Experimental Evaluation of Gamma-Ray Shielding Effectiveness of Lead and Concrete

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Introduction

As the nuclear technology industry grows, it is essential to enhance the control of hazardous radiation effects on people and the environment in gamma irradiation facilities [1]. There are numerous applications where Nuclear Radiation is used like in nuclear power plants, cancer treatment centres, nuclear medicine, food preservation, agriculture, archaeology, pest control, space exploration inspection, and instrumentation. However, its shielding is unavoidable given the associated negative effects on the environment and living beings.

This study, focuses on experimentally evaluating the gamma-ray shielding effectiveness of lead and concrete [2] by determining their buildup factors and attenuation coefficients. Gamma-ray buildup factors are essential for accurate radiation dose predictions behind shields, accounting for scattered radiation that contributes to overall exposure.

Experimental Details

Measurement

In this experiment shielding material considered for 999kBq ^{137}Cs Gamma source, lead (Pb)which have thickness is 3.175mm and Portland Cement having a thickness of 1500 mm. As lead and cement being dense material acts as good shield against gamma radiation. For optimization of shields, we calculate the build-up factor using monoenergetic ^{137}Cs Gamma source (which is commonly used in industry). NaI(Tl) scintillator detector was used for the present measurement .

Build up factor arises for bad geometry when we use uncollimated isotropic source radiating in 4π direction vs good geometry where we use a collimated beam (where collimator gap size is of height 2.5 cm and width 0.5 cm). Good geometry and bad geometry have been depicted in Fig.1.

Build up factor for good geometry is considered as one.

$$I = Io \exp(-\mu x) \text{------ (1)}$$

Equation for Bad Geometry is

$$I = B\,(Io \exp(-\mu x)) \text{------ (2)}$$

Where:

I - gamma rays intensity passing through thickness x of the shield material.

Io - Incident gamma rays' intensity without shield material.

B= Build up factor

μ - linear gamma attenuation coefficient.

x - thickness of shield.

Using equation (1),

$$\ln(I/Io)_{good} = -\mu x \text{------ (3)}$$

Using equation (2),

$$\ln(I/Io)_{bad} = \ln B - \ln(-\mu x) \text{ (4)}$$

After Solving (3) and (4)

$$B = \frac{\ln(I/Io)\text{ bad}}{\ln(I/Io)\text{ good}}$$

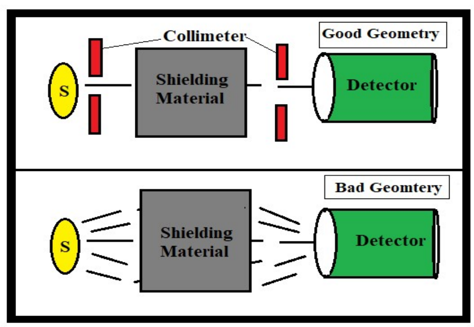

Fig 1: Good and Bad Geometry

Results, Discussions and Future Scope

The calculated attenuation coefficients for both lead and Portland cement were derived using experimental data and compared with NIST data. The results, illustrated in Fig2. demonstrate distinct differences in attenuation behaviour between the two materials under both good and bad geometrical setups. Specifically, lead exhibited a higher attenuation coefficient compared to Portland cement, indicating its superior effectiveness in radiation shielding.

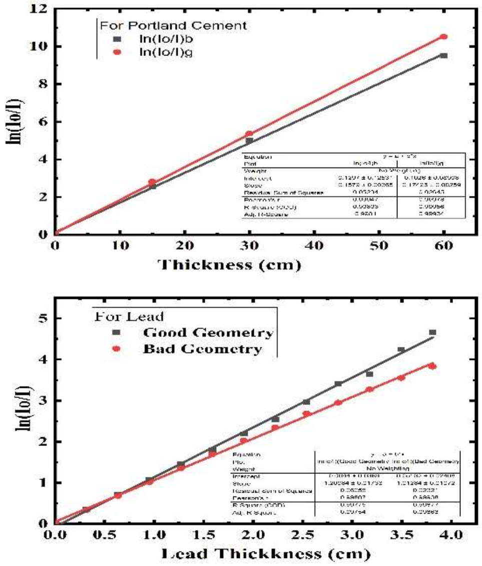

Fig2. Linear Attenuation of lead and Portland Cement

After calculating the linear attenuation coefficients, we proceeded to calculate the build-up factor using the derived formula. The results of the build-up factor calculations were compared for both lead and Portland cement, finds that lead have higher Build-up then Portland cement in terms of radiation shielding effectiveness.

This comparative analysis highlights the importance of both the linear attenuation coefficient and the build-up factor in evaluating the overall shielding performance of materials. The Results suggest that while Portland cement can be utilized in certain applications, lead remains the preferred choice for optimal radiation protection due to its superior attenuation properties.

In future work, we plan to exchange the positions of lead and cement placing one after another, to find out which acts as a better shielding material, we will also validate our experimental results on lead and Portland cement's attenuation properties using Geant4 simulations. This will involve replicating our setups in Geant4, comparing simulation outcomes with experimental and NIST data [4]. Our aim is to optimize material usage for effective yet economical radiation shielding solutions.

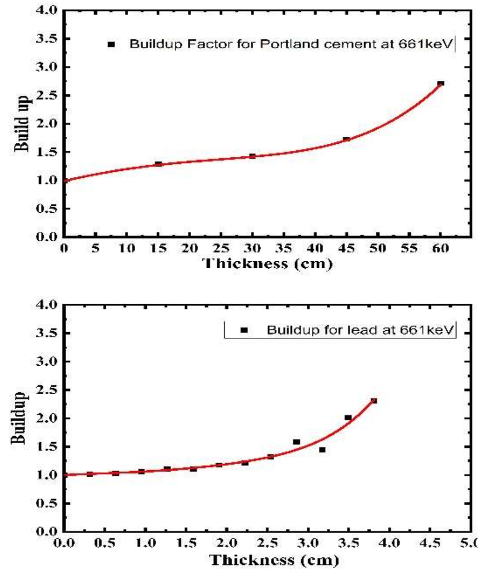

Fig3. Buildup factor for lead and Portland Cement

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