Measuring Wet-Night Delineation Reflectivity

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Reflectorized pavement markings provide drivers valuable continuous information about the roadway and its characteristics. In particular, edge lines provide a strong orientational influence, whereas centerlines indicate the direction of traffic and further delineate the traveling lane. Unfortunately, pavement markings can lose their reflectivity, and thus their visibility, on dark rainy nights just when drivers are more apt to actively look to them for guidance. Much research has been devoted to the issue of wet-night visibility. Available methods of measurement have been limited to panels of visual evaluators and telephotometers. Both methods are difficult to apply in field test programs. This paper focuses on the problems involved in measuring wet performance easily and effectively and discusses an alternative measuring system. A new concept in retroreflectometers currently being researched uses a laser light source and a narrow band-pass filter to block ambient light. This mobile, day/night, wet/dry instrument should help accelerate development and demonstration of wet reflective delineation and provide insights and better understanding of the relationship between delineation performance and drivers' visual needs.

Driving decisions are based 90 percent on visual cues *(1)*. The roadway environment must provide clear and uniform information messages to support those decisions. Rain, fog, and darkness can obscure vital visual communication from the road (Figure 1). Approximately 54 percent of fatal crashes occur at night; 14 percent occur when the road is wet *(2)*, even though there is relatively less driving under those conditions. Crashes of this type can be reduced cost effectively by enhancing visual communication from the road with delineation that is more easily seen under rainy night conditions.

The need for both wet reflective systems and methods for measuring their performance has been widely acknowledged and has been noted in the soon-to-be-published report "Visual Aspects of Road Markings" from the Commission Internationale De l'Éclairage. Potters Industries Inc. has been involved in numerous efforts to demonstrate the wet-night visibility effectiveness of various striping systems, particularly those using large glass beads (Figure 2). Measurements of effectiveness using telephotometers and lights were erratic at best. A low-light video camera system and standard headlights enabled objective, permanently recorded wet performance demonstrations. However, it has been recognized that, although this method provides a good demonstration, this system does not give the quantitative comparison desired for good research.

Descriptions follow of two methods that have been used and the ways in which their deficiencies ultimately led to the development of a laser-illuminated retroreflectometer. This instrument is currently being tested and will probably lead to a mobile system for collecting quantitative, calibrated data.

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THE BOPPARD SYSTEM

One effective system for quantitative comparison of either wet- or dry-night retroreflection was established in conjunction with a wet visibility study near Boppard, Federal Republic of Germany. To achieve an objective and reproducible comparison, a method of simulating a fixed rainfall was developed. The rain was generated in a tent-like enclosure by using a metered water flow sprayed as a mist, which then coalesced and dripped from a net below the spray. This system was placed over the test spot at night and could be used for either visual or instrument readings.

For the instrument readings, a luxmeter was used to monitor illuminance, and a Morass telephotometer was used to read luminance. The spotlight was 0.67 m above the road and 28.5 m from the target, which was a coentrance angle of 1.5 degrees. The telephotometer was 1.2 m above the road and 30 m from the target, giving a coviewing angle of 2.5 degrees and an observation angle of 1.0 degree.

As part of the study, this system was used to observe changes in the retroreflectivity of test lines when the rain was turned on and again when it was turned off. The primary purpose of the study was to periodically measure the performance of 13 test lines in the field over a period of 3 years. Readings were taken under both dry and wet conditions. Generally, the test lines that performed best under wet conditions retained up to 50 percent of their coefficient of dry retroreflectivity in the artificial rain. These results have been reported in detail in German *(3)*, and a summarized English translation will probably be available soon. However, it is important to emphasize the need to forsake real-world conditions in this study to obtain the quantitative and reproducible results that can only be achieved under artificial conditions.

WOOD RESEARCH CENTER

The Wood Research Center was built as a research facility for the study of reflective materials in a dark environment under wet or dry conditions (Figure 3). This 75-m-long, 10-m-wide structure (Figure 4) houses a moveable vehicle simulator with headlights that can be adjusted vertically and a telephotomultiplier (Figure 5) that can be adjusted vertically and horizontally to simulate the driver's visual perspective. The

FIGURE 1 Ordinary stripes in the rain.

FIGURE 2 Large glass bead lines in the rain.

telephotomultiplier has a beam splitter that allows for visual aiming and a detector with a pinhole aperture that limits its field of view to about 7 cm at 50 m. Thus it can read the comparative retroreflection of lines placed 50 m away, using actual driver and headlight elevations. Longer visual distances can be simulated by lowering the driver and headlights to the appropriate angle.

The center has a grid of sprays about 4 m above the test lines that generates a rainfall of 6 to 18 cm/hr. Thus a series of test lines can be compared wet or dry. The floor of the center is designed as a typical two-lane road with crowned bituminous paving. To preserve this condition, test lines are applied to plates that are then laid on the crowned surface. In earlier tests, it had been found that lines on smooth plates do not equate in performance to lines on actual road surfaces, especially in rainfall. Currently, test lines are applied to simulated road surface panels cast on a mold of an actual road surface of medium roughness.

Instructive as the center has been about wet reflectivity, it did not allow for quantitative and reproducible field measurements. The video camera, although it greatly enhances objective and permanently recorded field studies, is not quantitative.

LASER RETROREFLECTOMETER

In the attempt to read retroreflectivity with a spotlight and photomultiplier in on-road, real-world tests, the geometric problems of measurement became clearer. Because of the small angles above the road surface, slight changes in equipment or road surface angles result in large errors in readings. Use of a laser beam to attempt to overcome these problems by tracking the positioning and angles of some normal optical equipment led to the development of the concept of a laser retroreflectometer. Described simply, a laser can serve as the light source, and a detector with a narrow band-pass filter can measure the returned laser light (Figures 6 and 7). Three major benefits of a

FIGURE 3 A view in the center.

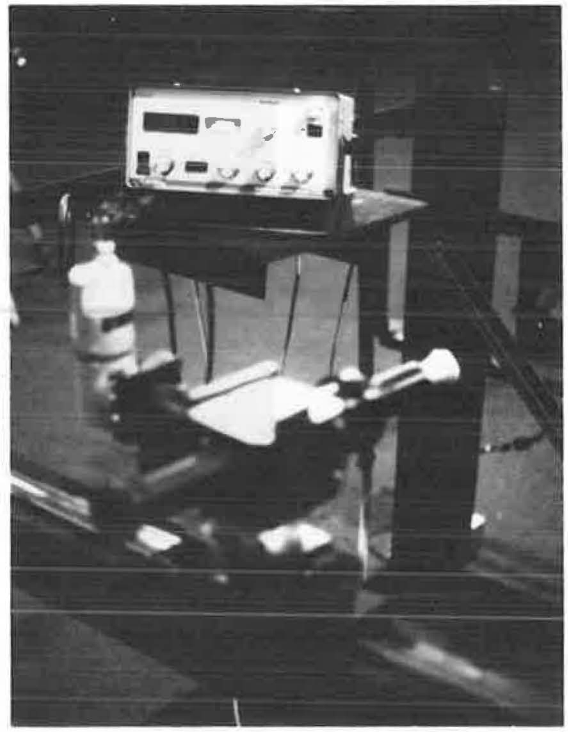

FIGURE 5 Telephotomultiplier.

laser retroreflectometer are immediately identifiable in the optical sense:

1. The detector, because of the narrow band-pass filter, automatically reads luminance from the same target area illuminated by the known light quantity in the laser beam. Hence the coefficient of rectroreflectivity can be calculated without measuring illuminance at the target.
2. The narrow band-pass filter also serves to eliminate nearly all ambient light so that a good signal-to-noise ratio is obtained without enclosing the target area.
3. The open target area allows for readings under adverse conditions, particularly rain, without interfering with those conditions.

This instrument, with its ability to reject ambient light, has the potential to be mobile and thus to take readings while mounted on a moving vehicle. The remaining foreseeable problem is that the distance between the instrument and the target may vary when the road is uneven. Because the luminance reading depends on the distance, either it must be held constant or the result must be corrected for variation. A tracking system that can solve this problem is anticipated.

CONCLUSIONS

Most of the work being done in retroreflective measurement is based on the coefficient of retroreflectivity. The coefficient

FIGURE 4 Wood Research Center.

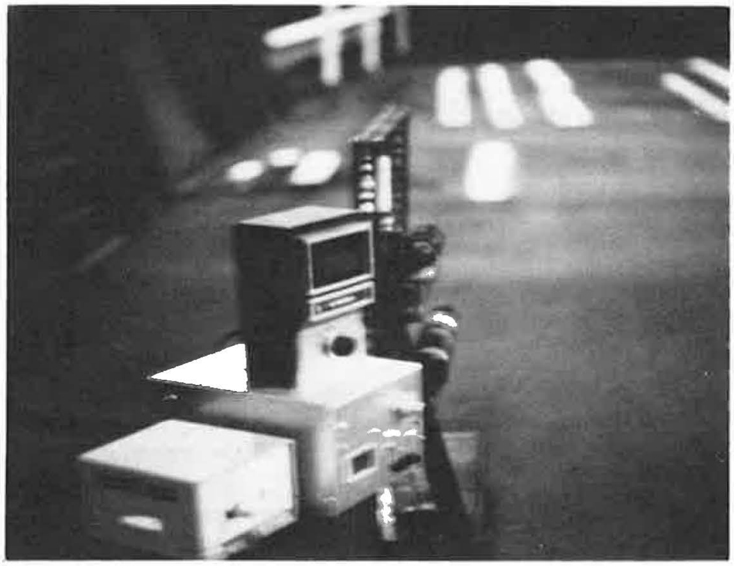

FIGURE 6 Laser retroreflectometer.

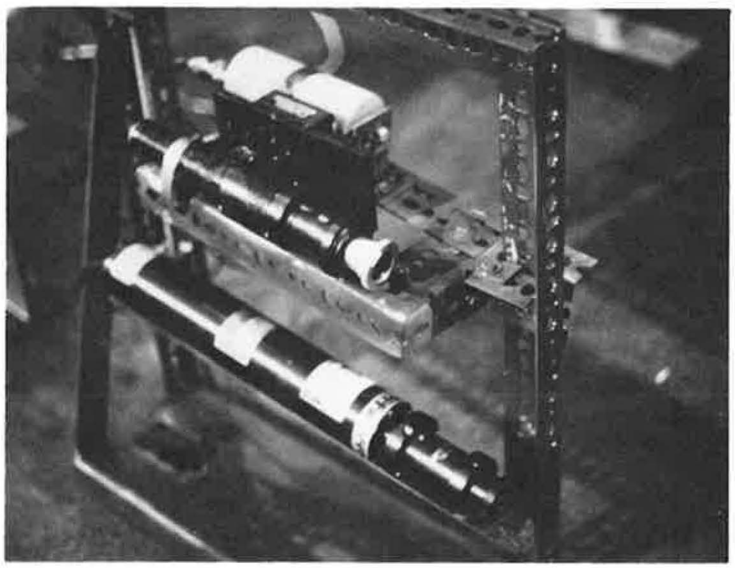

FIGURE 7 Telephotomultiplier and laser.

gives a quantitative and reproducible measure of the performance of a line. However, the eye sees primarily through contrast. The effort to connect delineation performance and drivers' needs has been somewhat clouded by this difference. With a mobile laser retroreflectometer, it will be possible to measure background luminance and record both the coefficient and the contrast luminance of a line along significant distances of road. This capability may provide some new insight into the relationship between delineation performance and drivers' needs. The development of a mobile laser retroreflectometer will enable, for the first time, quantitative measurement useful both to research scientists and traffic engineers in the evaluation of wet- and dry-night performance of lines under real-world conditions.

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