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USE OF LOCAL MATERIALS FOR CONSTRUCTION OF ANTINUCLEAR AIRPLANE SHELTERS (RADIATION SHIELDING)

N.A.El-Sharara*, M.M. El-Dessouky*, A.M.I. Kany ** and M.A.Mousa *

Abstract

The work aimed to prepare a high-density concrete for radiation shielding for construction of antinuclear shelters to protect airplanes and other military instruments against radiation emitted during nuclear burst, specially gamma and neutrons. Ordinary concrete can be used for shielding but excessive thickness may be required. The choice of suitable material will improve the attenuation of radiation and reduce the required thickness. In this study different concrete mixes were designed, produced, cured and tested for attenuation of both neutrons and gamma rays.

Key Word: Airplane protection, Heavy weight concrete, neutrons shielding, Gamma shielding.

* Egyptian Armed Forces.
** Al-Azhar University, Faculty of Science , Cairo, Egypt

Introduction

The high-density concrete provide complete protection from nuclear blast, primary radiation and radioactive fallout. In this study, ilmenite is used as coarse aggregate for gamma attenuation, and serpentine is used as five aggregate for thermalizing and absorption of neutrons. Gamma radiation is highly penetrating electromagnetic radiation. Gamma rays are attenuated primarily through elastic collision with electrons. High density material are good attenuators, the use of special high-density aggregate such as ilmenite is desirable. Attenuation of fast neutrons also requires a high density elements, while the presence of hydrogen atoms will cause moderation and slow neutrons to be absorbed. Serpentine aggregate contains hydrogen in the form of the water of crystallization. About (11.5%) [1]. For this reason the choice of suitable aggregate may be important.

Experimental Work

General

The samples under investigation were prepared in the form of cylinders made from ilmenite-serpentine heavy weight concrete (ISHWC), and ordinary concrete as a reference. The cylinders have 10 cm diameter and thickness varies from 2.5 up to 20 cm. The samples and their compositions are shown in table (1). All samples are heated at temepratures 100,300 and 500°C.

Gamma source Eu-152

European-152 was used as a gamma source in this study. Eu-152 has half life time of about 4.291×10^8 ($\approx$ 13.6 years) [2]. Its nuclear states have very well-defined energies, the gamma-ray energies and source yield of Eu-152 are given in table (2).

Gamma Detection

The measurements of the gamma-rays were performed using $3'' \times 3''$ crystal dimensions NaI(Tλ) detector [3]. The studies of gamma rays absorption were made through measurements of its transmission through the prepared samples of concrete. Fig.(1) shows the experimental arrangement for the measurement of the transmitted gamma rays (good geometry). The linear absorption coefficients (μ) are function of both the energy of the photons and the density of absorber as shown in equation (1), (Lambert law).

$$\frac{I}{I_o} = e^{-\mu_m d_m} \qquad (1)$$

where μ_m = total linear absorption coefficient

d_m = mass thickness

The ^{241}Americium-Beryllium neutron source

A 100 mCi activity ^{241}Am-Be the source was used in this study. The neutron yield from the source has a value of 0.86×10^7 neutron/sec. ^{241}Am isotope has a half life time of about 433 years. ^{241}Am decays by emitting alpha particles of 5.48 Mev, that followed by gamma rays of energy range 40-60 Kev. As a result of the interaction of α-particles with beryllium, neutrons are emitted as shown in equation (2) of average energy below 1.0 Mev.

$$
\begin{aligned}
&{}^{241}_{95}\mathrm{Am} \rightarrow {}^{4}_{2}\alpha + {}^{237}_{93}\mathrm{Np} + \gamma \\
&{}^{9}_{4}\mathrm{Be} + {}^{4}_{2}\alpha \rightarrow {}^{1}_{0}\mathrm{n} + {}^{12}_{6}\mathrm{C}
\end{aligned}
\qquad (2)
$$

Slow and epithermal neurons detection system

The measurement of the slow neutron spectrum can be achieved using an aluminum casing BF_3 gas filled proportional counter [4], (type 20344 LND) of 400 torr pressure, 25 cm sensitive length and outer diameter of 5 cm. Fig.(2) shows the pulse hieght distribution of BF_3 proportional counter due to ^{241}Am-Be source. The filling gas is enriched to greater than 96% with ^{10}B isotope. Aluminum construction minimizes weight and neutron absorption. For the measurements of the slow neutron, both the detector and the source are arranged as shown in Fig.(3). For measuring epithermal neutrons, the BF_3 detector was covered by cadmium filter of 0.6 mm thickness.

Results and Discussion

Slow and Epithermal neutron attenuation in ISHWC

The macroscopic cross-section (Σ) of slow and epithermal neutrons in ISHWC represented in the slopes of straight lines. Figures (4,6) and appendix (1) show an examples for slow and epithermal neutrons attenuation in sample B, where plotted for the relation between the neutrons fluxes (slow or epithermal) and the thickness of the shield concrete in plane normal to the beam axis. Results show that the intensity of slow and epithermal neutrons decreases as the concrete layer thickness increases, that for all types of ISHWC. This behavior is due to the absorption process of the elastic scattering of slow and epithermal neutrons through the ISHWC. Figures (5,7) show that slow and epithermal neutrons attenuation will decreases exponentially as the annealing temperatures increases. The ISHWC shows better attenuation properties to a large extent for slow neutrons. It was about 17%, 15%, 8% for samples B,A,C consequently than ordinary concrete (sample D), and it was 11.6%, 0.7% for samples B,C consequently for epithermal neutron, but the attenuation properties for samples A and D were the same values, all that at (R.T.). results show that slow and epithermal neutrons intensity will decreases exponentially as the annealing temperatures increase, while the rate of decrease changes from case to case and that regarding the role of crystallization water exist in serpentine aggregate as neutron moderator or absorption. The sample B which contains superplasticizer material showed better slow and epithermal neutrons absorption, than other types of ISHWC, may be because these material reach by hydrogen and carbon, and as a result the attenuation value of ISHWC depends mainly on the elastic scattering process between slow and epithermal neutrons emitted from ^{241}Am-Be source and the hydrogen exist in the aggregate (serpentine). Even at high temperatures heating of the ISHWC and up to 500°C the macroscopic cross-section (Σ) of slow and epithermal neutrons still high, while the ordinary concrete has lost its mechanical properties already at 300°C and thus lost its attenuation properties.

Attenuation of gamma rays in ISHWC

The attenuation curves of gamma rays were plotted for the relation between the gamma intensity and the thickness of the shield ISHWC in the plane normal to the beam axis. The linear absorption coefficients (μ) were derived from the slope of the attenuation curves. The results show that the gamma intensity decreases as the shield thicknesses of ISHWC increase, and that for all types of ISHWC and ordinary concrete, that decrease in gamma intensity follows an exponential law. The relation between μ_γ and E_γ (energies of gamma ray) at different annealing temperatures of concrete are represented in figures (8,9,10,11) for samples A,B,C,D consequently. The results shows that the annealing of ISHWC up to 500°C has no high effect on the gamma ray attenuation and that for all samples of ISHWC. The gamma rays attenuation properties shows better results as a whole for all proposed ISHWC concrete samples with that obtained from the ordinary concrete. The optimal results show that sample A has the best of (μ_γ) and that is regarding of high content of Ilmenite aggregate (67%). The experiments of annealing ISHWC up to 500°C show that linear absorption coefficient does not affect appreciably at different temperatures. The results show that as a gamma rays energies increase the value of (μ_γ) increases up to 1.5 Mev, which means that the ISHWC show good resistance against high energy of gamma rays. The high gamma rays attenuation confirm that no appreciable cracks generated in the ISHWC such as (μ_γ) does not affected too much by heating.

Conclusion

Results of the experimental study of the attenuation of ISHWC for slow and epithermal neutrons show that the attenuation increase with increasing the shield thickness exponentially. The decrease in the macroscopic cross-section of both slow and epithermal neutrons decreased when the concrete was annealed to 500°C. This decrease was thought due to the decrease in the hydrogen content in the aggregates which play important role in neutrons absorption, The sample B which contains superplasticizer material showed the best attenuation for neutrons due to the hydrogen content which acted as good moderator. The gamma ray intensity decreases with increasing the shield thickness exponentially. No appreciable change was absorved in gamma attenuation with annealing of ISHWC up to 500°C. With increasing the gamma ray energy up to 1.5 Mev, the (μ_γ) increased.

Reference

[1] Abulfaraj et al., 1st Radiation Physics Conference, Cairo, Egypt (1992).
[2] Knoll F., Radiation Detection and Measurements, V.5, pp 155-159, (1973).
[3] Frinck R., Nudear Measurements methods, V. 35, pp 559-560, (1976).
[4] Wikinson D.H., Ionization Chambers and Counters, Cambridge University Press, (1980).

Table (1) The samples and their comnposition

Type of sample	Composition			
	% Fine aggregate	Cement content Kg/m^3	Additives	W/C
A	33	400	-	0.65
B	33	400	S.P	0.56
C	20	350	-	0.58
D (ordinary concrete)	33	350	-	0.50

Table (2) *Gamma-ray energies of Eu-152.*

PN	CTRD key	FWHM key	Net Area	Backgrnd	Net C/S	%Err	E_γ
1	61.44	11.93	63906	85160	1253.059	0.94	121.8(28.2)
2	104.84	11.05	15849	59333	310.765	2.63	244.7 (7)
3	301.12	27.73	40581	1127725	795.706	1.91	344.14(26)
4	669.75	42.68	20039	80645	392.922	3.64	778.9 (13)
5	823.02	45.96	18959	51266	371.745	3.17	964 (14)
6	935.53	63.47	40026	51175	784.824	1.80	1086.4(12)
7	1179.12	59.03	22954	18816	448.118	1.93	1407.9(21)

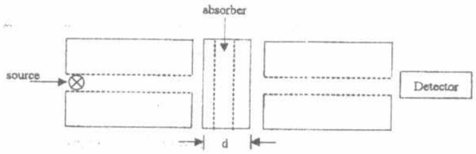

Fig.(1) *Experimental arrangement for the measurement of the transmitted gamma ray.*

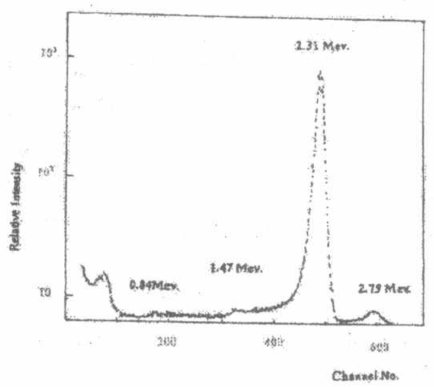

Fig.(2) *Pulse height spectrum of the BF3 proportional counter due to an ^{241}Am-Be source*

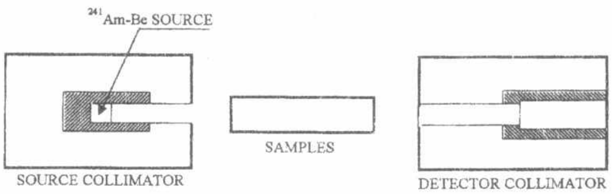

Fig.(3) *Experimental geometry of the detection system*

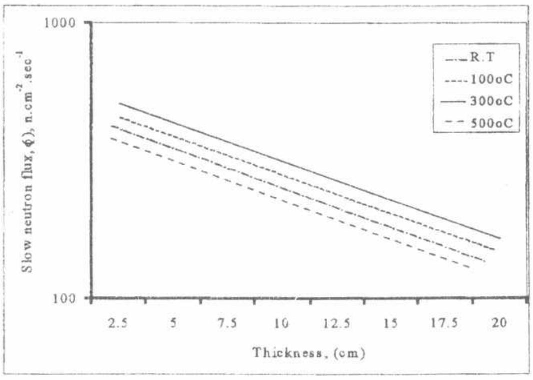

Fig.(4) Slow neutron attenuation in sample B

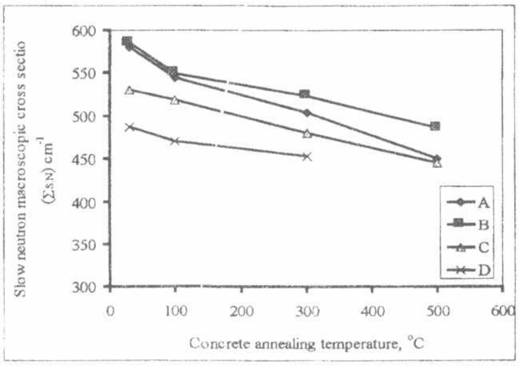

Fig.(5) Slow neutron attenuation in ISHWC

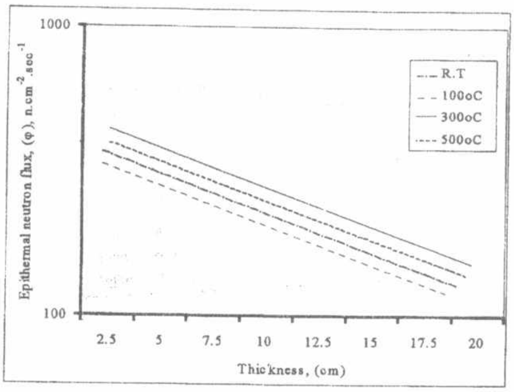

Fig.(6) Epithermal neutron attenuation in sample B

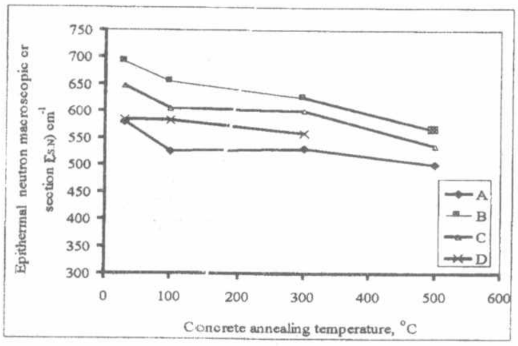

Fig.(7) Epithermal neutron attenuation in ISHWC

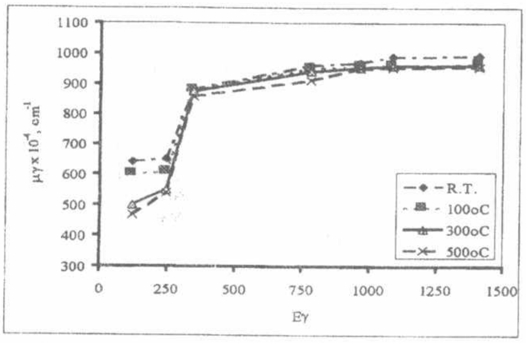

Fig.(8) Relation between μ_γ and E_γ at different temperature for sample A.

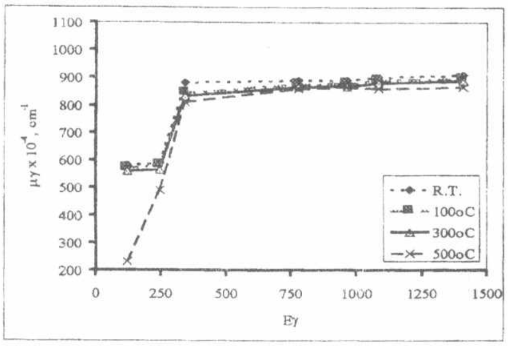

Fig.(9) Relation between μ_γ and E_γ at different temperature for sample B.

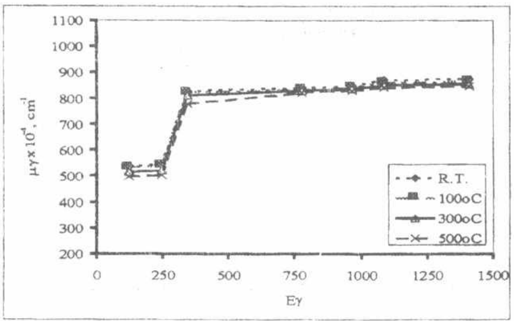

Fig.(10) Relation between μ_γ and E_γ at different temperature for sample C.

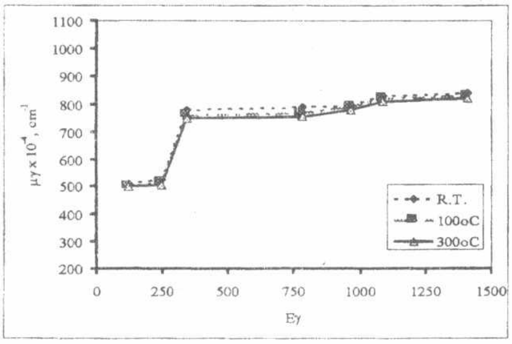

Fig.(11) Relation between μ_γ and E_γ at different temperature for sample D.

Appendix-1

Slow neutron flux in sample B

Thickness cm	30 °C	10 °C	300 °C	500°C
2.5	685	692	713	676
5	585	559	563	555
7.5	475	522	480	453
10	437	386	412	421
12.5	366	352	361	374
15	335	328	315	328
17.5	298	287	299	287
20	274	268	261	279

Epithermal neutron flux in sample B

Thickness cm	30 °C	100°C	300 °C	500 °C
2.5	575	608	602	619
5	477	503	474	495
7.5	365	431	403	414
10	346	341	324	247
12.5	304	294	318	346
15	273	274	274	289
17.5	239	263	255	256
20	209	229	209	241