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EVALUATION OF RADON RESISTANT CONSTRUCTION TECHNIQUES IN THE FLORIDA NEW HOUSE EVALUATION PROGRAM

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ABSTRACT

The primary objective of the Florida New House Evaluation program is to field-test the draft provisions of the Florida radon resistant construction code and to make recommendations to the Florida Radon Research Program (FFFP) standards committee. Thirty-three homes are currently being evaluated in this program by two contractors: GEOMET Technologies (20 houses), and the Florida Solar Energy Research Center (13 houses). Each home receives a common core set of measurements to evaluate the radon potential of the soil, the building's overall resistance to radon entry as well as detailed data to evaluate dynamic forces that influence radon entry and subsystem performance.

BACKGROUND

The Florida New House Evaluation Program (NHEP) is a research project within the Florida Radon Research Program (FRRP). The goal of the Florida NHEP is to evaluate the performance of houses built by local home builders to specifications contained in the Florida draft radon resistant construction code. Study results will provide guidance to the FRRP standards committee for recommended refinements to the draft code. The draft code (see Dixon 1991) covers slab design, soilcovers, space conditioning systems (including duct sealing) and subslab depressurization (SSD) system design. Two types of SSD systems are described in the draft code: suction pits, and ventilation mats.

Thirty-three homes are currently being evaluated under this program by two contractors: GEOMET Technologies (20 houses) and Florida Solar Energy Center (13 houses). During Phase I of this project builders were recruited to participate in the project. During Phase II, the houses are being built by the builders to the draft radon code and the houses will be monitored and evaluated upon completion.

FIELD MONITORING PROCEDURES

Each home receives a common core set of measurements to evaluate radon potential of the soil, the building's overall resistance to radon and soil gas entry. Additional measurements are made to evaluate dynamic forces that influence building performance and to evaluate subsystems performance. The measurement package is summarized in Table 1.

After sites have been selected, the testing is done in two steps. Step I, preconstruction testing, characterizes the soil and fill material before construction. Step II, postconstruction testing, characterizes the building performance.

PRECONSTRUCTION TESTS

Each home is visited for preconstruction monitoring by a two-person field team. The measurements are typically taken after the fill material has been placed and before the polyelethene and reinforcing wire is in place.

During this first visit to the site, the preconstruction soil measurements are made and soil samples taken. The soil measurements include permeability and soil gas radon using the MKII permeameter and a Pylon AB5 according to FRRP protocols. One hole is sampled in the center of the house at three depths: (1) in the fill material only; (2) in the native soil (about 2 feet); and (3) at approximately 3 feet. Soil permeability is measured at each depth and a grab sample of soil gas is collected at 3 feet for radon analysis. Samples of soil at each depth are collected and packaged for laboratory analysis. Soil samples are collected and sent to the University of Florida for lab analysis. The lab analysis includes Radium-226, Radon emanation coefficient, moisture content, Lead-210, texture classification and particle size analysis.

After the site analysis, we meet with the builders to review the provisions of the draft radon code, select the subslab depressurization system design, locate the suction pit or ventilation mat, and locate the measurement points below the slab.

A network of plastic tubing is laid in the fill material before the polyethylene is laid to be used for (1) subslab pressure measurements, (2) subslab radon grab samples, and (3) possible tracer gas injection points. The end of the tubing under the slab is wrapped in ENKA material to prevent clogging and the other end is run to the outside of the foundation wall and capped. Details of the subslab measurement techniques are given by Tyson (1991).

Table 1. Summary of Measurement Package.

MEASUREMENT	EQUIPMENT AND TECHNIQUES	PROTOCOL GUIDANCE
PRECONSTRUCTION		
Soil permeability Soil gas radon	MK-II permeameter Pylon AB5 scaler Scintillation cells	FRRP Protocols (Williamson and Finkel 1990)
POSTCONSTRUCTION		
Soil gas entry efficiency	4 PFTs in soil 1 PFT in house 1 CAT sample in house	D'Ottavio et al. (1987), and Kunz (1989)
Short-term indoor radon	3-day charcoal canister	EPA (1989)
Long-term indoor radon	30-day ATD	EPA (1989)
Short-term subslab radon	Grab sample	EPA (1989)
Long-term subslab radon	30-day ATD	EPA (1989)
Pressure Field Extension	Subslab tubing network Micromanometer	Tyson (1991)
Air Leakage	Blower door Micromanometer Electronic anemometer Digital thermometer PFTs	FRRP Protocols (Williamson and Finkel 1990) Dietz and Cote (1982)
Duct Leakage	Blower door Flowhood	GEOMET (1991)

POSTCONSTRUCTION TESTS

After the home is completed and ready to be occupied the postconstruction evaluation is started. The following activities are performed on each home.

1. Scale floor plans are made and all HVAC equipment is documented as to manufacturer, make, model, rating and capacity.

2. Prior to concealment by floor coverings, the slab area of each home is inspected to characterize cracks. Cracks are located on scale floor plans of the home showing length, depth and classified as follows:

Size	Category
Visible	Hairline
<0.04 cm	Fine
≥0.04 & <0.08 cm	Medium
>0.08 cm	Wide

Steps 3 to 14 are conducted with the house configured in a passive radon- resistant mode. The subslab depressurization (SSD) system is installed with the pipe through the roof and capped. The SSD fan generally is not installed. If the SSD fan is installed, it is not activated.

3. A subslab radon grab sample is taken from one of the subslab pressure taps.

4. Indoor radon is measured with a 2-day charcoal test.

5. After the 2-day charcoal test, blower door tests are done. The house is depressurized with a blower door and the CFM flow through the blower door and subslab pressure at the pressure taps is recorded at house pressure of 10, 20, 30, 40 and 50 pascals. Blower door tests are done according to ASTM-E-779-87.

6. Duct leakage measurements are made using the blower door. All supply and return registers of the heating and air conditioning (HAC) system are sealed with tape and paper except for one supply and one return register. The supply is sealed from return at the air handler. The blower door test is repeated and airflow from the open supply register and return grill is measured with a flow hood. The house is then returned to normal.

7. Pressure differential measurements are made between inside and outside with the HAC system fan on, fan off, all interior doors open and closed. Pressure measurements are made according to FRRP standard test method 2.3.

8. Subslab pressure field extension measurements are made with SSD fan operating. If the house does not have an active system, a temporary fan is installed for the pressure field extension measurements. Pressures are measured at each pressure tab below the slab and at the suction pipe.

9. Four types of perfluorocarbon tracer (PFT) sources (one for each building face) are placed in the soil around the perimeter of the building. PFT sources wrapped in ENKA™ are installed about 5 meters apart, 18 inches deep and within 18 inches of the foundation wall. Soil temperature is recorded at the time of

placement.

10. A fifth type of PFT source is placed inside the home to provide the means to measure air exchange.

11. An alpha track detector (ATD) is placed in the subslab depressurization pipe tied to a string for removal and the pipe is capped with a removable rubber cap.

12. The CATs and a second ATD are placed inside the house for 30 days.

13. Subslab and house ATD, PFTs and CATs are retrieved after 30 days.

14. If indoor radon concentrations are above 4 pCi/L after the 30-day measurement, the SSD pipe is uncapped (passive stack mode) and another 30-day ATD test is performed.

15. If indoor radon concentrations are still above 4 pCi/L, the builder is notified to activate the SSD fan.

16. A final 30-day ATD test is conducted with the SSD system activated.

POSTCONSTRUCTION EVALUATION

The fundamental question in evaluating the effectiveness of radon resistant construction techniques focuses on how to measure soil gas entry rate into homes. We know that the primary transport mechanism for radon is through soil gas infiltration into the house and that diffusion of radon through the floor slab is minimal. Therefore, if we could easily quantify the soil gas entry rate, we could begin to quantify the soil gas infiltration characteristics of various construction techniques. Traditionally, radon has been the measure of soil gas entry. Methodology has focused on measuring subslab radon and indoor radon to calculate a radon entry efficiency.

Soil gas entry rate can be measured by using PFT tracer gas. Researchers at Brookhaven National Laboratory, (D'Ottavio et al. 1987) in cooperation with researchers from the New York State Health Department (Kunz 1989) have experimented with deploying perfluorocarbon tracers (PFTs) in the soil under and around houses, then measuring the PFT concentrations in the home. PFTs have been used for some time to measure air exchange rates in buildings (Dietz and Cote 1982), using passive capillary absorption tubes (CATs) to sample tracer levels over time periods ranging from a few hours to a few days to as much as a year. Under the steady state assumption, average air exchange rates (n, air changes per hour) are in direct proportion to the ratio of the known source rate (S, nL of PFT per hour) and PFT concentration (C, nL/m^3) per unit volume of the indoor air space (V, m^3):

$$n = \frac{S}{VxC}$$

The PFT technology has matured to allow multiple tracers, setting up the basis for directly measuring source-receptor relationships by labeling individual external source areas with separate PFTs. Given the air exchange rate (estimated from the PFT dedicated to the air volume of interest), effective source rates (S_i, nL/h) can be estimated from concentration data (C_i, nL/m^3):

$$S_i = n \times V \times C_i$$

Because the release rate of the external PFTs is also known, we can estimate the entry efficiency directly by comparing measured entry rates with know release rates. This is the basis for the field experiments conducted in New York (D'Ottavio et al. 1987; Kunz 1989). These researchers utilized one type of PFT to label the soil, and two other PFTs to separate the homes into upstairs versus downstairs zones (Figure 1).

Currently, four separate PFTs are available for field use. This allows us to consider the basic pattern depicted in Figure 2 to identify entry rates from the soil near the footer along each edge of the building.

The use of PFTs as a surrogate for radon in measuring soil gas entry efficiency has numerous advantages:

1. The PFT sources are stable and well characterized, eliminating problems of fluctuating source strengths and the inability to accurately measure radon source strength.

2. The analytical methodology is well developed which allows for a reliable quantification of the soil gas (PFT) entry rate.

3. The PFTs have a 10-year operating life, allowing long-term studies to measure the persistence of radon prevention techniques.

4. Up to four PFTs can be deployed to support more detailed studies of soil gas entry while reserving the fifth PFT to serve as an indoor tracer. When analyzed for different tracers, one can quantify the soil gas entry from different segments of the soil using established mathematical techniques.

5. PFT-based soil gas entry efficiency studies can distinguish cases of low radon availability from cases of low entry rates of high concentration soil gas.

6. Using standard algorithms, radon entry rates can be measured from concurrent radon/PFT measurements in a house without disturbing the soil to monitor soil gas concentrations.

Subslab and indoor radon levels are correlated both for short-term and long-term. The subslab grab sample is correlated with the two-day indoor radon measurement and the 30-day ATD indoor measurement is correlated with the 30-day subslab ATD. These measurements are influenced by various seasonal factors such as soil moisture, water table and outdoor temperature. For this reason the measurements are done both in the summer (high water table, soil moisture and temperature) and again in the winter (low water table, soil moisture, temperature).

Additional measurements of relative slab integrity are made using the blower door to depressurize the house accompanied by measurements of the outdoor/subslab pressure difference using the subslab pressure taps. Figure 3 summarizes results for three houses. Two of these (RNB 19 and RNB 22) exhibited a fair degree of pressure coupling (approximately 30 percent of the depressurization is transferred to the subslab region in the vicinity of the

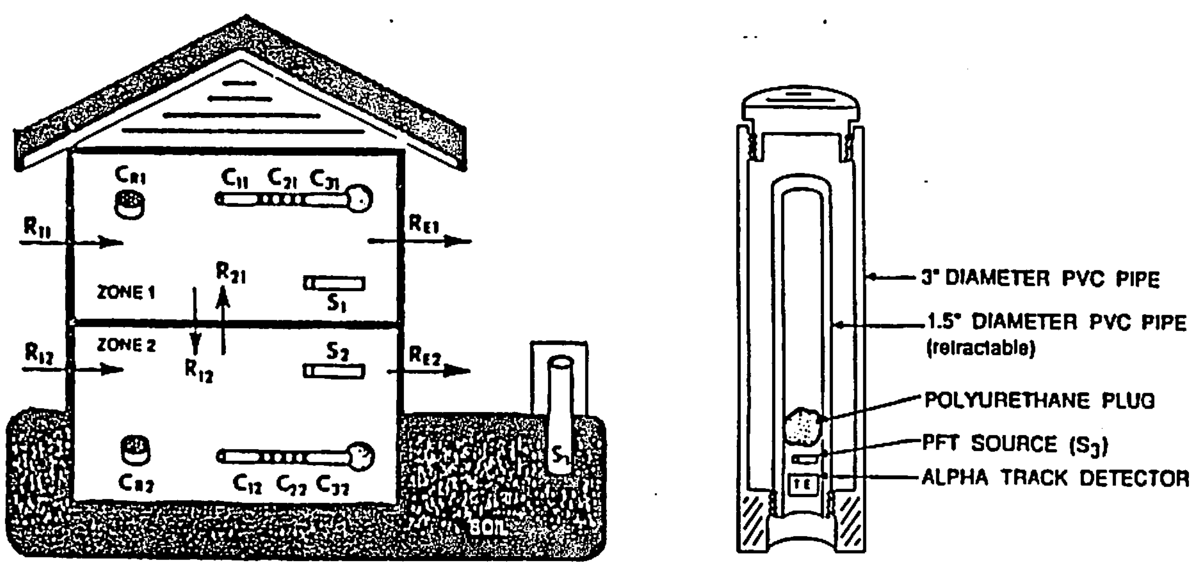

Figure 1. Schematic Representation of the Experimental System Used to Determine Multizone Radon Source Rates (after Kunz 1989)

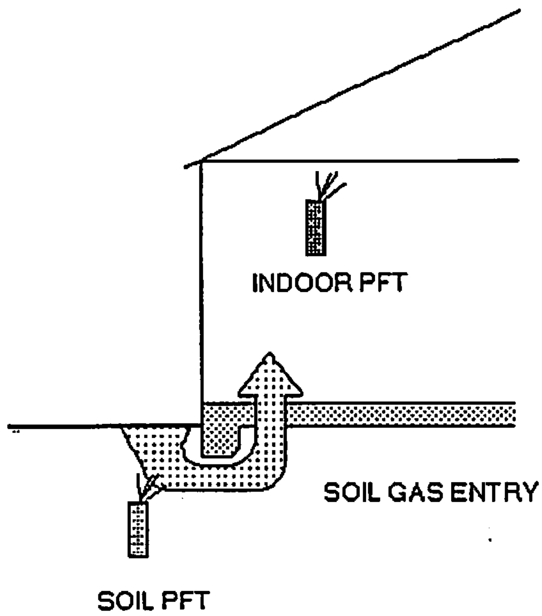

Figure 2. Schematic Representation of Deployment of PFTs to Label Soil Gas Entry in Florida Homes

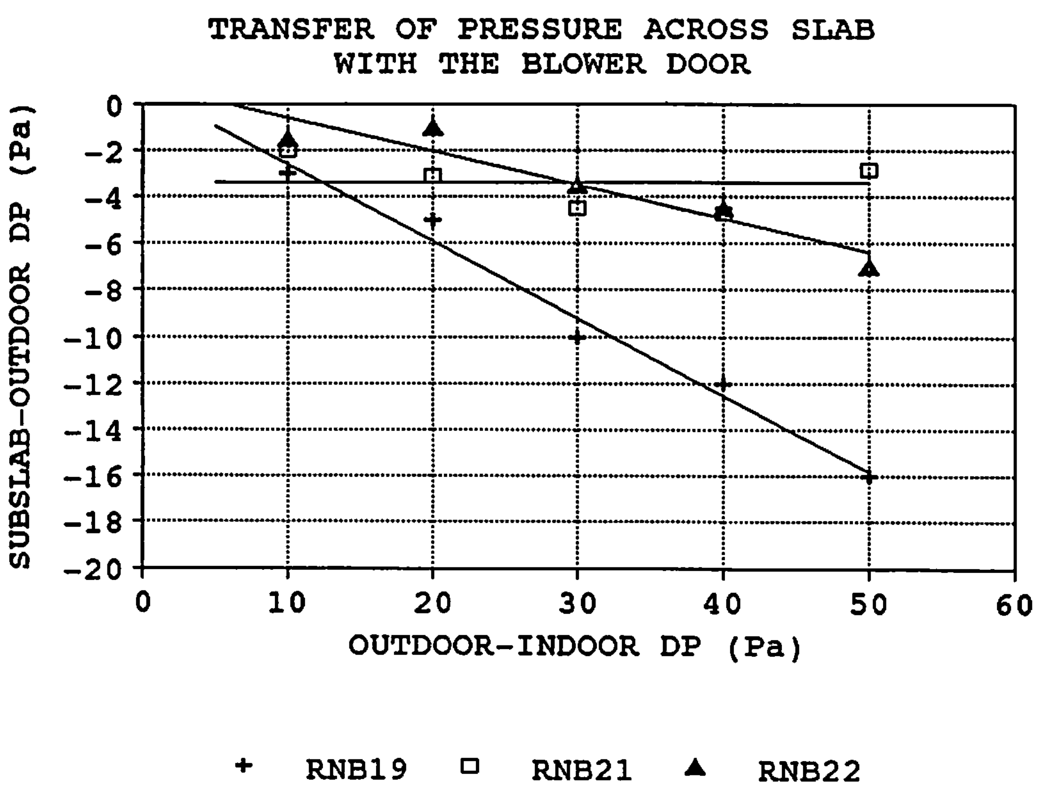

Figure 3. Depressurization of Subslab with the Blower Door.

subslab taps) while house RNB 21 showed no discernable effect. At naturally occurring levels of depressurization, however, subslab depressurization was comparable to indoor depressurization.

The primary driving force for radon entry is the pressure differentials between the subslab area and the house. Pressure differential measurements are made under a variety of operational scenaraos in order to identify the primary sources depressurization. One significant source of depressurization is duct leakage. In many Florida homes, supply ducts are run through the attic and the air handler is served by a single return. If duct runs in the attic leak, unbalanced flow depressurizes the living space (Figure 4). This effect can be measured directly using the blower door to regulate house depressurization and the flowhood to observe the flow of unconditioned air through the ducts.

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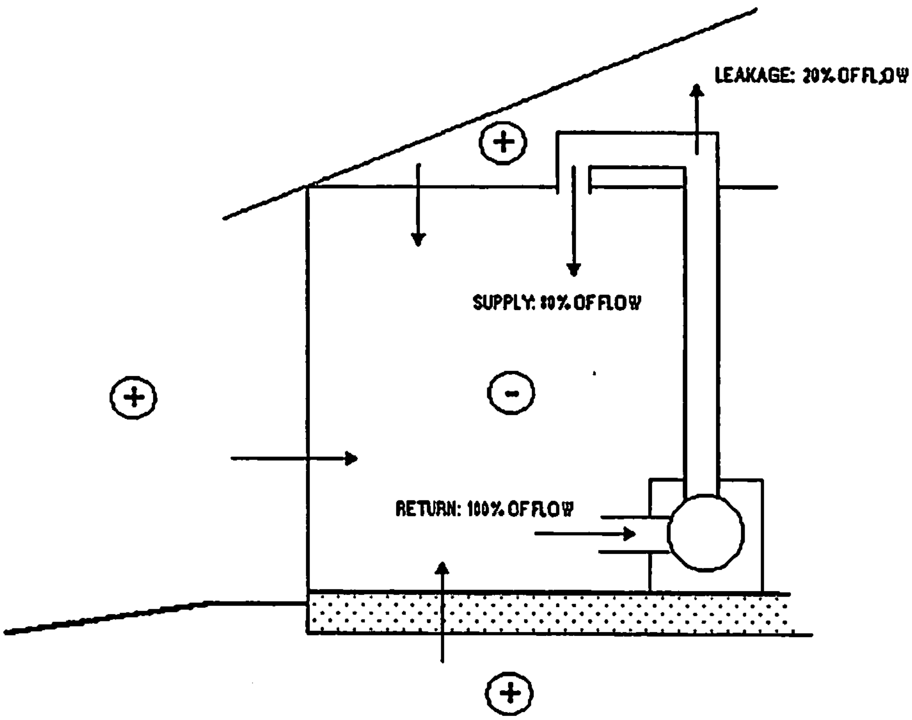

Figure 4. Depressurization of Indoor Airspace By Duct Leakage.