4031

New-Construction Techniques and HVAC Overpressurization for Radon Reduction in Schools

K.A. Witter A.B. Craig D. Saum

ABSTRACT

Construction of a school in Fairfax County, Virginia, is being carefully monitored since elevated indoor radon levels have been identified in many existing houses near the site. Soil gas radon concentrations measured prior to pouring of the slabs were also indicative of a potential radon problem should the soil gas enter the school; however, subslab radon measurements collected thus far are lower than anticipated.

Radon-resistant features have been incorporated into construction of the school and include the placing of at least 100 mm of clean coarse aggregate under the slab and a plastic film barrier between the aggregate and the slab, the sealing of all expansion joints, the sealing or plugging of all utility penetrations where possible, and the painting of interior block walls. In addition, the school's heating, ventilating, and air-conditioning (HVAC) system has been designed to operate continuously in overpressurization to help reduce pressure-driven entry of radon-containing soil gas into the building. Following completion, indoor radon levels in the school will be monitored to determine the effectiveness of these radon-resistant new-construction techniques and HVAC overpressurization in limiting radon entry into the school.

INTRODUCTION

Elevated levels of indoor radon have been found in houses throughout the United States, and the growing concern of the lung cancer risks associated with radon is spreading to high occupancy public buildings such as schools. Since children spend a large portion of time in schools, elevated radon levels in schools represent a significant health concern. However, experience in installation of radon-resistant construction features in new schools and radon mitigation of existing schools is limited.

Construction recently began on an elementary school in Fairfax County, Virginia, and as plans developed, it became evident that many houses near the school site had in-

K.A. Witter is an Environmental Engineer, Indoor Air Branch, US EPA, Research Triangle Park, NC; A.B. Craig is a Senior Research Scientist for Radon, US EPA, Research Triangle Park, NC; D. Saum is President of Infiltec, Falls Church, VA.

door radon levels much above the 4 picocuries per liter (pCi/l) action level recommended by the U.S. Environmental Protection Agency (EPA). Consequently, the construction of the school is being carefully monitored, and several radon-resistant new-construction features are being installed in an effort to reduce the potential for elevated levels of radon in the school.

Construction details of the school, evaluation of the on-site soils and subslab radon levels (to determine the potential for elevated levels of indoor radon), specific radon-resistant new-construction features installed in the school, and to the extent possible, the effectiveness of these new-construction features in reducing radon levels in the school are discussed in the paper. The effectiveness of HVAC overpressurization in reducing indoor radon levels will be evaluated following its installation in May 1988 and published in a subsequent paper.

In addition, radon data collected from two other Fairfax County Schools will be briefly presented. One school in nearing completion, and the other is approximately 20 years old. The latter has had elevated radon levels successfully mitigated with a subslab ventilation system.

BACKGROUND

The school is located on a 5.5 hectare site, and the first floor of the building in contact with the ground covers approximately 5200 m². Test borings of soil on the building site indicated reddish-brown, gray, and yellow sandy silt, silty sand, and lean to fat clay, some with weathered rock fragments. These soils represent residual material that was derived primarily from the chemical weathering of the parent bedrock and range from the ground surface to depths of 0.75 to 4.5 m. The predominant underlying parent bedrock in the area is interbedded grayish sandstone and reddish-brown siltstone, exhibiting relatively high and low permeabilities, respectively. It is expected that, due to its higher permeability, the sandstone material will probably exhibit a higher radon availability. The natural soils on the site were considered suitable for construction and backfill. Up to approximately 1.5 m of cut was necessary to reach floor grade in cut areas and about 1.5 m of fill needed to reach floor grade in the fill areas. Cut and fill were balanced so that no dirt was brought in or removed from the site.

The slabs are 100 mm thick, reinforced with welded wire fabric, and poured in areas of less than 85 m² with tongue and groove joints between pours. Both above- and below-grade walls are constructed of concrete blocks.

Construction on the school began during the summer of 1987, and slabs were poured in the fall. The roofing was completed in February 1988, and installation of the HVAC system is expected in May 1988. All work on the school is scheduled to be completed by September 1, 1988.

EVALUATION AND DISCUSSION OF SITE RADON POTENTIAL

To help anticipate the school's potential for an indoor radon problem, two sets of soil gas radon measurements were made on the site by the U.S. Geological Survey (USGS). One set of measurements was collected prior to site grading, and the other followed completion of cut/fill distributions on the site. For each soil gas measurement, a 35 mm diameter hole was bored to a depth of approximately 0.5 to 1.0 m, a test probe inserted, soil gas sucked from the ground under carefully controlled conditions, the alpha radio-activity of the soil gas measured and converted to radon gas concentration, gas permeability in the ground at the sampling point determined, diffusion coefficient estimated, mean migration distance computed, and radon availability calculated.

The soil gas radon measurements collected within the building perimeter prior to grading of the site ranged from 200 to 4300 pCi/l. As construction progressed and cut/fill distributions on the site were completed, radon levels in the soil gas within the building perimeter ranged from 100 to 3650 pCi/l, with half of the test holes measuring over 1000 pCi/l. Figure 1 displays the test locations and associated soil gas radon levels for the soil gas samples collected after grading of the site. These soil gas radon concentrations are indicative of a potential radon problem should the soil gas enter the school.

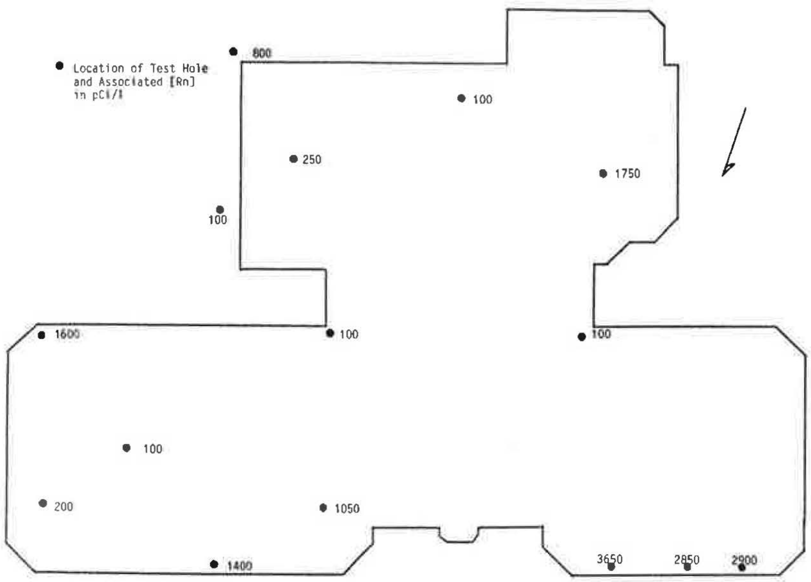

Figure 1 Radon soil gas measurements prior to pouring of slabs (July 1987)

In an effort to correlate radon levels on the site throughout construction, grab samples of radon concentration have been taken underneath the slab and will continue to be collected throughout construction of the school. To date, four sets of subslab radon measurements have been made. The measurements are collected by drilling a 6.35 mm hole through the 100 mm slab, removing the dust with a vacuum cleaner, then inserting a tube, and pumping the gas sample to a continuous radon monitor. When time permits collecting subsequent subslab radon measurements in the same area, an effort is made to use previous test holes for retesting.

Most of the subslab radon measurements collected thus far were considerably lower than the soil gas measurements taken prior to pouring of the slabs; subslab radon levels were often an order of magnitude lower, ranging from less than 5 to almost 500 pCi/l.

The results of these subslab radon measurements, collected in September 1987, December 1987, and March 1988 (2 sets), are displayed in Figures 2, 3, 4, and 5, respectively. The data collected thus far exhibit no consistent trends between radon concentrations in the soil gas (Figure 1) and subslab radon levels (Figures 2, 3, 4, and 5). There are also variations in the four sets of subslab radon measurements collected over the 6 month period. For example, some subslab measurements in the northeast section of the building in September 1987 (Figure 2) increased in December 1987 (Figure 3) while others remained fairly constant. The set of data collected in mid-March 1988 (Figure 4) showed a consistent decrease in radon levels in this area, with the exception of a hallway that increased from the previous soil gas measurements. The most recent set of subslab radon levels, collected in late-March 1988 (Figure 5), also showed a consistent decrease in both the east and west wings.

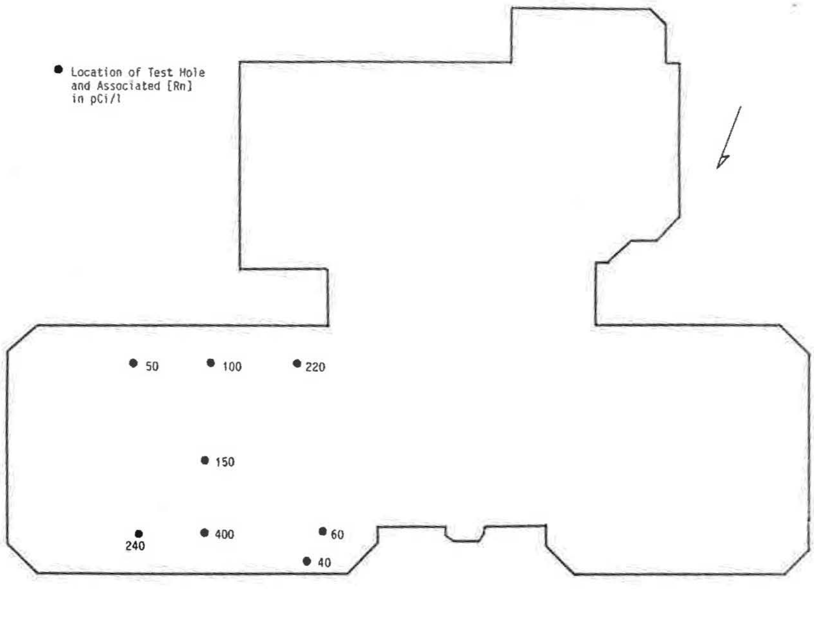

Figure 2 Subslab radon measurements; slabs in place approximately 3 weeks (September 1987)

It was anticipated that subslab radon levels would increase to a point as radon-containing soil gas accumulated under the slab. However, the data do not consistently support this theory. The results thus far indicate the possible dilution of subslab soil gas probably resulting from a combination of the radon-resistant new-construction features incorporated into the building as discussed below and the construction activity in the building. Two other explanations for the lower than expected subslab radon concentrations are the compacting of the subslab soil and the depth of the foundation. It is possible that the compacting of the soil for structural purposes reduced the soil permeability, consequently limiting the amount of radon reaching the surface. It is also possible that, since the soil gas samples were collected at depths of approximately 1 m, the radon availabil

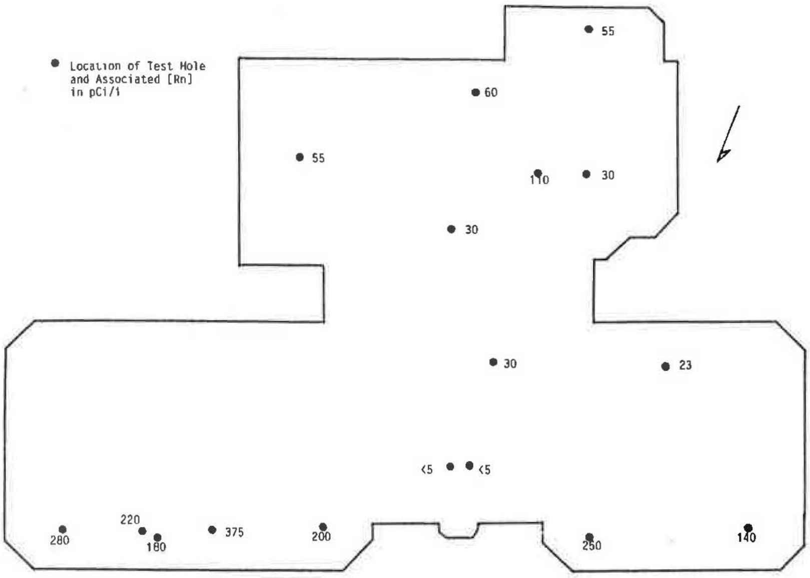

Figure 3 Subslab radon measurements; slabs in place approximately 4 months; most walls and some roofing complete (December 1987)

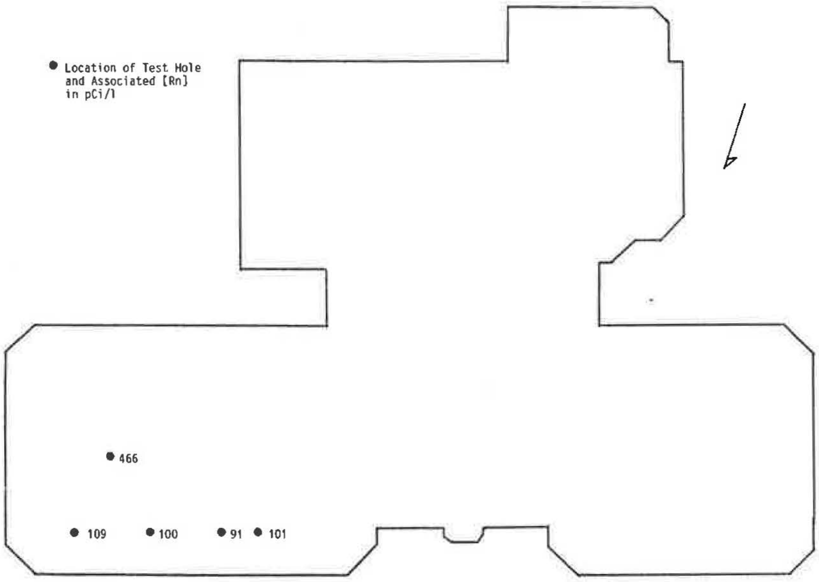

Figure 4 Subslab radon measurements; slabs in place approximately 7 months; most construction complete (March 1988)

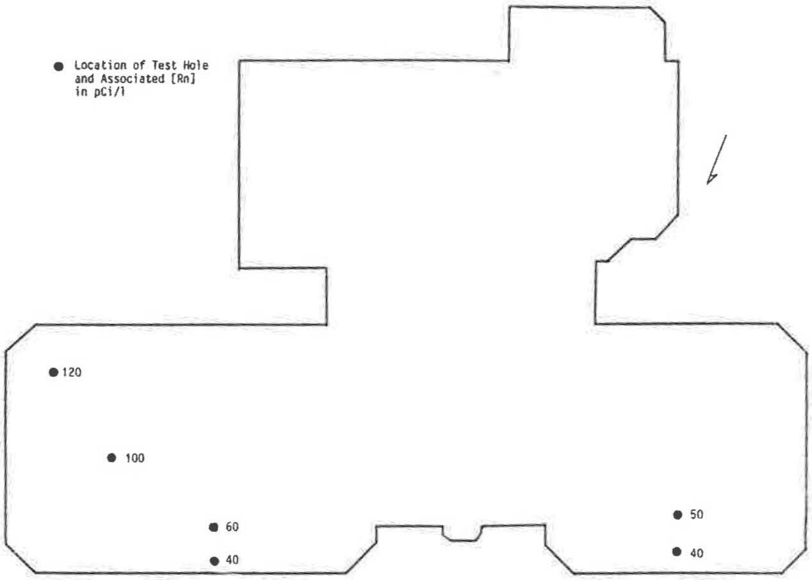

Figure 5 Subslab radon measurements; slabs in place approximately 7 1/2 months; most construction complete (March 1988)

is not as great closer to the surface. (A qualitative assessment of radon levels in the surrounding neighborhood indicates higher radon levels in houses with poured concrete wall basements with open sumps than in split-level houses. It is not known if this is a consequence of specific construction features, or rather the depth of the foundation.) Mapping of subslab radon concentrations will be continued in order to observe any changes and to highlight areas of potential concern in the school. When the school is completed, indoor radon concentrations will be carefully monitored and correlated with the subslab measurements.

RADON-RESISTANT CONSTRUCTION FEATURES

As mentioned above, construction of the school is being carefully monitored and, where feasible, radon-resistant new-construction features are being incorporated in the building to reduce the potential for elevated levels of radon in the school. These features include the placing of at least 100 mm of clean, coarse aggregate under the slab (#57 stone) and a plastic film barrier between the aggregate and the slab, the installation of a removable plastic strip (20 by 25 mm) at the expansion joint to allow for effective sealing of the floor/wall joint with flowable polyurethane caulking, the sealing or plugging of utility penetrations where possible, and the painting of interior block walls. (Laboratory testing is currently in progress to determine the effectiveness of the paint in reducing airflow through block walls.) Should elevated levels of radon be detected in the school following completion of the building, the void space in the aggregate under the slab will allow efficient and cost-effective mitigation via subslab ventilation.

In addition to the above new-construction techniques incorporated into the school, the HVAC system has been designed to operate continuously in an overpressurization mode. Successful pressure control in the school building will be significant in reducing or eliminating negative pressure-driven entry of radon-containing soil gas.

OTHER SCHOOLS

Construction on another school in Fairfax County began in the summer of 1987, one month after the school discussed above. Both schools will be completed by late summer, 1988. A few external soil gas and subslab soil gas radon measurements recently collected indicate a potential radon problem in the school. As a follow-up, subslab radon mapping was performed in mid-March 1988, and subslab radon concentrations ranged from less than 100 to over 600 pCi/l. Ten of the 14 measurements collected were over 200 pCi/l, indicating higher subslab levels than those found at the school discussed above. Since the HVAC air-circulation fans will run continuously, it is believed that maintaining a positive pressure in the school will be an effective means of reducing indoor radon concentrations. Upon completion, radon levels in the school will be monitored to confirm the effectiveness of HVAC overpressurization.

In December 1987, indoor radon concentrations exceeding 10 pCi/l were discovered in several classrooms in a 20-year-old school also located in Fairfax County. The building has an exhaust-only ventilation system consisting of continuously operating powered roof vents that draw air from a plenum above the ceilings; there is no other mechanical system to provide makeup air, only infiltration.

Measurements of subslab radon levels in the classrooms with elevated indoor radon levels ranged from 250 pCi/l (along the outside walls) to approximately 2000 pCi/l (near the center of the slab area). These radon levels and their distribution are typical of those found in residential housing where higher levels of radon are often found near the center of the slab (where dilution is usually minimized), and lower levels are found around the perimeter. Pressure measurements taken when the ventilation system was operating and doors and windows were closed, indicated approximately 15 Pascals (Pa) of negative pressure in the classrooms relative to the outdoors. As a result, radon-containing soil gas was being pulled into the school.

Based on the subslab radon measurements, pressure gradients, and the ventilation system, it was concluded that a subslab depressurization system would be most effective in reducing radon levels in the school. Following installation of the system and extensive sealing, indoor radon levels were reduced to less than 1 pCi/l.

CONCLUSIONS

Unless indicated otherwise, the conclusions below apply to the newly constructed school discussed in detail in this paper.

1. For the school studied, soil gas radon measurements collected prior to pouring of the slabs do not consistently correlate with subslab radon measurements.
2. In general, subslab radon levels were lower than anticipated when compared to the soil gas measurements. Since construction was in progress during the subslab measurements, this could result from dilution of the soil gas underneath the slab due to enhanced airflow in the subslab aggregate. It is also possible that compaction of the soil for structural purposes reduced the soil permeability and consequently radon availability at the surface or that, since the soil gas samples were

collected at a slightly lower depth than the slab, the resulting radon availability is not as great.

3. Subslab radon measurements had a tendency to vary in the four data sets collected over a six-month period. The most recent data indicate a decrease in subslab radon levels.
4. The overpressurization of HVAC systems will play a significant role in limiting pressure-driven entry of radon containing soil gas into schools. Comparison of indoor radon levels between the two newly constructed schools should yield information on the relative effectiveness of HVAC overpressurization alone versus HVAC overpressurization combined with the installation of radon resistant new-construction features.
5. In the existing school with elevated indoor radon levels, it was apparent that significant building depressurization was occurring and that radon-containing subslab soil gas was being drawn into the building.

DISCUSSION

C. Schweider, BCM Eastern, Plymouth Meeting, PA: You said, in response to my questions, that a single mini-grab sample reading was taken for the data! Since radon concentrations vary with ground pressure and other conditions, many more readings are needed to get statistically usable data. Therefore, how could you make or draw any conclusions now or after the HVAC system is installed?

K.A. Witter: I understand Mr. Schweider's concerns pertaining to grab samples; however, since it is necessary to collect a large number of samples covering a large area (55,000 ft^2) during school construction, it is not reasonable to set up several continuous radon monitors on the construction site over an extended time period. Perhaps an elaboration of the procedures for collection of the grab samples would be useful. Prior to sampling, subslab soil gas was allowed to flow through the cell for several minutes; samples were then collected for five one-minute integration periods with a correction made for nominal cell sensitivity. As a check-up, a cell was periodically set aside to equilibrate for four hours.

W.A. Spaul, University of Florida, Tampa: What are the limitations and advantages of charcoal vs. alpha etch methods for measuring radon in schools using passive samples?

Witter: There are different time periods for the two types of measurements—charcoal canister is a 2-7 day test period (preferably closer to two days) and the alpha track detector should have a minimum of thirty days exposure (often, test period is one year).