Reprinted from the *Indian Journal of Pure Applied Physics*, Vol. 17, No. 12, 1979, pp. 583-854

A Method for Measurement of Diffuse Reflectance

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Received 13 *July* 1978; *revised received* 30 *November* 1978

An economical and simple instrument based on the principle of the integrating sphere, has been designed for the quick determination of diffuse reflectance of various building surfaces. The results have been compared with the Eel's reflectometer and found in agreement within ± 5·0%.

The luminous flux transfer problems in buildings often demand reflectance values of various surfaces e.g. walls, roofs, floors, wooden panels etc. The surface reflectance depends upon the mode of irradiation, the spectral composition and the state of polarization of the incident radiation. On the macroscopic scale, there is hardly any regular reflection from building surfaces and the reflected light is also not completely polarized. Therefore, diffuse reflectance value should be used in problems related to buildings. There are several methods in use for the measurement of this property.[1-5] Some methods are based on simple techniques, require less time and less skilled staff, whereas the others, employing rigorous techniques yield precise results. The instrument described in this note is based on the 'substitution method' using an integrating sphere. Compatible with the desired accuracy in buildings, this instrument optimizes cost and time.

The measurements are made with a 12·5 cm radius integrating sphere, coated from inside with the normally recommended paint.[6] The colour and cosine corrected photoreceptor has been arranged at right angles to the collimator tube shown diagrammatically in Fig. 1. The arrangement is such that no direct light falls on the sample. From Fig. 1 it is obvious that part of the light would reach the test sample from the direct lit patch of the sphere and it would not be diffused to the extent as reflected from rest of

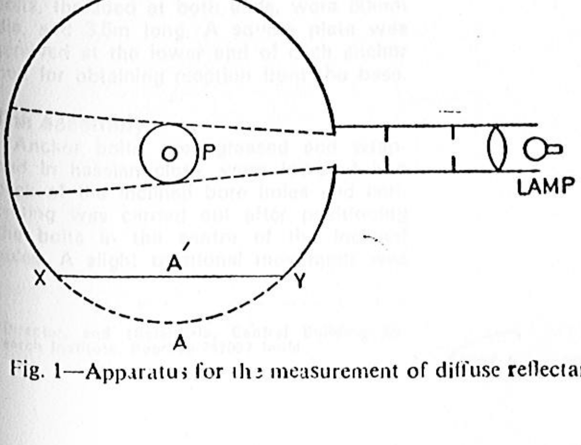

Fig. 1—Apparatus for the measurement of diffuse reflectance

the sphere. This error has been minimized by keeping the ratio of diffused to direct light as large as possible. Here α is considered to be the total luminous flux going into the sphere of reflectance R_s and area A_s. The segment of area A has been replaced by a plane surface of area A' and reflectance R (test sample), then the first reflected flux α' within the sphere is given by the equation

$$\alpha' = \alpha R_s - \alpha R_s a (1 - R) \quad \ldots(1)$$

where the areas A and A' when expressed as fraction of area of the sphere A_s, are denoted by a and a' respectively. If E is the final illumination as recorded by a photocell placed at P, such that it receives the first as well as subsequent reflected flux, the final fluxes α_T available on spherical part and plane surface of the integrating sphere are given by $(1 - a) E$ and $a' R_s E$ respectively.

Hence

$$\alpha_T = (1 - a) E + a' R_s E \quad \ldots(2)$$

The subsequent reflected flux α_r which can be obtained by multiplying the final flux with the respective reflectance of the different surfaces could be expressed by the following equation, viz.

$$\alpha_r = (1 - a) E R_s + a' R_s E . R \quad \ldots(3)$$

With the help of Eqs. (1)-(3), the following flux balance equation can be written:

$$(1 - a) E + a' R_s E = \alpha R_s - a \alpha R_s (1 - R) + (1 - a) E R_s + a' E R_s . R$$

which on simplification and making use of the relation $a' = a(1 - a)$ reduces to following form:

$$\alpha R_s \{1 - (1 - a) a\}/(1 - R_s) = E \{(1 - R_s) + a (1 - R) R_s\} \quad \ldots(4)$$

If the flux is let out through XY, i.e. $R = 0$ and the illumination measured is E', then Eq. (4) modifies to the following form:

$$\alpha R_s = E' (1 - R_s + a R_s) \quad \ldots(5)$$

When XY is covered with a surface of the same reflectance as that of the sphere's internal surface, and the corresponding illumination recorded by the photocell is E'', Eq. (4) modifies to the form.

$$\alpha R_s \{1 - (1 - R_s) a\}/(1 - a) = E'' \{(1 - R_s) + a (1 - R_s) R_s\} \quad \ldots(6)$$

On substituting the value of the apparatus constant, viz. $a = 0{\cdot}1$ and making use of Eqs. (4) and (5), the reflectance (R) of the various test samples could be obtained by the following equation

$$R = (0{\cdot}9 - 0{\cdot}81 R_s)/\{0{\cdot}1 E'/(E - E') + 0{\cdot}09 R_s\} \quad \ldots(7)$$

where R_t could be calculated by solving the quadratic equation [Eq. (8)] in R_t, obtained from Eqs. (5) and (6), viz.

$$0{\cdot}09\, R_t^2 (E' - E') + R_t\, (0{\cdot}81\, E' - 0{\cdot}71\, E') - 0{\cdot}9\, (E'' - E') = 0 \quad ...(8)$$

Table 1—Diffuse Reflection Coefficients for Different Building Materials

Material	Reflectance	
	Integrated reflectometer	Eel's reflectometer
Foam concrete slab	38·0	40·0
Bloated aggregate slab	20·2	22·0
Varnished table top	18·7	17·0
Lime wash	71·4	70·0
Distemper white	74·2	78·0
Distemper cream	65·7	70·0
Distemper grey	38·8	42·0
Distemper yellow	59·0	60·0
Jolly board	33·9	35·0
Nu board	48·4	50·0
Sita board	38·5	40·0
Mosaic tiles	28·7	30·0
Magnesium oxychloride tiles	37·4	40·0
Portland cement tiles	45·6	45·0
Hard board	16·6	18·0
Mysore chip board	39·2	40·0
Teak three ply	22·5	25·0
Ordinary three ply	23·9	25·0

The accuracy of the method depends on the relative values of illumination, viz. E, E' and E'' measured under three conditions. To obtain large change in illumination for the small changes in R, R_t is to be kept as high as possible. Therefore, the recommended paint has been used inside the integrating sphere. The method has been used to measure the reflection coefficients for various types of materials commonly used in buildings. The values so obtained have been compared with the values from "Eel's" reflectance spectrometer using Y filter, and are presented in Table 1. The advantage of this reflectometer is that it directly measures the average diffuse reflectance of a larger surface than the precise 'Eel' reflectometer.

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