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EPA

Project Summary

Testing of Indoor Radon Reduction Techniques in Basement Houses Having Adjoining Wings

Marc Messing

Indoor radon reduction techniques were tested in 12 existing houses in Maryland. These houses had premitigation radon concentrations ranging from 2 to 23 pCi/L*. The primary objectives were to assess active soil depressurization methods in basement houses having either an adjoining slab-on-grade wing or an adjoining crawl-space wing. The intent was to determine: a) under what conditions radon levels could be adequately reduced throughout the entire house through sub-slab depressurization (SSD) or drain tile depressurization (DTD) in the basement alone; and b) what additional (incremental) reductions could be achieved by also applying SSD under the adjoining slab-on-grade wing, or sub-liner depressurization (SLD) in the adjoining crawl space. The houses were selected to include both good and poor communication beneath the basement slab, and different degrees of importance of the adjoining wing as a radon source. Another objective of this project was to determine whether a simple, one-pipe SSD system would provide high reductions in a large slab-on-grade house having forced-air heating supply ducts under the slab.

In the five basement-plus-slab-on-grade houses, simultaneous treatment of both slabs always gave better performance (relative to treatment of either one of the slabs alone), providing an incremental additional reduction ranging from 0.1 to 5.2 pCi/L in the basement, and from 0 to 2.9 pCi/L in the living area above the slab on grade. With simultaneous treatment, levels in all five houses were reduced below 1 pCi/L in the living areas and below 1-2 pCi/L in the basements. Basement-only treatment always reduced levels throughout the house below 4 pCi/L, even when communication was poor and the adjoining slab was a source, and sometimes reduced levels below 2 pCi/L. Treatment of only the adjoining slab reduced living area levels below 2 pCi/L, but often left basement levels above 4 pCi/L.

In the six basement-plus-crawl-space houses, basement-only treatment achieved reductions throughout the house comparable to the reductions obtained with simultaneous treatment of both wings (i.e., to less than 1 pCi/L), even when the crawl space was a radon source, if communication beneath the basement slab was very good. When sub-slab communication was poor, treatment of both wings was required. Treatment of only the crawl space always reduced concentrations throughout the house below 3 pCi/L. However, the incremental additional reductions achieved with simultaneous treatment, compared to crawl-space SLD alone, were significant (ranging from 1.0 to 2.7 pCi/L in the basement, and from 0.7 to 2.1 pCi/L in the living area); in no case would it appear desirable to install a crawl-space SLD system without also installing SSD in the basement.

Radon levels in the one slab-on-grade house were effectively re-

* 1 pCi/L = 37 Bq/m^3

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duced, from 7.1-15.7 pCi/L to below 1 pCi/L, with the one-pipe SSD system, despite the large size and the sub-slab ducts.

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

The U. S. Environmental Protection Agency (EPA) is conducting a radon mitigation program to develop, demonstrate and optimize cost-effective techniques for reducing elevated radon concentrations in houses, schools and other types of buildings. The total EPA program addressing houses will evaluate the full range of radon reduction methods (i.e., house ventilation, sealing of entry routes, soil depressurization/pressurization, house pressure adjustment, radon removal from well water, and air cleaning), in the full range of housing substructure types, construction methods, and geological conditions representative of the U. S. housing stock. The program described in this report was to demonstrate radon reduction methods in selected housing types and with the geology typical of Maryland.

The major objective of this project was to evaluate the application of active (fan-assisted) soil depressurization as the mitigation approach in basement houses having an adjoining slab-on-grade or crawl-space wing. The active soil depressurization methods tested included sub-slab depressurization (SSD), drain tile depressurization (DTD) via a sump, and sub-liner depressurization (SLD) in unpaved crawl spaces (i.e., crawl spaces with dirt floors). The intent of the testing was to identify under what conditions SSD or DTD in the basement alone is sufficient to treat the entire house in such basement-plus-adjoining-wing houses, and what additional reductions might be achieved by also treating the adjoining wing. It was also desired to determine whether simple diagnostic tools could be used prior to mitigation, to predict whether the adjoining wing should also be treated.

To address this objective, testing was carried out in six basement houses having an adjoining crawl space, and five basement houses having an adjoining slab on grade. In each case, an SSD system (usually with only one suction pipe) or a DTD system was installed in the basement, and another suction pipe was installed beneath the adjoining slab on grade or through polyethylene sheeting placed over the unpaved floor of the adjoining crawl space. Radon concentrations were then measured in the basement and in the upstairs living area with: none of the suction pipes operating; SSD or DTD applied to the basement slab only; SSD beneath the adjoining slab on grade only, or SLD in the crawl space only; and simultaneous treatment of both the basement slab and the adjoining wing. Another variable investigated during the testing in basement-plus-crawl-space houses was the effect of increased sealing of the polyethylene liner in the crawl space, and of increased isolation of the crawl space from the basement.

Another objective of this project was to determine whether a simple SSD system (with only one or two suction pipes) would be sufficient to treat a pure slab-on-grade house with forced-air heating supply ducts under the slab, when there is good sub-slab aggregate. The concern is whether the sub-slab ducts might prevent effective extension of the suction field under the slab, requiring a large number of SSD pipes in a substructure type where locating suction pipes can often be complicated by the presence of a highly finished living area on most of the slab. This objective was addressed by testing one slab-on-grade house.

Measurement Methods

The performance of the radon reduction methods was determined utilizing several radon measurement methods. The primary method involved hourly measurements with a Pylon continuous radon monitor as the mitigation system was cycled through various test configurations over a 10- to 14-day period. This monitoring provided an immediate indication of the approximate percentage radon reduction. A typical test cycle in the basement houses having adjoining wings involved collecting Pylon data for 2 to 4 days in each of five mitigation system configurations: 1) system off; 2) basement leg operating alone; 3) adjoining wing leg operating alone; 4) both legs operating simultaneously; and 5) system off. Measurements were made both in the basement and in the living area above the adjoining wing.

Another measurement method involved alpha-track detectors (ATDs), to provide a longer-term measure of system performance. Quarterly post-mitigation ATD measurements, both upstairs and in the basement of each house, were conducted over the first (summer) quarter following completion of the mitigation installations, with the most effective of the mitigation configurations in operation. Subsequently, year-long ATDs were deployed from September 1989 to September 1990.

Radon measurements using Electret Ion Chambers were conducted in parallel with the Pylon and ATD measurements.

In addition to the radon measurements, various diagnostic measurements were also completed in each house. These diagnostic measurements included: suction and flow measurements in system piping; sub-slab communication measurements prior to mitigation, using a vacuum cleaner to induce suction; suction field extension measurements beneath the basement and adjoining slabs, and beneath the crawl-space liners, with the mitigation system operating; and measurement of the effective leakage area of the houses using a blower door.

Results and Conclusions

Basement Houses Having Adjoining Slabs on Grade

Active soil depressurization techniques were tested in five Maryland houses having basements with adjoining slabs on grade. Pre-mitigation radon concentrations in these houses ranged from 9.5 to 23.4 pCi/L in the basement, and from 2.3 to 15.7 pCi/L in the living area above the slab on grade.

This testing led to several conclusions.

1. In all five houses tested here, simultaneous treatment of both slabs always gave better radon reductions, in both the basement and the living area above the slab on grade, than did operation of either the basement or the slab-on-grade system alone. The percentage radon reduction in the basement was increased by 2 to 25 percentage points by simultaneous operation (compared to treatment of either one of the slabs alone), and percentage reduction in the living area was increased by 0 to 11 percentage points. With both slabs being treated, concentrations were reduced below 1 pCi/L in the living area in all houses; four of the houses were reduced below 1 pCi/L in the basement, and all were reduced below 2 pCi/L in the basement.
2. In all five study houses, SSD or DTD in the basement alone, without direct treatment of the adjoining slab, was sufficient to reduce concentrations throughout the house below 4 pCi/L. In three of the houses, concentrations were reduced below 2 pCi/L throughout the house. The incremental benefit of treating both slabs simultaneously, relative to base–

ment-only treatment, was an additional reduction of 0.3 to 2.9 pCi/L in the basement, and of exactly the same range in the living area above the slab on grade. Thus, it would appear to be generally advantageous to add a slab-on-grade leg to a basement treatment system; however, it will not always be necessary, depending upon the radon reduction desired and the importance of the adjoining slab as a radon source.

3. In all five houses, SSD under the adjoining slab alone, without direct treatment of the basement, was sufficient to reduce concentrations below 4 pCi/L in the living area above the slab on grade; concentrations were reduced below 2 pCi/L in the living area in four of the houses. Living-area reductions were usually greater than they had been with basement-only treatment. However, adjoining-slab-only treatment reduced concentrations in the basement below 4 pCi/L in only three of the five houses, and below 2 pCi/L in only one. The incremental benefit of treating both slabs simultaneously, relative to adjoining-slab-only treatment, was 0.1 to 5.2 pCi/L in the basement (averaging 2.9 pCi/L), and 0 to 0.5 pCi/L in the living area. Thus, if the basement is rarely occupied, it might be sufficient to treat the adjoining slab alone; however, in terms of house-wide reductions, it would appear generally not desirable to install a system to treat the adjoining slab without also installing a leg to treat the basement.
4. If the adjoining slab is an important contributor to radon levels inside the house, the chances appear increased that treatment of both slabs will be necessary in order to achieve high house-wide reductions. In no case where the adjoining slab was an important source, was basement-only treatment adequate to reduce basement levels below 3.3 pCi/L, even when sub-slab communication was good. However, in the one case where communication was good, basement-only treatment was sufficient to reduce living-area levels below 2 pCi/L despite the apparent importance of the adjoining slab as a source.
5. Houses where sub-slab communication is poor are most likely to require simultaneous treatment of both slabs, especially when both wings are important contributors to indoor radon levels.
6. Where sub-slab communication is good, performance of the basement treatment system (either by itself, or in conjunction with the adjoining slab system) is not noticeably influenced by whether or not a sump/drain tile system is present. That is, where communication is good, a SSD system performs as well as a DTD system in otherwise comparable houses.
7. While a definitive conclusion is not possible from these data regarding the effects of house size, the results are consistent with the expectation that larger houses (e.g., with a house footprint larger than 1,250 ft^2*) are more likely to require simultaneous treatment of both slabs to achieve high house-wide radon reductions.
8. In the houses tested here, the presence of forced-air supply ducts beneath the adjoining slab on grade did not appear to detract from the performance of the mitigation systems, in any of the system configurations.

Basement Houses Having Adjoining Crawl Spaces

Active soil depressurization techniques were tested in six Maryland houses having basements with adjoining crawl spaces. Pre-mitigation radon concentrations in these houses ranged from 4.2 to 12.7 pCi/L in the basement, and from 3.0 to 5.4 pCi/L in the living area above the crawl space.

This testing led to several conclusions.

1. Where communication beneath the basement slab was excellent, treatment of the basement alone gave radon reductions, in both the basement and the living area, comparable to (or only marginally poorer than) those achieved when both wings were treated. In the two houses where communication was excellent and where testing was successfully completed, concentrations were reduced below 1 pCi/L both by basement-only treatment and by simultaneous treatment of both wings. This effective basement-only result was obtained despite the fact that the crawl space clearly appeared to be a major radon source in one of the two houses. Thus, where sub-slab communication is very good, it might not always be necessary to incur the cost of treating the crawl space.
2. In the one house where sub-slab communication was very poor and where the crawl space appeared to be a radon source, SSD in the basement alone gave only moderate house-wide reductions (about 50%), failing to reduce the basement below 4 pCi/L. But combined SSD in the basement and SLD in the crawl space reduced concentrations to about 1 pCi/L. Thus, these worst-case conditions (communication is poor and crawl space is an important source) increase the likelihood that simultaneous treatment of both wings will be necessary.
3. In all three houses where crawl-space-only treatment was successfully tested, SLD in the crawl space alone was sufficient to reduce concentrations below 3 pCi/L throughout the house (reductions of 17 to 76%). In the two houses where sub-slab communication was very good, basement-only treatment gave clearly better reductions than did crawl-space-only treatment. But in the third house, with poor communication and with the crawl space being an important radon source, crawl-space-only treatment gave better reductions than did basement-only treatment. In all cases, simultaneous treatment of both wings gave distinctly superior reductions compared to crawl-space-only treatment. The incremental benefit of treating both the basement and the crawl space, relative to crawl-space-only treatment, was an additional reduction of 1.0 to 2.7 pCi/L in the basement, and of 0.7 to 2.1 pCi/L in the living area. Thus, in no case would it appear desirable to install a crawl-space SLD system without also installing a leg to treat the basement.
4. With the SLD system in the crawl space operating alone, without direct treatment of the basement, the system was tested with alternate degrees of sealing of the polyethylene liner. In one case, the liner was sealed only at seams between the sheets of plastic, but not around the perimeter where the liner met the foundation wall. In the second case, the liner was also sealed to the foundation wall, as well as at seams between sheets. In all cases, sealing around the perimeter resulted in a small but noticeable improvement in radon reductions on both stories, giving an incremental reduction in concentrations of 1.2 to 1.6 pCi/L in the basement, and of 0.5 to 1.2 pCi/L in the living area.
5. When the crawl space is an important radon source, performance of the

* 1 ft^2 = 0.093 m^2

mitigation system does not appear to be significantly affected, so long as the communication beneath the basement slab is good. That is, basement-only treatment can apparently still treat the entire house, as indicated previously. But if sub-slab communication is poor, simultaneous treatment of both wings is more likely to be required when the crawl space is an important source.

6. When communication beneath the basement slab is poor, a simple one-pipe SSD system in the basement combined with a SLD system in the crawl space will not always be sufficient. In one house tested here, three SSD pipes in the basement were required in order to achieve concentrations below 4 pCi/L in the basement.
7. The results from this testing do not permit any definitive conclusions regarding any possible effect or mitigation performance of: a) the presence of a sump in the basement, permitting installation of a DTD system, which might improve the distribution of suction under the slab; b) the size of the house; c) the material of construction of the foundation wall (hollow block vs. poured concrete); or d) the nature of the crawl-space floor (bare soil vs. gravel over soil).

Slab-on-grade House Having Sub-slab Forced-air Supply Ducts

An active SSD system was tested in one large (2,700 ft^2) slab-on-grade house in Maryland, having forced-air heating supply ducts beneath the slab. The SSD system included one suction pipe at a central location in the house. The objective of this testing was to determine whether such a simple SSD system could achieve high radon reductions in a slab-on-grade house having several complications (sub-slab heating ducts, large slab, block foundation wall), in cases where there is good aggregate under the slab. This testing was to confirm results on similar slab-on-grade houses in Ohio, where high reductions were achieved with one- or two-pipe SSD systems despite the concern that the sub-slab ducts would prevent the effective distribution of suction under the slab.

Pre-mitigation concentrations of 7.1 to 21.0 pCi/L were reduced below 1 pCi/L by operation of the one-pipe SSD system in the Maryland house. This performance was even better than had been achieved in the one house in Ohio which was completely comparable (sub-slab ducts, large, block foundation). The Ohio house (with a pre-mitigation level of 15.7 pCi/L) had been reduced to 1.7 pCi/L with two suction pipes, and to 6.7-7.7 pCi/L with one suction pipe. This testing demonstrates that, when there is a good layer of aggregate beneath the slab. large slab-on-grade houses can be treated with relatively simple SSD systems, even when there are sub-slab ducts.

Marc Messing is with *Infiltec, Falls Church, VA 22041.*
D. Bruce Henschel is the EPA Project Officer (see below).
The complete report, entitled "Testing of Indoor Radon Reduction Techniques in Basement Houses Having Adjoining Wings," (Order No. PB91-125 831/AS; Cost: $31.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
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The EPA Project Officer can be contacted at:
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