BUILDING HVAC/FOUNDATION DIAGNOSTICS FOR RADON MITIGATION IN SCHOOLS AND COMMERCIAL BUILDINGS: PART 1

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During the summer of 1989 US EPA embarked on the School Evaluation Program. In its initial stages this program has focussed on performing diagnostics on schools which have been determined to have elevated radon levels. To date these diagnostics have been performed in several diverse geographic areas of the United States, with more activity scheduled throughout the remainder of 1989 and 1990. The evaluated buildings have also been, and will continue to be utilized for teaching purposes for regional school personnel. Early in the program it was observed that schools, like commercial buildings, are typically designed with a more extensive and sophisticated heating, ventilating and air conditioning (HVAC) system than homes. The air handling system has a high likelihood of affecting the pressure relationship of the building envelope, which affects the radon gas entry rate. Through the implementation of a diagnostic protocol which includes foundation and subslab testing along with HVAC system testing, much has been learned concerning the dynamic interaction of the ventilation system and the subslab gases. This presentation will focus on the diagnostic procedures which have been utilized and the mitigation steps which have been recommended as a result of conducting the diagnostics. As they relate to diagnostic procedures, geographic differences and building construction details will be discussed.

Introduction

The conceptual model for radon entry into buildings has directed field investigations of indoor radon problems towards two areas. These are an investigation of the ways in which the operation of the mechanical equipment in the building affects radon entry and could potentially be used to control radon entry. The second area is the ways in which the foundation and underlying materials affect radon entry and could be used to control entry by soil depressurization.

Conceptual Model of Radon Control and Entry

Both approaches, HVAC and soil depressurization control methods prevent soil air entry by managing the air pressure differential relationships between the air in the soil and the air in the building. In addition dilution by increased ventilation plays a role in the HVAC approach and sometimes plays a role in a soil depressurization approach.

The radon concentration in a school or an individual room of a school is the results of interactions between the climate, occupants,underlying geology, HVAC system and the fabric of the interior partitions and the building shell. In school rooms with radon levels greater than 4 pCi/L the majority of radon enters from the soil or bedrock beneath the building by mass air flow or molecular diffusion through cracks and holes in the foundation. If the building is depressurized relative to the outside air then air pressure differentials draw radon laden soil air into the building. The same pressure difference also draws outdoor air in through the above grade leakage sites, diluting the indoor radon concentration. The net effect on the indoor radon concentration of depressurizing the building depends on whether the increased radon entry overwhelms the effect of the increased amount of outside air entering.

Operation of the HVAC system sometimes has a dramatic effect on both the ventilation rate and the entry rate of soil air. The particular effect depends on the details of the equipment and the triggers it's operation strategy uses. For example, if the system pressurizes the building indoor radon is practically eliminated. However if the building is depressurized it will increase the rate at which radon enters the building.

Radon Levels in Schools

The radon levels in school buildings have been observed to vary considerably spatialy and temporally. Both have been known to vary by an order of magnitude. Figure I shows the room average concentrations of radon for schools investigated. Error bars show one standard deviation to give some sense of the spatial variation. Temporal variation is often explained by the operation of HVAC equipment. This is discussed at some length in the text. Additional more detailed data from this work is reported in Reference 3.

HVAC Diagnostics

(System Design) In evaluating the expected impact of an HVAC system on measured radon levels, one of the first steps is to review the design of the system as portrayed by the architect/engineer's drawings. In particular it is important to review the planned relationship between exhaust fan rates and outside air supply rates. In addition the planned control sequence and triggering parameters must be considered. The possible effects of various types of system designs have been reported on by Leovic, Craig, and Turner elsewhere.(1)

In general, areas of the building designed for containment of local sources (exhausted areas) might be expected to cause local negative pressures with respect to the subslab, and areas designed to be supplied with filtered fresh outside air might be expected to cause local positive pressures with respect to the subslab.

The resultant overall pressure relationship of the building would be expected to be the combined result of the overall balance of the amount of makeup air vs. exhaust air, the degree of duct leakage, and the tightness of the building shell itself.

Ventilation systems which are designed to keep a building under negative pressure, such as exhaust only systems with leaky window walls would be expected and have been observed to exacerbate radon entry.

(System Operation) Review of system plans is only the first step in evaluating the expected effect of the HVAC system's effect on radon. Equipment observations must be performed in order to determine just what equipment is actually being operated, its operation schedule, the control sequence, and wether the air flows are near the design quantities. Air flow observations may be as simple as visually observing the position of an outside air damper blade or the operation of an exhaust fan and the direction of air flow with a chemical smoke pencil, or may be more involved. Measurement of actual exhaust flow rates with an air balancing hood has proven valuable for determining the operational status of exhaust systems and for conducting a building shell tightness test. Observations of closed outside air intakes or inoperative make-up air supply fans are typical indicators of HVAC system not being operated or maintained as they were design to be.

(Ventilation Air Delivery Rate) In an occupied school with its normal population of students, the measurement of Carbon Dioxide levels with a portable real time Carbon Dioxide meter has proven very valuable. From these readings inadequate ventilation rates (amount of dilution air) can readily be determined. Current ASHRAE guidelines require a minimum delivery of 7 l/s (15 cfm) of outside air per student in a classroom.(2) Carbon Dioxide readings in classrooms, (taken before lunch time or during mid-afternoon before school lets out), are a good indicator of the ventilation rate occurring on the day of the measurement. Levels over 1000 ppm (with 350 ppm outside) are an indicator of a need for improved ventilation for Indoor Air Quality reasons other than radon dilution.

In a significant number of the schools which have been evaluated in the US EPA SEP program, increasing the observed ventilation rate to meet the current ASHRAE guideline through the use of powered supply make-up air would be expected to lower the radon level to acceptable levels while the system is operating.

(Building Shell Pressure Relationship) A measurement of the pressure relationship between the inside of the building and outside is one of the key parameters which needs to be investigated. This can be accomplished on a not too windy day by simply making measurements through a crack in a closed doorway or window utilizing a sensitive electronic micromanometer (pressure transducer). Readings of slight positive pressure (+.001 to +.010 inches water) will help to keep radon out during operation of the HVAC system, while negative readings will cause increased radon entry.

(Building Shell Tightness Test) In order to determine how much make-up air would be needed to slightly pressurize a building, the equivalent of a fan door pressure test can be performed. The results of this test will reveal the practicality of "building pressurization" to mitigate an observed radon problem.

Foundation Investigation

An investigation is carried out in a school with elevated radon levels that collects information on the foundation and the materials immediately beneath it. The bulk of schools investigated have been slab on grade structures. The material beneath the slab is often sand fill or sand and gravel that was native to the site. A layer of stone pebbles has been found under 1/3 of the buildings investigated to date. This detail provides a plenum like space for lowering the air pressure under the slab with ease.

A vacuum cleaner with a variable speed control is used to assess the airflow resistance of the sub slab material and the distance which a low pressure field can be extended from the suction point. This information can be used to plan the number and location of suction points and the fan performance characteristics of a soil depressurization approach. Suction is ordinarily applied near the outside edge of slabs. This is done because drain tile, stone pebbles or soil settling will most likely be found in this location.

Soil air radon measurements are also made beneath the slab. This has some value in locating "hot spots" and understanding radon sources.

Major limitations in this part of the investigation are finding locations where holes through the slab can be made and repaired unobtrusively. The tests are performed in only one or two areas of the schools, usually in the rooms with the most elevated radon levels. There is the risk that the limited sampling will find areas that are not representative of the school in general or even of the room in which the tests are being made.

Conclusions

A comprehensive approach to Radon diagnostics which includes both HVAC diagnostics and foundation diagnostics has been demonstrated to work effectively. In seven out nine schools investigated an HVAC approach was recommended as the first choice. Often this was the case because the existing ventilation strategy did not meet current ASHRAE guidelines or in some cases state regulation. Many of the HVAC systems in the schools were not operating the way they were originally designed because of operator intervention or disrepair of equipment.

Soil depressurization approaches were considered for each school but only recommended as the first choice in two buildings. These buildings had adequate outside air and could easily control radon by depressurizing under the slab in a small number of rooms.

Acknowledgements

The authors wish to express their thanks to the support staff of Camroden Associates and Harriman Associates for the preparation of this manuscript, and school department personnel whom have facilitated our field efforts.

References

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Figure 1 Radon Levels in School Rooms
Error bars are one standard deviation