A Simplified Method for Obtaining Pavement Reflectance Data

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A pavement reflectometer for measuring the directional reflectance properties of pavement surfaces was developed by the authors for making field measurements on several pavement surfaces. This paper describes the apparatus and the operating procedure and presents a typical set of directional reflectance factors obtained with the reflectometer.

•ALTHOUGH illuminating engineers in the United States now generally recognize that one of the principal objectives of roadway lighting is "to enhance the brightness of the pavement and the uniformity of brightness along and across the full width of the roadway..." (1), it is still common practice in this country to specify such lighting in terms of illumination rather than luminance. This practice implies that the roadway brightness patterns are adequate if the average horizontal illumination is at the recommended level. But rather than rely entirely on the light incident on the surface to reveal the roadway scene, we should consider the amount of light emitted from the surface in the direction of the observer, because the information needed by the motorist to evaluate the visual scene is provided by the brightness patterns on the roadway (2). In this regard, the roadway ahead of the motorist should present an average brightness adequate to maintain eye adaptation, a minimum brightness to assure adequate visibility of any object on or near the roadway, and a uniformity sufficient to maintain continuity within the visual scene, to insure comfort, and to render frequent and rapid eye movements by the driver unnecessary. Many illuminating engineers have long been aware of the inadequacy of an illumination specification, and have frequently suggested roadway luminance as a substitute parameter for design purposes, but the latter has seldom been used in this country.

The statement, "the apparent brightness of the pavement depends upon the intensity and angle of incident and reflected light and the pavement reflecting characteristics (specular and diffuse) at typical angles of view" (1), perhaps gives a clue to the reasons for adhering to an illumination specification even though it is generally acknowledged that a luminance specification would be preferable. Whereas levels of illumination are relatively easy to determine, either by measurement or calculation, the derivation of roadway luminance from photometric data involves tedious measurement of pavement reflectance, as well as a formidable number of calculations. Developments in recent years, however, have greatly simplified this task, a straightforward method for computing roadway luminance having been previously reported by one of the authors (2). The calculations, moreover, by their repetitive nature, lend themselves readily to simple computer programming.

Nevertheless, the lack of reliable information concerning the reflecting characteristics of pavements seems to be a retarding factor in this process. Several attempts in the past to measure directional reflectance factors for representative roadway surfaces have met with only limited success (3, 4, 5). Field and laboratory studies have produced few published data, and of this only the field data appear usable. The collection of field data has generally employed either visual photometry or photographic

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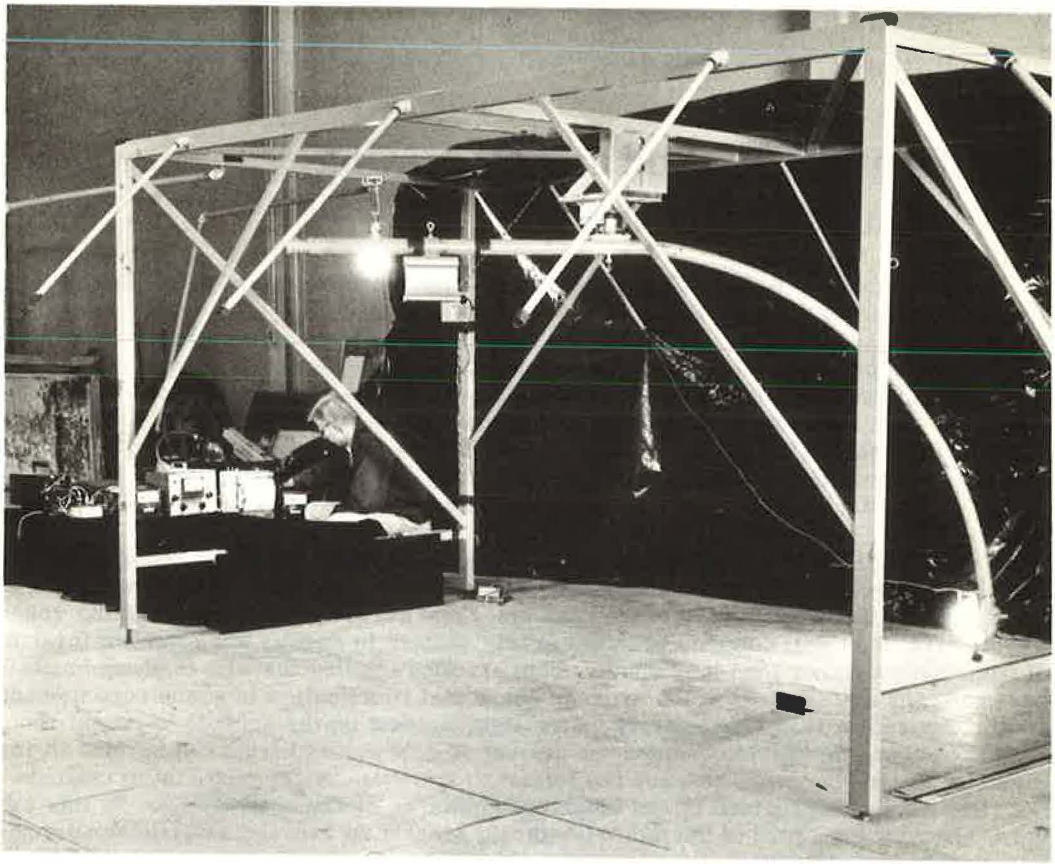

Figure 1. Pavement reflectometer, set up for operation.

techniques, and while both of these methods offered advantages at the time they were used, the direct reading instruments available today provide a basis for a more mechanized and less time-consuming procedure.

This paper describes a method of obtaining the directional reflectance factors of road surfaces based on field measurements with a pavement reflectometer developed by the authors. The operation of the apparatus is described and a typical set of directional reflectance data in the form of curves is shown.

PAVEMENT REFLECTOMETER

The reflectometer (Fig. 1) is basically a form of goniometer consisting essentially of an incandescent lamp mounted on a curved rotating boom and a rigidly mounted telephotometer with provisions for angular position adjustments (Fig. 2). By means of detents in the boom, the lamp may be positioned to illuminate a given spot on the pavement surface from any of a number of vertical angles. The boom is motor driven and rotates the lamp through a 360-deg horizontal angle about the illuminated spot. The telephotometer is aimed and focused on the illuminated spot, and its position can be adjusted to correspond to typical driver viewing angles.

The output of the telephotometer is amplified and fed to a strip-chart recorder which provides a continuous trace of the telephotometer output as the boom rotates the lamp through 360 deg. The amplitude of the trace is directly proportional to the output of the

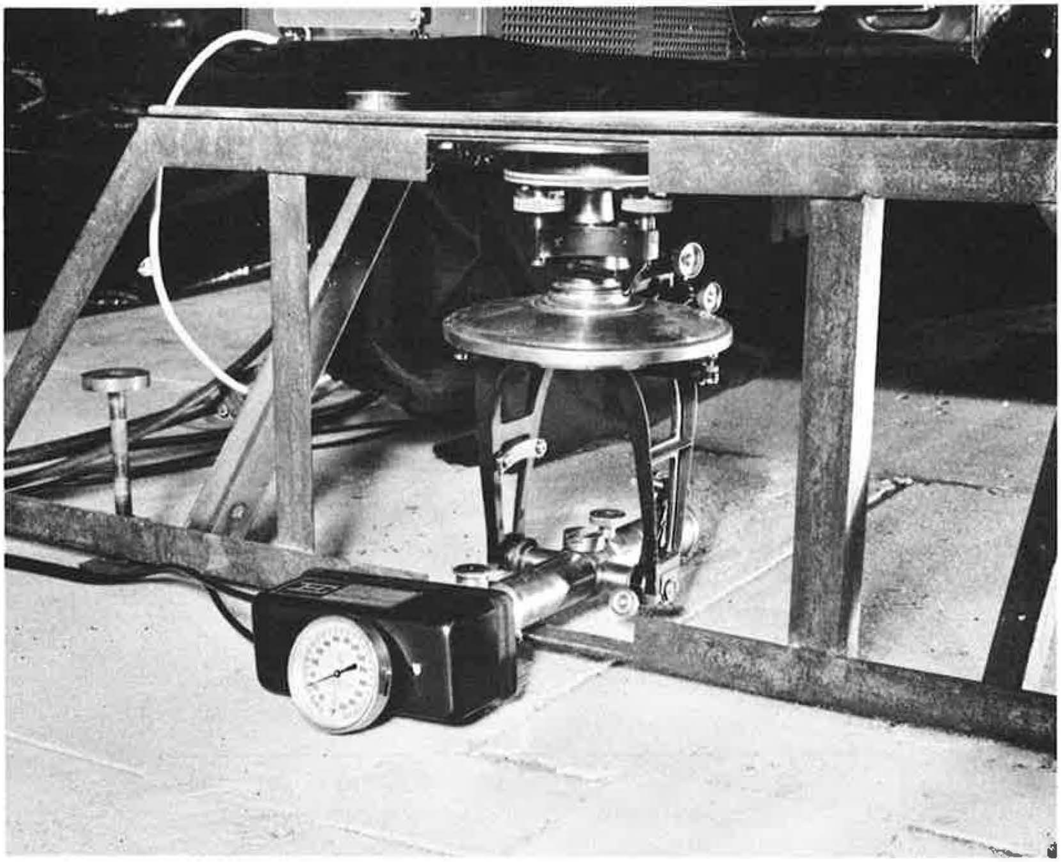

Figure 2. Telephotometer used in pavement reflectometer.

telephotometer, and previous calibration allows the determination of the directional reflectance factor of the pavement surface for any combination of observer and light source positions.

The overall dimensions of the reflectometer permit it to fit within a single 12-ft traffic lane. The framework is made of steel members braced and welded to form a rigid structure.

The reflectometer boom has a 4-ft radius and is driven by a 115-VAC, 10-rpm, synchronous motor through a gear train salvaged from a radar antenna turntable.

The light source, a 120-volt, 300-watt, type R-40 inside-coated reflector lamp, is accurately positioned on the boom by a spring-loaded pin and detent arrangement. Locations corresponding to vertical angles of 5, 20, 35, 50, 60, 65, 70, 75, 80, 82, 84, and 86 deg are provided for. Adjustments are also provided for the alignment of the lamp. Figure 3 shows the isocandle diagram for the lamp in percentage of maximum candlepower. The central 30-deg cone is quite uniform, the greatest deviation from the maximum being approximately 10 percent.

The telephotometer consists of a modified surveyor's transit and a photomultiplier tube whose signal is fed into a dc amplifying unit. Provision is made within the telephotometer for inserting various apertures to limit the acceptance angle and filters to correct for the color response of the phototube. Figure 4 shows the stray-light rejection curve for the aperture used in obtaining the data in this paper. This curve shows

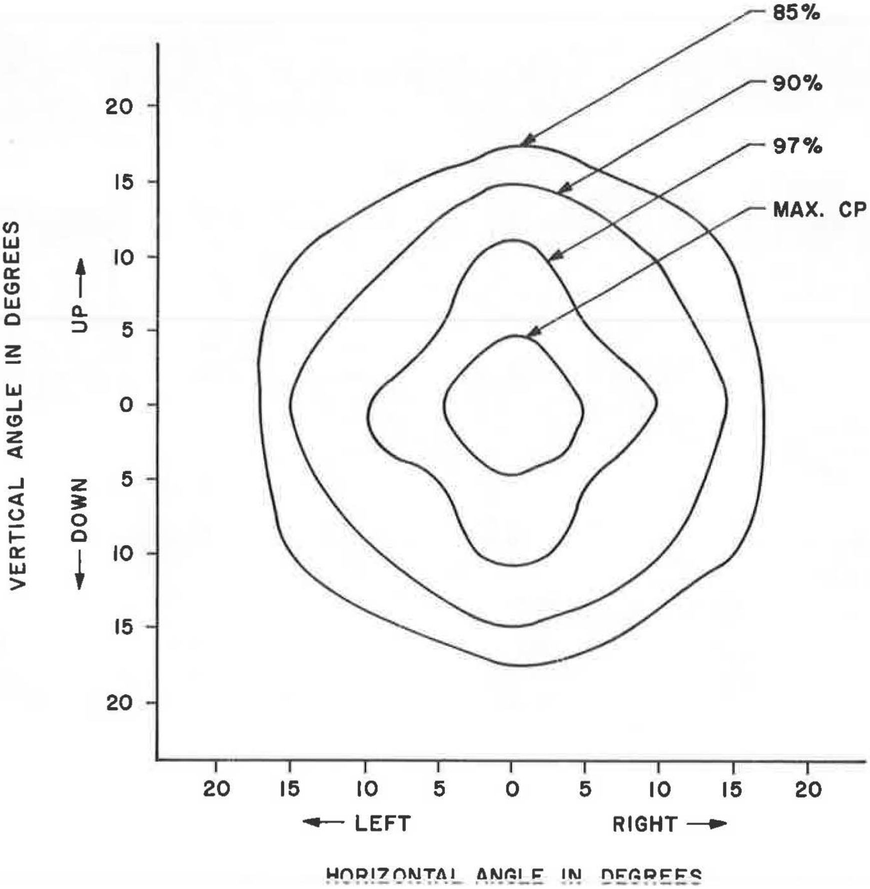

Figure 3. Isocandle diagram for test lamp used in pavement reflectometer.

the effective acceptance angle to be approximately 3 min. The output of the telephotometer-amplifier unit is calibrated in terms of foot-Lamberts. Standardizing checks are performed by making luminance measurements on a strip of white matte blotting paper with both the telephotometer and a spectra brightness spot meter (½-deg UB model) and comparing the results.

The framework of the "tunnel" in which the telephotometer is housed serves to position the instrument precisely relative to the illuminated spot on the pavement surface; the distance between the telephotometer and the center of the illuminated spot is 12 ft. A covering over the tunnel provides additional stray light protection, and the entire tunnel can be moved to either left or right to simulate various observer lane positions. Various viewing distances are simulated by placing spacers of appropriate thickness under the rear legs of the tunnel, and thus elevating the telephotometer.

The output of the telephotometer-amplifier unit is recorded on a 5-in. strip chart, with the repeated actuation of a microswitch in the boom-drive mechanism causing the recording chart to be marked at 5-deg intervals to simplify the data reduction (Fig. 5).

The pavement reflectometer requires a 115-volt ac power source. Some of the equipment for regulating, stabilizing, and monitoring both the primary power and the various electrical elements of the system is shown in Figure 1.

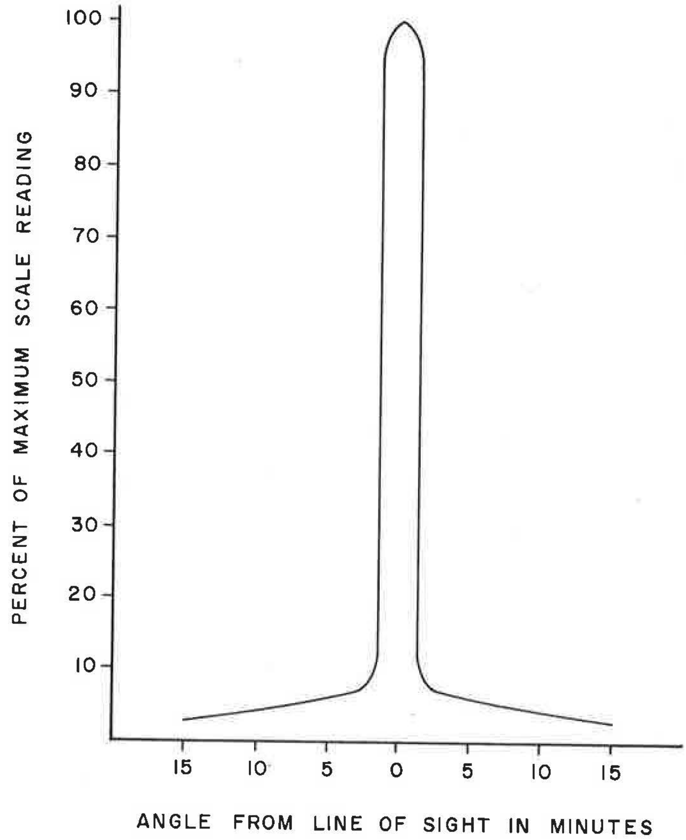

Figure 4. Stray-light rejection curve for telephotometer used in pavement reflectometer.

OPERATING PROCEDURE

The reflectometer, partially disassembled, is customarily transported to the site of a flatbed truck and then completely assembled in place. Each leg of the goniometer framework is adjusted by a leveling screw so that the lower end of the boom rotates in a plane parallel to the surface of the roadway and the center of the illuminated area on the pavement is located by stretching two wires diagonally between the legs of the framework.

To avoid interference from external light sources, the entire reflectometer is enclosed by a lightproof covering. With the cover in place, final adjustment of the apparatus is made as follows: a source of light approximating a point source is placed in the center of the pavement area illuminated by the goniometer lamp, and the telephotometer is visually aligned with this source. After the initial visual alignment, fine adjustments are made to obtain a maximum reading on the recording equipment. The telephotometer is then ready to make measurements for one observer viewing position and viewing angle. Before actual test data are taken, however, the operation of the apparatus is checked by placing a strip of white, matte-finish paper on the roadway test spot and recording the photometer output for a single 360-deg rotation of the goniometer boom. The resulting trace is compared to a similar trace produced under laboratory conditions and if there is no discrepancy, the equipment is assumed to be functioning properly.

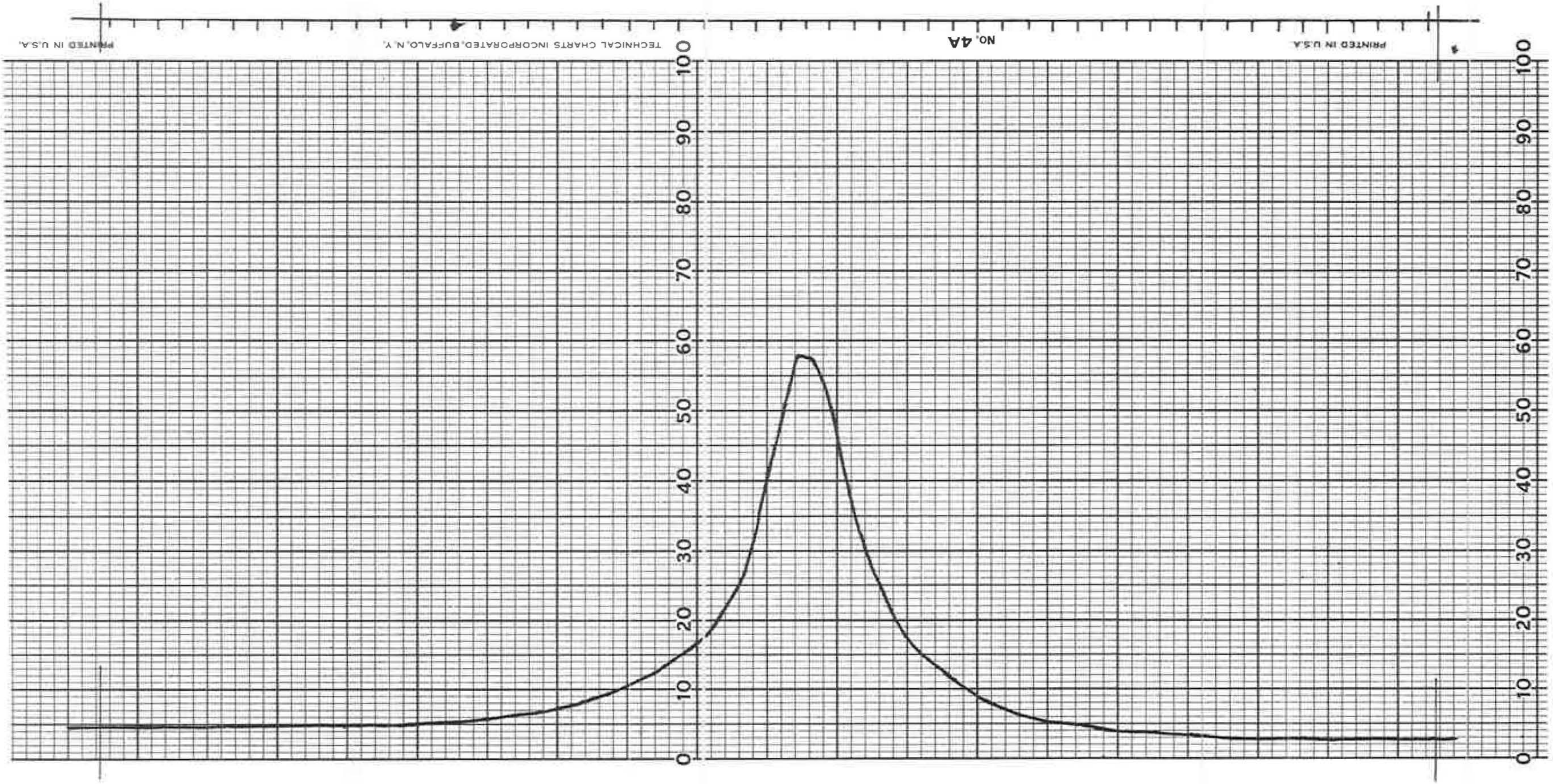

Figure 5. Typical strip-chart trace obtained with pavement reflectometer.

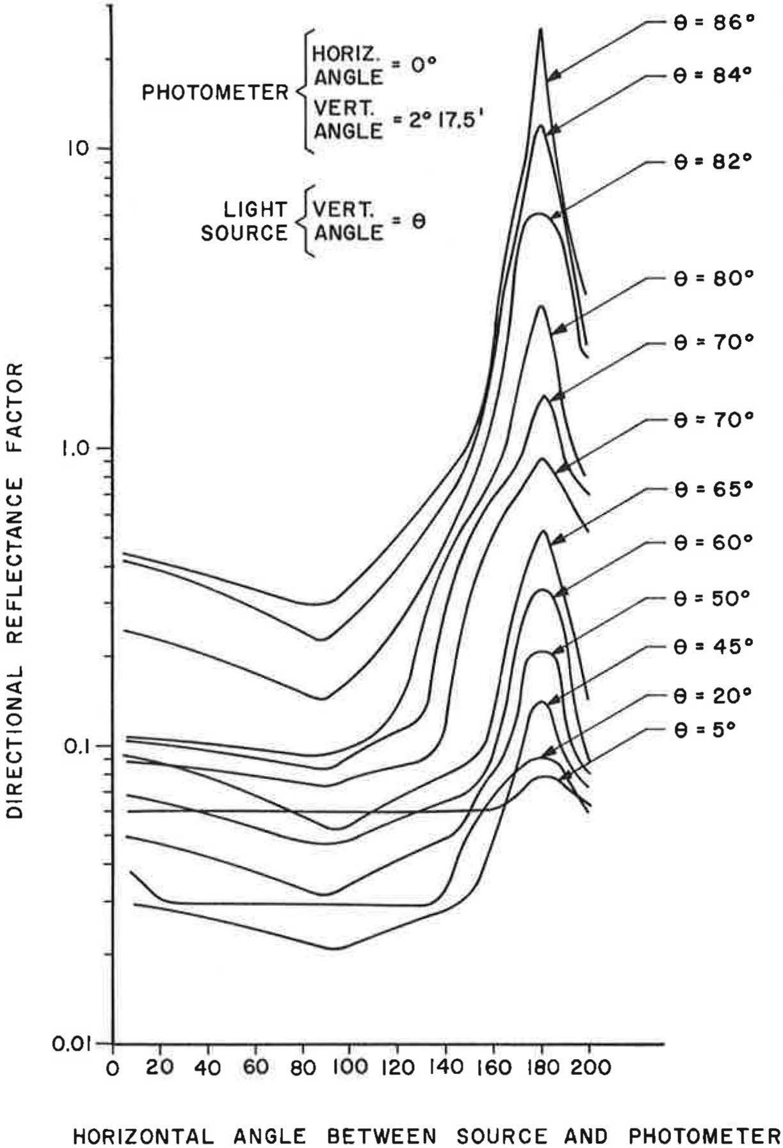

Figure 6. Directional reflectance factors for an epoxy surface asphaltic pavement.

Chart recordings are made with the goniometer lamp at each of its 12 boom settings so that all the previously mentioned vertical angles from 5 to 86 deg are covered. At this point, the apparatus is again checked by the white test strip. In addition, the calibration of the apparatus is further checked by making horizontal footcandle measurements in the center of the illuminated area. The telephotometer is now moved to a new position and the whole procedure of aiming, adjusting, checking, and recording repeated. This is done for as many viewing angles as time permits.

DISCUSSION OF TEST RESULTS

Figure 6 shows a set of typical curves of directional reflectance factors as a function of horizontal and vertical angles of incident light for an observer position at a horizontal

viewing angle of zero degrees and a vertical angle corresponding to a viewing distance of 100 ft. The values for such a plot are read from the strip-chart traces at 5-deg intervals. A method for using these directional reflectance factors and other readily available photometric data in making roadway luminance calculations is described elsewhere (2). The curves shown are for an epoxy-surface asphaltic pavement. Similar data have been compiled for other observer viewing positions and angles and for other pavement surfaces (6). Plotting of the reflectance factors is necessary only for visualizing the data more clearly, because a high-speed electronic computer is capable of handling the individual reflection factors picked at 5-deg intervals directly from the strip-chart recording. A total of 864 reflectance factors are necessary to describe one observer viewing angle and twelve vertical angles of the light source. Even the smaller computers have adequate storage capacity to accommodate data for several observer viewing angles.

The pavement reflectometer was used to make repeated measurements on the same type of roadway surface. Agreement between the reflectance factors obtained at different locations is quite good.

Even with the degree of mechanization achieved with this reflectometer, data gathering is still a relatively slow process. Equipment setup time is approximately three hours and the time required to obtain recordings for one driver viewing angle and twelve vertical angles of the source is about one hour.

In many field locations it is difficult to obtain a well-regulated 115-volt, ac power supply. In addition, any nearby traffic can present a safety hazard to both the equipment and its operators. Many of these problems can be eliminated by a similar apparatus designed for laboratory use in conjunction with readily available pavement core samples. Such a device is now being worked on by the authors.

CONCLUSIONS

The pavement reflectometer described was developed and used for measuring the directional reflectance characteristics of pavement surfaces in the field. The directional reflectance factors so derived enable the illuminating engineer to design or evaluate proposed roadway lighting systems on the basis of roadway luminance rather than roadway illumination. Although the amount of data collected with this apparatus to date is small, it does provide a relatively efficient means of accumulating comprehensive data on various types of pavement surfaces.

The field collection of data on pavement surface characteristics has always been a cumbersome and slow process, and the nature of the problem is such that a laboratory setup appears to be the answer to the problem of collecting a large volume of data on several pavement surfaces.

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