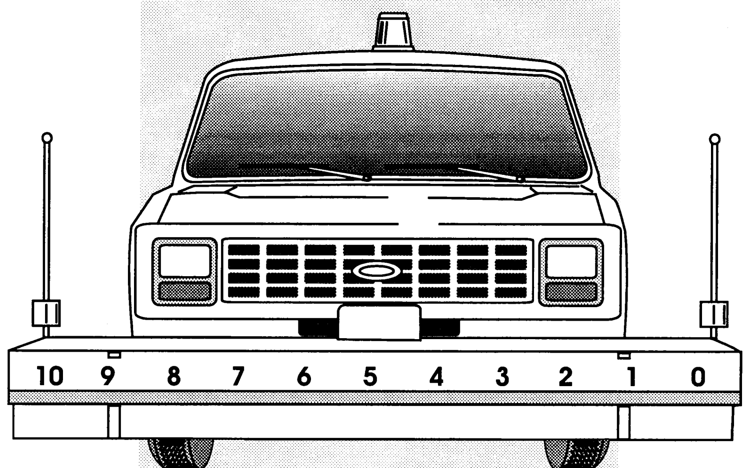
SUMMARY REPORT

EVALUATION OF A LASER ROAD SURFACE TESTER



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Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
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ABSTRACT

The purpose of this study was to evaluate the accuracy and usefulness of pavement distress data derived from a laser road surface tester (RST) operating on Virginia's interstate highway system. The evaluation was conducted by comparing rut depth, roughness, cracking, and macrotexture measurements generated by the Laser RST with those obtained using conventional methods.

The study concluded that the laser RST was not adequate as a crack pattern recognition tool. The device was not capable of generating surface macrotexture or rut depth measurements that would be of use to the Virginia Department of Transportation. Roughness information collected by the laser RST correlated well with the May's ridemeter and the K.J. Law 8300 roughness surveyor. It should be noted, however, that several years have passed since the data used in this study were collected, during which time the laser technology changed significantly.

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INTRODUCTION

A major commitment of pavement management resources is the collection by field rating teams of data from which the surface condition of pavements can be determined. Another is the automated collection of ride quality and skid resistance data. One of the authors estimated that some 10,000 staff hours are required annually in Virginia to collect the data pertaining to the surface condition of pavements. Since these data are essential to the pavement management process, pavement management personnel are constantly looking for means to automate the data collection and minimize the exposure of staff to the hazards of working in traffic.

One avenue showing potential for automated data collection is the use of multi-instrumented vehicles capable of accomplishing many of the desired tasks in one pass at near normal traffic speeds. In recent years, several such vehicles have been developed in the United States and abroad. One of them is the laser road surface tester (RST).

This equipment, developed in Sweden, uses noncontact high-speed laser technology to measure pavement condition. Data outputs purportedly can be reduced to evaluate pavement discontinuities (cracking, faulting, etc.), rut depths, ride quality, and surface texture (which may correlate with skid resistance). Data collection and reduction are fully automated and supposedly can be easily interfaced with existing pavement management systems.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the accuracy and usefulness of data collected by a laser RST operating on Virginia's interstate highway system. In addition, a limited study of the reproducibility of the equipment's measurements was conducted.

The timing of the study corresponded approximately with the spring 1988 interstate flexible pavement condition surveys conducted by field rating teams. The reason for these concurrent activities was to permit the ready assessment of RST measurements in the pavement management process at both the project and network levels.

The laser RST tests were conducted in a timely manner by the RST contractor. However, because of other priorities, the research staff was able to conduct only a superficial evaluation of the laser work. Further, several years have passed since the data were collected, during which laser technology changed significantly. Thus, the information no longer reflects current technology. For these reasons, a summary report rather than a standard research report was prepared.

DATA COLLECTION

In the interest of supporting new pavement management technologies, the Maintenance Division of the Virginia Department of Transportation (VDOT) contracted for and funded laser RST data collection for the entire interstate system. Data were collected in the outside (truck) lane in both directions of all interstate pavements, providing a database of approximately 3900 lane km (2,400 lane miles). For much of the work, a VDOT representative, from either the Maintenance Division or the Virginia Transportation Research Council (VTRC), rode in the van to observe the collection of data and gain an understanding of the process. These observations ceased once VDOT was satisfied that the contractor's staff was producing data of a quality commensurate with the capability of the equipment.

Data were collected through the use of 11 lasers spaced across a bar 2.6 m (8.5 ft) long mounted on the front of the contractor's van, as shown in Figure 1.

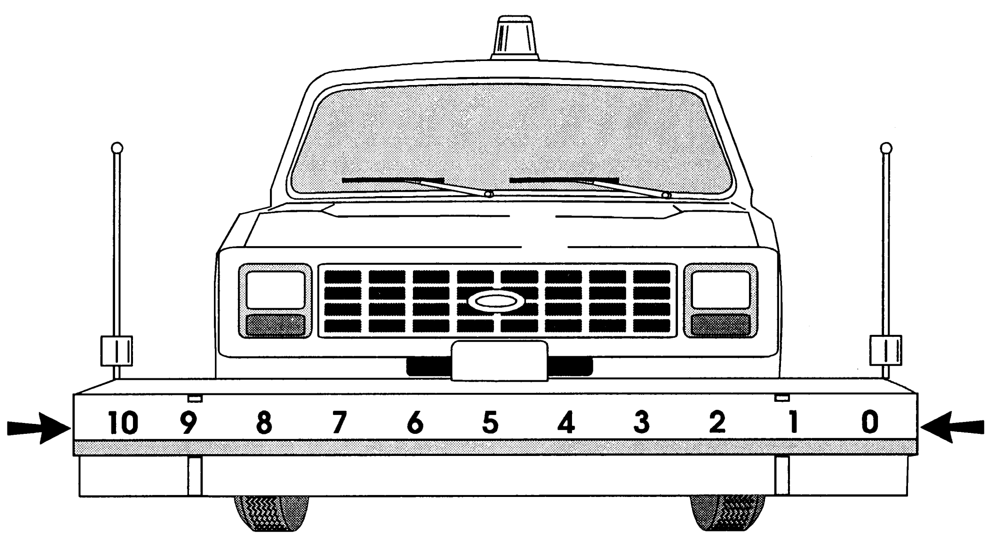

Figure 1. Employment of lasers.

The lasers served to discern the following features (laser numbers refer to Figure 1):

- *rut depth,* used all 11 lasers
- *longitudinal profile,* used lasers 2 or 8
- *macrotexture,* used lasers 2 and 8
- *cracking,* used lasers 2, 4, 6, and 8.

The following description of laser configurations, speeds of operation, and functions is consistent with the RST contractor's documentation at the time the measurements were made in early 1989.[1] Lasers 1, 3, 5, 7, and 9 are "regular" lasers, which operate at 16 kHz and send signals to the computer card that computes rut depth only. Lasers 0 and 10 are angled lasers, which operate at 16 kHz and are positioned at a 45-degree angle outward, making it possible to measure a width of 3.1 m (10 ft) with a laser bar only 2.6 m (8.5 ft) wide. The angled lasers send signals to the computer card that computes only the rut depth. Lasers 2, 4, 6, and 8 are combination lasers, which operate at 32 kHz and send signals to the rut depth, macrotexture, cracking, and profile-measuring computer cards.

The system is based on the principle that the angular relationships between the light emitted by a laser transducer and that detected by the transducer are dependent on the elevation of the transducer with respect to the pavement over time.

Through negotiation with the contractor, the data elements discussed in subsequent sections of this report were defined for the work in Virginia. In each case, data were written to the automated files in pavement increments of, on average, both 160 m (1/10 mile) and 1.6 km (1 mile). Files were written in ASCII format on 133 mm (5 1/4 in) floppy disks for transfer to VDOT's personal computers for database management and statistical analysis.

Bridges were omitted from the testing except for a few very long bridges where the contractor deemed the test necessary in order to provide continuity of the data.

Rut Depth Measurement

All 11 lasers supply signals to a computer card that computes rut depth. Every 0.10 mm, the deepest rut encountered by each laser is recorded. A transverse profile of the pavement is then plotted by the computer card.

Rut depth is measured by the wire method (see Figure 2). In this method, a straight line (the wire) is projected between the 1st and 11th lasers, and that line is used as the datum for measurement of deviations from a plane surface by the other 9 lasers. At the end of the test

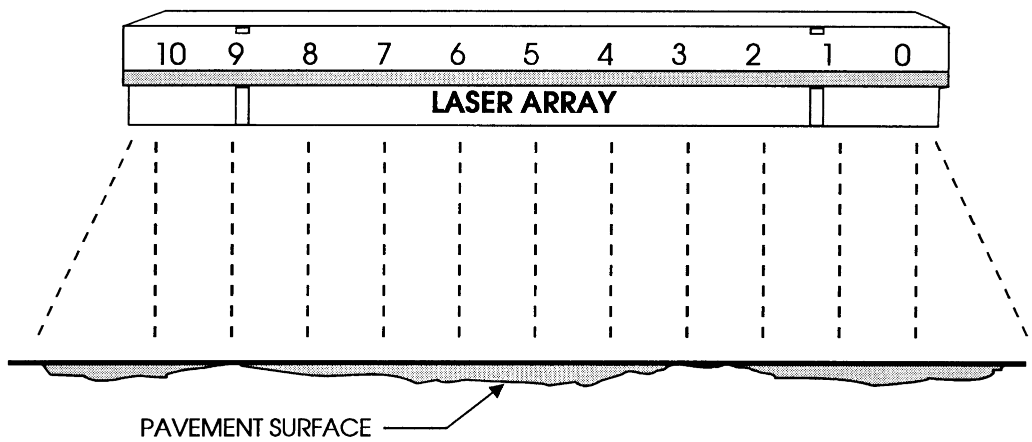

Figure 2. Sample transverse laser array and rut plot.

section, an average rut depth is reported and the percentage of the distance where the rutting was greater than 13 mm (1/2 in) and 25 mm (1 in) is reported.

Measurement of Longitudinal Profile and Determination of Roughness

To measure longitudinal profile, three measurements are recorded simultaneously at a frequency of 250 Hz over the length of the test section:

1. vertical movement of laser 8, measured with an accelerometer used to maintain a horizontal plane of reference

2. vertical movement of the pavement with respect to the laser, recorded with laser 8

3. horizontal velocity of the laser, measured with the pulse transducer (a speed measuring device mounted on the right front wheel).

With these measurements, a true profile slope is calculated at a sampling rate of 250 Hz. The international roughness index (IRI) (quarter car) and root-mean-square-vertical acceleration index are calculated from the true profile slope for each 20-m section within the test limits.[2]

Measurement of Cracking

Lasers 2, 4, 6, and 8 supply signals to crack-measuring computer cards that register cracking and categorize it according to its width and depth. The cards essentially determine that variations in surface elevation greater than the pavement texture are cracks (see Figure 3). Average depths and widths of cracks are stored in the computer in the appropriate categories. The measurement ranges chosen for Virginia were widths of 1.5 to 3.0 mm (1/16 to 1/8 in), 3 to 6 mm (1/8 to 1/4 in), 6 to 13 mm (1/4 to 1/2 in), and over 13 mm (1/2 in) measured at depths of 3 to 6 mm (1/8 to 1/4 in) and over 6 mm (1/4 in). Since the lasers must cross a crack in order to measure it, longitudinal cracks, having no transverse component, are ignored.

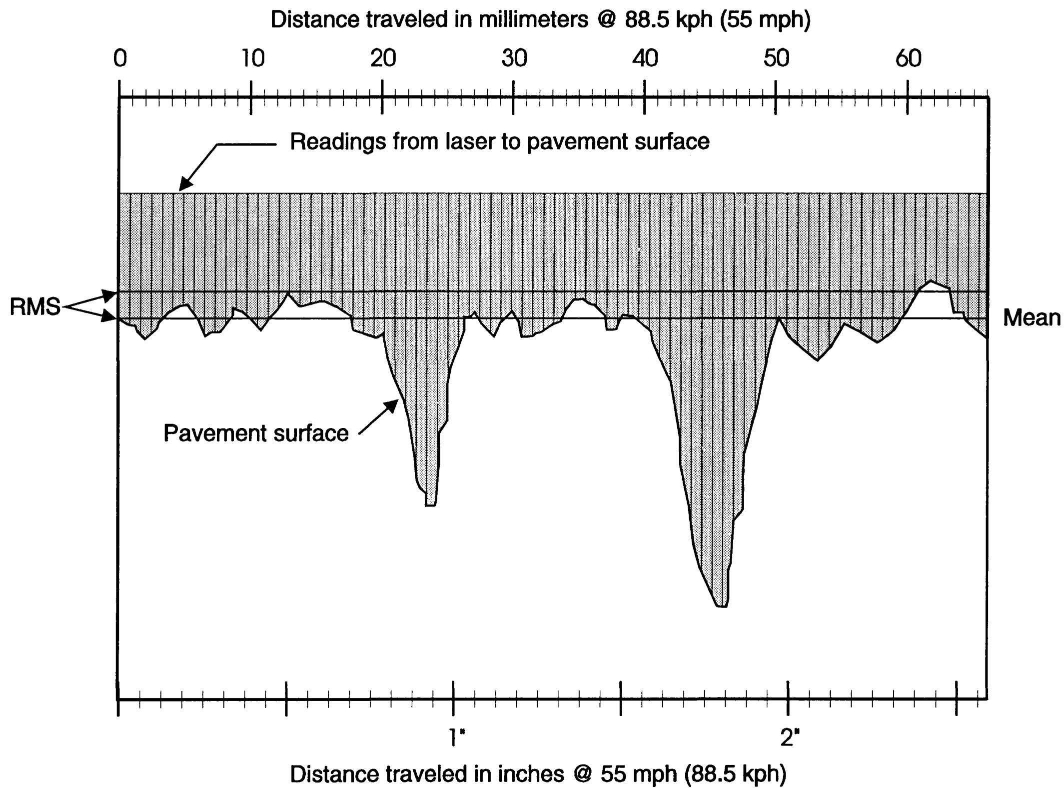

Figure 3. Sample laser crack measurement.

Macrotexture Measurements

Lasers 2 and 8 supply signals to macrotexture measuring cards in the computer. The 32-kHz lasers (one in each wheel path) provide one measurement each 0.75 mm (0.03 in) of travel at a speed of 55 mph.

The two parameters used to represent texture are the root-mean-square amplitude and the average wave length.

The texture is sorted into various wave forms in the computer where wave lengths of 2 to 10 mm (0.08 to 0.40 in) are considered to be fine macrotexture and those between 10 and 100 mm (0.40 to 4 in) are classed as rough macrotexture. The values reported for each 160-m (0.1-mile) pavement section are the wave length, the root-mean-square amplitude for each class of texture, and a distribution of the texture over 10 amplitude ranges from 0 to 5 mm (0 to 0.20 in). These definitions of *texture,* including the usual physical manifestations, are given in Table 1.[1]

Table 1: Texture Definitions

Texture	Length (mm)	Influences
Macro	>100	Ride
Rough	10 to 100	Noise
Fine	2 to 10	Friction

RESULTS AND DISCUSSION

Repeatability Testing

In order to provide a basis for comparing the laser RST results to other means of pavement evaluation, a series of 30 tests was conducted on two pavements having two very different levels of distress. One was newly resurfaced, and the other was severely cracked with significant wheel-path rutting. In addition to establishing the degrees of reliability of the single-pass network tests to be conducted on the interstate system, this activity was intended to provide an indication of how much testing would be necessary to validate the various data elements. It was hoped that no more than about 30 test sections would be needed to establish a high degree of confidence in correlations or other measures of compatibility between laser RST measurements and other pavement evaluation methods.

Unfortunately, on the cracking parameter, the lasers were unable to distinguish between a badly cracked old surface and a new surface with a harsh texture, so testing on the first two sites was abandoned. No further attempts were made to use the laser data to characterize cracking.

Rut Depth Measurements

The capacity of the laser RST to measure rut depth was evaluated by comparing transverse point elevations (corrected for cross slope) measured by laser to the same elevations measured manually. A static inclinometer (Face Dipstick[R]) was used to make the comparative measurements after establishing that a good correlation ($R^2 = 0.99$) existed between sample readings obtained with the Dipstick^R and those obtained with a metal straightedge.

Transverse point elevations were measured with the Dipstick^R at 50-ft stations along 30 randomly selected test sections. Each test section was 0.16 km (1/10 mile) in length. After correcting the elevations for cross slope, the readings for each station were averaged and compared to the average transverse point elevations measured by the laser RST at the same locations.

Results of the regression analysis indicated that the RST rut depth data correlated poorly with the Dipstick data ($R^2 = 0.23$). The regression equation is not presented because of the low resulting correlation coefficient.

The authors are not able to offer an explanation for the poor rut depth correlation obtained in this study. It is worth noting, however, that a similar study conducted in 1987 by the Georgia Department of Transportation attributed their poorly correlated laser RST vs. stringline rut depth measurements to improper calibration of the laser sensors.[3] In that study, subsequent correction of the calibration procedure resulted in a much improved correlation ($R^2 = 0.86$).

Longitudinal Profile Measurements and Determination of Roughness

A total of eight 1.61-km (1-mile) sections of roadway were measured for roughness with a calibrated Mays ridemeter, a K.J. Law Model 8300 roughness surveyor, and the laser RST. A total of five tests per site were made with each device, and the resulting IRI values were then averaged and compared to the laser RST quarter-car results.

Results of the linear regression analysis for laser RST IRI vs. Mays IRI and K.J. Law 8300 IRI, presented in Figures 4 and 5, respectively, indicated that the RST roughness measurements correlated well with both devices. The coefficients of determination, R^2, were on the order of 0.86 and 0.91 for laser RST vs. Mays and laser RST vs. K.J. Law 8300, respectively. A standard error of 0.096 m/km showed that one could be reasonably certain (95%) that the laser RST would predict the Mays results within about 0.2 m/km (two standard errors). Similarly, a standard error of 0.074 m/km suggested that the K.J. Law 8300 roughness predicted by the laser RST should be within 0.15 m/km 95% of the time.

Macrotexture Measurements

An attempt was made to define the relationship between pavement texture measured by the sand patch method and macrotexture measurements made by the laser RST. The sand patch method is a means of determining surface macrotexture depth by applying a known volume of sand on the pavement surface and measuring the total area covered. The relationship between sand volume and measured patch area is then used to calculate the average depth of the interstices created by the pavement's macrotexture, which may be a suitable indicator of overall

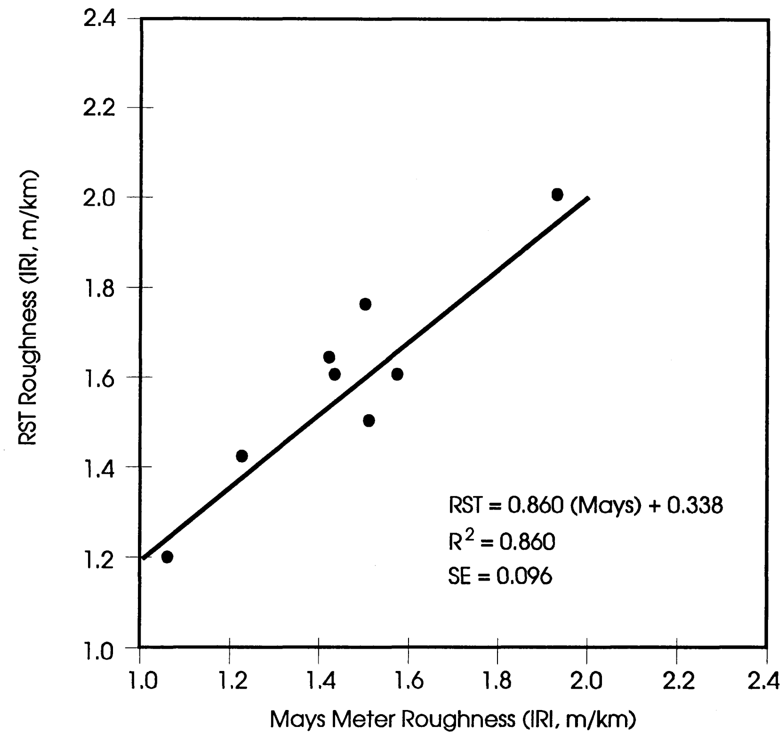

Figure 4. RST - predicted Roughness v. Mays Meter Roughness

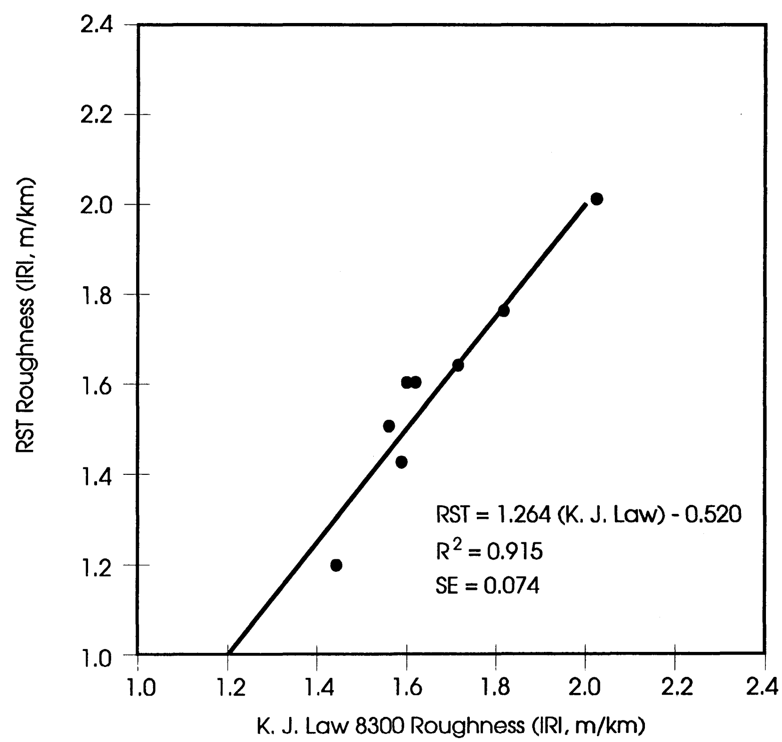

Figure 5. RST - predicted Roughness v. K. J. Law 8300 Roughness

texture and skid resistance. A total of 30 sites (representing a wide range of textures) that were surveyed for macrotexture by the laser RST were selected for sand patch testing to enable a comparison of texture distribution as defined by the two methods. Sand patch tests were conducted in the wheel paths to coincide with the RST lasers used to measure texture.

Results of the repeatability testing phase suggested that the laser RST was not capable of distinguishing between the harsh texture and large cracks exhibited by many of the pavements in this study. Analysis of the RST macrotexture data demonstrated that they correlated poorly with sand patch texture. Consequently, the data were of little value in our effort to assess the skid resistance of Virginia's interstate pavements.

CONCLUSIONS

The laser RST was modified in recent years to take advantage of significant advances in automated pavement data collection technology.[4] Although a number of the shortcomings reported here may have been corrected since this study was initiated, these conclusions are based entirely on observations made during our 1988 evaluation and do not reflect any improvements or changes made to the equipment since that time.

The following conclusions are offered:

1. The laser RST is not capable of distinguishing between large cracks and macrotexture and, therefore, is inadequate as a crack pattern recognition tool at the network and project levels.

2. Macrotexture measurements by the laser RST are not sufficiently repeatable to establish a correlation with the sand patch method.

3. The laser RST does not correlate well with the Face Dipstick[R] with regard to rut depth measurements.

4. Useful roughness information for Virginia's interstate system can be collected by the laser RST. The device correlates well with both the Mays ridemeter and the K.J. Law 8300 roughness surveyor with regard to such information.

Because of the rapidly changing technology upon which this device's operating principles are based and the resulting modifications made by the manufacturer since this study was initiated, additional research is recommended to evaluate the laser RST with regard to its current capacity to measure, at a minimum, cracking, macrotexture, and rut depth.

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