A 5-YEAR REPORT ON EVALUATION OF PAVEMENT SERVICEABILITY WITH SEVERAL ROAD METERS

M. P. Brokaw, Portland Cement Association

The paper reports an evaluation of results of pavement serviceability tests made with the PCA road meter and with modifications of the original road meter developed by several states and provinces. Results of calibrations with serviceability ratings or serviceability indexes from 8 sources are shown. Repeatability tests are reported from 7 sources, along with tests by the original road meter over the same site throughout a 5-year period. The road meter and its modifications rank with the AASHO profilometer in ability to relate with serviceability ratings. Variations in measured roughness resulting from changes in wind velocity, air temperature, automobile speed, mechanical factors within road meters and test automobiles, and seasonal fluctuations caused by frost action are reported and discussed. Effects of wind velocity and direction, as related to direction of test car travel, and air temperature deserve further field observation. Seasonal fluctuations due to frost have a distinct effect, and the magnitude indicates that serviceability measurements to be used in extended studies of pavement behavior in conjunction with traffic loading should be made during a limited period between full recovery (as late as July or August) and the onset of the next winter. The simple digital counting system and unique computing method enable the PCA road meter to produce a statistic corresponding to roughness power spectrum. Data from 2 north central states are used to illustrate the usefulness of this attribute in analyzing serviceability indexes resulting from various treatments and construction methods.

After development of the PCA road meter (3) in 1965, highway departments and individuals in several states and provinces have acquired or manufactured facsimiles, or designed modifications of this original meter. Some have published reports outlining results of tests showing calibrations with panel serviceability ratings, repeatability, response of different automobiles of the same make and model, effects of heavy-duty and standard suspension systems, effects of changes in air temperature and speed of test automobile, and results of using digital counters having different sensitivities (3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15).

The author has conducted tests with the original PCA road meter installed in 3 different automobiles during the period 1965-1970. Data were collected to determine variations in measured roughness resulting from changes in wind velocity, air temperature,

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speed of automobile, model change of automobile, position of rear-seat occupants of automobile, errors in initial centering of roller contactor over zero segment of switch plate, and seasonal fluctuations in pavement roughness caused by frost effects.

These data are summarized and discussed in the following sections.

CALIBRATION TESTS

Panel serviceability ratings of pavement systems can be correlated with measures of pavement roughness, as established at the AASHO Road Test (1). Figures 1 and 2 show the basic AASHO data for rigid and flexible pavements when tested with the AASHO longitudinal profilometer. The squared correlation coefficients for panel ratings are only slightly inferior to those for serviceability index where cracking, patching, and rut depth are measured separately. The standard errors of estimate are also slightly inferior. The AASHO correlation statistics should serve as a standard for evaluating the efficiencies of other roughness measuring devices (16).

Several states and provinces have reported correlation data for the PCA road meter and for its various modifications (4, 5, 9, 10, 12, 13, 14, 15). Table 1 gives a summary of tests, including those from the AASHO Road Test. Figures 3 and 4 show sample relationships between panel rating and log (Σ count) for rigid and flexible pavements developed by the Minnesota Department of Highways in 1966.

Analysis of the data given in Table 1 discloses that the average squared correlation coefficients for rigid and flexible pavements are 0.92 and 0.82 respectively. These compare with 0.89 and 0.81 for the AASHO profilometer and panel ratings. Average road meter standard errors of estimate (computed as coefficients of variation to accommodate Canadian rating systems) for rigid and flexible pavements are 6.2 and 10.2 percent respectively. These compare with 10.6 and 12.0 percent from the AASHO tests.

Data given in Table 1 also show that different pavement types should be rated and measured separately. In the 3 cases reported, pooled data gave a squared correlation coefficient of 0.68 and a coefficient of variation of 13.6 percent. This observation verifies the use of different regression equations for rigid and flexible pavement at the AASHO Road Test.

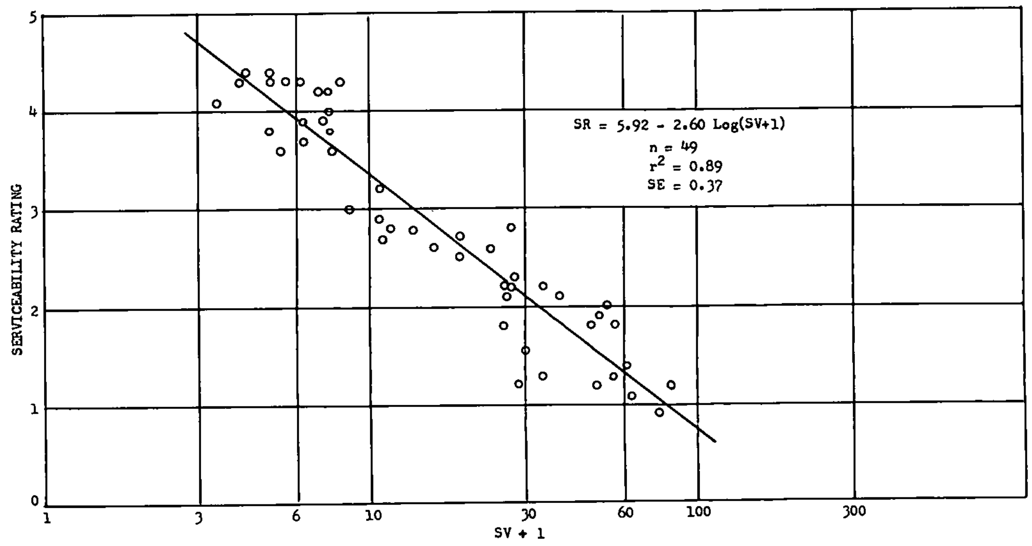

Figure 1. Calibration curve for AASHO profilometer rigid pavements (1).

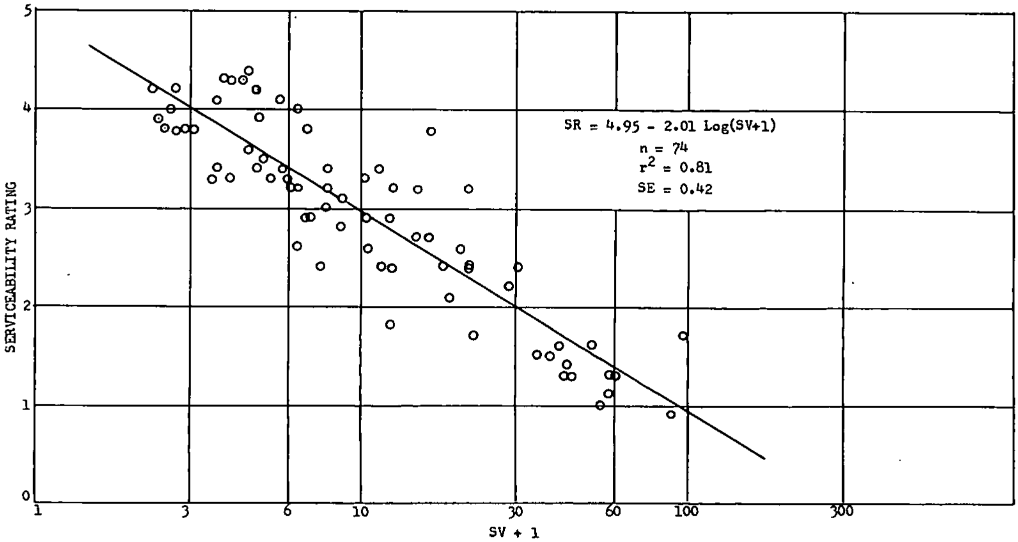

Figure 2. Calibration curve for AASHO profilometer flexible pavements (1).

TABLE 1

RESULTS OF CALIBRATION TESTS SERVICEABILITY (Y) VERSUS ROUGHNESS INDEX (X)

Equipment	Source	Reference	Serviceability Range	Pavement[a]	Equation[b]	Standard Error of Estimate (Y)	Coefficient of Variation at 3.5 or 7.0 (percent)	r^2
Profilometer	AASHO	1	0 to 5	R	PSR = 5.92 - 2.60 log (SV + 1)	0.37	10.6	0.89
Profilometer	AASHO	1	0 to 5	F	PSR = 4.95 - 2.01 log (SV + 1)	0.42	12.0	0.81
PCA road meter	Minnesota	4	0 to 5	R	PSR = 12.72 - 3.04 log Σ count	0.20	7.1	0.96
PCA road meter	Minnesota	4	0 to 5	F	PSR = 10.51 - 2.46 log Σ count	0.35	13.4	0.80
Mays 40	Texas	5	0 to 5	R and F	PSR = 4.32 - 0.0107 (in./mi)	0.53	15.1	0.72
Mays 50	Texas	5	0 to 5	R and F	PSR = 4.60 - 0.0116 (in./mi)	0.57	16.3	0.68
Modified PCA road meter	Alberta	9	0 to 10	F	PSR = 16.03 - 3.35 log Σ count	0.61	8.7	0.71
PCA road meter	Ontario	10	0 to 10	R	PSR = 25.07 - 6.49 log Σ count	0.60	8.6	0.86
PCA road meter	Ontario	10	0 to 10	F	PSR = 16.44 - 3.44 log Σ count	0.70	10.0	0.82
PCA road meter	Oklahoma	12	0 to 5	R	PSI = 9.12 - 1.79 log Σ count	0.21	6.0	0.88
PCA road meter	Oklahoma	12	0 to 5	F	PSI = 13.05 - 3.11 log Σ count	0.42	12.0	0.88
PCA road meter	Iowa	13	0 to 5	R	PSI = 5.41 - 1.80 log (4.18 + 0.0056 Σ count + 0.00000066 Σ count²)	0.10	2.9	0.96
PCA road meter	Quebec	14	0 to 10	R and F	PSI = 19.84 - 4.64 log Σ count	0.65	9.3	0.64
PCA road meter	Minnesota	15	0 to 5	R	PSR = 8.43 - 1.82 log Σ count	0.23	6.6	0.92
PCA road meter	Minnesota	15	0 to 5	F	PSR = 6.45 - 1.24 log Σ count	0.24	6.7	0.90

[a]R = rigid; F = flexible.
[b]PSI does not include deductions for cracking, patching, and rut depth.

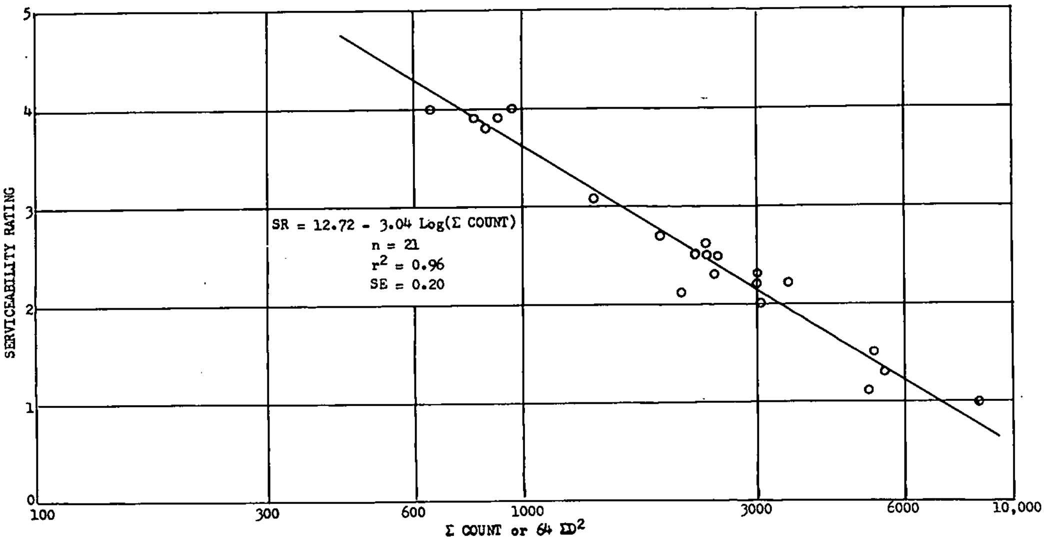

Figure 3. Calibration curve for PCA road meter rigid pavements (4).

REPEATABILITY

Repeatability must include both that of the pavement rating panel and that of the device used for measuring pavement roughness. Obviously, average panel ratings should be considered in view of the number of raters and the standard deviation among raters. This calls for a number of raters such that the standard error of mean rating is within tolerable limits. Wide differences in individual panel ratings may result in a mean

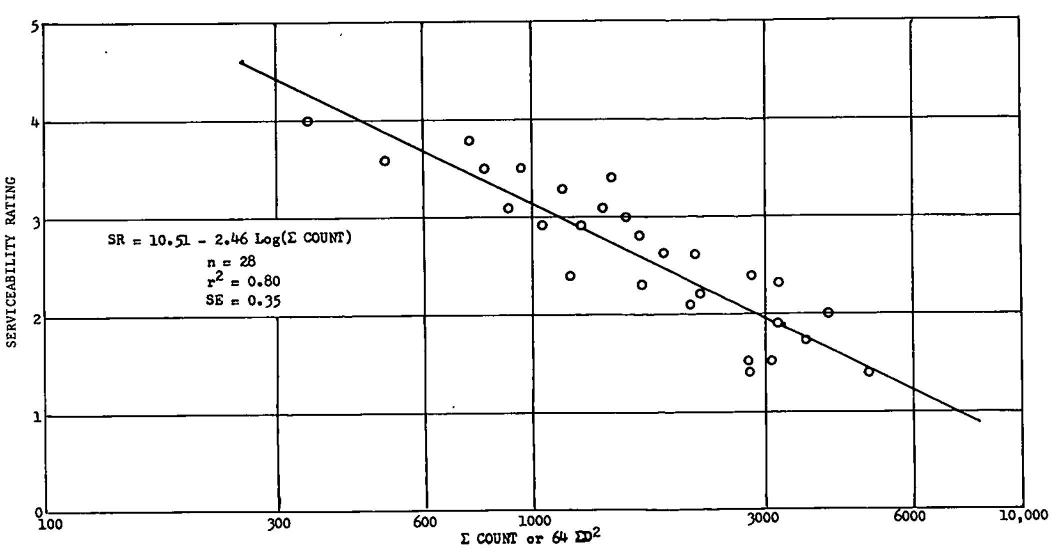

Figure 4. Calibration curve for PCA road meter flexible pavements (4).

that does not correspond to objective measurements, unless the number of ratings is very large.

Repeatability of pavement roughness measuring devices may be complicated by unrecognized physical changes in the device itself, by inconsistencies in initial adjustment before test, by effects of wind and temperature on the measuring device, by the effects of temperature on the macroroughness profile, and by increasing or decreasing frost effects.

Data from repeatability tests of the AASHO profilometer have not been disclosed. Several states and provinces and the Portland Cement Association have reported repeatability data for a number of different road meters. The data are probably for transient tests, conducted in a short period of time (3, 5, 6, 7, 8, 9, 13). These data are given in Table 2. Table 3 gives data from a series of repeatability tests made by the Iowa State Highway Commission (13).

All of the test data given in Table 2 indicate a remarkable degree of consistency for within-test standard deviation. These range from 0.03 to 0.09 serviceability point, with coefficients of variation from 0.8 to 3.5 percent. All but one of the test series correspond to the rating of "excellent laboratory control" established by the American Concrete Institute for evaluating testing procedure.

Results of repeatability tests under a variety of conditions are given in Table 4. These data show results from the original PCA road meter installed in 3 different automobiles while testing 2 companion bridge decks during the period 1965-1970. Table 4 also gives measurements of air temperature and wind velocity at the time of test. Figure 5 shows a graphical representation of the data given in Table 4, in which automobile model, air temperature, and wind velocity have been indicated. Observations for the

TABLE 2

RESULTS OF REPEATABILITY TESTS

Road Meter	Source	Reference	Statistic[a]	Sites	Tests per Site	Within-Test Standard Deviation	Coefficient of Variation (percent)	Range
PCA	PCA	3	PSI	3	8	0.05	1.4	2.00 to 4.64
Modified PCA	Missouri	6	PSI	8	2	0.08	2.4	2.68 to 4.27
PCA	Iowa	7	PSI	4	8 and 9	0.03	0.8	2.52 to 3.95
Modified PCA	Louisiana	8	PSI	3	20	0.09	3.5	2.63 (avg)
Mays 40	Texas	5	PSR	6	4	0.05	1.3	3.53 to 3.99
Mays 40	Texas	5	PSR	6	4	0.06	1.7	3.29 to 3.89
PCA	Alberta	9	PSR	1	6	0.03	0.5	5.93 (avg)
Modified PCA	Alberta	9	Log Σ count	77	2	0.05	1.3	2.53 to 3.48
PCA	Iowa	13	PSI	9	9	0.05	1.5	2.83 to 4.14

[a]PSI does not include deductions for cracking, patching, and rut depth.

TABLE 3

EXAMPLE OF REPEATABILITY TESTS WITH PCA ROAD METER

Test Section	9-Test Average PSI[a]	Standard Deviation	Range	Coefficient of Variation (percent)	BPR Rating
5	4.06	0.077	3.92 to 4.14	1.91	Good
6	2.93	0.050	2.83 to 2.98	1.70	Poor
8	2.99	0.051	2.88 to 3.05	1.70	Poor
9	2.96	0.033	2.89 to 3.00	1.11	Poor
10	3.81	0.046	3.76 to 3.90	1.19	Good
11	3.85	0.033	3.79 to 3.90	0.96	Good
12	3.99	0.057	3.90 to 4.09	1.43	Good
13	4.01	0.052	3.90 to 4.07	1.29	Good
14	3.91	0.052	3.83 to 3.98	1.32	Good

Source: Iowa State Highway Commission (13).

[a]PSI does not include deductions for cracking, patching, and rut depth.

TABLE 4

REPEATABILITY TESTS WITH PCA ROAD METER INSTALLED IN 3 DIFFERENT AUTOMOBILES WHILE TESTING 2 BRIDGE DECKS DURING PERIOD 1965-1970

Automobile[a]	Date	Time	Temperature	Wind	Northbound PSI	Southbound PSI
1	11-08-65	10 a.m.	45	NW 15	3.56	3.61
1	2-16-66	2 p.m.	28	SE 5		3.44
1	3-04-66	2 p.m.	45	S 15		3.40
1	3-08-66	2 p.m.	38	S 15		3.85
1	4-24-66	1 p.m.	67	NW 14	3.33	
1	8-23-66	11 a.m.	58	NW 10	3.46	3.43
1	10-25-66	4 p.m.	50	W 10		3.40
Avg					3.45	3.52
2	1-05-67	11 a.m.	20	0		3.54
2	1-23-67	10 a.m.	40	SW 4		3.38
2	3-26-67	10 a.m.	40	NE 4	3.84	3.61
2	4-19-67	1 p.m.	44	E 10	3.91	3.75
2	2-08-68	9 a.m.	20	NW 5	3.74	
2	3-05-68	9 a.m.	35	S 10	3.57	3.56
2	5-17-68	10 a.m.	55	W 10		3.48
2	10-18-68	10 a.m.	50	SW 15	3.41	
Avg					3.69	3.55
3	5-02-69	11 a.m.	68	NW 14	3.46	3.26
3	6-18-69	11 a.m.	60	SW 12	3.55	
3	9-24-69	1 p.m.	50	NE 9		3.72
3	11-05-69	11 a.m.	43	SW 4	3.85	
3	2-10-70	11 a.m.	28	N 8	3.74	
3	2-24-70	11 a.m.	34	SW 6	3.62	
Avg					3.64	3.49
Avg					3.62	3.53
Standard deviation					0.18	0.16
Coefficient of variation, percent					5.0	4.5

Note: Separate northbound and southbound structures for Interstates 90-94, Wisconsin River, between Madison and Wisconsin Dells. Structure design: 4 continuous welded-plate girders, each with three 140-ft spans, supporting 7-in. concrete deck. Road meter test section: 1,400 ft.

[a]Automobile 1 was a 1965 Ford, 4-door, 352 ci engine, AC, 7.75 x 15 rayon tires; automobile 2 was a 1967 Ford, 4-door, 289 ci engine, AC, 7.75 x 15 rayon tires; and automobile 3 was a 1969 Ford, 4-door, 390 ci engine, AC, 8.25 x 15 rayon tires.

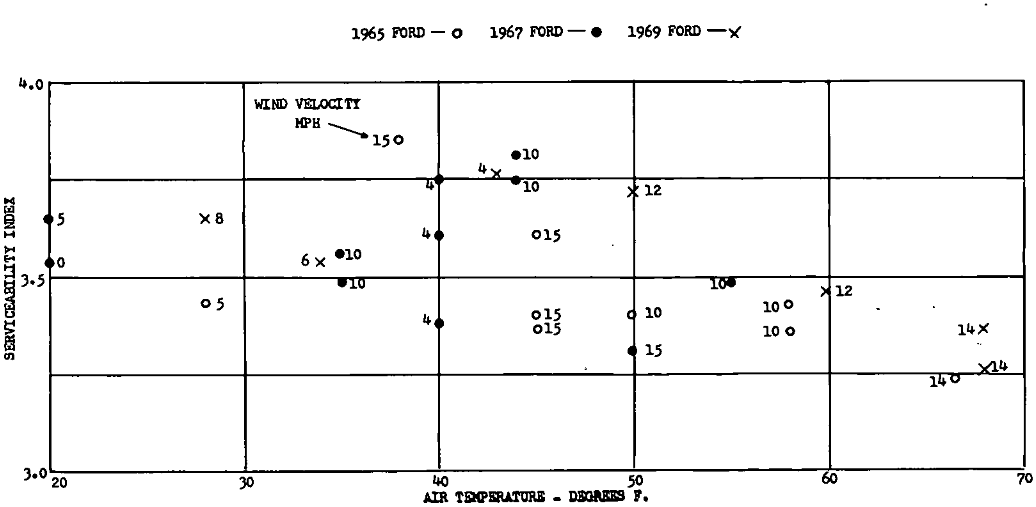

Figure 5. Repeatability of PCA road meter installed in 3 different automobiles while testing 2 bridge decks during the period 1965-1970.

2 bridge decks were combined by the expedient of subtracting 0.09 PSI point from all northbound PSI's. By including the additional variables of 3 different automobiles, air temperature, wind velocity, and 5 years' time, standard deviation of serviceability index for the 2 bridge decks is only 0.17 PSI point, corresponding to a coefficient of variation of 4.75 percent.

SPEED OF AUTOMOBILE

Effects of speed changes were studied in Louisiana and Texas and by the Portland Cement Association. In the Texas and PCA tests, the road meters were installed in full-sized Ford automobiles with coil springs. In Louisiana, the meter was installed in a lighter Ford Fairlane with leaf springs. The results given in Table 5 show that lightweight automobiles are affected more by speed of operation. The Texas and PCA tests in full-sized Fords with coil springs at speeds of 40 and 50 mph are in good agreement. These results suggest that road meters should be installed in larger automobiles with coil springs.

Although little has been published relative to wind effects related to automobile size and weight, the author recently completed tests with the North Dakota State Highway Department in which results were compared from similar road meters mounted in a 1969 Ford Custom and a 1970 Chevrolet Chevelle. These are in good agreement when wind velocities are below about 5 mph and when both automobiles are operated at 50 mph. At the same test speed, but with wind velocity at 15 to 20 mph, test results were greatly different. Complete test data are not available for this observation or experiment, but results compare with those for speed effects and they further the argument for use of standard-sized automobiles for pavement evaluation.

AIR TEMPERATURE

Effects of changes in air temperature were also studied in Louisiana and Texas and by the Portland Cement Association (5, 8).

In Louisiana a change was established in PSI amounting to 0.1 PSI point per 10-deg change in temperature from 70 deg, PSI decreasing with increased temperature. Tests were conducted when wind velocity was less than 5 mph and temperatures were in the range of 40 to 70 deg. Applicable range of PSI was not stated.

Results in Texas showed a decrease in PSI with increase in temperature. Plots of these data show a change of about 0.15 PSI point for each 10-deg within the range of 65 to 85 deg. Pavements tested had PSI's of about 2.5 and 3.7. The Mays road meter showed a nonsignificant change in these tests. Mays tests were conducted in May and June, and the PCA road meter tests were conducted in late September. Companion wind velocities were not reported.

Results of Portland Cement Association tests on bridge decks are given in Table 4 and shown in Figure 5. In general, higher temperatures accompanied higher wind

TABLE 5

COMPARISON OF RESULTS OF SPEED CORRECTIONS AS RELATED TO SIZE AND WEIGHT OF AUTOMOBILES

Test	Automobile	Springs	Test Speed (mph)	PSI Correction Ratio[a]		
				Smooth	Average	Rough
Louisiana	Ford Fairlane	Leaf	50	1.00	1.00	1.00
			40	0.85	0.90	0.85
			30	0.82	0.87	0.77
PCA	Ford Galaxie	Coil	50	1.00	1.00	1.00
			40	0.97	0.96	0.93
			30	0.90	0.90	0.87
Texas	Ford Custom	Coil	50	1.00	1.00	1.00
			40	0.94	0.94	0.96
			30	—	—	—

Note: This comparison is based on Louisiana data that showed serviceability indexes of 3.30, 3.06, and 1.55 for the categories of smooth, average, and rough when tested at 50 mph.

[a]PSI correction ratios are those needed to convert to 50 mph. Texas and PCA correction ratios are those provided by Mays 50 and Mays 40 and by the PCA equation as follows: CHLOE slope variance = $(1.18 - 0.01 \text{ mph}) \Sigma (D^2) + 0.8$.

velocities, and these appear to reduce the serviceability index by a small amount. When analyzed separately in the southbound structure, temperature and wind were not significantly related to PSI, the squared correlation coefficients being 0.12 and 0.003 respectively. In the northbound structure, wind showed a better correlation with PSI than did temperature. The squared correlation coefficients are 0.57 and 0.40 respectively. More data are needed to evaluate these variables, especially in the matter of wind direction as related to direction of test car travel.

SEASONAL FLUCTUATIONS OF PAVEMENT ROUGHNESS

None of the reporting agencies mentions tests conducted to show changes in pavement roughness not associated with accumulation of traffic and load.

Soon after development of the PCA road meter, the author started regular tests on a 1-mile section of reinforced concrete pavement on a lightly traveled state highway near Madison, Wisconsin. Pavement design is identical to that for most of the Interstate Highway System in Wisconsin. Truck traffic is very light and does not exceed about 25 tractor semitrailers per day.

Results of tests made during the period 1965-1970 are given in Table 6. The data show the great effects of frost on winter pavement roughness, and the remarkable ability of the pavement to recover during the following summer and fall. After an extremely severe winter, full recovery may be delayed until July or August. These tests serve as a warning to those trying to evaluate long-term effects of traffic loadings while field data are being confounded by the vagaries of climate and weather. Measurements of pavement roughness, to be used in such studies, should be performed during restricted calendar time. In Wisconsin, this time is from about September 1 to December 1, unless tests in a control section indicate more liberal time limits.

TABLE 6

SEASONAL CHANGES IN SERVICEABILITY INDEX FOR TYPICAL WISCONSIN ROAD AS MEASURED BY PCA ROAD METER DURING PERIOD 1965-1970

Date	Time	Temperature	Wind	Serviceability Index
10-29-65	3 p.m.	60	NW 10	4.20
2-06-66	2 p.m.	28	SE 5	3.48
6-27-66	1 p.m.	80	W 5	3.77
11-01-66	9 a.m.	34	NW 15	4.26
11-30-66	1 p.m.	35	NW 20	4.25
12-02-66	1 p.m.	11	NW 15	4.29
12-05-66	1 p.m.	33	0	4.34
12-06-66	1 p.m.	49	SW 12	4.07
1-28-67	1 p.m.	28	NW 5	3.64
3-03-67	10 a.m.	33	N 10	3.85
3-26-67	10 a.m.	40	NE 4	3.73
4-19-67	11 a.m.	44	E 10	4.27
5-25-67	2 p.m.	76	S 5	4.03
11-24-67	9 a.m.	35	W 8	4.46
2-06-68	8 a.m.	32	SW 5	3.84
3-05-68	9 a.m.	35	S 10	3.76
4-19-68	2 p.m.	—	E 8	3.45
5-17-68	10 a.m.	55	W 10	3.77
10-18-68	9 a.m.	50	SW 15	4.18
5-02-69	11 a.m.	68	NW 14	3.84
5-27-69	9 a.m.	58	SW 12	4.42
9-24-69	1 p.m.	50	NE 9	4.17
2-10-70	11 a.m.	28	N 8	3.94
6-23-70	9 a.m.	71	SW 7	4.01
Summer-fall avg		46.6	10.6	4.23
Winter-spring avg		42.7	7.6	3.74

Note: Road meter test section was 0.9 mile in northbound lane of Route 113, Madison-Waunakee Road, in Dane County, Wisconsin. Constructed in 1965, the road has a pavement of 9-in. reinforced concrete with mesh and dowels, a 6-in. subbase of graded aggregate plus 9 in. of sand ballast (both through the shoulders), and a subgrade of Miami silt loam developed from low end moraine. Dual-tire commercial ADT does not exceed 25.

MECHANICAL FACTORS THAT INFLUENCE PCA ROAD METER RESULTS

Differences Among Identical Automobiles

Highway departments in some states, such as Wisconsin, use a single road meter for all pavement evaluations. These are checked periodically in reference pavement sections by panel ratings or by the CHLOE profilometer. In other states, such as Minnesota, a number of road meters are used. These are usually assigned to district offices and are calibrated with a master road meter located at the central office. The need for individual calibrations and the variability among identical automobiles are given in Table 7 (15).

In this example, the laboratory meter was calibrated with panel ratings. District meters, installed in 5 identical automobiles, were calibrated with the laboratory meter. The calibration curves were compared at 4 levels of road meter output. Car-to-car standard deviations of serviceability index averaged 0.09 serviceability point. This compares with data from the repeatability tests, given in Table 2, where the average within-test standard deviation was about

TABLE 7

COMPARISON OF SERVICEABILITY INDEXES GIVEN BY PCA ROAD METERS INSTALLED IN 6 SIMILAR AUTOMOBILES

Automobile Number[a]	Serviceability Index at (Σ Count)				Standard Error	r^2
	159	500	1,585	6,300		
Lab B	4.43	3.52	2.61	1.52	0.23[b]	0.92
Dist. 1	4.49	3.54	2.60	1.46	0.08[c]	0.99
Dist. 3	4.35	3.43	2.51	1.40	0.09[c]	0.99
Dist. 7	4.39	3.52	2.64	1.59	0.09[c]	0.99
Dist. 8	4.56	3.65	2.74	1.64	0.12[c]	0.97
Dist. 9	4.62	3.67	2.72	1.57	0.21[c]	0.92
Avg	4.47	3.56	2.64	1.53		
Standard deviation	0.10	0.09	0.08	0.09		

Note: Results of tests by Minnesota Department of Highways (15) in 17 to 21 different sections of rigid pavement with PSR range = 1.00 to 4.00.

[a]All 6 automobiles were 1969 Fords with heavy-duty suspensions and heavy-duty shock absorbers. Each had a digital counter sensitivity of 0.025 sec.

[b]Standard error and squared correlation coefficient relate panel rating and log (Σ count).

[c]Standard error and squared correlation coefficient relate laboratory and district automobile.

0.06 serviceability point. Although the car-to-car and within-car standard deviations varied only slightly, it is apparent that pairing of the extremes (district cars 9 and 3), without calibration adjustments, would result in serviceability index differences that could be of consequence.

Differences Among Suspension Systems

Differences in regression equations, relating panel ratings or CHLOE slope variance with road meter output, can be caused by differences in basic automobile suspension systems, as well as in size and weight of the car.

Data from Minnesota (Table 8) show the comparison of heavy duty and standard suspension systems in one make of automobile with coil springs. Road meter output, at 4 levels of serviceability index, was computed for 3 different automobiles. As expected, heavy-duty suspension greatly reduced movement between rear axle housing and body of automobile when operated on smooth roads. However, the difference diminished with increased road roughness and the suspension systems gave about the same road meter output at a serviceability index of 1.5. District car 2 did not correlate as well with the laboratory vehicle, as did the other district cars with heavy-duty suspension (Table 7). The reasons are not apparent, especially in view of the excellent correlation with panel ratings given by laboratory car A, which had standard suspension.

As a matter of choice of vehicle for road test purposes, the author favors standard suspension because it is probably more responsive to minor irregularities in pavement surface caused by different kinds of paving machinery and to faulting of transverse pavement joints and cracks.

TABLE 8

COMPARISON OF OUTPUTS OF PCA ROAD METERS INSTALLED IN 3 DIFFERENT AUTOMOBILES AT VARIOUS SERVICEABILITY INDEXES

Automobile			Suspension and Shock Absorbers	Digital Counter Sensitivity (sec)	Road Meter Output (Σ Count) at Serviceability Index				Standard Error	r^2
Number	Make	Year			4.5	3.5	2.5	1.5		
Lab. B	Ford	1969	Heavy duty	0.025	145	515	1,830	6,500	0.23[a]	0.92
Dist. 2	Ford	1970	Standard	0.025	500	1,180	2,785	6,590	0.26[b]	0.89
Lab. A	Ford	1966	Standard	0.030	545	1,165	2,485	5,310	0.20[c]	0.96

Note: Results of test by Minnesota Department of Highways (4, 15) in 17 to 21 sections of rigid pavement with PSR range = 1.00 to 4.00.

[a]Standard error and squared correlation coefficient relate 1970 panel ratings and log (Σ count).

[b]Standard error and squared correlation coefficient relate laboratory automobile B and district automobile having a different suspension system.

[c]Standard error and squared correlation coefficient relate 1966 panel ratings and log (Σ count).

Effects of Digital Counter Sensitivity

The original PCA road meter was equipped with digital counters having a manufacturer's rating of 1,000 cpm. According to definition, count time is made up of 2 equal time intervals (0.03 sec) for "make" and "break" action. A counter will be actuated if the roller contactor remains on a given switch plate segment for at least 0.03 sec. When the roller moves on to the next segment, there will be sufficient time for the break action.

However, if the road tested is very rough, some irregularities will cause the roller contactor to move across switch segments so rapidly that minimum make time is not achieved and counts are not recorded. These omissions are nearly all accounted for in the coefficients of the regression equation relating panel ratings or serviceability index with road meter output. Furthermore, the effects in rough roads are minimized because the logarithm of meter output is used in the regression.

Many road meters have been constructed with higher speed digital counters. Most of these use counters rated at 1,200 cpm, with a make time of 0.025 sec. Tests by the Minnesota Department of State Highways (Table 8) illustrate the general differences in road meter output at 4 levels of serviceability index when counter sensitivity was changed from 0.03 to 0.025 sec. Counters rated at even higher speeds are available. The author doubts that these would be beneficial, and they could be detrimental because of "chatter" in the mechanical switching system.

Pretest Adjustments and Operating Procedure

Satisfactory performance of the PCA road meter depends on good pretest centering of the roller contactor over the null segment of the switch plate. Precise centering can be attained only when the test vehicle is parked without brakes and with the transmission in a locked position. A solid attachment between roller contactor and flexible steel strand (Fig. 2) to prevent slippage during a test is recommended (3).

During test, fore-to-aft movement of front seat occupants has little effect on initial centering. However, movements of rear-seat occupants (such as moving forward to witness the test after the centering operation) can change the initial setting. This might amount to a ⅛-in. centering error. The effects of centering error or change in initial adjustment has been investigated by the author. A ⅛-in. error or change can reduce apparent serviceability index from 3.9 to 3.6 and from 3.3 to 3.1. The reduction in PSI diminishes as the total roughness increases. With ordinary care, these differences can be largely eliminated.

UTILITY OF THE PCA ROAD METER

Road meters are being extensively used for road inventory and sufficiency rating purposes. Several states have started programs to evaluate performance as related to design, traffic, time, and other variables. In these cases, the road meter has been attractive because of its economy and speed of operation and because it does not interfere with normal traffic movement.

Recent improvements in road meter design include a duplicate set of digital counters. Sets can be used interchangeably by turning a simple rotary switch. This feature allows almost continuous operation of the survey automobile without need for stops to record data and reset counters. The survey observer normally operates the meter and tabulates data from one set or the other as the survey progresses in designated sections or miles within a project. The operator of the survey automobile can devote his full time to safe driving and is relieved of most hazardous excursions from the traveled highway to record data. Use of selective, automatic speed has also improved survey car operation.

Another attribute of the PCA road meter, often overlooked, is the additional information that can be derived from data recorded in the digital counters. Normally, these recordings are reduced to the sum of squares of road-car deviations, ΣD^2, as the author shows in a previous paper (3, p. 147). The logarithm of this statistic can then be related to serviceability rating or serviceability index, or directly to CHLOE slope variance. Some agencies prefer to use Σ count, which is equal to 64 ΣD^2 for switch plates

TABLE 9

UTILITY OF PCA ROAD METER IN DIFFERENTIATING PERFORMANCE FEATURES RELATED TO SUBGRADE SOILS AND TREATMENTS

Section	Year Constructed	Soils Area	Soils Control Method	Area Under Power Spectrum Curve 64 ΣD^2 at Road-Car Deviation in 1/8-in. Increments									PSI Oct. 1969
				1	2	3	4	5	6	7	8	9	
1	1965	Nonexpansive	Old	152	252	234	32	25	0				4.0
2 and 3	1962	Expansive	Old	95	224	418	264	172	90	74	96	0	3.4
4	1967	Expansive	New	113	184	50	16	0					4.7
5 and 6	1968	Expansive	New	97	144	40	12	0					4.8+
6 and 8	1969	Expansive	New	78	162	40	20	0					4.8+

TABLE 10

UTILITY OF PCA ROAD METER IN COMPARISONS OF INITIAL SERVICEABILITY OF PAVEMENTS PLACED BY DIFFERENT SLIP-FORM PAVERS

Section	Year Constructed	Slip-Form Paver	Area Under Power Spectrum Curve 64 ΣD^2 at Road-Car Deviation in 1/8-in. Increments						PSI Nov. 1968
			1	2	3	4	5	6	
1	1968	Type A	111	312	225	0	0	0	4.05
2	1968	Type B	75	268	171	80	75	0	4.01

divided into 1/8-in. segments. An investigator can also reduce the counter data by the method given in the author's earlier paper (3, p. 146) and obtain the number of road-car deviations in each 1/8-in. increment. Individual products of number and D^2 may be summed to give ΣD^2, or the individual products may be viewed separately. In both cases, the results correspond to power spectrum (11), ΣD^2 representing the total power and individual products representing the portion of roughness power spectrum contributed at each deviation.

This is a valuable tool when used to analyze serviceability indexes resulting from an array of treatments or conditions. Table 9 gives a typical example for differentiating the effects of soils control in areas of expansive and nonexpansive soils in a north central state. Table 10 shows another example where pavements placed by 2 different types of slip-form pavers were compared.

SUMMARY

The PCA road meter and modifications of the device rank with the AASHO profilometer in ability to relate with serviceability ratings. Both instruments had higher correlation coefficients when rigid and flexible pavements were analyzed separately.

Repeatability is consistent among most of the meters reported. Within-test coefficients of variation ranged from 0.8 to 3.5 percent. The average coefficient was 1.6 percent.

Effects of wind velocity and direction, as related to direction of test-car travel, and air temperature deserve additional field observations. In particular, more information is needed on the influence of high air temperature to determine if serviceability reductions are due to changes in automobile suspension characteristics or to real increases in pavement roughness.

Tests show that larger, standard-sized automobiles are affected less by speed and wind velocity.

When several road meters are used by one agency, even if mounted in automobiles of identical make and model, each should be correlated with panel ratings or each should be correlated with a master meter situated in the central office or laboratory.

Attention should be directed to good pretest centering of the switch components, and passengers should not be permitted in the rear seat of a test automobile. These precautions should reduce variability in test results.

The PCA road meter has great utility in a type of roughness power spectrum analysis that can be helpful in interpretation of serviceability measurements related to various treatments or conditions.

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