DEVELOPMENT OF THE ROAD METER: 1965 TO 1972

M. P. Brokaw

The Portland Cement Association (PCA) road meter was developed by the author in April 1965 to provide a rapid, simple, and inexpensive way of measuring road roughness, the principal ingredient of the present serviceability index (PSI) established as a result of the AASHO Road Test (1, 2). With the cooperation of Karl Dunn, tests were made that related PCA road meter output to AASHO slope variance as measured by the Wisconsin CHLOE profilometer.

The road meter was used extensively in Wisconsin and at special sites in the United States during 1966. Based on these experiences, the PCA road meter was announced and described at the 1967 Annual Meeting of the Highway Research Board (3).

As a result of the announcement, several state highway departments constructed meters according to the original version, with numerous variations. Many of these meters were described in individual engineering reports that received limited circulation. The author summarized parts of the reports in a paper given at the 1970 Summer Meeting of the Highway Research Board (4).

Increased use, familiarity, and confidence in the device have resulted in this workshop. The meeting is timely and provides an opportunity for the exchange of ideas and applications and makes these available to others unable to attend.

During the past 7 years, the author has recognized a number of factors that tend to disturb road meter users. These are (a) differences in mechanical and electrical components that control road meter output, (b) differences in road meter output when a meter is used in various automobiles, (c) effects of seasonal and diurnal ambient air temperature on the meter and pavement, (d) differences in road meter output caused by ambient wind velocities during test, and (e) need for a dependable standard for road roughness measurements that is essentially time-stable and is available for calibrating all road meters and profilometers.

The following sections include a discussion of each factor along with recommendations where appropriate and suggestions for additional field evaluation.

DIFFERENCES IN MECHANICAL AND ELECTRICAL COMPONENTS

Road meter output is controlled by the sensitivity of electric digital counters (make and break time) and also by the width of switch segment. Uniformity of these parts should enable interchange of meter data without risk of losing the built-in advantage of mechanical switching and counting and filtration of extraneous electrical impulses.

At present, reliable digital counters with a capacity of 1,500 cpm are available (Hecon, Hengstler). These give consistent results when combined with switch plate segments having a net width of 0.10 in. and with insulated interstices of 0.025 in.

DIFFERENCES RESULTING FROM AUTOMOBILES

Assembly-line automobiles are not alike, even when produced for the same order in a given assembly plant. In general, the differences are not of consequence to highway users. However, road meter outputs can be affected.

Major differences are related to standard versus heavy-duty suspension within cars, coil-spring versus leaf-spring suspension within or among different makes and models, and size and weight of the automobile itself.

Because the choice of road meter vehicle does control road meter output, the author has always recommended standard supension in a coil-spring vehicle of conventional size, e.g., Ford Custom 500. The recommendation is also extended to specification of automatic speed control, built-in air-conditioning, and maximum available size of engine. These specifications provide better control and comfort of road meter crews, reduce the effects of crosswinds on a vehicle with open windows, and increase the front stability of the survey vehicle because of the additional weight of the air-conditioning unit and large engine.

Additional discussion of these factors will take place at this workshop. The important point is that an acceptable vehicle can be calibrated with panel serviceability ratings, a standard profilometer, or a precalibrated vehicle if due care is exercised in the number of tests per site.

DIFFERENCES RESULTING FROM CHANGES IN AMBIENT AIR TEMPERATURE

Changes in ambient air temperature are known to change pavement roughness. Sustained low temperature results in frozen bases and subgrades and causes frost heave and increased pavement roughness. Sustained high temperature can place a pavement structure in compressive restraint, and this can result in increased pavement roughness also. Extremes of high and low temperatures probably change automobile suspension characteristics and thus influence road meter outputs, with low output accompanying low temperatures and high output accompanying high temperatures.

Interaction of these roughness factors tends to impair field research of the effect of ambient air temperature on road meter alone. For example, a test made at low temperature, say 15 F, might result in low meter output because of stiffness in the automobile suspension system. At the same time, it might result in high meter output if the pavement is subjected to frost heave. In this case, the amount of roughness can be very erratic, especially during spring thaws when foundation material can switch from liquid to solid state during a single day and when the changeability can continue for several weeks. Meter output can be attenuated in a different way if the 15 F test is conducted before onset of freezing of base and subgrade when pavements are usually smoothest.

Another example is a test conducted at high air temperature, e.g., at 95 F, when the automobile suspension might be more limber and give high meter outputs. These high outputs can be amplified by real increases in road roughness caused by pavement expansion. Sudden increase in maximum daily temperature is less apt to affect pavement roughness if the pavement is in a relaxed state at the onset of summer rather than in full restraint during midsummer. In the latter case, pavement roughness can increase hourly with an increase in ambient air temperature but recedes rapidly with a lowering of temperature. The rate depends also on the volume of heavy vehicles.

Within the extremes set forth, there is no limit to seasonal and diurnal combinations that are capable of confusing research appraisal of temperature effects on real road roughness and road meter output. Results of a few tests have been reported (3, 4), but these appear inconclusive and suggest the need for additional investigation.

DIFFERENCES RESULTING FROM AMBIENT WIND VELOCITY

Road meter output can be affected by changes in external conditions during a single test. All of the changes tend to shift the initial centering of the roller contactor and zero segment of the switch plate and result in high meter outputs and a low serviceability index. Shifts can be caused by changes in position of car load (especially rear-seat passengers) after a test commences, by rapid acceleration or deceleration of the survey vehicle, and most important by uplift of the automobile body caused by aerodynamics and ambient wind direction and velocity.

Automatic correction for aerodynamic and wind shift could be expected to reduce within-test variability, afford the closest measure of real road roughness, and remove present wind restrictions on meter operation. A device capable of achieving the objectives has been developed by the author and is described in another paper (5).

CALIBRATION OF ROAD METERS AND PROFILOMETERS

Interpretation and extension of AASHO Road Test results and continued application of the methods developed require that mechanical road roughness measuring devices be calibrated to a universal standard. Initial plans envisioned that the standard should be the present serviceability rating (PSR) (the judgment of an observer as to current ability of a pavement to serve the traffic it is meant to serve) and consequently the present serviceability index (PSI) (an estimate of the mean of serviceability ratings made by a panel of judges). Because PSI is the output of a mathematical equation relating serviceability rating and physical measurements of road roughness and road condition, it is apparent that road meters and profilometers must be calibrated in common.

The best procedure would be calibration via PSR's. Unfortunately, PSR's are not a universal standard. Judgments of an individual or panel in a given geographical and political area can be quite different from those in another area. The differences arise from accustomed levels of highway service afforded the local highway user, and these are decided by types of pavement constructed, maintenance practices, timing of resurfacing, and availability of highway funds.

Serviceability ratings are also subject to human vagaries. These result in high intrapanel standard deviations and high standard deviations of mean rating, unless the panel is composed of at least 50 raters. For example, at the AASHO Road Test, the standard deviation of serviceability rating among raters was 0.47 PSR unit. With a 10-rater panel, standard error of mean rating amounts to about 0.15 PSR unit. Once adopted, panel ratings are considered inviolate, yet they probably contribute most to the variability observed in correlations of serviceability rating and road meter output.

The author believes that road meters and profilometers cannot be calibrated in common on a universal basis by panel serviceability ratings. Nevertheless, equipment measurements of attributes ought to be standardized. With a common standard, results of tests can be exchanged universally and without loss of the advantage of subsequent local serviceability ratings. This can be accomplished by cooperative effort with the Federal Highway Administration, or even the Bureau of Standards, to provide a single instrument (such as the AASHO profilometer) that can provide timely bench marks of pavement roughness for calibration with other devices.

SUMMARY

Progressive acceptance of the road meter as a viable instrument for pavement evaluation has been established. Simplicity, economy, and safety of operation are especially attractive to those agencies engaged in mass inventory of highway systems. Future improvements and increased precision are possible. Some of these avenues have been discussed in this paper and in others presented at the workshop.

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