Different concrete compositions as a reactor shielding material for neutrons and gamma rays

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Introduction

In a reactor during the fission or fusion reaction the prime radiation produced are neutrons and photons [1]. The shielding design of a reactor or any radiation facility is a crucial part. The selection of a shielding material is based on its efficiency to shield the radiation and effective in cost. The major shielding materials for neutrons are HDPE, B_4C, concrete, etc. Whereas gamma rays can be shielded with Pb, W, U_2O, etc. [2]. The concrete is used as a common shielding material as it is very cost effective and has long durability [3]. The ordinary and reactor grade concrete provides shielding to both neutrons and gammas. For high neutron flux the thickness of the concrete required must be large. Hence, this will increase the cost and the occupied space. In present paper we have tried to introduce some materials in concrete composition to get more effective shielding. The materials are added in such a way that the overall density of the concrete doesn't change but the effect in reduction of the neutron and gamma flux will be more.

Material selection

We have taken the normal concrete as a test material. In normal concrete we have added WC and B4C as shielding materials. The WC is selected mainly because of tungsten. Tungsten is a very good shielding material for gamma as its density and the atomic number is very high. The amount of concrete 80% kept fixed and remaining 20% are changed. We have taken a sum of WC and B4C in different amount for the remaining 20%.

Methodology

We have used the Monte Carlo based MCNP code for the simulation of the attenuation of neutron and gamma. The MCNP is a worldwide used code for shielding and particle transportation [4]. We have modelled a block of material with 10 x 10 cm^2 area with different thicknesses. The neutron and photon sources are taken as disc sources emission in one direction to one of the face of the material block. The neutron source was considered ^{252}Cf and gamma source was considered standard ^{60}Co. The ^{252}Cf neutrons were taken mono-energetic (2.1 MeV) for average peak neutrons. For ^{60}Co we have considered standard 1.173 MeV and 1.332 MeV. Including the experimentally possible sources we have also simulated for the other discrete neutrons and gamma energies. We have calculated the flux for normal concrete as well as for the different combination of the material. All the combinations are shown in Table 1. The neutron and gamma flux were calculated using the F2 tally which gives surface average flux.

Results and Discussion

The simulated fluxes are presented in Figs. 1 and 2. The effect of different composites can be clearly observable. Normal concrete shows least attenuation in the both cases of neutrons and gamma. The highest attenuation can be observed in the case of only tungsten and lead. The objective of the present work is to make a suitable composition certain elements in concrete that serve the purpose of shielding for the neutrons as well as for gammas. In view of this, we have taken different combinations of these heavy Z and high density materials for gamma and low Z with high neutron interaction probability material B_4C. It can be seen that as we increase the concentration of W the efficiency of shielding also increases. But parallelly, the irradiated tungsten can become the radioactive. Further, an appreciable amount of B_4C must be there to absorb and slow down the neutron in the interaction with the concrete. At present in all different combination the material 80% Concrete + 15% W + 5% B_4C gives the best shielding for neutrons and gammas (Table 1).

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

Material	Density (g/cc)
Concrete	2.400
Tungsten	19.25
Lead	11.34
80% Concrete + 20% W	2.838
80% Concrete + 20% Pb	2.781
80% Concrete + 20% Zr	2.683
80% Concrete + 9% WC + 11% B4C	2.555
80% Concrete + 8% WC + 12% B4C	2.534
80% Concrete + 7% WC + 13% B4C	2.512
80% Concrete + 6% WC + 14% B4C	2.492
80% Concrete + 5% WC + 15% B4C	2.471
80% Concrete + 11% WC + 9% B4C	2.599
80% Concrete + 12% WC + 8% B4C	2.622
80% Concrete + 13% WC + 7% B4C	2.645
80% Concrete + 14% WC + 6% B4C	2.669
80% Concrete + 15% WC + 5% B4C	2.693

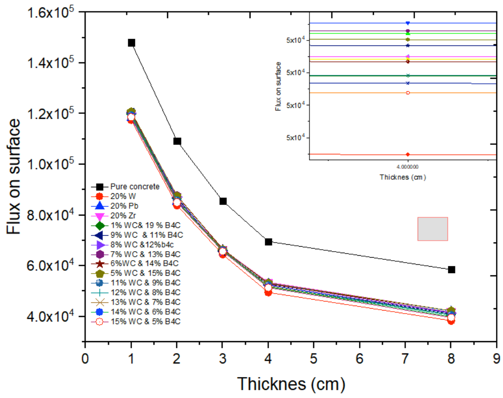

Fig. 1 Attenuation of neutrons provided by different concrete composite

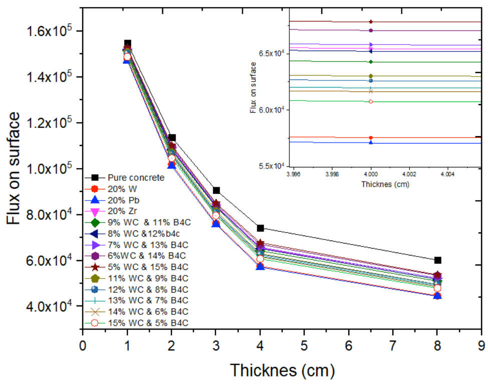

Fig. 2 Attenuation of gamma provided by different concrete composite

References

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