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Introduction

An assembly of concrete blocks has widely been used to make a wall for radiation shielding because of easy dismantling and restoration when needed. But some attention must be paid to the radiation leakage through the air gaps between the blocks. Recently, concrete blocks having the smallest air gaps when assembled them have been specially fabricated by Takenaka Civil Eng. Co.Ltd. and other companies, and used in nuclear power plant. This study was done to measure the performance of radiation shielding against neutrons and photons of an assembly of concrete blocks by changing the thickness of concrete blocks. In order to clarify the effect of air gaps between concrete blocks, we also changed the width of air gaps. The experimental results were compared with the calculated results obtained from the MCNP Monte Carlo Code1).

Experiment

In this study, we used a ^{252}Cf (0.92mCi) neutron source with polyethylene collimator and ^{60}Co gamma-ray source (11mCi) with lead collimator. The schematic views of experimental arrangement and collimators are shown in Fig. 1. Polyethylene collimator is a sphere of 35cm diameter having a collimator hole of 5.1cm diameter by 15cm length and lead collimator is a cylinder of 10cm diameter by 10cm height having a tapered collimator hole of 30cm outer diameter by 3.5cm length. For neutron detection, we used dose equivalent surveymeter, rem counter, NSN1, fabricated by Fuji Electric Co. Ltd. and Bonner sphere spectrometer loading ^{3}He proportional counter2), and for photon detection, we used NaI(Tl) scintillation surveymeter, TCS-161, fabricated by ALOKA Co.Ltd. and NaI(Tl) scintillation spectrometer of 7.62cm diameter by 7.62cm length. The concrete blocks were assembled to have a concrete wall of 130cm height and 145cm width and the wall thickness was changed as 50, 60, 80, and 100cm. The collimator exit of neutron or photon source was fixed to be 10cm distant from the concrete wall surface and the collimator hole was kept for collimated neutron and photon beams to be normally incident on the wall surface. The detectors were placed in contact with the rear surface of the concrete wall.

The experiment was done in the room of 6.05m × 9.92m × 4.58m and to estimate the contribution of room-scattered radiation, we repeated twice the measurements with and without the shadow bar of the collimator. By subtracting these two measured results, we approximately excluded the room-scattered radiation. Both the sources and detectors were placed at a few positions faced on the flat block surface and on the gap of two blocks as shown in Fig.1. For further investigation of air gap leakage effect, both at 50 and 80cm wall thicknesses, we inserted metal washers with 1mm or 3mm thickness between the blocks to enlarge the air gaps as also indicated in Fig. 1.

The counts measured with Bonner ball were converted to the neutron energy spectra using the SAND-2 code3) with an initial guess based on the MCNP calculation and the calculated response functions2) and the neutron dose equivalent values were obtained from these-obtained spectra and the dose conversion factor given by ICRP-514).

The pulse height distribution measured with NaI(Tl) were also converted to the photon energy spectra using the FERDO-U code5) and the calculated response function6), and the dose equivalent values were also directly obtained from the pulse height distributions using the G(E) function7), which includes the dose conversion factor.

Calculation

To compare with the experimental data, we calculated the neutron and photon energy spectra and dose equivalents penetrated through concrete shields with the MCNP Monte Carlo code2). In this calculation, the cross section data library, ENDF/B-IV was used. The atomic composition of the concrete used in the calculation is listed in Table 1. The density of the concrete blocks was determined as 2.15 g/cm^3.

Results and discussion

Figs. 2 and 3 show the calculated and measured neutron energy spectra, respectively. Although the units of spectra are different in both figures, the spectral shapes are in good agreement between calculation and experiment.

Figs. 4 and 5 show the measured and calculated attenuation curves of neutron and photon dose equivalent rates as a function of the concrete thickness, respectively. Since the source-to-detector distance was changed at different wall thickness, the dose values were normalized at the distance of 1m. In these figures, 'pos.a-b' indicates that the source position is 'a' and the detection position is 'b', where 'pos.1-1' faces to the flat concrete surface with no air gaps, while 'pos.2-2' and 'pos.2-3' face just at air gaps as seen in Fig. 1. There can be seen no noticeable difference between two experimental results at 'pos.1-1' and 'pos.2-2'/ 'pos.2-3', which means that the leakage effect of neutrons and photons through air gaps between concrete blocks are negligibly small for this specially-designed blocks.

The agreement between experimental and calculated dose equivalent data is rather good for photons, but some discrepancy can be seen for neutrons. This discrepancy may be caused by the difference of actual water content (not available in this concrete blocks) and that used in the calculation, because the neutron attenuation through concrete is strongly influenced by water content, especially hydrogen content. Figs.6 and 7 shows the variation of measured neutron and photon dose equivalent rates with the slit width inserted between concrete blocks at t (shield thickness) = 50 and 80cm. At t = 50cm, slight increase of neutron and photon dose equivalent rates can be seen with slit width (about 40% up to 3mm slit width) but at t = 80cm, there can be seen no increase of dose rates with slit width. The leakage effect through air gaps of slits may be canceled out with decreasing the direct radiation components.

Conclusion

It can be clarified from this study that an assembly of specially-designed concrete blocks has enough shielding performance compared with normal(slab) concrete wall.

References

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Table 1. Concrete data used in the MCNP Monte Calro Code.

Element	Atomic Density
H	7.1929-3
O	4.0323-2
Mg	1.2782-4
Al	2.1883-3
Si	1.4556-2
Ca	2.6683-3
Fe	2.8282-4
Na	9.6302-4
K	6.3578-4

unit (10^{24}/cm^3)

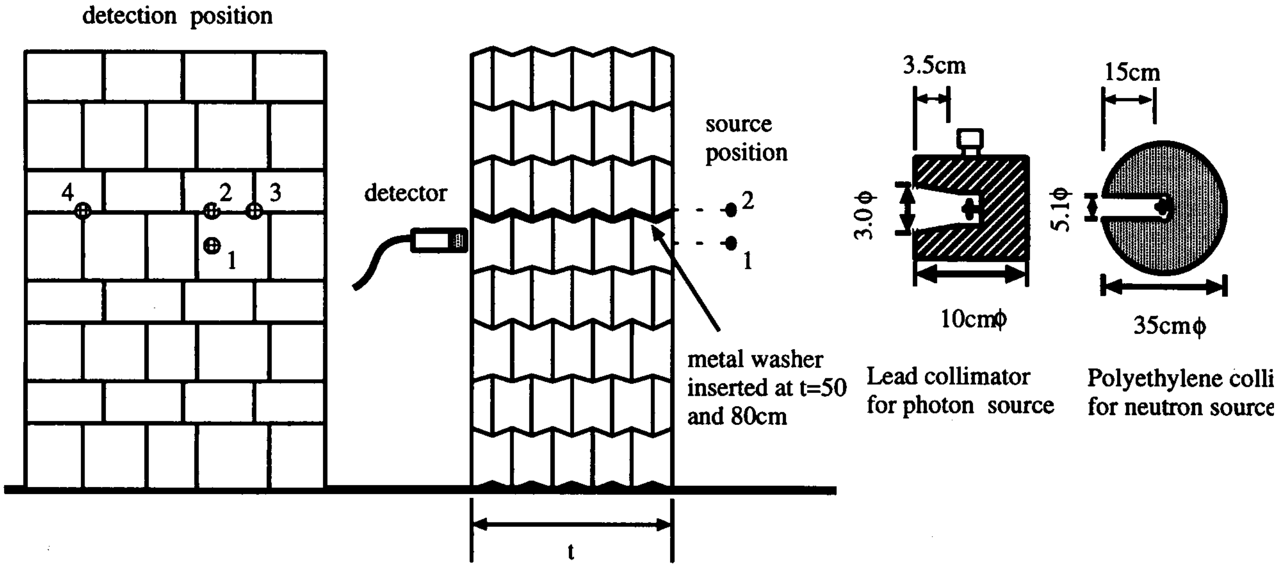

Fig. 1. Schematic view of experimental arrangement and radiation source.

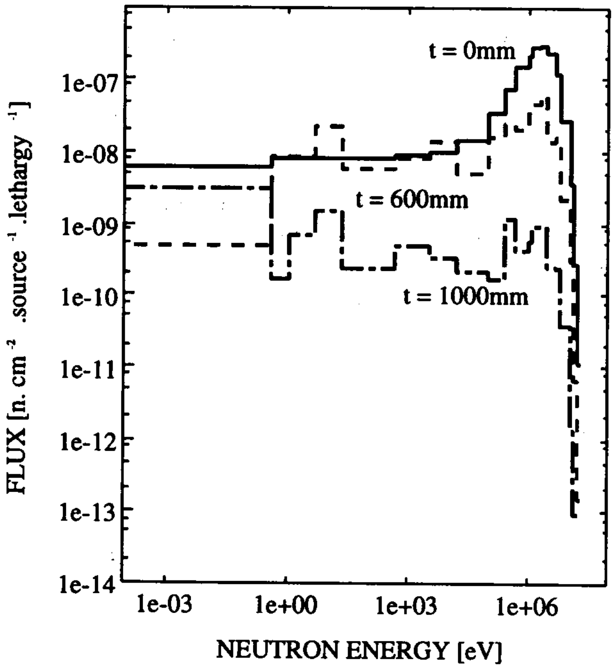

Fig. 2. Calculated neutron spectra at each concrete thickness.

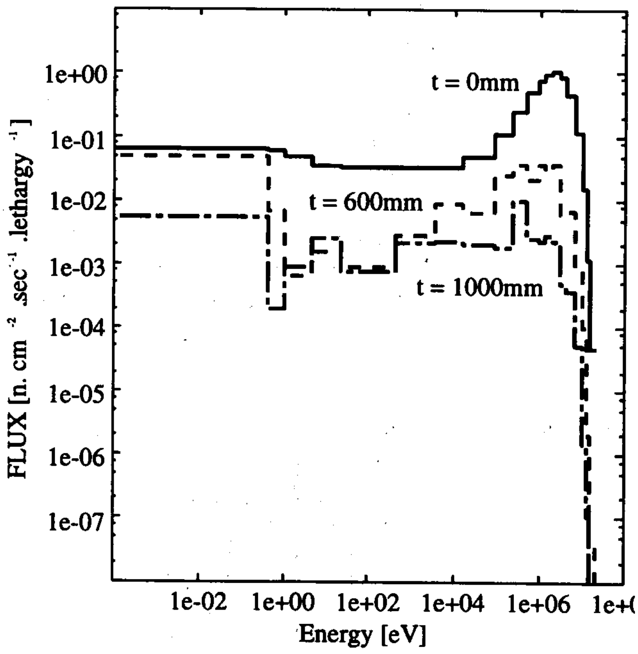

Fig. 3. Measured neutron spectra at each concrete thickness.

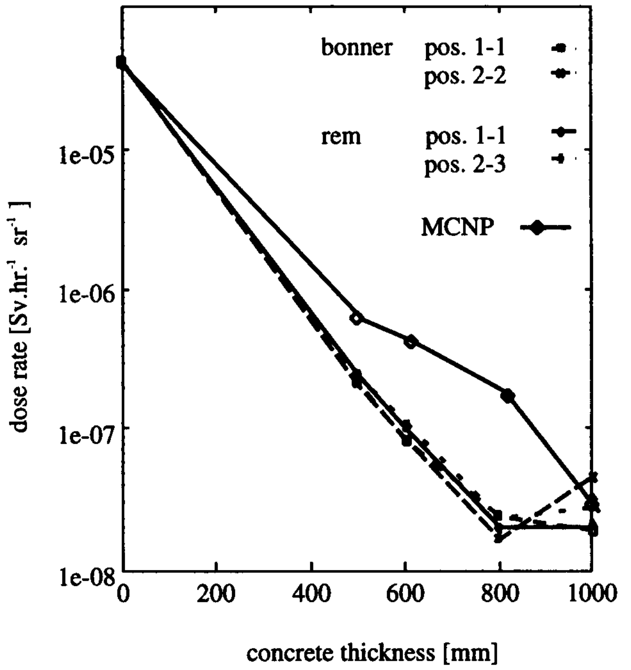

Fig. 4. Attenuation of neutron dose equivalent rate as a function of the concrete thickness.

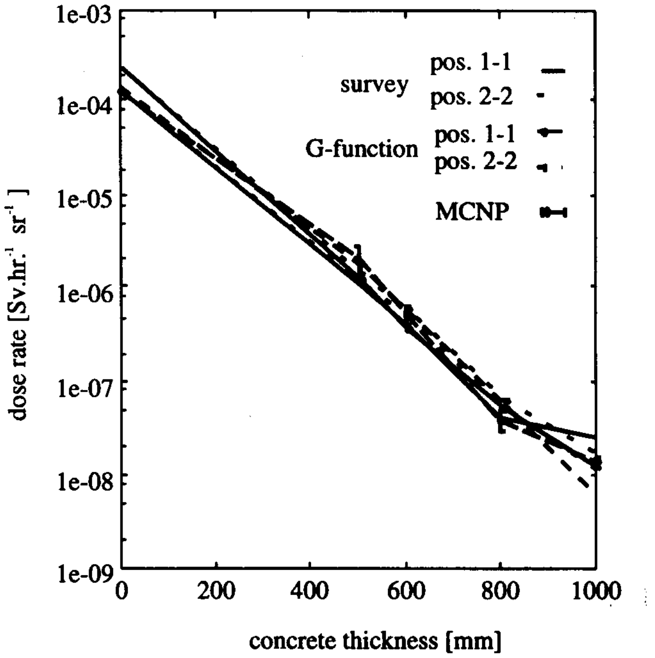

Fig. 5. Attenuation of photon dose equlvalent rate as a function of the concrete

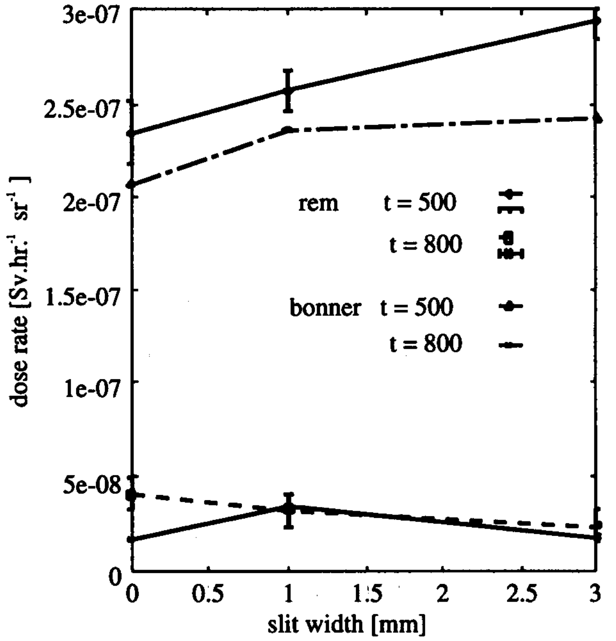

Fig. 6. Dependence of neutron dose equlvalent rate on the slit width.

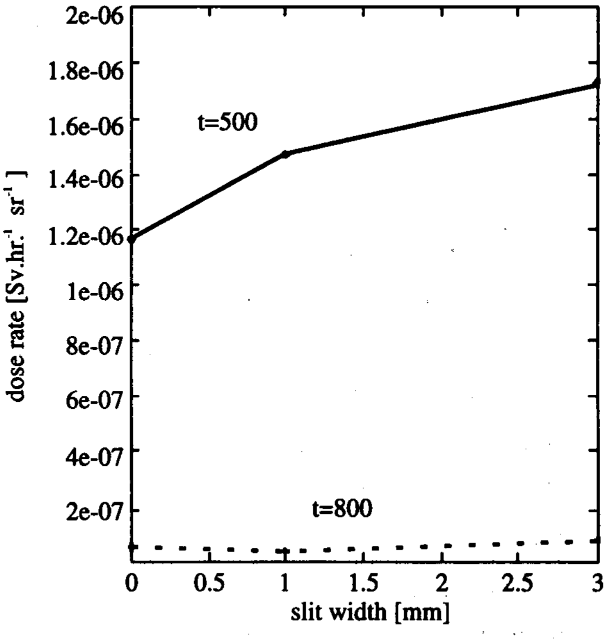

Fig. 7. Dependence of photon dose equivalent rate on the slit width.