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Project Summary

Testing of Indoor Radon Reduction Techniques in Central Ohio Houses: Phase 1 (Winter 1987-88)

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Developmental radon reduction techniques have been installed in 16 houses near Dayton, Ohio, in Phase 1 of a two-phase project in that area. Sub-slab suction and sump (drain tile) suction have reduced radon levels in five basement houses below 4 picocuries per liter (pCi/L)*, based on short-term measurements. In one of these houses, the reduction was achieved despite the fact that soil gas flow in the system was only 2 L/sec. In two other houses, which had a basement plus an adjoining slab on grade, sub-slab suction in the basement alone adequately reduced radon levels in the entire house, without any direct treatment of the adjoining slab. Radon was reduced by over 90 percent in each of four slab-on-grade houses using a single sub-slab suction point from outdoors, even though forced-air heating supply ducts under the slabs appeared to prevent effective extension of the suction field under the slab. Forced-air exhaust of the crawl space in four crawl-space houses proved more effective in reducing radon in the living area than did natural ventilation of the crawl space. Closure of the wall/floor joint in two basement houses with concrete foundation walls, and of a sump in one of the houses, appears to have given, at best, moderate reductions in the house with the sump, and limited (if any) reduction in the other house. Operation of sub-slab ventilation systems in suction proved consistently more effective in reducing radon than did operation of the systems in pressure.

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

As part of the U. S. Environmental Protection Agency (EPA) program to develop and demonstrate cost-effective methods for reducing concentrations of radon inside houses, developmental radon reduction measures were installed and tested in 16 existing houses near Dayton, Ohio. This testing, conducted during the 1987-88 heating season, was intended to develop understanding of the design and performance of selected radon reduction systems in selected house sub-structure types, with geological and house construction characteristics representative of Ohio (as well as of other areas of the country).

The test program had five objectives.

1. To verify that traditional sub-slab ventilation systems and sump (drain tile) ventilation systems can provide

(*) 1 pCi/L = 37 becquerels per cubic meter (Bq/m^3)

high radon reductions in "pure" basement houses in Ohio (i.e., basement houses having no adjoining slab on grade or crawl space). These active soil ventilation systems have proven very effective in testing elsewhere.

2. To demonstrate whether sub-slab ventilation in the basement alone can sufficiently reduce radon levels throughout basement houses with adjoining slabs on grade (i.e., to determine whether separate vent pipes directly treating the adjoining slab can be avoided).
3. To explore alternative mitigation methods for slab-on-grade houses having forced-air heating supply ducts underneath the slab. Methods tested included: operating the central furnace fan continuously to pressurize the sub-slab space using the heating ducts; sealing accessible slab openings; and single-point sub-slab ventilation.
4. To test alternative methods for treating crawl-space houses, including: natural ventilation of the crawl space, by opening foundation vents; and forced-air ventilation of the crawl space (with the ventilation fan operating to exhaust air from the crawl space).
5. To test sealing alone as a method for reducing radon in basement houses particularly amenable to sealing (i.e., poured concrete foundation walls, basement unfinished, and slab and walls reasonably free of cracking).

Measurement Methods

The performance of the radon reduction systems was determined using two types of radon measurements on the indoor air. One involved 2 - 4 days of hourly measurements with a Pylon continuous radon monitor ("short-term" monitoring). This monitoring provided an immediate indication of the approximate percentage radon reduction. The Pylon monitoring was conducted 2 - 4 days before, and 2 - 4 days after, any changes to the system; system on/off measurements were made back-to-back, to the extent possible, to reduce temporal variations. Measurements were made in different parts of the house, as warranted, under closed-house conditions. Much of the monitoring was completed during the heating season, although some of the last measurements were not completed until mid-April 1988.

The other involved alpha-track detectors (ATD's), to provide a longer-term measure of system performance. Premitigation ATD's were exposed for approximately 2 - 3 months during cold weather, just prior to installation of the mitigation systems. Quarterly postmitigation ATD measurements are now planned for a 1- year period.

In addition to the radon measurements, various diagnostic tests were conducted (e.g., sub-slab communication tests, and suction/flow measurements in mitigation system piping).

Results and Conclusions

Objective 1 - Sub-slab ventilation and sump ventilation in basement houses

1. In three basement houses without sumps, traditional active sub-slab suction (involving a single sub-slab suction pipe through the basement slab) typically achieved reductions greater than 90%, consistent with experience in other states where sub-slab communication was as good as that in the Dayton houses.
2. In two basement houses with sumps and reasonably complete drain tile loops, active sump suction achieved radon reductions greater than 95%, again consistent with experience elsewhere when sub-slab communication was good.
3. With sub-slab suction, one suction pipe through the slab was sufficient even in one house where the pipe had to be placed at one end of a large basement slab (170 m^2). Thus, where communication is good and where fan performance specifications are sufficient, it would appear that, at least in some cases, high reductions can be achieved with a limited number of suction pipes and with reasonable flexibility in pipe location. (The fans in these installations were capable of 127 L/sec at zero static pressure, and could develop 350 Pa suction before stalling.)
4. The sub-slab suction systems in two of the houses gave high reductions despite unusually low flow rates (2-10 L/sec). It would thus appear that high flows are not necessary to obtain high radon reductions, as long as the suction field extends well. Premitigation sub-slab communication tests had suggested that high flows would be expected in these houses, indicating that the premitigation diagnostic testing does not fully reveal all aspects of the sub-slab condition.
5. Operation of these active soil ventilation systems with the fans drawing suction was always distinctly superior to operation with the fans reversed to pressurize the sub-slab region. Reduction of 80-96% with the fans in suction fell to 47-89% with the fans in pressure. Sub-slab pressurization depends on creation of a good flow of air under the slab to dilute the radon in the sub-slab gas, and flows are not high in many of these homes.

Objective 2 - Sub-slab ventilatio in the basement of basement plus slab-on-grade houses

1. Sub-slab suction in the basements c two basement plus slab-on-grad houses effectively reduced rado levels throughout the houses, givin reductions of 96% in the basement (consistent with the goo communication under the basemei slab) and about 93% above th adjoining slab.
2. Available data did not indicate if tl radon reductions upstairs were fact due to extension of the bas ment suction field under tl adjoining slab, actually treating tl entry routes associated with tl adjoining slab; or if the observed u stairs reductions resulted only b cause the system reduced tl amount of radon migrating upstai from the basement.
3. Both of these houses had pour concrete foundation walls. If tl basement sub-slab suction field we to extend under the adjoining sl there is a greater likelihood that tl would occur with concrete walls th with hollow-block walls. A hollc block stem wall could provide channel for air leakage into t system which could interrupt t suction field.
4. As with the "pure" basement hou in Objective 1, reversal of the fan pressurize the sub-slab resulted distinctly poorer radon reducti than when the fan operated suction.

Objective 3 - Slab-on-grade houses (with sub-slab heating ducts)

1. Premitigation sub-slab commun tion testing confirmed that the s slab heating ducts did in fact ap to prevent extension of a suction t underneath the slab. Thus, in efforts on the four slab-on-gr

houses focussed on approaches other than sub-slab suction.

2. Initial efforts on the slab-on-grade houses involved continuous operation of the central furnace fan, in an effort to pressurize the sub-slab via the forced-air heating supply ducts under the slab. This approach resulted in moderate radon reductions (51-74%) in two of the houses, and little, if any, effect in the other two.
3. The second effort in the slab-on-grade houses was to close the major accessible opening through the slab, namely, the opening under the bathtub where the bath plumbing comes up through the slab. This step was not expected to be sufficient by itself to reduce radon levels below 150 Bq/m^3, in view of the other slab openings left unclosed (such as the heating supply registers and the inaccessible wall/floor joint). However, the approach was tested as a measure which homeowners could easily implement them-selves. Closing the bathtub opening appeared to give limited radon reductions (33-49%) in two of the houses, and no meaningful reduction in a third. (The fourth house had no opening under the bathtub.) Closure of the bathtub opening improved the radon reduction effectiveness of central fan operation in the two houses where fan operation had had a significant effect prior to closure. Radon reductions with fan operation in those two houses increased to 67-94% after closure.
4. A simple sub-slab suction approach proved very effective in all four slab-on-grade houses, even though the sub-slab ducts were preventing effective distribution of the suction field under the slab. This approach involved mounting a 127 L/sec soil ventilation fan over a single hole cored horizontally through the foundation wall from outdoors, below slab level. The hole was cored either at one end of the house, or near the middle of the rear of the house. Radon reductions ranged from 94 to 97%.
5. Of these sub-slab suction results, the most tentative are those from the house which had a block foundation, and which also had a slab area (190 m^2) twice the size of the other three. This house was the only one which rose above 4 pCi/L (to 10.6 pCi/L) when the central furnace fan was operated continuously in conjunction with sub-slab suction, suggesting that high reductions might not be maintained if the mitigation system is challenged. The problem in this house might be the block foundation, with the block cores facilitating the short-circuiting of house air into the system. Or perhaps the slab is too large for one suction point, in view of the obstructions presented by the heating ducts.
6. Reversal of the sub-slab ventilation fan to operate in pressure distinctly decreased the performance of these sub-slab systems, relative to operation in suction.

Objective 4 - Crawl-space houses

1. Initially, the four crawl-space houses were tested using natural ventilation of the crawl space as the mitigation approach. Each house had between five and seven foundation vents around the perimeter of the crawl space foundation wall. Indoor radon levels were measured with these vents open and closed, in an effort to reduce indoor levels by diluting the radon concentrations in the crawl space and by reducing the forces drawing soil gas up out of the soil. Opening the vents caused radon reductions of 37-84% in the living area, and reductions of 56-91% in the crawl space.
2. The houses were also tested with forced ventilation of the crawl space, with the 127 L/sec ventilation fan exhausting crawl space air. In addition to increasing ventilation, forced-air exhaust might be expected to depressurize the crawl space relative to the living area, thus reducing migration of radon from the crawl space into the living area. To increase crawl space depressurization, the foundation vents were closed during forced exhaust ventilation; however, no additional sealing of the crawl-space foundation wall or of the subflooring under the living area was attempted. In all four houses, radon levels in the living area were reduced to a distinctly greater extent by forced exhaust than by natural ventilation of the crawl space. Reductions in the living area with forced exhaust were 69-93%. However, reductions in crawl space concentrations with forced ventilation (8-50%) were distinctly poorer than with natural ventilation, as expected. In depressurizing the crawl space, forced exhaust draws more soil gas into the crawl space, largely offsetting the benefits of increased ventilation. The potential of the crawl space depressurization mechanism is demonstrated by the fact that concentrations in the living area can be substantially decreased while the crawl space concentrations are being decreased only slightly to moderately.

Objective 5 - Sealing alone in amenable basement houses

1. In one of the two houses tested under this objective, closure of the sump, caulking of the wall/floor joint, and sealing around utility line penetrations through the slab resulted in a radon reduction of about 62% in the basement. But in the second house, which had no sump, caulking of the wall/floor joint appeared to result in no significant reduction. If only slight to moderate reductions can be achieved with this type of closure in "textbook-case" houses, the incentive for attempting such closure by itself in more complex cases (e.g., combined substructures, block foundations, finished basements) might be questioned.
2. The wall/floor joints in these two houses were closed using non-flowable polyurethane caulk after wire-brushing and carefully cleaning the surfaces. Flowable urethane caulk was tried, but was unsatisfactory because it flowed out onto the slab, and disappeared down the 1 - 3 mm wide wall/floor crack. The sump was closed using a circular clear plastic cover cut to fit the sump opening, sealed around the perimeter and around the sump penetrations (water discharge line, electrical connection to pump).
3. Diagnostic testing indicates that radon is still entering these houses through the wall/floor joint, despite the fact that the caulk bead visually appears to be adhering well to both the concrete foundation wall and the slab. One hypothesis is that the radon might be bypassing the caulk bead, moving through the porous surface of the concrete (the "laitance") near the base of the foundation wall. If this hypothesis is correct, and if a suitable primer will not close the laitance, then the reductions that can be achieved using the type of sealing effort that homeowners could reasonably perform themselves will be limited.

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The complete report, entitled "Testing of Indoor Radon Reduction Techniques in Central Ohio Houses: Phase 1 (Winter 1987-88)," (Order No. PB 89-219 984/AS; Cost: $36.95, subject to change) will be available only from:
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