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Gamma radiation transmission along the multibend mazes

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HIGHLIGHTS

- Gamma transmission was measured along mazes for nondestructive testing.
- An effective dose of 1 Bq was calculated in single-, double-, and triple-bend mazes.
- Ir-192 was used as the main gamma source with Co-60 to make a comparison.

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ABSTRACT

Installing a maze on the corridor reduces much shielding materials in shielding door at the end of the pathway. In this study, gamma transmission was measured along single-, double-, and triple-bend mazes, which were applied to nondestructive test workplace by Monte Carlo method. In the facility using ^{192}Ir 1.85 TBq, the lengths of corridors to reduce the effective dose under the limitation without shielding door were 10 and 6 m in double- and triple-bend mazes, respectively.

1. Introduction

A maze is a good cost-effective shielding structure to replace expensive shielding materials, such as lead or steel, in the shielding door, and much research had focused on the evaluation of transmission of radiation levels along a maze. LaRiviere and Tochilin (1986) measured a photon transmission in lead at the maze entrance to a 6- and 18-MV medical electron accelerator room and calculated a photon tenth-value layer (TVL). McGinley and Butker (1991) measured neutron dose equivalent levels at the maze entrances to 13 medical accelerator treatment rooms, where 10 mazes had a single 90° turn and others had two 90° turns. Mukherjee and Parcell (1997) measured transmission of neutron and gamma radiation fields along the four-bend maze to the cyclotron vault. In this study, four analytical formulas were proposed for dose calculations in each four sections of the maze. Wu and McGinley (2003) measured the neutron and capture gamma rays along the single-bend maze to the linear accelerator vaults, and confirmed that the measured values were in good agreement with calculated values using an empirical equation suggested by McGinley (2002). Raisali et al. (2006) measured neutron and gamma-ray streaming along the three-bend maze to the cyclotron vault and found that the deviation between the values calculated by Monte Carlo method and the measured dose values along the maze is $<20\%$. Ghiasi and Mesbahi (2012) calculated capture gamma dose equivalents in double-bend maze to the radiation therapy rooms using a linear accelerator by varying the maze conditions using the Monte Carlo method and proposed a new analytical formula modified from the empirical equation suggested by McGinley (2002).

Although the formula and empirical equations are suggested for facilities using linear accelerator and cyclotron, little attention has been paid to nondestructive test (NDT) buildings using radioisotopes. However, Matsuda and Sasamoto (2010) developed a formula based on the algorithm of the DIN's formula (DEUTSCHE NORMEN, 1977) for the duct streaming of gamma rays. In unstandardized work conditions, such as NDT workplace, calculations by the Monte Carlo method were used, unlike medical treatment room normally.

Mobile sources for NDT have been forced to be used with shielding facilities by radiation regulation, since the occurrence of

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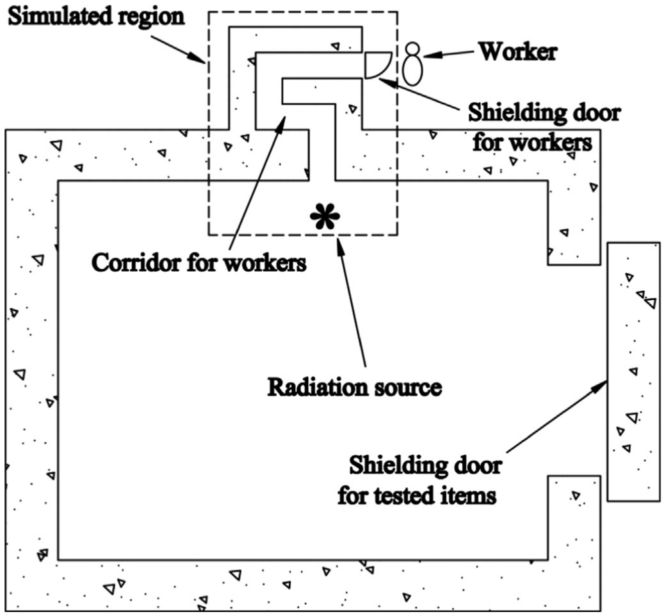

Fig. 1. Schematic of NDT facility installed in a maze.

a fatal accident during NDT in shipbuilding without shielding in South Korea. This resulted in generalized shielding structures in NDT building design, including an exclusive corridor for workers of the irradiation room, as shown in Fig. 1. Thus, requests for dose calculation method for a maze to NDT buildings have risen rapidly since the previous equations caused by megavoltage X-ray facilities cannot be used to design NDT structures.

The aim of this study is to calculate gamma dose transmission in single-, double-, and triple-bend mazes to NDT facilities using radioisotopes.

2. Materials and methods

In this study, gamma transmission was simulated along mazes using MCNPX version 2.6 (MCNP, 2008), which is commonly used for dose evaluation in mazes (Raisali et al., 2006; Ghiasi et al., 2012). The results of this study were verified by comparing with a semiempirical formula recommended by Matsuda and Sasamoto (2010), which is one of the most frequently used formulas for gamma-ray streaming through bend duct.

2.1. Maze geometry

Recently, the International Atomic Energy Agency (IAEA) has reported that dose albedo (wall reflection coefficient) on an ordinary concrete for 0.5-MeV monoenergetic photons ranges from 0.008 to 0.022 for various reflection angles (NCRP Report No. 151, 2005). This indicates that a bend on the walkway considerably reduces the dose and thickness of shielding door installed at the end of corridor. In order to confirm dose decrease by the number of bends and distance from the source point, three types of maze are used in this study (Fig. 2).

The mazes were described without an NDT building, a collimator, and tested materials in simulations for time-efficiency calculation, because their geometries did not contribute to accuracy. Material of all structures was ordinary concrete, which is the cheapest shielding material if sufficient space was provided (NCRP Report No. 49, 1978); thickness of all walls including ceiling was 1 m; and the height and width of the corridor were 3 and 1 m, respectively. In this study, the concrete composition was

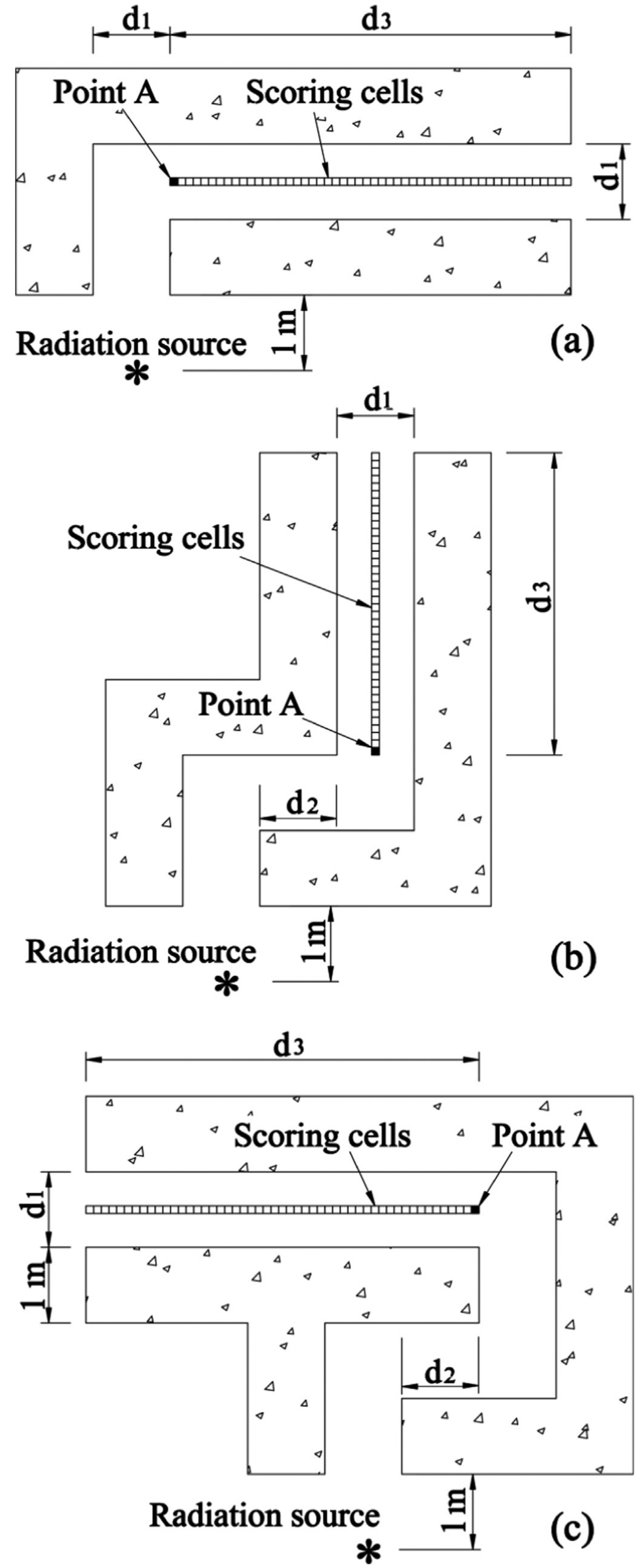

Fig. 2. Top views of a single bend (a), double bend (b), and triple bend (c) maze layout. d_1 is the width of aisle and asterisks are gamma source positions.

referenced by the previous study shown as Table 1 (Jr, 2011). In order to apply the results to vary NDT fields, two additional calculations were implemented with corridor cross sections of