Gamma-ray shielding study of different concrete compositions as a reactor shielding

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Introduction

Nuclear reactor in its operating stage through fission or fusion reaction, produces different radiation (α, β, γ, n, p, etc.). Among all, neutron and gamma are considered as a prime radiation corresponds to its energy and penetration [1]. The kind and quantity of material which is used for shielding depend upon the factors like a type of radiation, the dose rate, intensity of radiations. Including these, the other factors such as cost, weight, fabrication and most important its availability in the country [2] are one has to consider.

On the above mention points, the studies of the absorption of radiation in materials have become an important issue and thus it is desirable to have the knowledge about the effective materials for neutron and gamma. For neutron shielding low atomic elements (Z) are used, mainly which have more hydrogen contain [3]. Considering this major shielding materials for neutrons are High-density polyethylene (HDPE), Boron Carbide (B_4C), etc. Whereas high Z elements used for shielding against gamma (Z^4), like Lead (Pb), Tungsten (W), Uranium Dioxide (U_2O), etc. [4].

In the previous DAE 2018 [5] we presented the theoretical data of different concrete compositions to get more effective shielding. Whereas in present paper we provide comparison of previous theoretical data with experimental data for gamma-ray (Co-60) source. The final results match with 2-5 % uncertainty.

Sample preparation

Apart from radiation shielding, to maintain the other mechanical and physical properties of concrete are crucial. By consideration of this we have kept 80% amount of concrete fixed and remaining amount change for shielding purpose. In this respect, we have first made a sample of normal concrete as a test material. Then after in normal concrete we have added WC and B_4C as a shielding material. The purpose of selecting WC is because of its availability and cheaper then pure W. As its density and atomic number are high, it is a very good shielding material for gamma and neutron.

For the experiment, after extensive trials, we have settled on the mineral aggregate (sand and crushed stone) 80% of sample, cement and adding material contains 20% for all the mixture. Seven different concrete samples were made for the present study. Variation of elements in all seven different sample given in table 1. Slabs of 10 x 10 x 1 cm^3 and 10 x 10 x 2 cm^3 dimensions were fabricated to check the element effect in the samples.

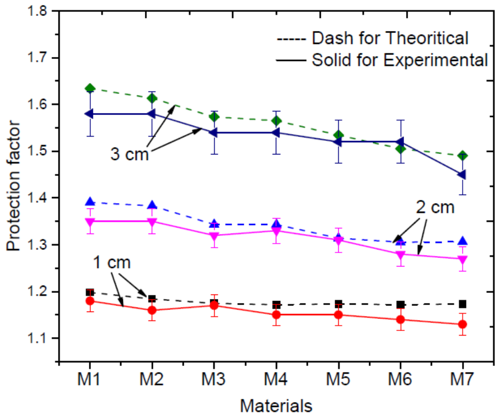

Fig. 1 Protection factor studied for different concrete composition.

Experimental and Simulation

The experiment for the dose rate measurement using the Co-60 gamma source was conducted at the Defence Lab, Jodhpur. A 15 Ci Co-60 source was used to irradiate the samples and doserates were measured without and with samples.

All the samples with the same irradiation geometry were modeled in Monte Carlo based MCNP code. In collaboration with K. Katovsky Brno University, Czeq Republic, the simulations were performed.

Result and Discussions

Methodology and simulation specifications of the Monte Carlo based MCNP code were briefly discussed in the conference proceedings [5]. Seven different concrete samples, each having different WC/B_4C ratio, at different thickness (1, 2 and 3 cm), were used to test the contribution of this ratio content in concrete to protect against gamma shielding. The protection factor for prepare samples using Co-60 source are presented in Fig.1. The effect of different composites is clearly observable. The protection factor decreasing from M1 to M7 for all the three thickness. Which indicates the highe protection can be observed in the M1 which have more WC compared to other. The objective of our previous proceedings [5] consistent with the present experiment i.e. as density decreases the protection factor decreases. At present in all different combination the material M1: 80% concrete + 20% WC gives the best protection factor for gamma and further calculations (Transmission factor, TVL, HVL, Linear attenuation coefficient) is in progress.

Table 1: Different concrete composition used for the testing of shielding efficiency

Material	**Theoretical Density (g/cc)**	**Density for 1 cm sample (g/cc)**	**Density for 2 cm sample (g/cc)**
M1: 80% concrete + 20% WC	2.77	2.44	2.45
M1: 80% concrete + 16% WC + 4% B4C	2.67	2.39	2.43
M3: 80% concrete + 12% WC + 8 %B4C	2.58	2.36	2.41
M4 80% concrete + 8% WC + 12% B4C	2.49	2.38	2.40
M5: 80% concrete + 4% WC + 16% B4C	2.41	2.32	2.37
M6: 80% concrete + 20% B4C	2.34	2.18	2.28
M7: 100% Concrete	2.34	2.07	2.17

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