the unit can be used in production.