



Gamma radiation determination of absorption coefficients of cement sand block

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Abstract

Three bands of cement with different trade names, Dangote, UNICEM, and Eagle cement were separately molded into cement-sand blocks at different proportions of cement sand ratio of 2:3, 3:7 and 1:4 by weight for each of the cement brand were prepared and allowed to cure. We exposed the blocks to gamma radiation for the determination of attenuation coefficient, half thickness, and mass absorption coefficient. We also determined density values for the blocks. The results for the cement samples show that the higher the cement content in the cement sand block, the higher the density value and the gamma attenuation coefficient, suggesting that cement sand block with a high proportion of cement content makes for a good shielding in gamma radiation exposed environment, Gamma radiation attenuation the method can equally be a useful technique for cement sand block quality control in building construction industry.

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1. Introduction

Electromagnetic waves, uncharged in nature and similar to X-ray, but with a shorter wavelength approximately one hundred times more penetrating than X-rays is known as gamma rays [1]. Particles of some matter can scatter or absorb the rays. Dense materials are said to absorb the rays better than less dense materials. This suggests that the absorption of gamma rays is density dependent among other properties [2]. Gamma rays are, however, more penetrating natural radiation.

Several researchers and workers have in recent time used cobalt-60 for the determination of densities of several materials [3]. Ekpe et al. (2000) used gamma radiation from Cobalt-60 for transverse absorption coefficients determination of wood. Gamma radiation from Cobalt-60 was used by [4] for the measurement of the absorption coefficient of selected Nigerian crude oil, whereas [1] used Cobalt-60 for determination of

adulteration of engine oil with diesel fuel by the method of gamma radiation.

In this research work, the same gamma radiation from Cobalt-60 is adopted for the determination of the absorption coefficient of different cement-sand block samples of different proportion by ratio in weight of sand to cement from different cement companies which products are locally available in Akwa Ibom State, Nigeria. We use the radiation to estimate the absorption coefficient of the different block samples, hence forming the basis for estimating the quantity of cement or sand in cement-sand block. That, apart, the work also investigates the level of attenuation of gamma rays by cement sand block with different percentage composition to estimate the range of composition that can be a protective shield in building in gamma radiation environment including laboratory buildings considering that lead is very expensive, which may not be afforded by some. The cement sample are Portland cement, consisting mostly of calcium and aluminum silicates.

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Concrete blocks are made by a combination of cement aggregates and water. In some cases, specialty additives are added. Sand and stone, which may be coarse or fine, make up the aggregate component. Some research work on the strength of cement mortars have been carried out. The work of [5] on the evaluation of strengthening through stress relaxation testing of organomodified montmorillonite reinforced cement mortars, is one of such work. That work proposes a commensurate quantity of organomodified montmorillonite particles needed to give cement mortars a better compressive strength, elastic modulus and activation energy of stress relaxation. Continue curing of concrete enables it to grow stronger. Curing process, however, is time-dependent. This means that concrete becomes stronger as the curing time becomes longer [6].

2. Theory

Absorption of radiation by material involves the outcome of the entire energy exchange mechanisms owing to the interaction between radiation and the particle content in the material. This results in the reduction in the transmitted intensity of the radiation incident as the radiation get to the material. The intensity transmitted through a material depends on the length of the absorbing layer, size of the particles and density of the material and other factors [4, 7 - 8]. The radiation not transmitted is deemed to be absorbed. Absorption of radiation includes true absorption and scattered radiation. Imperially, the transmitted intensity of the radiation I expressed thus;

$$I = I_o \exp(-\alpha x) \tag{1}$$

where I_o is the intensity of the incident radiation

x is the thickness of absorbing material

α is the absorption coefficient in mm^{-1} or cm^{-1}

Equation (1) above may further, be expressed linearly as

$$\ln\left(\frac{I_o}{I}\right) = \alpha x \tag{2}$$

for easy deduction of absorption coefficient α for the cement – sand block sample from the plot of $\ln\left(\frac{I_o}{I}\right)$ against x .

Alternatively, the absorption coefficient of various absorbers of gamma radiation can be deduced from half thickness ($x_{1/2}$) value, which is the thickness of the absorbing material required to bring down the intensity of radiation to 50% of its initial incident radiation value. This can be expressed as

$$I_o = \frac{1}{2} I \tag{3}$$

and further as

$$\ln(2) = \alpha x_{1/2} \tag{4}$$

resulting in $x_{1/2} = \frac{\ln 2}{\alpha}$ and $x_{1/2} = \frac{0.693}{\alpha}$

[9, 10] on their part express the relationship between the intensity of incident radiation I_o and the relaxation length L thus

$$I = I_o e^{\frac{-x}{L}} \tag{5}$$

whereas absorption coefficient α relates with half thickness $x_{1/2}$ thus

$$x_{1/2} = \frac{0.693}{\alpha} \tag{6}$$

3. Material and Method

3.1. Materials

Three different cement samples popularly available in Akwa Ibom State, Nigeria from three different cement companies in Nigeria were obtained from their respective depots. The cement companies are Dangote cement, Eagle cement, and Unicem cement. Akwa Ibom state which covers a total land area of 8412km² encompassing the entire Qua Iboe River basin lies between latitude 4^o32¹ and 5^o33¹ North and longitude 7^o55¹ and 8^o25¹ East [11].

Coarse sand was obtained from a stream in Oboyo Ikot Ita in Nsit Ibom local government area, Akwa Ibom state, Nigeria. The sand was kept for twelve months in a dry laboratory environment to drain off the excess water. A portion of the sand was kept to dry and weighed at intervals of time until about a constant mass was observed. A sensitive weighing balance, measuring cylinders, beakers, square metal molds,

measuring about $0.07 \times 0.07\text{m}^2$, but of varying depth ranging from 0.0088m to 0.0707m, for varying thickness of blocks, hydraulic press, Cobalt-60 (^{60}Co , $5\mu\text{Ci}$) gamma source model P66340/8, Geiger Muller (G) tube detector and scalar counter timer model P67520/4, were used in measuring the absorption coefficients of the blocks, produced by mixing cement with sand at the ratio of 2:3, 3:7, 1:4, identified as D2:3, D3:7, D1:4, for Dangote cement-sand block mixture; E2:3, E3:7, E1:4 for Eagle cement-sand block mixture and U2:3, U3:7, U1:4 for Unicem cement-sand block mixture. The initial dry cement-sand mixture in each case was added water after a proper mix and mixed again with the water before putting in a mold and pressed to form a block and kept in the sun for 12 hours after which water was sprinkled and allowed to stay for complete curing. The procedure was repeated for all the cement-sand mixture. The block samples so formed were kept in the laboratory for six months for dryness.

3.2. Experimental procedure

The gamma source, Cobalt-60 (^{60}Co) was placed facing up in a thick cylinder shield made of lead, with the help of a source holder and was kept to the fact the window of the detector (GM tube) connected to a calibrated scalar counter/timer model P67520/4. The source and the detector were arranged vertically and axially, maintaining a constant separation between the ends or opening of the lead the cylinder containing the source and the window of the detector to ensure a uniform distance of the gamma-ray source and the window. The GM tube was first calibrated for its operating voltage, which in this case was found to be 400V. The voltage was kept constant throughout the experimental process. The intensity of incident radiation, I_o was counted for one hour. Thereafter, the sample was placed transversely between the source and the detector, maintaining the vertical and axial arrangement with the separation. The number of counts for the intensity of transmitted radiation, I , for each sample (of varying thickness) was taken for the same duration of one hour in each case. The experiment was repeated for all the different cement-sand mixture block samples.

The bulk densities were determined by measuring mass and volume of the samples, using weighing and

displacement method as described by [8]. The conventional formula which abounds in several textbooks and journals as

$$\rho = \frac{m}{V} \quad (7)$$

was employed for density determination, where ρ designates density, M mass and V volume of the sample.

Absorption coefficient α was deduced from the slope of the graph of $\ln\left(\frac{I_o}{I}\right)$ plotted against x. The same plot was used to deduce relaxation length for the prepared block samples respectively. Half thickness value $x_{1/2}$, for each of the prepared block samples was determined using equation (6) above. Mass absorption coefficient was determined for the block samples of each of the proportions of mixture, as the quotient of absorption coefficient to the respective density. Absorption coefficient values was plotted against the respective density value. The gradient of the graph was deduced. The mean of the mass absorption coefficient obtained by direct calculation from the quotient of the absorption coefficient direct calculated values was equally computed for comparison with the mass absorption coefficient deduced from the graph.

4. Results and Discussion

The experimental results seen in table 1, having absorption coefficient α , density ρ , relaxation length L_R , half thickness value $x_{1/2}$ and mass absorption coefficient α for the block samples of varying cement-sand samples. The plots of $\ln\left(\frac{I_o}{I}\right)$ against thickness x, for the different ratios cement sand mixed block samples as seen in figures 1 – 3 yielded attenuation coefficients deduced from the slopes of the plots. Mass coefficients values were determined for block samples.

Table 1. Density, Attenuation coefficient, half thickness and mass absorption coefficient of cement sand ratios.

Sample Code	Density, $\rho \pm 0.011$ (gcm ⁻³)	Attenuation Coefficient, μ (cm ⁻¹)	Half Thickness Value, $x_{1/2}$ (cm)	Mass Absorption Coefficient, m (cm ² g ⁻¹)
D 1:4	1.947	0.15262 ± 0.00181	4.541 ± 0.058	0.078
D 2:3	2.183	0.23098 ± 0.00237	3.000 ± 0.028	0.106
D 3:7	1.980	0.19656 ± 0.00386	3.526 ± 0.071	0.099
E 1:4	1.893	0.15036 ± 0.00144	4.608 ± 0.058	0.079
E 2:3	2.143	0.21979 ± 0.01579	3.153 ± 0.214	0.103
E 3:7	1.964	0.19445 ± 0.00324	3.564 ± 0.072	0.099
U 1:4	1.939	0.15494 ± 0.00177	4.473 ± 0.056	0.080
U 2:3	2.151	0.22628 ± 0.00321	3.063 ± 0.058	0.105
U 3:7	1.952	0.19047 ± 0.00517	3.638 ± 0.111	0.098

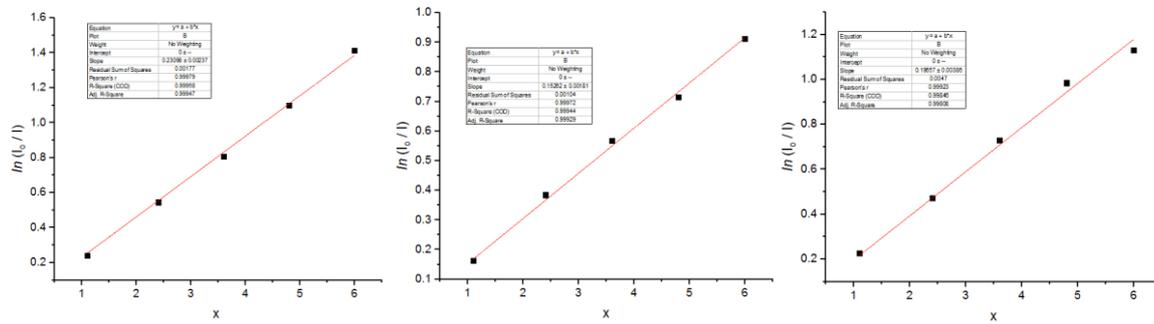


Figure 1: Plots of $\ln(I_0/I)$ against thickness x , for the different Dangote cement ratio

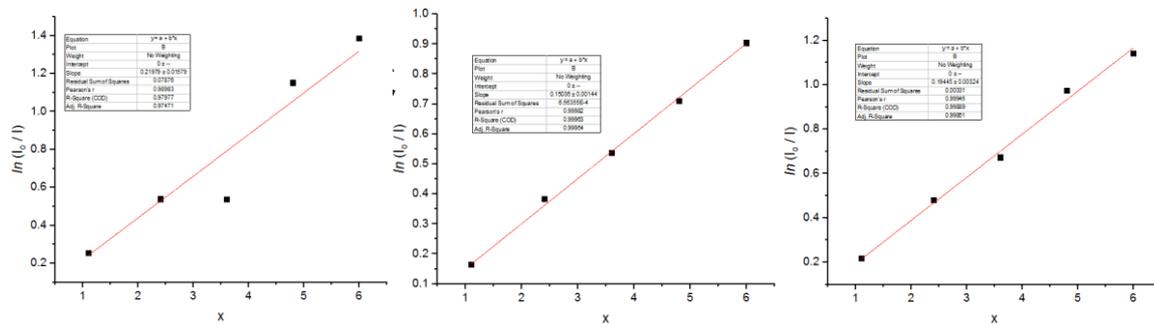


Figure 2: Plots of $\ln(I_0/I)$ against thickness x , for the different Eagle cement ratio

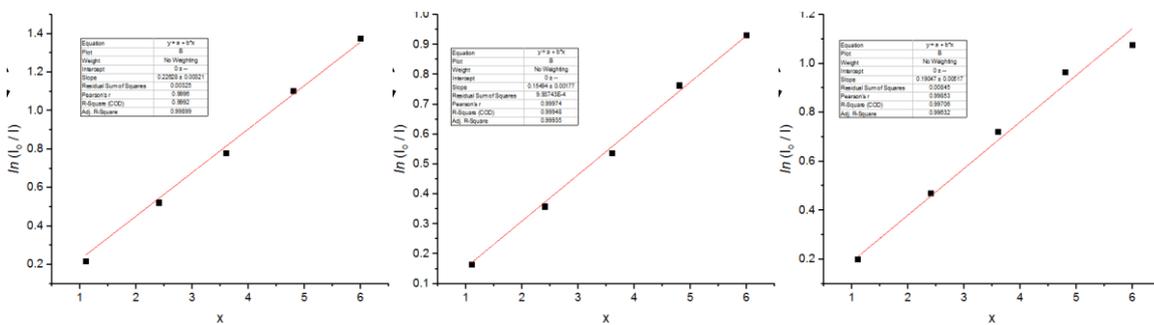


Figure 3: Plots of $\ln(I_0/I)$ against thickness x , for the different UNICEM cement ratio

Averaging the attenuation coefficient for block samples with a ratio of 2:3 cement to sand ratio for the three cement samples used we have (0.2257 ± 0.0045) cm^2g^{-1} , while that of 3:7 and 1:4 cement sand ratios are (0.1938 ± 0.0006) cm^2g^{-1} and (0.1526 ± 0.0001) cm^2g^{-1} respectively. The corresponding average density values are 2.159 ± 0.011 gcm^{-3} , 1.965 ± 0.011 gcm^{-3} and 1.926 ± 0.011 gcm^{-3} respectively. The attenuation coefficient shows positive density dependent. Meaning that attenuation coefficient increases as density increases. This is supported by the reports of [1 – 3, 6 – 9, 12]. The block samples with cement sand mixed ratio of 2:3 has the highest density value when compared with the other block samples corresponding that sample exhibits the highest attenuation coefficient when compared with other samples. This is plausibly due to the fact that the sample having more cement content, which particles are tightly packed than sand, resulting in the sample being denser than others. It is also observed that the higher the density of the block, the less the half thickness value.

5. Conclusion

Judging from the result of our experiments it can be concluded that the attenuation coefficient of cement sand block samples increases with an increase in the proportion of cement content of the block. On the other hand, the higher the proportion of cement content in the cement sand block samples the lower the half thickness value. In a gamma radiation invaded environment, cement sand blocks with a high proportion of cement content is recommended. Buildings for storing gamma radiation sources should be constructed with cement sand blocks, having a high proportion not less than 40%, of cement content. This is in addition to the lead containers or casing that such gamma radiation sources are stored.

Our results in addition suggests that gamma attenuation method can be adopted for determination of proportion of cement content in a cement sand block as a measure of quality control in construction companies and cement sand block molding factory. This points to the fact that gamma attenuation method can be used for determination of mechanical strength of cement sand block

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