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Opinion

The Calculation of the Parameters of Buildings Protection from Radon

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Abstract

Radon-222 and its progeny can accumulate in the lower floor premises and harm the people respiratory organs. One of the challenges for the construction industry is to provide indoor radon concentrations that are not much different from its concentrations in the outdoor air. The article proposes an approach to ensuring the buildings radon safety by the passive protective technologies. Its essence is in the determination at the design stage of the required radon protection characteristics of the building underground shell, which performs load-bearing functions and at the same time limits the radon flux from the soil air

Keywords: Radon; Progeny; Walling; Flux; Equilibrium concentration

Introduction

The danger of increased radioactive exposure for most people in the World is associated with accidents at nuclear fuel cycle plants or violations of the rules for handling radioactive substances. In fact, radon and its short-lived progeny (^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po) form about 70% of the population radiation dose in countries with temperate climates and harm the people respiratory organs [1]. Radon is a monatomic radioactive gas, it does not have stable isotopes and generated in the soil during the radium decay. The background radon concentration in the outdoor air is small, it rarely exceeds 10 $Bq \cdot m^{-3}$ and therefore radon does not harm human health. But under certain conditions, it is able to flow from the soil into the building and accumulate in the indoor air. Therefore, it is necessary to strive for the maximum, socially and economically justified decrease of radon concentration in buildings. Technical measures aimed at ensuring the minimum justified radon level in the building are implemented exclusively by construction means. Acceptable radon levels in buildings can be ensured through the rational design of underground walling, which perform the main load-bearing functions. This technology for buildings protecting from radon is called passive. The calculation radon protection characteristics is carried out at the stage of building design using data on:

1. The dimensions of the underground walling elements and the radon diffusion coefficients in the walling materials.
2. Specific radium-226 activity and the radon emanation coefficient of the soil under the building.
3. The expected ventilation type and the air exchange frequency in the most deeply located rooms.
4. In the calculation of radon protective characteristics, the design scheme includes the soil, horizontal and vertical walling bordering on the soil, the upper floor and internal walls (Figure 1).

The calculation purpose is to assess the compliance of the radon concentration expected value (C_{Rn}) in the deepest rooms indoor air. This value should not exceed the national reference level

(NRL), which is 150 Bq·m^{-3} in the United States and is about 250 Bq·m^{-3} in Russia [2,3].

$$C_{Rn} \leq NRL \quad (1)$$

The expected value of the radon concentration in the room is calculated by the formula

$$C_{Rn} = \frac{q_1 \cdot S_1 + q_2 \cdot S_2 + \sum_{i=3}^{8} q_i \cdot S_i}{V \cdot (\lambda + n)} \cdot F \quad (2)$$

where q_1 and q_2 are the radon flux densities from the soil through the horizontal and vertical walling, respectively, Bq·m^{-2}·s^{-1};

S_1 and S_2 are the areas of internal surfaces of horizontal and vertical walling, respectively, m^2;

q_i is the radon flux density into the room by the radon exhalation in the material of the i-th walling, Bq·m^{-2}·s^{-1};

S_i is the internal surface area of the i-th walling, m^2.

The radon flux densities from internal structures can be calculated using the formula

$$q_i = \frac{C_i \cdot \rho_i \cdot k_i \cdot D_i}{L_i} \cdot th\left(\frac{h_i}{2L_i}\right) \quad (3)$$

where C_i is the radium activity in walling material, Bq·kg^{-1};

ρ_i is the walling material density, kg·m^{-3};

k_i is the emanation coefficient value;

D_i is the coefficient of radon diffusion in walling material, m^2·s^{-1};

L_i is the radon diffusion length in walling material, m;

h_i is the walling thickness, m.

But the radon entry from internal surfaces is not the main source and with sufficient accuracy can be taken equal to 2.5 mBq·m^{-2} s^{-1} without calculating by (3). Most often, the radon entry from the soil through the vertical underground walling is negligible ($q_2 \approx 0$) since this structure does not interfere with the radon movement to the atmosphere. Then the density of radon flux from the soil

$$q_1 = \frac{P_{Rn}}{R} \quad (4)$$

where P_{Rn} is the radon potential of the soil, Bq·m^{-3};

R is the radon resistance of horizontal walling, s·m^{-1}.

The P_{Rn} value in (4) is calculated for the maximum values of C_{Ra} and ρ_s of soil at the building base, determined during engineering and geological surveys

$$P_{Rn} = \frac{C_{Ra} \cdot \rho_s \cdot k}{\varepsilon} \quad (5)$$

where C_{Ra} is the specific activity of radium in the soil, Bq·kg^{-1};

ρ is the soil density, kg·m^{-3};

k is the radon emanation coefficient of the soil;

ε is the soil porosity.

An accurate experimental determination of P_{Rn} for the soil at the construction site is important, since this value is (with a small margin) the radon load on the underground building shell [4].

The required radon resistance value of the horizontal walling is determined by the formula:

$$R = \frac{P_{Rn}}{q_{max}} \quad (6)$$

where q_{max} is the ultimate radon flux density through the horizontal walling, at which the value of C_{Rn} will not be exceeded, Bq·m^{-2}·s^{-1};

The total radon resistance of a n-layer structure is approximately equal to

$$R_{min} = R_1 + R_2 + \ldots R_n = \sum_{i=1}^{n} \frac{1}{\sqrt{\lambda_i \cdot D_i}} \cdot th\left(h_i \cdot \sqrt{\frac{\lambda}{D_i}}\right), \quad (7)$$

where R_i is the radon resistance of the i-th structure layer, s·m^{-1};

$\lambda = 2.1 \cdot 10^{-6}$ s^{-1} is the radon decay constant.

Formulas (5)– (7) make it possible to move from the soil physical characteristics at the construction site to the dimensions of underground horizontal walling, which will ensure the building radon safety. The proposed approach to ensure the buildings radon safety on most soils, but at the high radium specific activity or air permeability of the soil, passive technologies turn out to be ineffective and it is necessary to use a soil depressurization system.

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Conflict of Interest

No conflict of interest.

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