Comparison of Gamma Ray Attenuation Coefficient between Marble and Limestone Using NaI Detector

Nanda Phone Lin Wai*, Hnin Thidar Soe, Htet Htet Aung*****

Abstract

The aim of this research is to study the physical properties of marble and limestone and their transmitted intensities of gamma ray of each sample. The detector used in this research was 2 in x 2 in NaI (Tl) Scintillation detector with 5µCi of ^{137}Cs gamma radiation source. It can be seen that the density of marble is denser than that of limestone. The attenuation of marble sample is 0.275cm^{-1} and the limestone sample is 0.234 cm^{-1}. From these results, marble sample is more attenuate than limestone sample. It can be concluded that, the denser materials are more attenuate for radiation intensity.

Keywords: Attenuation, Scintillation detector, Gamma Ray

Introduction

The application of gamma radiation has been increased in science and technology; industry, medicine, agriculture, energy sectors, checking the homogeneity of materials and others etc. Ionizing radiation is widely used in many areas and it can be presented as a significant health hazard which can cause microscopic damage to living tissue. There are three general guidelines for controlling exposure to ionizing radiation: (1) minimizing exposure time, (2) maximizing distance from the radiation source and (3) shielding yourself from the radiation source. In most cases, shielding is the main rule to be performed. Almost any material can act as a shield from gamma or x-rays if it is used in sufficient amount. Different types of ionizing radiation interact in different ways with shielding material. The effectiveness of shielding is dependent on the stopping power of radiation particles, which varies with the type and energy of radiation and the shielding material used. The attenuation coefficient is also an important parameter for studying interaction of γ-ray with matter that gives us the fraction of energy scattered or absorbed. Gamma rays can be absorbed in high-density materials such as lead, tungsten, concretes and building materials. The purpose of the present work is to study the physical properties of marble and limestone, and their transmitted intensities of gamma ray.

* Demonstrator, Department of Physics, Yadanabon University

** Associate Professor, Dr, Department of Physics, Yadanabon University

*** Demonstrator, Department of Physics, Yadanabon University

Background Theory of Marble

Marble is a rock resulting from metamorphism of sedimentary carbonate rocks, most commonly limestone or dolomite rock. Metamorphism causes variable recrystallization of the original carbonate mineral grains. The marble rock is typically composed of an interlocking mosaic of carbonate crystals. Primary sedimentary textures and structures of the original carbonate rock (protolith) have typically been modified or destroyed. Pure white marble is the result of metamorphism of a very pure (silicate-poor) limestone or dolomite protolith.

Background Theory of Limestone

Limestone is one of the most common types of rock found on the surface of the Earth. About 10% of the land surface of our planet is made of limestone or similar types of rock; while around 25% of the world's population either live on or take their water from limestone. It is thought that 50% of all our oil and gas reserves are trapped in limestone buried beneath the surface. The rock limestone is mostly made up of one of two types of mineral-either calcite or aragonic.

Fundamental Law of Gamma Ray Attenuation

When a beam of gamma ray photon hits on any material, it can be removed in a single event. The event may be an actual absorption process in which case photon disappears or the photon may be scattered out of the beam. When a gamma ray passes through the matter, probability for absorption proportional to thickness of the layer, the density of the material and absorption cross section of the material. The total absorption shows an exponential decrease of intensity with distance from the decrease of the incident surface. The attenuation coefficient of each sample was calculated by using Beer Lambert Law.

$$I(x) = I_0.e^{-\mu x}$$

where, x = the distance from the incident surface

$\mu = n\sigma$ is the absorption coefficient, measured in cm^{-1}

n = the number of atoms per cm^3 of the material (atomic density)

σ = the absorption cross section in cm^2

The linear attenuation coefficient (cm^{-1}) can be obtained

$$\mu = \frac{1}{x}\ln\left(\frac{Io}{I(x)}\right)$$

The mass attenuation coefficient is defined as, $\mu_m = \frac{\mu}{\rho}$.

Materials and Methods

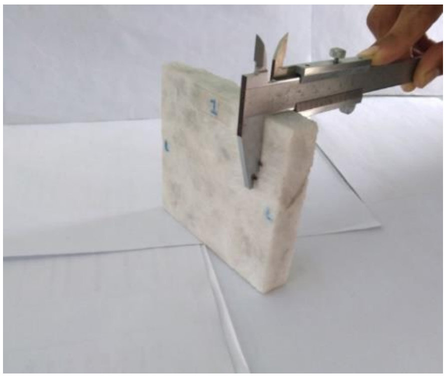
Marble and limestone were collected from local market in Mandalay Division and cut into four slides of each about 2inches square as shown in Figure. (1) and (2). The length, breadth, and thickness measured by using Slide calliper and are described in Figure. (3) and (4). The mass of the samples were determined with digital balance as shown in Figure. (5) and the density of these materials can be calculated.

Instrumentation and Experimental Setup

The linear attenuation coefficient was determined for various thicknesses of the absorber and for each sample of marble and limestone. The radioactive gamma ray source of ^{137}Cs with energy 662 keV and activity of 5 µCi can be used. But, the present activities of gamma ray sources used in this research are 4.838 µCi. The detector was 2 inches × 2 inches NaI (Tl) scintillation crystal coupled to a photomultiplier tube. Source and detector are fixed; the samples were placed between gamma source and detector and it was mounted about 14 cm apart. The readings were taken for 100 seconds with varying the absorber material for every three times. The detection of the materials studied with NaI(Tl) detector is shown in Figure. (6).

Figure. (1) Marble Samples

Figure. (2) Limestone Samples



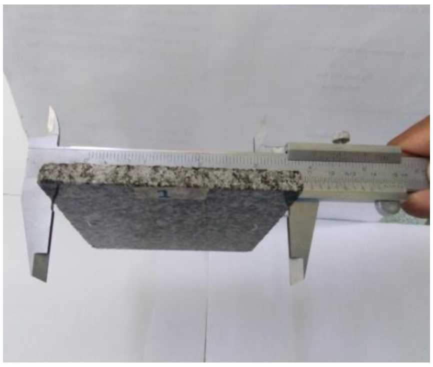


Figure. (3) Measurement of Thickness

Figure. (4) Measurement of length

Figure. (5) Measurement of Mass

Figure. (6) Detection of Gamma Ray Intensity

Operation of NaI (Tl) Detector

NaI (Tl) scintillation detector is one of the first gamma detectors used for Spectroscopy. The high Z iodine in NaI gives good efficiency for gamma ray detection. A small amount of Tl is added in order to activate the crystal, so that the designation is usually NaI (Tl) for the crystal.

The function of the detector is to produce a signal for every particle entering into it. Scintillators are materials such as solids, liquids, gases that produce sparks or scintillators of light, when ionization passes through them. The amount of light produced in the scintillators is very small. It must be amplified before it can be recorded as a plus or in any other way. The amplification or multiplication of the scintillator's light is achieved with a device known as the photomultiplier tube (or phototube).

Results and Discussion

The measurement values of physical properties for marble and limestone with standard values are presented in Table (2.1). It was found that the measured value of marble is 2.12 g/cm3 and limestone is 1.81 g/cm3. They are less than the standard values.

The values of intensity and thickness for marble and limestone are shown in Table (2.2) and (2.3). Their relations are presented in Fig. (3.1) and Fig. (3.2). It was found that the average value of counts per second in marble is less than the limestone sample.

Then the linear attenuation coefficient of marble and limestone are shown in Table (2.4) and (2.5) and the relation of thickness and ln I/I0 are shown in Fig. (3.3) and Fig. (3.4). It can be seen that the attenuation of marble sample is 0.275cm-1 and the limestone sample is 0.234 cm-1. From these results, marble sample is more attenuate than limestone sample.

The comparison of attenuation coefficient with standard value are shown in Table (2.6), it can be seen that marble is nearly the same as standard value and limestone is slightly different from standard value.

Table (1) Physical Properties of Marble and Limestone

Sr. No	Sample Name	Mass (g)	Volume (cm^3)	Density (g/cm^3)	Std. Density (g/cm^3)
1.	Marble	383.51± 0.000	180.83 ± 0.050	2.12 ± 0.001	2.71
2.	Limestone	230.20 ± 0.000	127.33 ± 0.200	1.81 0±.001	2.65

Table (2) Values of Intensity for Various Thickness of Marble

Sr.No	Thickness (cm)	Counts			Average Count (Iavg, cnt/s)
		I1 (cnt/s)	I2 (cnt/s)	I3 (cnt/s)	
1.	0	112.8±2.72	121.66±3.16	107.93±2.94	114.14±2.94
2.	2.22±0.033	57.34±2.53	60.96±2.52	70.26±2.43	62.85±2.49
3.	4.40±0.020	37.48±2.11	38.91±2.06	32.40±2.15	36.26±2.11
4.	6.62±0.013	17.34±1.82	20.99±1.82	20.59±1.82	19.64±1.82
5.	8.87±0.014	10.86±1.57	10.66±1.55	9.28±1.56	10.27±1.56
6.	10.90±0.039	6.19±1.35	4.76±1.41	4.39±1.44	5.11±1.40

Table (3) Values of Intensity for Various Thickness of Limestone

Sr.No	Thickness (cm)	Counts			Average Count (Iavg, cnt/s)
		I1 (cnt/s)	I2 (cnt/s)	I3 (cnt/s)	
1.	0	116.37±2.92	119.85±2.76	125.64±3.08	120.62±2.92
2.	1.40±0.000	96.22±2.73	91.02±2.77	93.51±2.75	93.58±2.75
3.	2.80±0.000	71.96±2.52	70.94±2.57	70.36±2.54	71.08±2.54
4.	4.00±0.066	49.29±2.42	56.77±2.35	60.68±2.32	55.58±2.36
5.	5.10±0.086	43.22±2.04	40.13±2.12	37.98±2.12	40.44±2.09
6.	6.30±0.067	25.54±1.97	26.08±1.99	28.23±1.92	26.62±1.96

Table (4) Linear Attenuation Coefficient of Marble (I_0 = 114.14±2.94), (ρ = 2.12 g/cm^3)

Sr. No.	Thickness (cm)	Avg. Counts (cnt/s)	ln I/I_0	Linear Attenuation Coefficient (μ, cm^{-1})	Mass Attenuation Coefficient (μ_m, cm^2/g)
1.	2.22±0.033	62.85±2.49	-0.597±0.04	0.269±0.02	0.125
2.	4.40±0.020	36.26±2.11	-1.148±0.06	0.261±0.01	0.123
3.	6.62±0.013	19.64±1.82	-1.760±0.09	0.265±0.01	0.128
4.	8.87±0.014	10.27±1.56	-2.419±0.09	0.272±0.01	0.129
5.	10.90±0.039	5.11±1.40	-3.123±0.09	0.286±0.02	0.133

Table (5) Linear Attenuation Coefficient of Limestone (I_0 = 120.62±2.92), (ρ = 1.81 g/cm^3)

Sr. No.	Thickness (cm)	Avg. Counts (cnt/s)	ln I/I_0	Linear Attenuation Coefficient (μ, cm^{-1})	Mass Attenuation Coefficient (μ_m, cm^2/g)
1.	1.40±0.000	93.58±2.75	-0.253±0.04	0.181±0.02	0.108
2.	2.80±0.000	71.08±2.54	-0.529±0.04	0.189±0.01	0.112
3.	4.00±0.066	55.58±2.36	-0.774±0.04	0.193±0.01	0.106
4.	5.10±0.086	40.44±2.09	-1.093±0.05	0.214±0.01	0.113
5.	6.30±0.067	26.62±1.96	-1.509±0.07	0.239±0.01	0.121

Table (6) Comparison of Attenuation Coefficient with Standard Value

Sample Name	Linear Attenuation Coefficient (μ_l)		Mass Attenuation Coefficient (μ_m)	
	Exp:	Std:	Exp:	Std:
Marble	0.275	0.230	0.127	0.114
Limestone	0.234	0.217	0.112	0.086

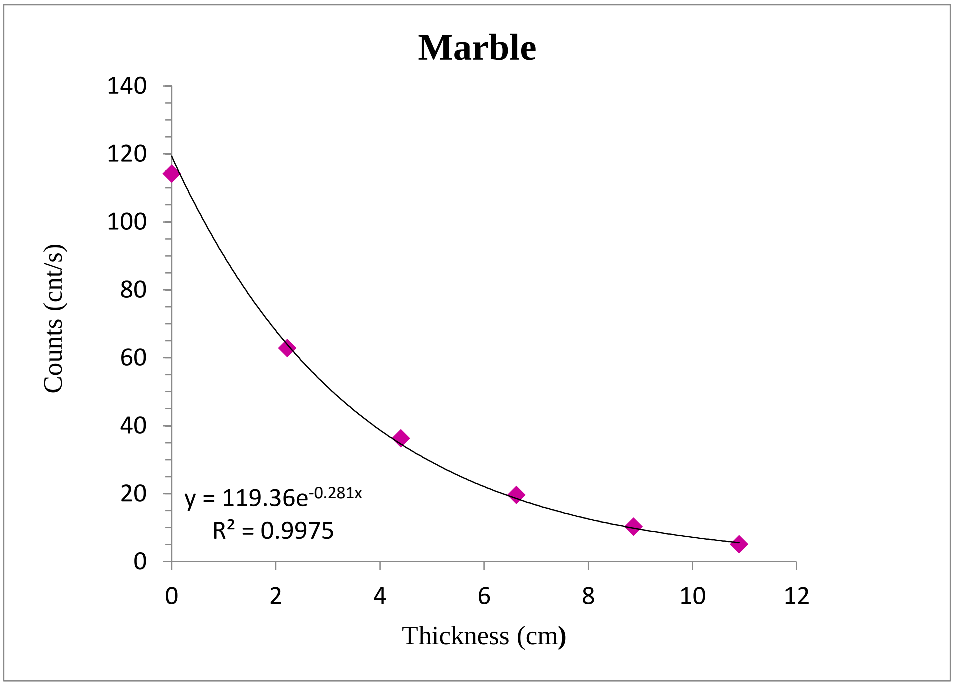


Figure. (1) Relation of Thickness and Counts for Marble

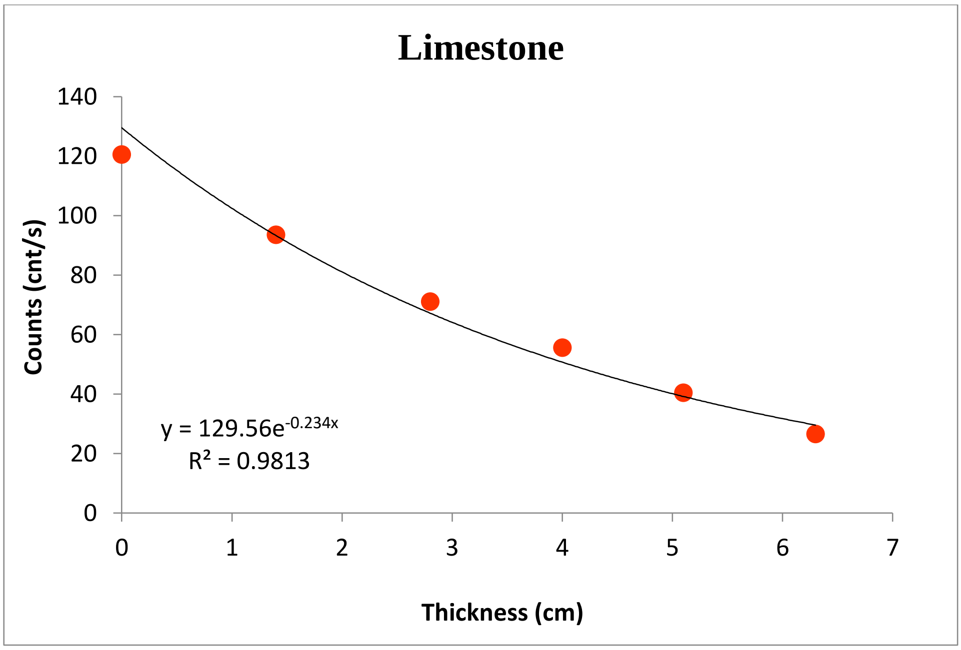


Figure. (2) Relation of Thickness and Counts for Limestone

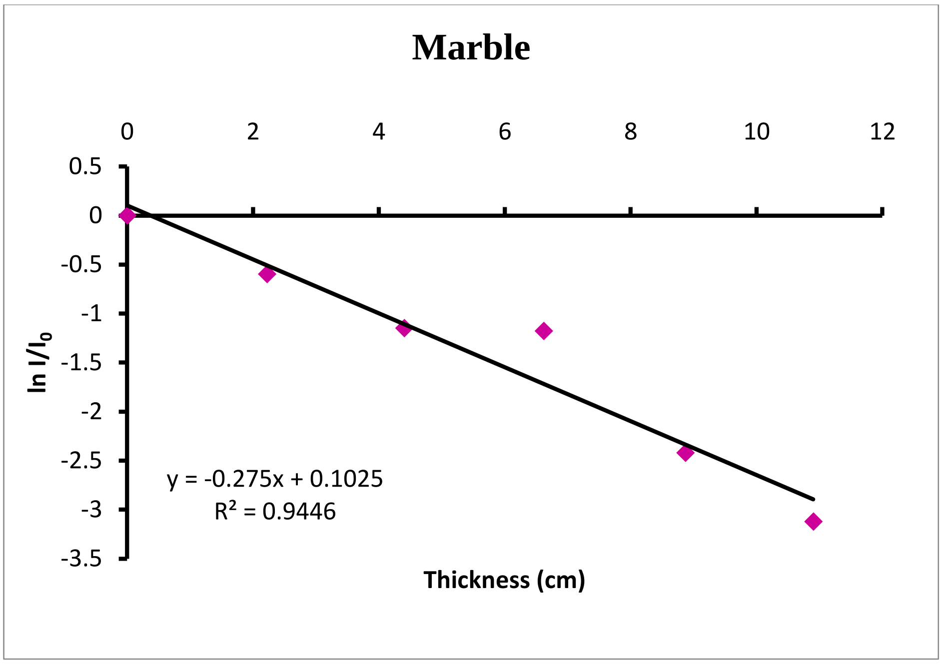


Figure. (3) Relation of Thickness and ln $I/I_0$for Marble

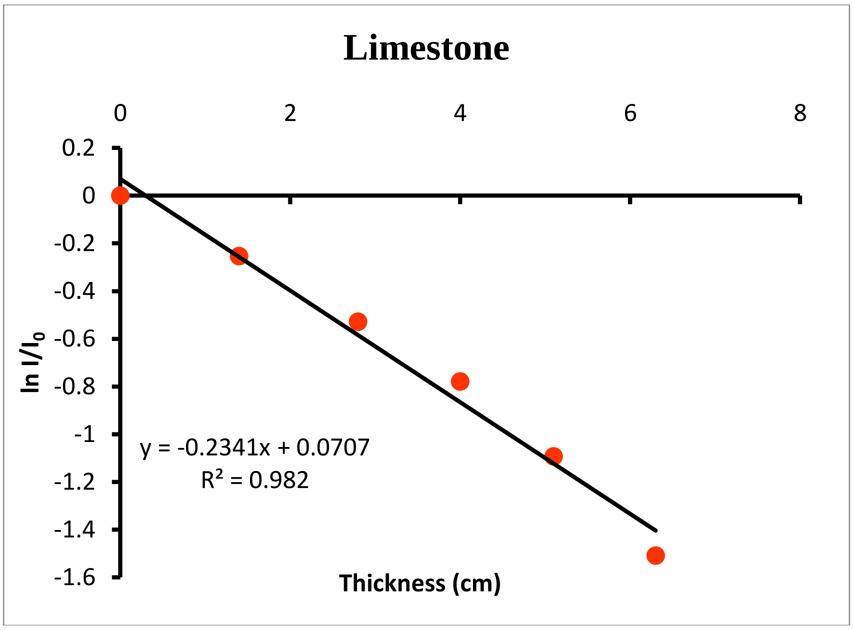


Figure. (4) Relation of Thickness and ln I/I_0 for Limestone

Conclusion

From the experimental results,the building material of marble and limestone can also be used for radiation protection. The density of marble is denser than that of limestone. So, it can be concluded that, the denser materials are more attenuate for radiation intensity.

Acknowledgements

I would like to thank Rector Dr Tint Moe Thu Zar, Yadanabon University, for her kind permission to do this paper, Pro-Rector Dr U Khin Myo, Pro-Rector Dr Myint Myint Oo and Pro-Rector Dr Khin Maw Maw Soe, Yadanabon University, for their permission to do this paper. I am very thankful to Professor Dr Khin Thida, Head of Department, Professor Dr Sandar Min and Associate Professor Dr Hnin Thidar Soe, Physics Department, Yadanabon University, for their encouragement and suggestion to do this paper.

References

ALI H. TAQI, HERO J.KHALIL," EXPERIMENTAL AND THEORETICAL INVESTIGATION OF GAMMA ATTENUATION OF BUILDING MATERIALS", JOURNAL OF NUCLEAR AND PARTICLE PHYSICS, 2017.

GORDON GILMORE, "PRACTICAL GAMMA-RAY SPECTROSCOPY", (1995) CHAP. 2 INTERACTION OF GAMMA RADIATION WITH MATTER.

HTTPS://EN.M.WIKIPEDIA.ORG> WIKI > GRANITE, MARBLE, LIMESTONE.