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Study on Method of Asphalt Density Measurement Using Low Level Radioactive Isotope

Chung Jin-young, Kim Jung-hoon, Whang Joo-ho
Department of Nuclear Engineering, KyungHee Univ., SeoChun-Dong, Kiheung-Gu, Yongin-Shi, Kyeongki-Do,
jinyoung@khu.ac.kr

1. Introduction

The fundamental cause of damage to road pavement is insufficient management of asphalt density during construction. Currently, asphalt density in Korea is measured in a laboratory by extracting a core sample after construction [1]. This method delays the overall time of measurement and therefore it is difficult to achieve real-time density management. Using a radioactive isotope for measuring asphalt density during construction reduces measuring time thus enabling real-time measurement [2]. Also, it is provided reliable density measurement to achieve effective density management at work sites. However, existing radiological equipment has not been widely used because of management restrictions and regulations due to the high radiation dose. In this study, we employed a non-destructive method for density measurement. Density is measured by using a portable gamma-ray backscatter device having a radioactivity emission of 100 μCi or less (notice No. 2002-23, Ministry of Science and Technology, standards on radiation protection, etc.), a sealed radioactive source subject to declaration [3].

2. Methods and Results

2.1 Theory

Most reactions generated by γ-ray as well as oxygen and silicon, the major elements of soil, are a result of Compton scattering. We derived the probability of Compton scattering by formula (1), the Klein-Nishina formula. The result is shown in *Figure 1*. [4].

$$\frac{d\sigma}{d\Omega} = \frac{1}{2} r_e^2 (P(E_\gamma,\theta) - P(E_\gamma,\theta)^2 \sin^2(\theta) + P(E_\gamma,\theta)^3) \quad (1)$$

As shown in *Figure 1*, scattering takes place in the front and rear areas more evenly when the energy of the incident γ-ray is smaller. Formula (2) shows that, as the energy of incident gamma-rays becomes smaller, an even scattering occurs in the forward and rearward directions and the change in energy after scattering decreases.

$$P(E_\gamma,\theta) = \frac{1}{1 + \frac{E_\gamma}{m_e c^2}(1-\cos\theta)} \quad (2)$$

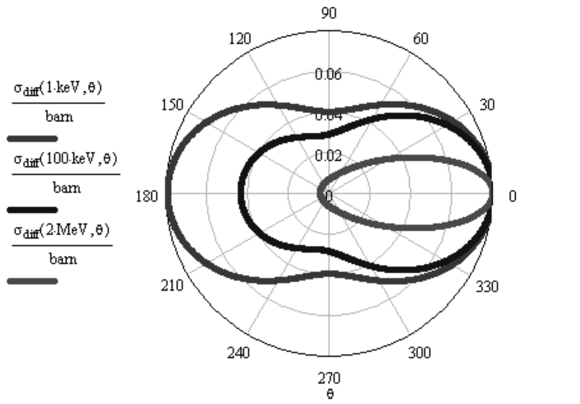

Fig. 1. Probability of γ-ray reaction according to the scattering angle.

For that reason, we selected 100 μCi ^{60}Co (1.17 MeV, 1.33 MeV) as the gamma ray source.

2.2 Method

The relationship between the measured value (I) and density (ρ) according to the differences in asphalt density produces a low value at high density and a high value at low density. In fact, the rate between I and ρ is nonlinear. I is found according to the function of ρ as it relates to the distance between the radiation source and the detector (d). This is expressed with formula (3).

$$I = k\frac{\rho}{d} e^{-\mu\rho d} \quad (3)$$

In formula (3), k is the correlation coefficient of the measurement ratio and is obtained from the configured measuring system and asphalt properties [5].

2.3 MCNPX code simulation

The radiation source used in the MCNPX code simulation was 100 μCi 60Co, and a NaI(Tl) scintillator was used. The housing was made from 150 mm aluminum plate and the measuring substance was standard asphalt. The distance between the radiation source and shield/detector, as well as the thickness, were optimized using MCNPX code. They were configured as shown in Fig. 2. To check the depth of merit, asphalt blocks were placed at 5 cm intervals.

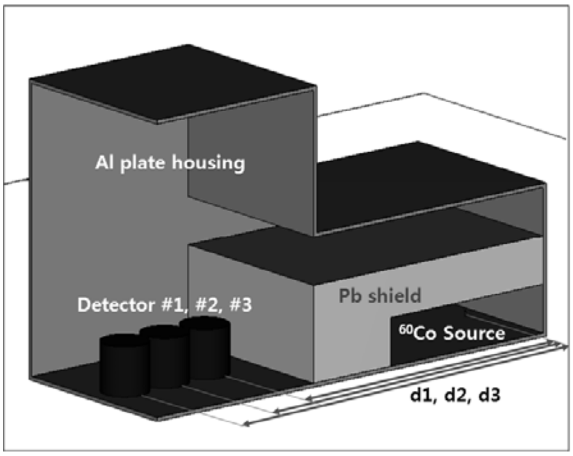

Fig. 2. 3D Geometry (SABRINA)

To obtain a coefficient ratio according to the change in distance between the radiation source and detector, three detectors were placed in a row.

2.4 Result

Table I. shows the result of the simulation to measured asphalt placed at 5cm intervals for 10 minutes.

Table I : Calculation of depth of merit

distance (cm)	Counts Rate	Counts (100 μCi,10 min)
5	1.542E-06	6,662
10	2.402E-06	10,376
15	2.680E-06	11,578
20	2.737E-06	11,824
25	2.754E-06	11,898
30	2.762E-06	11,932
35	2.761E-06	11,928
40	2.765E-06	11,944
45	2.765E-06	11,944
50	2.765E-06	11,944

As in Table 1., gamma backscattering takes place to a depth of 40 cm. However, since approximately 99% of responses are produced within 20 cm of depth, we determined the depth of merit as 20 cm.

The measurement ratio was found through the ratio between the measured value per density and distance. As shown in Fig. 3, the measured gradient per distance decreased as density increased. Also, the measured gradient per asphalt density holds a unique value.

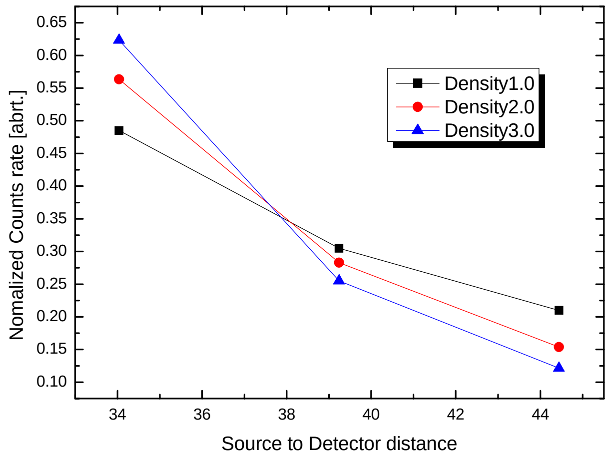

Fig. 3. Counting rate per distance according to density

3. Conclusions

Through this study, we confirmed the possibility of measuring the density of asphalt having a thickness of 20 cm by using a 100 μCi ^{60}Co radiation source and a NaI(Tl) scintillator. An optimized correlation can be derived in the future using code simulation and replication / verification of the experiment to consider any other variables. The basic data of this study will be utilized for developing an asphalt density meter.

Acknowledgement

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