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Project Summary

Recommended Foundation Fill Materials Construction Standard of the Florida Radon Research Program

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The Florida Radon Research Program (FRRP), sponsored by the Environmental Protection Agency and the Florida Department of Community Affairs, has developed the technical basis for a radon-control construction standard for foundation fill materials. Results of the research conducted under the FRRP are presented in several technical reports. This report summarizes the technical basis for the recommended foundation fill materials standard for new construction in Florida. The recommended standard is first presented, followed by a summary of the technical basis for the standard.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Elevated indoor radon gas concentrations generally come from radon gas that is formed from radium in the foundation soils under the structure. One of the most effective ways to limit indoor radon concentrations is to limit the rate of radon gas generation or its resulting concentration in the foundation soils. This portion of the standard defines acceptable limits for the concentrations of radon gas and its parent radium in the earthen materials under a structure.

The ease with which the radon gas can move through soils toward a house foundation also affects the amount of radon entering the house. In this standard, the ease of radon movement through earthen materials is characterized in terms of the soil air permeability coefficient. Therefore, the acceptable limits on sub-foundation radium or radon gas also vary according to the permeability coefficient of the material.

The Recommended Foundation Fill Materials Standard

The recommended foundation fill materials standard is:

302.1 Natural Foundation Soils

Natural earthen materials under buildings, that have relatively uniform radium and emanation properties with depth, shall have radium concentrations less than those given in Figure 302.1. If soil classification is used to estimate permeability, the upper limit in the classification range should be used to determine the radium limit. For the purposes of this standard, soils either shown or demonstrated to contain less than 0.8 pCi/g of radium shall be considered in compliance with this Section. Tests shall be conducted according to the procedures identified in Section 305. The acceptable radium concentration in foundation soils depends on their radon transport characteristics, principally soil air permeability. The permeability may be estimated from soil textural and moisture properties using the relation

$$K = 2 \times 10^{-5} d^{4/3} \exp(-12m^4)$$

where

K = soil air permeability (cm^2)

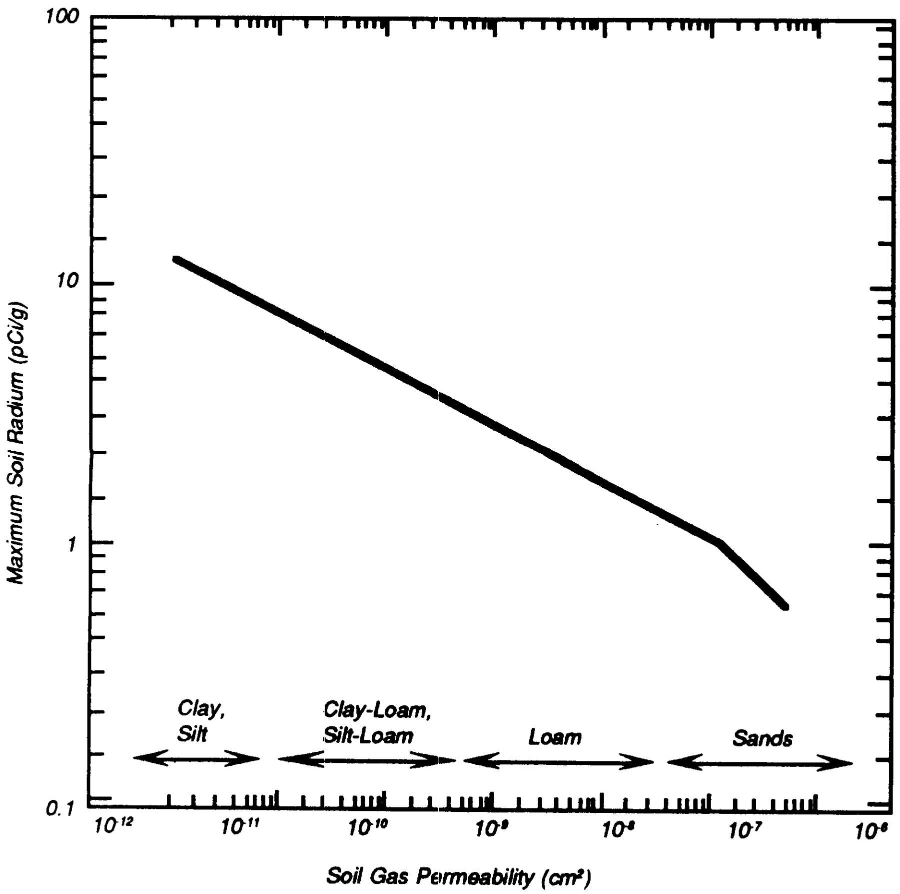

Figure 302.1 *Maximum soil radium concentrations for slab-on-grade buildings constructed on soils with uniform radiological properties.*

d = mass-weighted arithmetic average diameter of all soil grains passing a No. 4 sieve (cm)

m = fraction of soil moisture saturation.

For sandy soils it is sufficient to set m=0.

Site-specific measurements of permeability also are acceptable if they are performed with procedures identified in Section 305.

302.2 Fill Materials or Layered Natural Soils

Natural earthen materials under buildings whose radiological properties vary significantly with depth, or fill materials that are placed directly under the building or within 10 feet of the building perimeter shall result in radon concentrations in soil air that are less than those given in Figure 302.2.

For the purposes of this standard, building sites shown to have less than 600 pCi/l of radon in the soil gas shall be considered to be in compliance with this Section. For planned buildings the radon measurement will be made at a depth of at least four feet beneath the free surface. The measurements shall be made in accordance with procedures identified in Section 305.

303 Foundation Backfill Materials

Foundation backfill materials shall have radium concentrations less than 0.8 pCi/g. Tests shall be conducted according to the procedures identified in Section 305.

304 Building Materials

All materials used in concrete for the construction of habitable structures shall have a radium concentration of 5 pCi/g or less, as measured in accordance with procedures identified in Section 305.

305 Testing Procedures

Tests for radium, soil gas radon and insitu site and fill materials permeability shall be conducted according to the procedures of the "Standard Measurement Protocols, Florida Radon Research Program," compiled and edited by Southern Research Institute, January 15, 1990. Test protocols are as follows: Section 1.6 - Soil Radium Content/Radon Emanation and Section 1.1 - Permeability/Soil Radon/Soil/Fill Sample Collection.

Why the Standard Limits Soil Radium or Radon for Different Soil Permeabilities

Radon gas is generated from the radioactive decay of radium, an element that is present in virtually all earthen materials. Elevated soil radium concentrations cause elevated rates of radon generation, which in turn cause higher radon gas concentrations in the air spaces in the soil. Thus, the standard includes a soil radium concentration limit. Suction pressures in the house, due to appliances, thermal gradients, heating and air conditioning systems or winds, pull the soil air with its radon gas into the house. The ease with which soil air can move through the soil is characterized by its air permeability coefficient which also is included in the standard. Even in the absence of soil air movement, radon migrates from regions of high radon concentration, such as soil, to regions of lower concentration, such as the house. This migration mechanism is called diffusion, and the ease with which radon diffuses through an earthen material is characterized by its diffusion coefficient. The permeability and diffusion coefficients are closely related, and exhibit similar trends with soil type, compaction and moisture. Thus the permeability coefficient can be used to specify soil conditions in a way that also includes the effects of diffusion. Both effects are included in the analysis supporting the standard, even though the standard only refers explicitly to the permeability coefficient.

Some regions or house locations may have natural soils or fill materials with sufficiently low radium concentrations to satisfy the soil radium limit of the standards and yet have a soil layer several feet deep that has unacceptably high radium concentration. The radon from the deeper layer may still enter the house at excessive rates. A reliable measure of whether this condition occurs is the radon concentration in the soil gas under the slab, or at a depth of at least 1.2 m (4 ft) from the free surface. The limiting radon concentrations in the soil gas for layered systems protects against excessive radon entry from deeper soil layers with elevated radium concentrations.

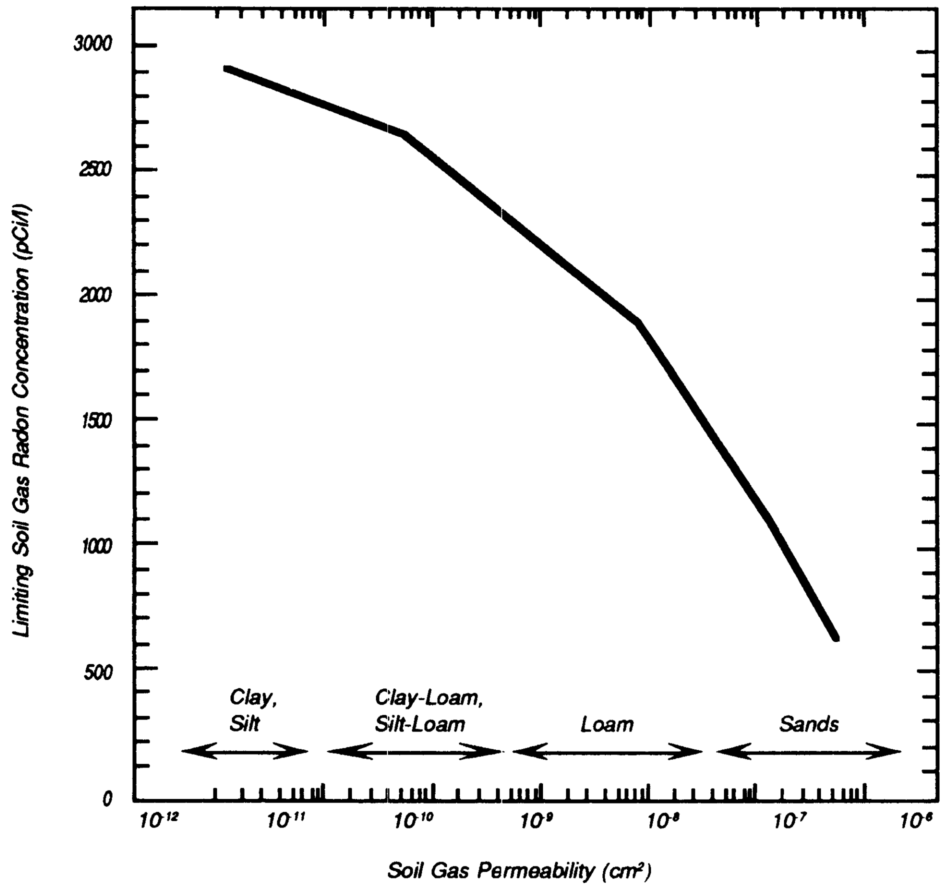

Figure 302.2 *Limiting soil gas radon concentrations for slab-on-grade buildings constructed on soils with uniform radiological properties.*

Radon Entry Rates Into Houses

The rate at which radon enters houses depends not only on the subslab soil conditions, but also on the house structure and conditions. This is one of the reasons that adjacent houses built on the same soil can have different average indoor radon concentrations.

The standard is based on an allowable radon entry rate into the house that is consistent with an indoor radon concentration of 2 pCi/l for many average house conditions.

The calculations are performed with a two-dimensional steady-state radon advection and diffusion code called RAETRAD. In the calculations, negative house pressure causes an inflow of outdoor air into the soils near the house and a general movement of soil air towards the house. The soil air enters the house through concrete joints, cracks around concrete penetrations and other cracks in the concrete. The soil air contains radon from the soil, and the radon moves into the house along with the soil air. Radon also diffuses through the cracks and through the concrete slab.

Indoor radon concentrations can vary widely over short time periods mainly due to variations in the house pressure relative to atmospheric pressure and variations in the house air changeover or ventilation rate. The calculations supporting the foundation fill materials standard are based on a reasonably conservative long-term average negative pressure of 2.4 Pa (0.01 in. H_2O) in the house, relative to the atmospheric pressure. Slab-on-grade house construction is assumed because that is the dominant construction mode in Florida. The main radon entry modes are assumed to be through cracks at the slab-footing joints, and by radon diffusion through the entire slab.

Subslab soils range from coarse sand to fine clay. The smaller particle silts and clays have higher ambient moisture contents and generally lower permeability and diffusion coefficients, so that radon gas in the soil air cannot move as easily to the entry points into the house. This feature allows for the higher radium concentrations in the subslab soils shown in Figure 302.1.

Field measurements of soil permeabilities, soil air radon, and densities were made in 16 general locations throughout Florida. Soil samples were also obtained to make laboratory measurements of additional soil parameters such as: radon diffusion coefficient (D), radium concentration, radon emanation coefficient, ambient moisture, and soil grain size.

Existing, simple diffusion coefficient models can generally predict radon gas diffusion coefficients to within 50% for dry soils ($m < 0.4$) and to within about a factor of two for soils with moistures above 0.5 of saturation. The model used for Florida soils is

$D = 0.11\ p\ \exp(-6mp-6m^{14p})$

where

D = radon diffusion coefficient ($cm^2 sec^{-1}$).

Both K and D decrease significantly with moisture for $m > 0.5$. Finer grained soils, such as silts and clays, have higher moistures under normal environmental conditions. Thus, they have lower K and D values than the sands, so that radon gas does not move as easily through them. For a specified radon entry rate into a house, the silts and clays can have higher radium concentrations because more of the radon gas is held in the soil.

Radium concentrations for over 700 undisturbed Florida soils averaged 0.6 pCi/g and ranged from 0.1 to 2.9 pCi/g. Higher values of 25 to 65 pCi/g have been observed in certain profiles of the Hawthorn formation or in certain soils disturbed by phosphate mining. Radon emanation coefficients range from 0.1 to 0.45 for most soils. Emanation coefficients measured for 48 Florida soils averaged 0.33 ± 0.11.

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The complete report, entitled "Recommended Foundation Fill Materials Construction Standard of the Florida Radon Research Program," (Order No. PB92-105865/AS; Cost: $17.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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