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Gamma ray attenuation Study with Varying Moisture Content of Clay Brick

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ABSTRACT: *This paper presents the experimental work of understanding the variation of gamma attenuation coefficient on moisture of clay brick using Gamma radiations. 662 keV Gamma ray beam from Cs-137 radioactive source was used for determination of lineasr attenuation coefficient of the clay brick and also the study of variation of linear attenuation coefficient with moisture content of the clay brick. The gamma ray transmission technique is a non- destructive technique in which there is no need of direct contact between material under study and detector assembly. In this work GSpec gamma spectroscopy system consisting of 2″× 2″ NaI (Tl) detector and MCA has been used. The spectral analysis was made using Spectrum Analysis and Analyzing Software (SAAS). The experimental results confirmed that the gamma linear attenuation coefficient varies with moisture content of the clay brick. The very important result obtained by this experimental work is that percentage of fractional change in linear attenuation coefficient is very close to the moisture content of the clay brick.*

KEYWORDS: *Attenuation coefficient, clay brick, Cs-137 radioactive source, GSpec, moisture, NaI (Tl) detector*

I. INTRODUCTION

In the present work, an attempt was made to study the gamma attenuation properties of clay brick when exposed to Gamma ray beam of energy 662 keV and an effort was made to determine the variation of linear attenuation coefficient with moisture content of the clay brick under study. In Industrial radiography Gamma radiation is used to inspect metal parts and welds for defects. Gamma radiations are used for measuring viscosity, density and thickness in conditions where other methods would be difficult or impossible to apply. The study of absorption of gamma radiations in materials is important subject in the field of radiation physics [1]. The study of absorption of X- and Gamma radiations through different materials is of wide interest in industrial, medical and agricultural fields. The x-rays and gamma radiations can penetrate solid materials. The extent of penetration depends upon several factors including density of the intervening material and the energy of the radiation. The x-rays and gamma radiations are used in industry to monitor the thickness of sheet metal, paper napkins, newspaper, plastics, and photographic film. X- and Gamma radiations are used in the automobile industry to test steel quality and in the aircraft industry to check flaws in jet engines. In radiography, Gamma rays are used to examine pipe, pressure vessels, and other assemblies in which access to the interior is difficult. The study of X- and Gamma photon attenuation coefficients is an important parameter for characterizing the penetration and attenuation properties of x-ray and gamma rays in materials. Accurate data on photon attenuation coefficients are required in a verity of applications in nuclear science, technology and medicine [2].The thickness of metallic coatings can be determined by x-ray fluorescence spectrometry [3].The transmission factors; linear and mass attenuation coefficients, effective atomic numbers, cross-sections and electron densities were studied for Al, Fe, Perspex, PVC and Brass by using gamma ray spectroscopy [4]. The gamma attenuation method has been used in the study of soil particle-size analysis [5, 6, 7]. Soil bulk density has been measured using gamma attenuation technique [8]. The Gamma transmission method was used to determine the moisture in soil by measuring the variation in density due to water addition [9]. Moisture is a common cause of brick delamination. Porosity is an important characteristic of brick; the porosity of brick is attributed to its fine capillaries. Porous materials are susceptible to Chemical attacks and liable to contamination from weathering agents like rain, running water and polluted air. Most constructional defects, e.g. movement, cracking, fungal attack, chemical reaction, are initiated and aggravated by the presence of moisture. Therefore estimation of moisture is very important.

II. EXPERIMENTAL WORK

A. Theory

The moisture in the clay brick is calculated using the following relation:

Moisture content = $\left(\frac{Mwet - Mdry}{Mwet}\right)100$

Where Mwet is the weight of wet sample and Mdry is the weight of the sample on completely drying. Previous to this experimental work preliminary experiments have done to understand the variation of linear attenuation coefficient with moisture content of material. It was found that the percentage of fractional change in linear attenuation coefficient due to presence of water is very nearly equal to moisture content of the sample. Therefore this experimental work was intended to study the dependence of linear attenuation coefficient on moisture content of sample and to verify the relation:

$$\left(\frac{\mu wet - \mu dry}{\mu wet}\right) 100 = \left(\frac{Mwet - Mdry}{Mwet}\right)100$$

Where µ*wet* is the linear attenuation coefficient of wet and µ*dry* is the linear attenuation coefficient of the sample under dry condition.

B. The gamma ray spectrometry

In this experimental work gamma ray spectroscopy system used was a high efficiency GSpec Gamma ray spectroscopy system consisting of NaI (Tl) crystal detector of size *2″× 2″* and MCA. GSPEC is a pc based Gamma Ray Spectroscopy system, which communicates with PC through USB port. The Figure (1) shows GSpec Gamma ray spectroscopy system with USB cable. Data Acquisition and Control is through PC based application software, SAAS. Calibration of multi-channel analyzer converts the channel number, which is proportional to the pulse amplitude into incident gamma energy. Energy calibration is done by selecting two or three energy peaks of known radio Isotopes. In the present work calibration was done using Co-60 (1.17 MeV, 1.333 MeV), and Cs-137 (0.662 MeV). The gamma spectrometry system was initially tested for resolution, linearity and stability characteristics to fix the best operating conditions by performing preliminary experiments. The resolution of the detector was found to be 6 % for 662 KeV gamma rays at operating voltage 750V.

C. **Spectral analysis**

This experimental work started with selecting of a wet clay brick. The clay brick was cut in to pieces of thickness 1.4 cm, 2.8 cm and 4.2cm using hacksaw blade. The weight of wet clay brick piece of thickness 2.8 cm was precisely measured using electronic balance and recorded. The weight of the wet sample was found to be 406.8g. The schematic of experimental arrangement is as shown in the Figure. (2). This arrangement provides good geometry setup. The inclusion of errors due to secondary photon transmission is avoided by the good geometry setup [10]. The Cs-137 radioactive source was kept in line with the Gamma spectrometer. Irrespective of complexity of interaction of gamma radiation, the height of the output pulse produced by the NaI (Tl) detector is in proportion with the energy of the incident gamma ray photon. It can be reasonably assumed with good approximation that the total energy deposited in the detector medium and the detector response are same as if the gamma photon has undergone a single interaction process, transferring all its energy to the electrons in the detector medium. The resulting peak appearing in the pulse height spectrum, commonly referred to as photo peak. Different researchers have employed different techniques to study the interaction of radiations with matter. In the present study the counts under the photo peak area were considered. First spectrum of ^{137}Cs source was acquired for 202seconds. For spectral analysis, it is necessary to select the peak regions. This is done by selecting the Region of Interest or ROI. ROI will be selected between the start and stop channels as desired. From the recorded spectrum the 662 keV photopeak has been identified and Region of Interest (ROI) was fixed for experimental work. The SAAS gives integral counts, background counts and background subtracted counts under ROI. The background subtracted counts under ROI used for the study of attenuation characteristics. With the same source and detector geometry the clay brick sample of thickness 2.8 cm and weight 406.8g was placed in between the detector assembly and the radioactive source. Gamma spectrum was obtained for 202seconds and number of counts under ROI was recorded. The sample was taken out from the experimental position and allowed to evaporate. Due to evaporation weight of the clay brick sample decreases. With the same detector and source geometry number of counts under ROI was recorded for 202 seconds without the sample. Then the clay brick sample weighing 403.8g was placed in between the detector and the source and number of counts under ROI was recorded for 202 seconds. This procedure was repeated for different weights of the clay brick sample. The second section of this experimental work deals the determination of linear attenuation coefficient for dry clay brick. With the same experimental geometry the number of counts under ROI was taken for 202 seconds. Then the complete dry brick sample of thickness 1.4cm was placed in between the detector and the source and number of counts under ROI was taken for 202 seconds. The experiment was repeated with varying thickness of dry clay brick. The linear attenuation coefficient of the complete dry clay brick (µ*dry)* was calculated and used in the verification of the relation:

$$\left(\frac{\mu wet - \mu dry}{\mu wet}\right) 100 = \left(\frac{Mwet - Mdry}{Mwet}\right)100$$

Fig. (1) Gspec with USB cable.

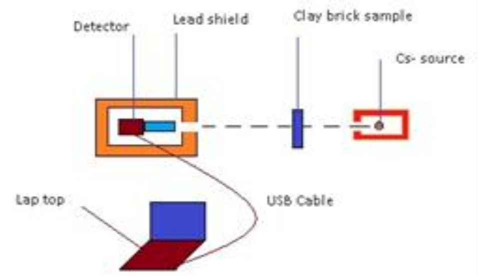

Fig. (2) Schematic of Experimental

III. RESULTS AND DISCUSSION

The narrow beam experimental geometry was set up for the study the attenuation characteristics of clay brick and to study the dependence of linear attenuation coefficient on moisture content of the clay brick. Due to fixed experimental geometry and the good stabilization the centroid has fixed at nearly 662 keV. The TABLE I shows the tabulation of linear attenuation coefficient against completely dry sample thickness and it also shows the mean value of linear attenuation coefficient (μdry). Figure (3) shows the variation of ln (I_0/I) with thickness of dry sample. The TABLEII shows the variation of linear attenuation coefficient with different moisture content of the sample. From this table it was found that linear attenuation coefficient varies with moisture content. In the TABLEIII, the values of linear attenuation coefficient and moisture content are compared. The Figure (4) shows the values of linear attenuation coefficient for different moisture content of the sample. From this figure it is clear that attenuation coefficient is maximum for moisture content 11.65% and minimum for moisture content 3.13%.

TABLE (1) Thickness and linear attenuation coefficient.

Thickness (cm)	Count rate (Counts/ sec)	ln(I_0/I)	Linear attenuation coefficient µ (cm^{-1})	Mean Linear attenuation coefficient, μdry (cm^{-1})
0	393.80	--	--	
1.4	319.57	0.2089	0.1492	0.1479
2.8	260.39	0.4137	0.1478	
4.2	212.04	0.6191	0.1474	
5.6	183.19	0.7653	0.1472	

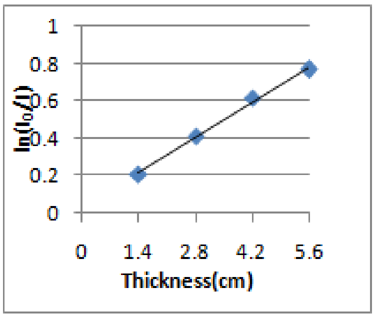

Fig. (3) Plot of ln (I_0/I) versus thickness

TABLE (2) Weight, moisture content and linear attenuation coefficient.

Weight of clay brick sample (g)	Moisture content (%)	Incident intensity, I_0	Transmitted intensity, I	ln(I_0/ I)	Linear attenuation coefficient,µ (cm^{-1})
406.8	11.65	78832	48755	0.4805	0.1716
403.8	11.00	78545	48797	0.4760	0.1700
385	6.65	78564	50108	0.4497	0.1606
381	5.62	78692	50644	0.4407	0.1574
376.5	4.54	77856	50246	0.4379	0.1564
371	3.13	77902	50660	0.4303	0.1537

TABLE (3) Comparison between % of fractional change in linear attenuation coefficient and moisture content.

Weight of the clay brick	Linear attenuation coefficient,μ (cm^{-1}) by experiment	% of fractional Change in Linear attenuation coefficient,μ (cm^{-1})	Moisture content of the clay brick sample by gravimetric method
406.8	0.1716	13.00	11.65
403.8	0.1700	12.18	11.00
385	0.1606	7.04	6.65
381	0.1574	5.15	5.62
376.5	0.1564	4.48	4.54
371	0.1537	2.86	3.13

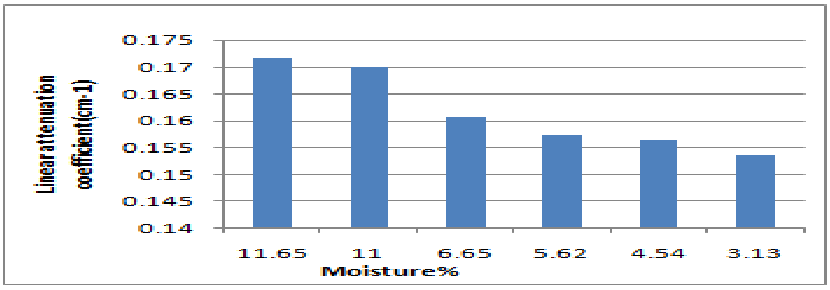

Fig. (4) Moisture versus linear attenuation coefficient.

IV. CONCLUSION

From this experimental work it can seen that gamma linear attenuation coefficient varies with moisture content of the clay brick. This gamma transmission technique is very simple. The Gspec gamma ray spectroscopy system and Cs- 137 radioactive source are readily portable and easy to use in nondestructive testing of materials. This experimental work clearly shows the correlation between the linear attenuation coefficient and moisture content of the clay brick. The values of % of fractional change in linear attenuation coefficient are found to be very close to the values of moisture content of the clay brick. This is very important relationship drawn from this experimental work. This type of experimental technique can be used to find moisture content of important structural materials like cement plaster, and concrete blocks used in the construction of houses, buildings and bridges and can also be used to study the moisture content of porous materials used in the laboratories, industries and daily life.

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