Shielding Performance Evaluation of the Alternative Design for a Concrete Plug of Calandria Vault in the Wolsong Units 3 and 4

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1. Introduction

For Wolsong units 3 and 4 which are CANDU-type PHWR(Pressurized Heavy Water Reactor), design of the flow-path (i.e. Calandria Vault Water Makeup (CVWM)) for supplying emergency cooling water to the calandria vault is being performed, which can be utilized in case that loss of cooling function for the reactor is lasted over a long period of time due to beyond design basis accidents such as Fukushima Daiichi nuclear disaster.

As part of the design, replacement of a concrete plug for the calandria vault by the transition plate (made of two plates of steel) is currently under review. In order to do so, the transition plate should be designed to provide at least an equivalent shielding effectiveness compared with a concrete plug.

For confirming feasibility of the replacement, the shielding analysis for each design has been carried out, and this paper describes a comparison result of the shielding performance between a concrete plug and the alternative design (i.e. transition plate).

2. Methods and Results

In this section, methodology applied to the shielding analysis and the calculation result are presented.

2.1 Computer Code System

In this paper, the shielding calculations for a concrete plug and the transition plate have been performed by a single program, MicroShield v9.05 [1], which makes the results consistent. This program incorporates the point kernel method for the gamma-ray shielding calculation. That is, in the calculation, the source region is divided into a number of small volumes first, and then dose contribution of each volume component is integrated with respect to space and energy.

2.2 Cases Evaluated

For confirming effectiveness of the alternative design, the shielding analysis for the transition plate is performed for the following four (4) cases in addition to the base case for a concrete plug.

- T-1: A concrete plug is replaced by the transition plate made of two (2) plates of steel, which are separated from each other by an air gap. It is assumed that steel and eight (8) cylindrical openings are homogeneously mixed in the transition plate. Accordingly, a density of the plate is adjusted considering the total volume of openings.
- T-2: This case is very similar to "T-1" as stated above. (i.e. Homogenization of steel and eight (8) openings) However, the homogenized density for half space of the plate is applied as that for the whole plate referring to the configuration of the transition plate.
- T-3 and T-4: Since there may be the radiation streaming through openings, a single plate (i.e. the lower or upper part) is only considered in each case. (A plate excluded from the calculation is assumed to be an air gap.)

2.3 Input Data and Assumptions

Principal input data applied to the shielding analysis are as follows. And, the geometric modeling for each case is depicted in Figures 1 through 4, respectively.

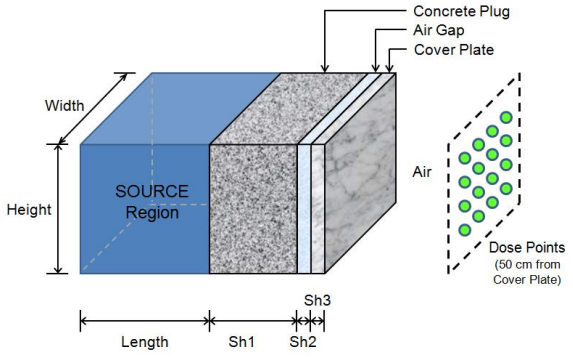


Fig. 1. MicroShield Model for Base Case

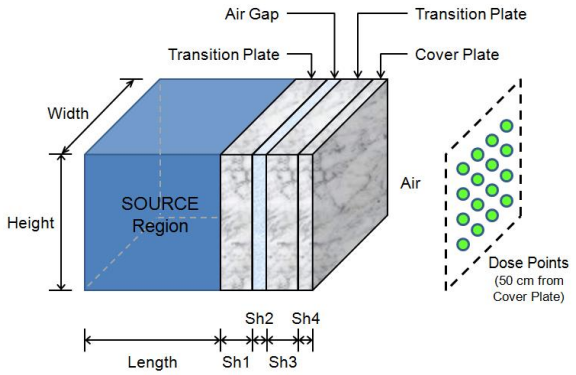


Fig. 2. MicroShield Model for Cases T-1 and T-2

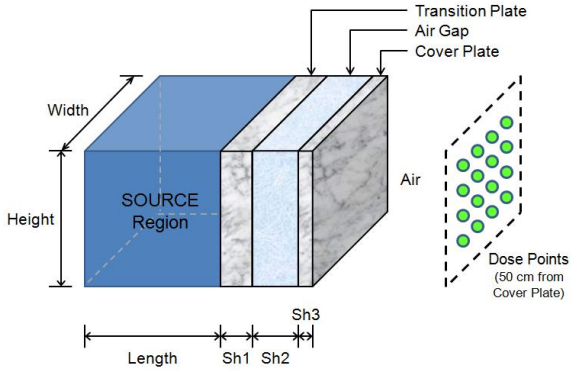


Fig. 3. MicroShield Model for Case T-3

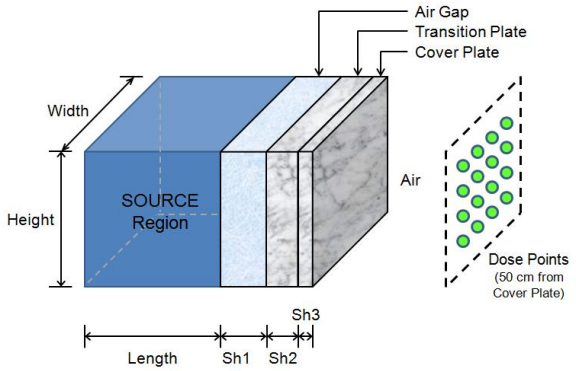


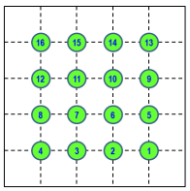
Fig. 4. MicroShield Model for Case T-4

- Dimensions: These are inputted referring to the drawings for the concrete plug and transition plate [2]. Due to lack of detailed information, some values are reasonably determined by the engineering judgment. (However, details are deliberately omitted in this paper since these are the proprietary information.)

- Material and density

Region		Material	Density [g/cc]
Source		Air	0.00122
Concrete Plug		Concrete	2.35
Transition Plate	T-1	Iron	6.67
	T-2	Iron	5.49
	T-3	Iron	7.86
	T-4	Iron	7.86
Air Gap		Air	0.00122
Cover Plate		Iron	7.86

- Source terms: It is assumed that 1 Ci of ^{16}N is uniformly distributed in the source region filled with air. Gamma-rays emitted from ^{16}N are sorted into energy groups using standard indices.
- Nuclide library: ICRP-107
- Flux-to-dose conversion factors: ICRP-74 (based on ICRP-60) → Effective Dose
- Dose points: A total of 16 intersections of imaginary lines which divide width and height into five (5) equal parts, respectively. (50 cm above the cover plate)



2.4 Results and discussion

For each case (i.e. base and T-1~4), the effective dose rate by dose point are evaluated, and the value obtained with a concrete plug is considered as the reference value (i.e. 100%) for each point. The fraction of dose rate can be calculated through dividing the value for the transition plate by that for a concrete plug. The comparison result of the shielding effectiveness between a concrete plug and the transition plate is visualized in Figure 5.

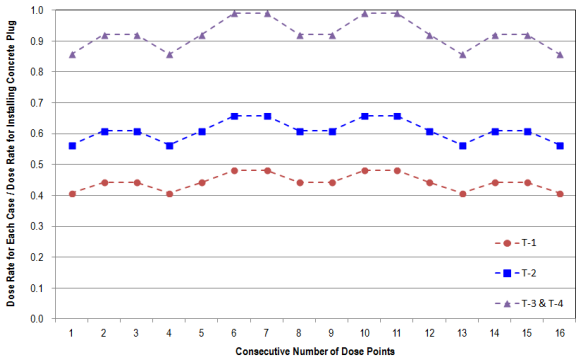


Fig. 5. Comparison of Shielding Effect Between Concrete Plug and Transition Plate

From this figure, it is found that the alternative shielding design using the transition plate, even if only a single plate is considered in the calculation, provides a better shielding than a concrete plug.

3. Conclusions

As shown in Figure 5, ratio of the dose rate for each case to that for base case is summarized as follows.

Cases	Ratio of Dose Rate to the Reference Value	
	Minimum	Maximum
T-1	0.408	0.482
T-2	0.563	0.659
T-3	0.857	0.989
T-4	0.857	0.989

Based on these results, the feasibility of replacement of a concrete plug by two (2) steel plates is confirmed. In other words, in the aspect of the gamma-ray shielding, it is judged that the transition plate is designed to provide an equivalent or up to about 50% better performance in comparison with the original design using a concrete plug. These results will be updated by the additional information, if necessary, and could be applied to the installation design for CVWM

ACKNOWLEDGMENT

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REFERENCES

[1] Grove Software, Inc., MicroShield User's Manual.
[2] Wolsong NPP CVWM-U2 Transition Plate and Cover, 02-928721D, Rev.00.