MEASUREMENTS AND MODELIZATION OF LIGHT REFLECTION ON ROAD PAVEMENT SAMPLES

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ABSTRACT

The development of a new apparatus for measuring the luminance factor on road pavements in all incidence and viewing angles is described. Then, a brief analysis of first measurements is presented. Finally, the improvements in modelling the light reflection on road pavement are discussed.

Keywords : calculations, photometry, reflection

1. INTRODUCTION

The photometric classification of road surfaces is presently based on the measurement of light reflection in a direction making an angle of 1° with the surface of the sample. However, these measurements are no longer sufficient in several applications, including tunnel lighting calculations, exterior lighting computer simulation and target visibility on road. More information is required on the reflection properties of road pavements at angles greater than 1°.

In this research, an apparatus has been realised to measure the luminance coefficient of road samples, for any direction of incidence and any viewing direction. The realisation is discussed at section 2. The first measurements made by this way are discussed at section 3.

A mathematical model developed at the University of Liège [1,2] has been applied to these measurements in order to test its accuracy and improved it. The results are explained at section 4.

2. REFLECTOMETER

This reflectometer must still be able to realise measurements under $\alpha = 1°$. These measurements close to the horizontal require very careful, repetitive and stable positioning of the sensor. To carry out measurements at other angles, a supporting arm must be rotated, both in the horizontal and vertical planes. A lower degree of accuracy can be tolerated for the positioning of this rotating arm. The constraints to both measurements have led to two independent arms, each with their own measurement system. The system is therefore comprised of a rigid, stable bracket which supports the source arm and the two ultra-light and rigid measurement arms.

Using a set of mirrors and a diaphragm, the source arm allows the use of a shifted back fixed 50 Watt Hallospot 111 source. This diaphragm defines a fixed circular lighted zone on the sample. It remains parallel to the plane of the sample and its shape is such that its thickness does not blank off the beam at very acute angles.

The sensors ($\alpha = 1°$ and $\alpha \neq 1°$) are luminancemeters. The measurement distance is 2.5 m in both cases. A second diaphragm is associated with the rotating arm ($\alpha \neq 1°$) to define a fixed circular measurement zone on the sample.

Due to :

- shadow zone existing around the circular lighted zone on the sample,
- missing of a shaped diaphragm associated with the $\alpha = 1°$ sensor,

the lighted zone and the measurement zone are greater than the area of the 100 mm diameter sample. This sample is embedded in a flat black plate. The luminance coefficient of the road sample is obtained as a difference between the measurement made on the sample embedded in the black plate and the noise which is the measurement without sample.

The system is entirely controlled by a computer which moves the arms, prevents collision, controls the source and takes measurements.

3. MEASUREMENT

The first measurements lead to two main observations :

- enhancement of backscattering;
- high value of the measured luminance factor in the plane of incidence at grazing angles.

Light backscattering is a well known phenomenon. It is much more important as grazing incidence angles are reached. This observation confirms theoretical descriptions of light reflection by very rough surfaces.

With regard to the grazing angles phenomenon, the luminance factor at grazing angles increases with the angle of incidence at the forward scattering side as well as at backward scattering side. For high angles of incidence, this is mainly explained by specular reflection and backscattering of the source, but it is less commonly understood why we already have high value for angles of incidence less than 50°.

These observations are illustrated by figures 1 to 3 below. These figures show the luminance factor in the plane of incidence for a porous asphalt and for several incident and viewing angles. Positive viewing angles indicate forward scattering. Each figure also represents the modelling (see section 4) of the luminance factor for this pavement.

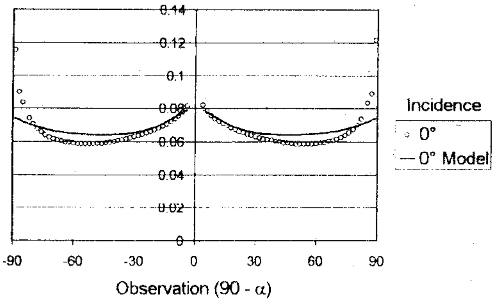

Figure 1 : Luminance factor in the plane of incidence of a porous asphalt

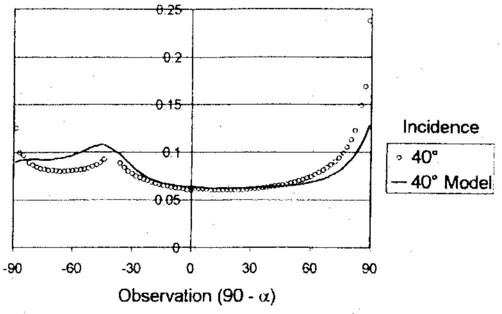

Figure 2 : Luminance factor in the plane of incidence of a porous asphalt

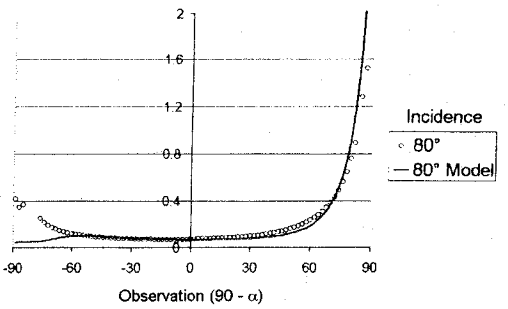

Figure 3 : Luminance factor in the plane of incidence of a porous asphalt

4. MODELIZATION

The attempt to use the model developed at the University of Liège [1,2] to represent the measured luminance factor has shown some errors. It gives a fairly good approximation of luminance factors, except in the retro-reflection area and at grazing viewing angles. Backscattering is always under estimated and grazing angles reflections are only well estimated in the forward scattering directions. In order to obtain a better fit with measurements, we attempt to correct the model in both regions.

First of all, we introduce a revised expression of the shadowing factor which takes into account the correlation between incident and viewing directions in the shadowing effect. This correction is reported in another communication [3].

Secondly, a significant correction has been developed in the backscattering area. An experimental correction factor has been introduced

$$F(\eta,\vartheta_1)=1+\left(\frac{4}{\cosh(5\eta)s}\left(7.3245e^{-9}\,\vartheta_1^5-1.246e^{-6}\,\vartheta_1^4+8.0528e^{-5}\,\vartheta_1^3-2.7303e^{-3}\,\vartheta_1^2+1.922e^{-2}\,\vartheta_1+2.2289\right)\right) \quad (1)$$

in the second term of the model which accounts for rough surface scattering. This factor (1) has been calculated in order to enhance the luminance factor in a cone-shaped area around the retro-reflection direction. In expression (1), $F(\eta,\vartheta_1)$ is the correction factor multiplying the shadowed Kirchhoff Approximation term accounting for incoherent surface reflection [3], ϑ_l is the angle of incidence in degrees ($\vartheta_l = 0$ identifies the normal to the surface), η is the angle in radians between the viewing and the retro-reflection directions and s is the roughness parameters of the surface.

Figures 1 to 3 show that the corrections lead to a rather good representation of the luminance factor in the retro-reflection zone. But, up to now, all attempts to improve the model at grazing angles haven't give significant results.

Other measurements are planned to still improve the correspondence between the model and the measured luminance factors.

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