data analyses in which the relevant RMSVA indices were derived. Also appreciated is the kind assistance of TSDHPT representative Brad Hubbard, who furnished the Mays meter data crucial to this study and who was first to point out certain deficiencies in the original calibration program. We are also pleased to acknowledge the combined efforts and support of the Center for Transportation Research at the University of Texas at Austin and the TSDHPT in cooperation with the Federal Highway Administration. The contents of this abridgment reflect our views, and we 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 or the TSDHPT. This paper does not constitute a standard, specification, or regulation.

REFERENCES

1. J.R. Darlington. Evaluation and Application Study of the General Motors Corporation Rapid Travel Profilometer. Michigan Department of State Highways, Lansing, Rept. R-731, April 1973.
2. J.P. Guilford. Psychometric Methods. McGraw-Hill, New York, 1954.
3. R.S. Walker and W.R. Hudson. Use of Profile Wave Amplitude Estimate for Pavement Serviceability Measures. HRB, Highway Research Record 471, 1973, pp. 110-117.

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Inertial Profilometer Uses in the Pavement Management Process

ELSON B. SPANGLER

The inertial profilometer has the potential to become one of the most important tools in the pavement condition evaluation process. This paper discusses its continuing development, including a noncontact profile sensor, digital profile computation, and an array of computer software developments that will further enhance the inertial profilometer's contribution to the pavement management process. For historical purposes the paper also discusses the original development of the inertial profilometer at the General Motors Research Laboratories in the early 1960s and its introduction into the user community by K.J. Law Engineers, Inc.

The inertial profilometer was developed in the early 1960s at the General Motors Corporation Research Laboratories (GMR) (1). It was developed for the purpose of measuring, recording, and bringing a replica of a pavement surface profile into the laboratory for use in vehicle suspension computer simulations. The original development task was thought to be trivial but took four years and cost $0.5 million in 1960 dollars. This paper discusses that original development, its continued development as a commercial product under license from General Motors, and some future developments that will enhance the device as an important pavement management tool.

GMR PROFILOMETER

The development of the inertial profilometer at the General Motors Research Laboratories in the 1960s was made possible by the availability of high quality force balance accelerometers used in the Aerospace Industry for inertial guidance. Also important in the development was the availability of high quality analog computer components, including the integrators used in the profile computation. The GMR profilometer developed at that time (Figure 1) used a 6-in diameter wheel to follow the pavement surface (W), a high-quality potentiometer to measure the relative motion (W-Z) of the pavement-following wheel, and an accelerometer isolated from large pavement profile acceleration by being mounted on the vehicle's sprung mass. The accelerometer output ($\ddot{Z}$) and the potentiometer output (W-Z) were inputs to an analog computation that produced the measured pavement profile, W_m:

$$W_m = (W - Z) + \iint \ddot{Z}\,dt\,dt \quad (1)$$

The capability for measuring the spatial wavelength (Figure 2) was found to be more than adequate for vehicle ride studies. Measuring response remained flat for wavelengths up to 200 ft for even the low measuring velocities. The profilometer's short wavelength measuring capability was demonstrated by the ability of the pavement-following wheel to follow a wood shingle (Figure 3) placed on the pavement surface. The profilometer's overall measuring capability was demonstrated by its ability to measure (Figure 4) and isolate (Figure 5) pavement spatial wavelengths that caused ride quality problems in General Motors' cars on California highways.

Much of the work at the General Motors Research Laboratories was reported by Spangler and Kelly (1). Work that was not reported included the use of the GMR profilometer to measure airport runways and taxis strips, city streets traveled by General Motor's buses, and rail profiles (2) traveled by General Motor's locomotives. One of the more important results of this early effort was the ability to measure and record an accurate replica of many different pavement surfaces (Figure 6) for later examination, analysis, and processing by more-sophisticated engineering computer tools.

COMMERCIAL PROFILOMETER

After the 1965 TRB presentation on the GMR profilometer (1) the General Motors Corporation was requested by several transportation agencies to make the inertial profilometer technology available to the transportation community. K. J. Law Engineers, Inc., of Farmington Hills, Michigan, was granted a

Figure 1. GMR inertial profilometer.

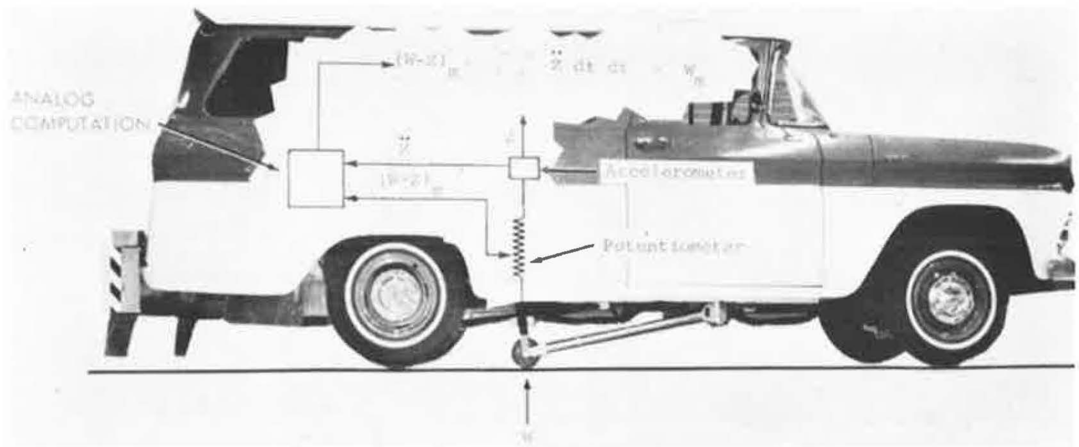


Figure 2. GMR profilometer wavelength measuring capability.

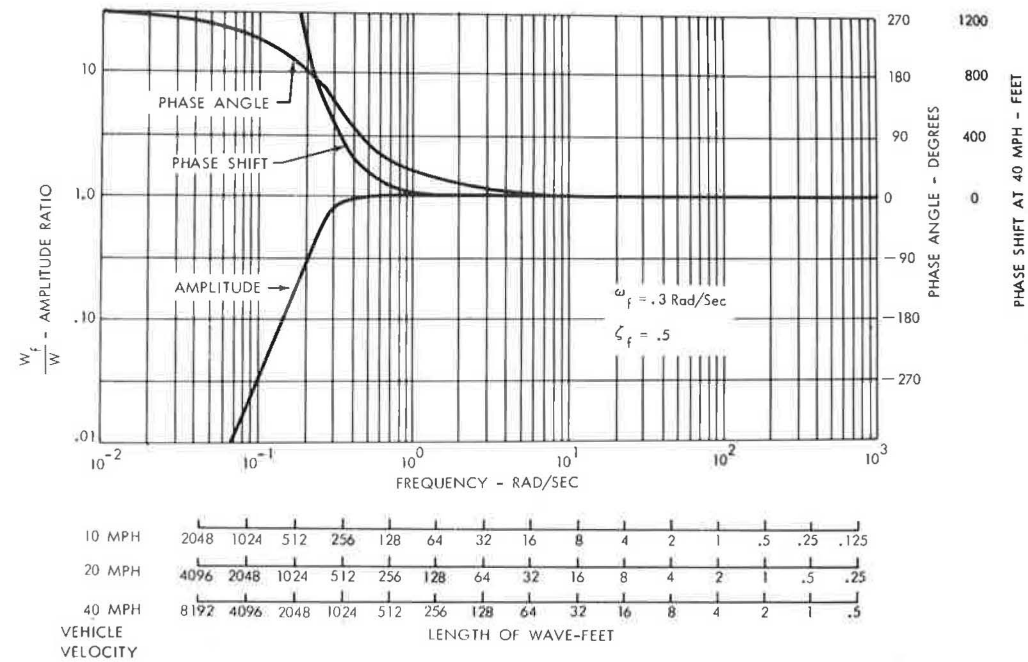


Figure 3. Pavement-following wheel response to wood shingle.

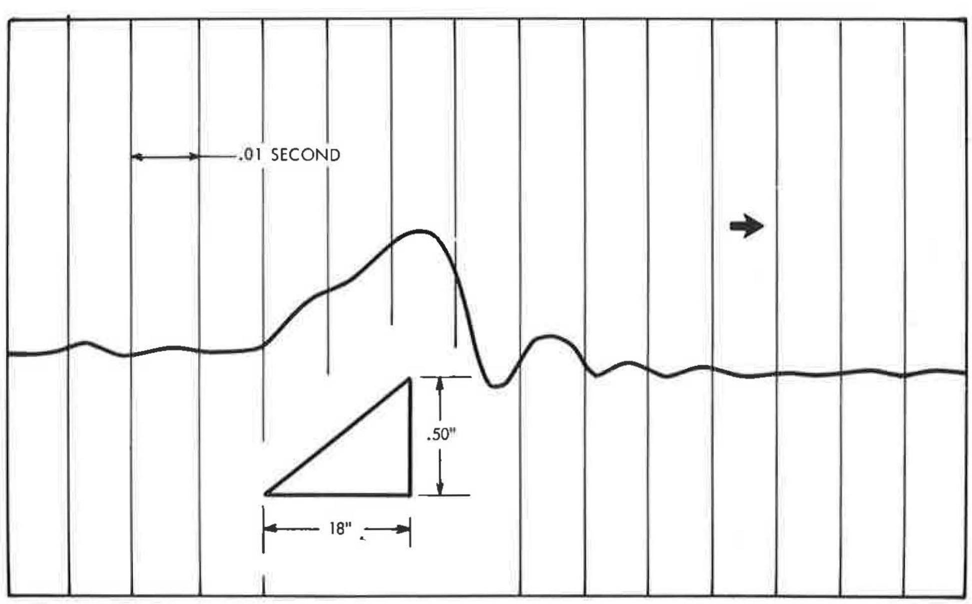


Figure 4. Pavement that induces automotive body shake.

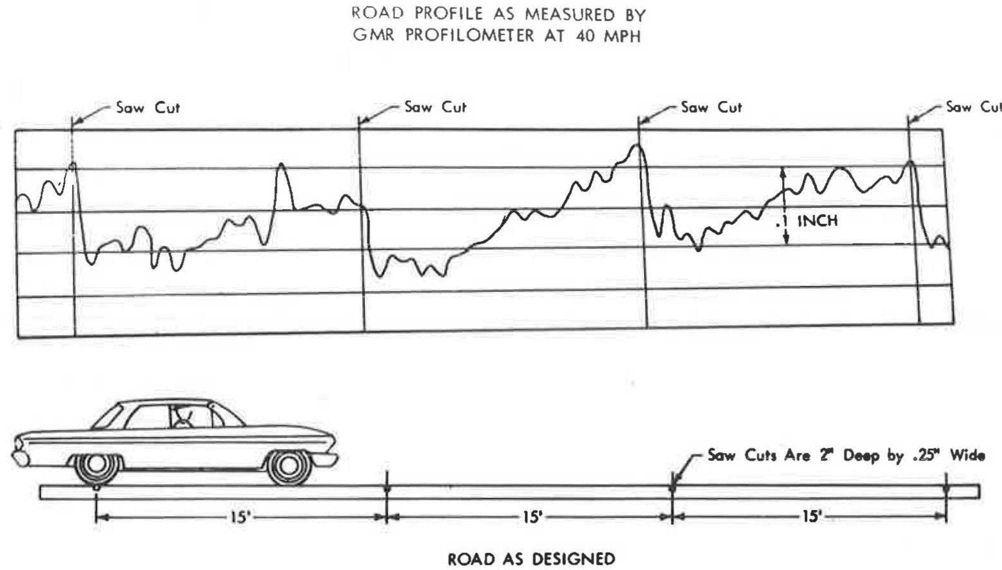


Figure 5. Harmonic analysis of measured pavement profile.

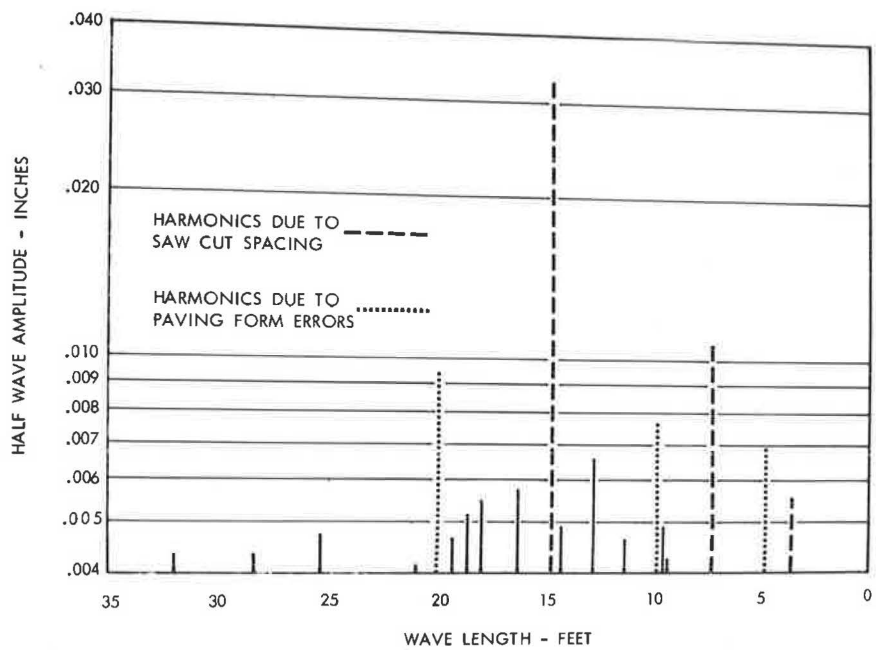
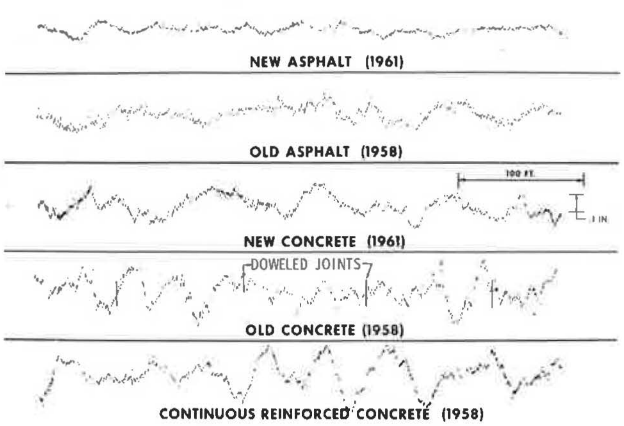


Figure 6. Characteristics of measured pavement surfaces.



license to manufacture and sell inertial profilometer equipment under a General Motors Corporation patent. The requests also resulted in a cooperative effort between GMR and the Michigan Department of Transportation (3) in the evaluation of the GMR profilometer for application in typical highway department projects. Continued efforts by the Michigan Department of Transportation have produced an array of profile processing computer programs, including a bituminous fill paving program that will be discussed later in the paper.

Texas Profilometer

The first commercial profilometer built by K. J. Law Engineers, Inc., was manufactured in 1966 for the Texas Department of Transportation and operated by the Center for Highway Research at the University of Texas (4). Profilometers were then manufactured by

K. J. Law Engineers, Inc., for Pennsylvania and Kentucky (5) and later for Brazil under a World Bank project. The Pennsylvania, Kentucky, and Brazil profilometers were supplied with a quarter-car simulation device (5), which processed the measured pavement profile to produce summary ride quality data.

Restricted Use

The four profilometers manufactured by K. J. Law Engineers, Inc., between 1966 and 1976, were essentially the same state of the art as the GMR profilometer (1). Although, it was a significant advancement over prior pavement measuring technology, expanded use was restricted by many factors, including

1. Required pavement friction measurements,
2. Technical complexity,
3. Pavement following wheels, and
4. Pavement profile data processing.

Required Pavement Friction Measurements

About the time state transportation agencies were considering the pavement roughness problem, new federal requirements diverted their attention to the problem of pavement friction. Both problems are worthy of attention, but most states had insufficient engineering resources to address both effectively. As a result, a significant pavement roughness effort was delayed for a decade. This, however, might have been an advantage.

Technical Complexity

The inertial profilometer is a fairly complex measuring system. In the early systems it was almost necessary to know how the system worked to use it effectively. Although the new profilometer is more complex, the system requires limited knowledge to use it effectively.

Pavement Following Wheel

The pavement following wheel has been the most serious operational problem. This problem was recognized in the original design and development work at General Motors. The electronics technology at that time would not support a noncontact approach. A significant design effort was exerted on the pavement following wheel assembly to attain the level of performance and reliability that has been exhibited over the years. However, wheel damage, costly replacement, and unscheduled down time could not be avoided. Fortunately, noncontact relief is in sight.

Pavement Profile Data Processing

Pavement profile data processing is essential to the pavement management process. The output from the early profilometers was analog profile amplitude signals displayed on a strip chart, recorded as a function of distance, and stored on analog magnetic tape as a function of time. It was nice to see pavement profiles drawn out on the strip chart recorder, but what can you do with a hard copy profile drawing? Several users converted the analog magnetic tape data to a digital format for processing on a big, main-frame computer. However, this did not appear to be the solution for most transportation agencies. As a result, I and K. J. Law Engineers, Inc., developed the electronic quarter-car simulator, which gave the user immediate information on ride quality. In addition, it provided the simulated output of the Bureau of Public Roads (BPR) roughometer, which allowed several transportation agencies to retire their antiquated BPR roughometer devices. The quarter-car simulation has become a recognized data processing tool and has now been implemented as a computer software program.

NEW PROFILOMETER DESIGN

With time, many of the factors that restricted expanded use of the inertial profilometer have abated. The nationwide mandated measurement of pavement friction has been implemented with new sophisticated equipment and technically trained staff to support that equipment. These trained staff now have the same skills required to operate and maintain the new generation of inertial profilometer equipment.

The remaining factors were addressed in the design of the new digital model 690D Surface Dynamics inertial profilometer manufactured by K. J. Law Engineers, Inc. The first model 690D profilometer was delivered to the West Virginia Department of Transportation in the fall 1979. The most significant improvement was the introduction of the digital computer used to perform the digital computation of the measured pavement profile and to store the computed profile data in digital format on the computer's digital magnetic tape recorder. The user interface with the profilometer system is a computer terminal that interactively leads the user through an array of computer programs designed to assist in the effective use of the profilometer system. The computer programs available to the profilometer user fall into two categories: profilometer systems programs and pavement profile data processing programs.

Profilometer Systems Programs

The profilometer system programs are basic to the operation of the profilometer itself and include programs to perform the following procedures:

1. System calibration,
2. Set-up,
3. Pavement profile computation, and
4. Magnetic tape playback.

The programs are designed to perform these procedures with minimal user involvement. Where involvement is required, the user is led, interactively, through a sequence of nontechnical question and answer exchanges.

System Calibration Program

The system calibration program is designed to assist the user in the calibration of the entire profilometer system. The program leads the user, interactively, through the calibration procedure, collects the calibration data, and compares the results with acceptable values for that data. Where possible, the calibration procedure has been automated to reduce the need for user involvement.

Set-Up Program

One of the more important procedures is the set-up program, which allows the user to input pertinent historical descriptive information on the pavement whose profile is to be measured. The information collected in the set-up program includes (a) date, (b) time, (c) run number, (d) project number, (e) laboratory number, (f) direction measured, (g) distance measured, (h) beginning mile post, (i)

beginning description, (j) ending description, (k) pavement surface, (l) material, (m) condition, (n) weather, (o) temperature, (p) measuring speed, (q) operator-driver, and (r) filter wavelength (ft).

Filter wavelength is the only technical question concerning the operation of the profilometer system itself. It could be easily omitted by making filter wavelength a constant. On completion of the set-up procedure, the set-up descriptive information is stored as text on the digital magnetic tape as a tape information header for the pavement profile measurements that will follow.

Profile Computation Program

The profile computation program performs the following important system functions: (a) reads transducer outputs, (b) computes pavement profiles, (c) stores pavement profiles on magnetic tape, and (d) outputs pavement profiles to strip chart recorder.

Pavement profile computations are made for the two wheel paths at least every inch longitudinally along the pavement surface. Pavement profile data point pairs are stored on magnetic tape at 6-in intervals. The pavement profile computation is independent of profile measuring velocity and changes in velocity that allow the driver to move at traffic speed during the pavement profile measuring process.

The pavement profile computation program, in addition to computing profile, can also compute a pavement profile summary statistic such as the simulated output of the BPR roughometer, Mays, PCA, or Cox ride meters, or root mean square (RMS) acceleration of a typical quarter-car vehicle. The summary statistic can be printed immediately on the users's computer terminal as it is computed.

Magnetic Tape Playback

After the profile measuring run has been completed, the magnetic tape playback program allows the user to play back and validate the pavement profile measurements just made.

Pavement Profile Data Processing Programs

In addition to the profilometer systems programs, an array of profile processing programs is available to the user for the analysis of the measured pavement profile stored on magnetic tape. Three profile processing programs will be discussed, including

1. Straightedge program,
2. Ride meter simulation and calibration program, and
3. Ski control bituminous fill program.

Straightedge Program

Most transportation agencies have, as part of their standard specification for roads, a surface tolerance specification that involves the use of a straightedge. For example, the West Virginia specification reads, "When tested with a 10-foot straightedge...the finished wearing course shall not show a deviation from the required surface greater than 3/16 inch."

The straightedge program is designed to automate the straightedge inspection of recorded pavement surfaces. The program gives the user the ability to enter the straightedge length (ft) and the maximum allowable straightedge deviation (in). The program then reads the desired pavement profile data from magnetic tape, simulates the movement of the straightedge down the pavement surface, and prints out, on the user's computer terminal, the straightedge deviations that exceed the allowable maximum for both wheel paths as a function of distance (ft). The typical output data format shown below would be preceded by the descriptive information entered by the user in the set-up program.

Distance From Beginning (ft)	Deviation (in) Left Track	Right Track
33.00	0.12	
33.50	0.11	
34.00	0.15	
34.50	0.18	0.10
35.00	0.14	
35.50	0.11	0.11
36.00		0.12
36.50		0.12
37.00		0.11
252.50	-0.10	-0.10
253.00	-0.14	
253.50	-0.13	
257.50	0.13	
259.00	0.16	

Negative straightedge deviation values indicate a hump in the pavement profile with the center point of the pavement surface being above the computed straightedge. With this information, the user can return to pavement locations that exceed the allowable specification tolerance for more detailed inspection if required.

Ride Meter Simulation and Calibration Program

The ride meter simulation and calibration program provides the user with the standard ride index (RI) for that pavement profile and assists the user in establishing a calibration for an actual ride meter when driven over an array of pavement surfaces. The vehicle simulation model used is based on the golden car parameters proposed by Gillespie (6). User inputs to the calibration part of the program are standard and measured RI data point pairs for an array of pavement surfaces that have a wide range of RIs. The output of the program yields a calibration equation and shows how well the calibration equation correlates with the data used, Figure 7.

Ski Control Bituminous Fill Program

The ski control bituminous fill program is based on the original work of the Michigan Department of Transportation. This program simulates the paving process of a bituminous paving machine (Figure 8) whose screed is controlled by the movement of the center point of a paving ski. A 30-ft ski, used in the Michigan and West Virginia bituminous fill programs, produces a good, predictable ride quality surface with a significant reduction in short wavelength content. By using a computer simulation of a straightedge or ride meter on these surfaces, improvement in ride quality can be evaluated. In the West Virginia bituminous fill program a reduction in the number of straightedge deviations is used as a measure of improved pavement surface quality.

Shown below is the interactive question-answer exchange that initiates the bituminous fill computation:

```
ENTER BITUMINOUS FILL PARAMETERS

ENTER BITUMINOUS FILL WIDTH:                  10.0
ENTER NUMBER BITUMINOUS FILL LAYERS:           2
ENTER THICKNESS OF FIRST LAYER:                1.0
ENTER WEIGHT OF MATERIAL FOR FIRST LAYER:    146
ENTER THICKNESS OF SECOND LAYER:               1.0
ENTER WEIGHT OF MATERIAL FOR SECOND LAYER:   146
```

Figure 7. Ride meter calibration data.

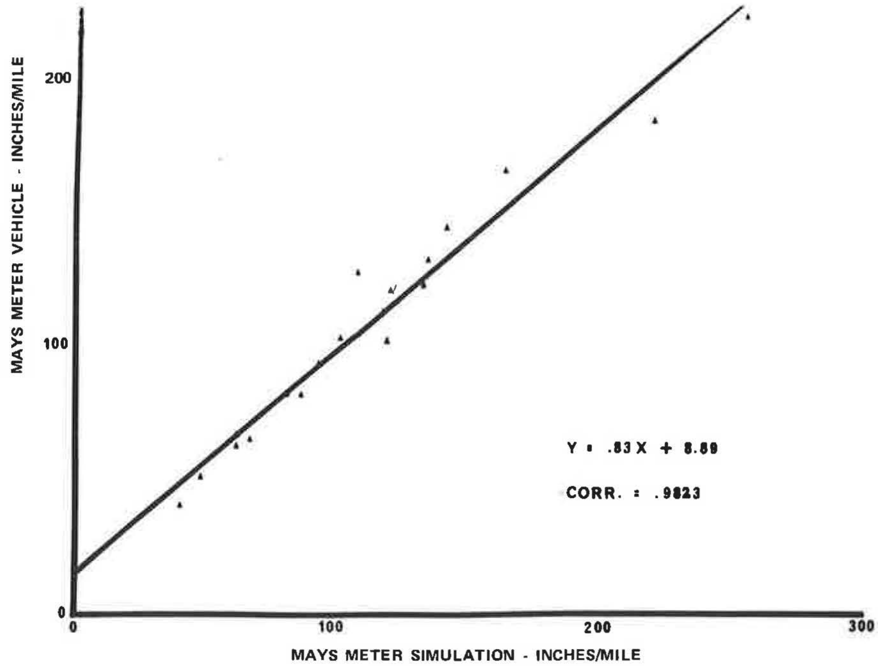


Figure 8. Ski-controlled bituminous paving machine.

While the bituminous fill computation is in progress the resulting paved surface profiles are drawn on the strip chart recorder as a function of distance. After the computation, results of the bituminous fill program are output on the user's computer terminal. Printed results from the two computed bituminous fill passes, including the straightedge deviations and RI before paving and after each paving pass, are shown in Figure 9. The fill or leveling material thickness is computed for each location along the profile surface by the simulation of the ski-controlled paver. The overlay thickness is added to the leveling thickness to get total thickness at each location. Volume is computed by multiplying by lane width. Multiplying the total computed volume by the unit weight of the material produces total weight, in tons, of material required for each paving pass. The Michigan Department of Transportation, in the use of their bituminous fill program, has found that the computed weights are within 5 percent of actual project amounts.

Noncontact Profile Sensor

A noncontact profile sensor was not available for the model 690D digital profilometer delivered to the West Virginia Department of Transportation in 1979. However, a new light-beam noncontact sensor has been developed by K. J. Law Engineers, Inc., and will be retrofitted on the West Virginia Profilometer in time for the 1982 measuring season.

Figure 9. Printed output of bituminous fill program.

```
LENGTH:     3168.00 FEET
 WIDTH:       10.00 FEET

STR. EDGE DEVIATIONS BEFORE 1ST FILL = 71.00
RIDE INDEX - RMS ACCELERATION        =   .093 G

FIRST LAYER:

           THICKNESS:       1.00 INCHES
     LEVELING VOLUME:       4.46 CU. YDS.
    THICKNESS VOLUME:      97.77 CU. YDS.
        TOTAL VOLUME:     102.23 CU. YDS.
     LEVELING WEIGHT:       8.80 TONS
    THICKNESS WEIGHT:     192.71 TONS
        TOTAL WEIGHT:     201.51 TONS

STR. EDGE DEVIATIONS AFTER 1ST FILL =     .00
RIDE INDEX - RMS ACCELERATION       =     .069 G

SECOND LAYER:

           THICKNESS:       1.00 INCHES
     LEVELING VOLUME:       2.24 CU. YDS.
    THICKNESS VOLUME:      97.77 CU. YDS.
        TOTAL VOLUME:     100.01 CU. YDS.
     LEVELING WEIGHT:       4.42 TONS
    THICKNESS WEIGHT:     192.71 TONS
        TOTAL WEIGHT:     197.13 TONS


STR. EDGE DEVIATIONS AFTER 2ND FILL =     .00
RIDE INDES - RMS ACCELERATION       =     .022 G
```

Second Texas Profilometer

One of the more aggressive user's of the inertial profilometer has been the Center for Highway Research, University of Texas at Austin. Funded by the Texas State Department of Highways and Public Transportation, the University of Texas Center for Highway Research has been a leader (7,8) in the

evaluation of the inertial profilometer's capabilities and pavement profile data processing techniques. They are also well acquainted with the inadequacies of their early vintage profilometer and have purchased a new model 690D Surface Dynamics profilometer, which is essentially the same as the West Virginia profilometer discussed earlier. Although Texas would like to have the noncontact profile sensor, they chose to stay with the pavement following wheel until the noncontact sensor has proven successful on the West Virginia profilometer. The new Texas profilometer will be in operation in the 1982 measuring season.

Ohio Profilometer

The first model 690D profilometer to be built with a noncontact pavement profile sensor will be a unit purchased by the Ohio Department of Transportation for delivery early in 1982. An important part of the Ohio profilometer acquisition is their desire for ongoing systems support for the use of the inertial profilometer in their pavement management process. This support, which is available through Surface Dynamics, Inc., as an engineering consulting service, will allow the profilometer system and pavement profile data processing programs to be tailored to their own particular needs. It will also allow development of new programs, required by the agency, to assist in their pavement management process.

NEW PROFILOMETER DEVELOPMENT

Much progress has been made in recent years to make the inertial profilometer a more useful tool in the pavement management process. This development work is continuing and will produce profilometer features designed to assist the profilometer user community.

Pavement Profile Computation Program

Several optional software extensions are being developed for the pavement profile computation program. These extensions, which are designed to provide additional pavement management information, include

1. Reinitialization,
2. Cross-slope computation, and
3. Rut depth measurement.

Reinitialization

The reinitialization option gives the pavement profile computation program the ability to instantly reinitialize the computation of pavement profile, remove all past profile history, and provide accurate profile measurement from the moment of reinitialization. This option is valuable where long wavelength content from prior pavement profile measurement masks short wavelength content of interest and the prior pavement profile is not required. It also provides a method for rapid recovery from transient response that results from measuring vehicle acceleration at start up.

Cross-Slope Computation

In the pavement profile computation program, the pavement profiles of the two wheel paths are computed independently with no established cross-slope relation between the two profiles. The cross-slope computation option provides a valid cross-slope relation between the computed profiles of the two wheel paths. Valid cross-slope information is important in the simulation of paving equipment and the computation of material quantities involved in the pavement resurfacing process.

Rut Depth Measurement

Rut depth information is also important in the computation of material requirements in the pavement resurfacing process. Information on rut depth can be obtained by measuring the relative elevations of the two wheel paths and the quarter-point (half way between wheel paths). To make the rut depth computation three pavement profiles need to be measured and their elevation related by cross-slope information. The rut depth measurement option, therefore, requires hardware to measure a third (quarter-point) pavement profile and cross-slope computation. The third pavement profile is stored on magnetic tape along with the profiles for the two wheel paths.

Profile Processing Programs

Additional pavement profile data processing programs in development include

1. Computer-control grind program and
2. Pavement management data base program.

Computer-Control Grind Program

In the computer-control grind program a computer algorithm is used to remove short wavelength content from the recorded measured pavement profile to produce a pavement profile that meets the desired ride quality. User inputs to the program are desired ride quality, unit cost of grinding, and desired printout distance interval. Outputs of the program, printed on the user's terminal, are depth-of-cut data at the selected distance intervals along the pavement surface, and the estimated total cost of the resulting grinding process. Figure 10 illustrates how the program computes a new pavement profile to meet a desired RMS acceleration ride quality. Figure 11 shows the grind depth-of-cut for each location along the pavement surface. Grind area is the cross-sectional area between the original and ground profiles. The grind cost is for a lane width of pavement. The computer-control grind program is designed to give a grind contractor a list of pavement grind depths that will bring a pavement surface back to a specified ride quality. A computer-control bituminous paving program is also being developed based on the same computer algorithm.

Pavement Management Data Base Program

The pavement management data base program is designed to use the profilometer's computer capacity to process and store large amounts of pavement management field data when the system is not being used for measuring profiles. The digital magnetic tape system can store up to 10 million characters of pavement field data on a 7-in reel of digital magnetic tape. The program gives the user a method for entering, storing, and retrieving field data related to pavement inventory condition by project or sections of a project. Items stored on tape in the field data base include (a) pavement geometrics, (b) traffic volume, (c) traffic loads, (d) structural capacity, (e) ride quality, (f) surface condition, and (g) skid resistance.

The pavement management data base program is intended as a starter system that can be expanded by the addition of a larger bulk storage device, such as a disk, as the user's requirements expand. The profilometer computer system can communicate with a

Figure 10. Computed ground pavement profile.

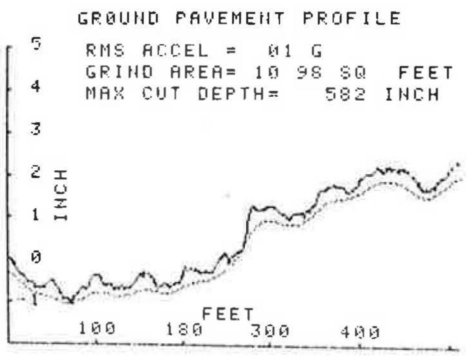
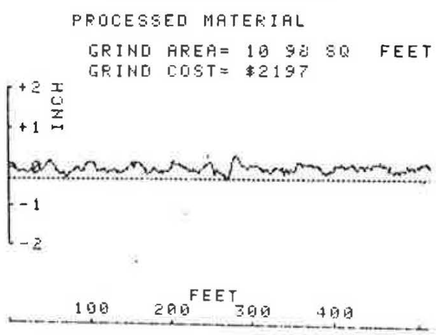


Figure 11. Pavement grind depth-of-cut.



data processing center through a conventional phone line interface.

CONCLUSIONS

The capabilities of the inertial profilometer have continued to improve since its early development at GMR in the 1960s. Its continued development has resulted from advancements in instrumentation, digital signal processing, and the expanded demands of the user community. These advancements have led to a high-quality, cost-effective tool for the evaluation of pavement condition, which has capabilities far beyond its original pavement profile measuring task. The profilometer system's ability to collect, store, retrieve, and process pavement management field data gives it the potential to be an important element in the total pavement management process.

REFERENCES

1. E.B. Spangler and W.J. Kelly. GMR Road Profilometer--A Method for Measuring Road Profile. HRB, Highway Research Record 121, 1966, pp. 27-54.
2. E.B. Spangler and H.A. Marta. Dynamic Measurement of Rail Profile and Related Locomotive Truck Motions. ASME, Rept. 66-RR-1, 1966.
3. J.R. Darlington and P. Milliman. A Progress Report on the Evaluation and Application Study of the General Motors Rapid Travel Road Profilometer. HRB, Highway Research Record 214, 1968, pp. 50-67.
4. W.R. Hudson. High-Speed Road Profile Equipment Evaluation. HRB, Highway Research Record 189, 1967, pp. 150-163.
5. J.L. Burchett, R.L. Rizenbergs, and T.A. Moore. Surface Dynamics Profilometer and Quarter-Car Simulator: Description, Evaluation, and Adaptation. Kentucky Department of Transportation, Lexington, Res. Rept. 465, 1977.
6. T.D. Gillespie, M.W. Sayers, and L. Segel. Calibration of Response-Type Road Roughness Measuring Systems. NCHRP, Rept. 228, Dec. 1980, 81 pp.
7. R.S. Walker and W.R. Hudson. Practical Uses of Spectral Analysis With the Surface Dynamics Road Profilometer. HRB, Highway Research Record 362, 1971, pp. 104-119.
8. R.S. Walker and W.R. Hudson. Use of Profile Wave Amplitude Estimates for Pavement Serviceability Measures. HRB, Highway Research Record 471, 1973, pp. 110-117.

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Prediction and Significance of Wet Skid Resistance of Pavement Marking Materials

D.A. ANDERSON, J.J. HENRY, AND G.F. HAYHOE

A data base of full-scale locked-wheel skid resistance is presented for typical marking materials, including traffic paints of various formulations, hot spray and extruded thermoplastics, cold preformed plastics, temporary tapes, and some two-part systems. A variety of pavement surface types, including dense- and open-graded asphalt and portland cement concrete, are used in the study. British pendulum numbers and macrotexture profile data are presented for field applications and for laboratory samples of marking materials. Equations are developed for predicting skid resistance from these data. The effects of glass beads, weathering, and polishing are examined in laboratory and field experiments. In all cases, the skid resistance of the marking materials is less than that of the pavement to which they are applied. From the results of a simulation study, a description is given of the effects of differential pavement friction on the handling and stability of four-wheeled vehicles and single-track vehicles. A tentative procedure for setting minimum acceptable levels of marking material skid resistance for four-wheeled vehicle operation is developed from the simulation results. A procedure for setting minimum levels of skid resistance for single-track vehicle operation could not be established. An alternative approach to the problem is suggested.

Little is known about the high-speed wet skid resistance of pavement marking materials. Michigan (1) measured the skid resistance of paints and plastics installed on concrete pavements. Skid resistance at 64 km/h (SN_{64}) ranged from 4 to 37 and British pendulum numbers (BPN) ranged from 14 to 31. These values are cause for concern, particularly during