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Project Summary

Testing of Indoor Radon Reduction Techniques in 19 Maryland Houses

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Indoor radon reduction techniques were tested in 19 existing houses in Maryland. The focus was on passive measures: various passive soil depressurization methods, where natural wind and temperature effects are utilized to develop suction in the system; and sealing of radon entry routes into the house. Active (fan-assisted) soil depressurization techniques were also tested.

Passive soil depressurization systems typically gave moderate radon reductions (30 to 70%), although the reductions ranged from zero to 90%. Only two houses were reduced below 4 pCi/L* with the passive systems. A passive system is most likely to be successful when sub-slab communication is very good, when the house is a basement with no adjoining slab-on-grade or crawl-space wings, and when the foundation walls are poured concrete instead of hollow block.

Entry route sealing as a stand-alone radon mitigation measure gave 0 to 50% reduction in the one house where it was tested.

Active soil depressurization, tested in 18 houses, reduced 16 of them below 4 pCi/L, and 12 of them below 2 pCi/L; reductions were often in excess of 90%. Poor sub-slab communication prevented this approach from being fully successful in the other two houses; later modifications to these two systems reduced these houses below 4 pCi/L also.

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).

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

Introduction

The U.S. EPA is conducting a radon mitigation research, development, and demonstration program to identify and evaluate cost-effective techniques for reducing elevated radon levels in houses. The total EPA program will evaluate the full range of radon reduction methods (i.e., house ventilation, sealing of entry routes, soil ventilation, 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 selected radon reduction methods in housing and geology typical of Maryland.

This project involved testing of radon mitigation systems in 19 existing Maryland houses. These houses have structures that are representative of this region: 18 have basements with concrete slabs (sometimes with an adjoining slab-on-grade or crawl-space wing), while the remaining house is of slab-on-grade construction. The foundation walls are hollow block in 13 of the houses, and poured concrete in the 6 others. Pre-mitigation radon levels ranged from 7 to 298 pCi/L, with most houses having radon levels greater than 10 pCi/L.

The major objective of this project was to evaluate passive systems (i.e., systems not requiring the operation of a fan). Such systems have not been widely tested in other projects. Passive systems include: passive soil depressurization, i.e., soil depressurization not involving the use of a fan; sealing of soil gas entry routes; and natural ventilation of the house or crawl space. A key potential advantage of passive systems is that they do not require homeowner maintenance of a fan, and avoid the cost and any noise associated with fan operation. Disadvantages include potentially limited and variable radon reduction performances due to, e.g., the limited nature of the natural suction that is developed in passive soil depressurization stacks by thermal and wind effects, and the difficulty in effectively accessing and addressing essentially all soil gas entry routes when attempting sealing as the sole mitigation measure. In this project, the intent was to determine the degrees of radon reduction that could be achieved with a reasonable best effort to retrofit passive systems into typical existing houses.

In view of this objective, passive systems were initially installed in 13 of the houses where structural features appeared reasonably conducive to this approach. Twelve of these were passive soil depressurization systems (often in conjunction with sealing or natural crawl-space ventilation), and one involved purely sealing. (In all cases, active, or fan-assisted, soil depressurization was considered a backup approach to be installed if the initial passive systems did not achieve sufficient reductions.) In the remaining six houses, where conditions appeared less favorable for passive measures, active soil depressurization systems were the initial approach of choice.

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. Measurements were made both in the basement and the upstairs living area, under closed-house conditions.

The other measurement method involved alpha-track detectors, (ATDs) to provide a longer-term measure of system performance. Quarterly post-mitigation ATD measurements were conducted for 1 to 4 quarters, depending upon how early in the project the mitigation installation was completed.

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

Results and Conclusions

1. Passive soil depressurization techniques, relying upon temperature and wind effects to create natural suction in the system, were tested with 14 mitigation installations in 12 houses. The passive techniques tested included sub-slab depressurization (SSD), drain tile (sump) depressurization (DTD), and sub-liner depressurization (SLD) in crawl spaces; these techniques were tested both by themselves, and in certain combinations with each other and with block wall depressurization (BWD). Commonly, some degree of entry route sealing and/or crawl-space isolation/natural ventilation was conducted in conjunction with the passive soil depressurization. House substructure types tested included basement houses, and basement houses having adjoining slab-on-grade or crawl-space wings.

2. The passive soil depressurization systems typically provided moderate radon reductions (30 to 70%), although the reductions ranged from as low as zero to as high as 90%. In only two houses (Houses 047 and 079) was the passive system sufficient to consistently reduce radon below 4 pCi/L both in the basement and in the living area.

3. The house which gave the best reductions consistently (House 079, which achieved 70 to 90% reduction with each measurement as the result of a one-pipe passive SSD system) was a textbook-case house for a passive system: a) it had a "pure" basement, without an adjoining wing; b) it had very good sub-slab communication; and c) it had poured concrete foundation walls, thus minimizing wall-related entry routes. The one other house which also met all three of these criteria (House 004) also achieved good reductions, 60 to 80% in the basement.

4. The other house which achieved radon concentrations below 4 pCi/L was House 047, a basement-plus-crawl-space house which achieved 20 to 70% reduction in the basement (and 90 to 96% in the crawl space) using a passive SLD system combined with basement sealing. This house, too, apparently was a textbook case: a) the exposed crawl-space soil was the primary radon source; b) the crawl space was unobstructed, small, and had reasonable head room; c) the furnace flue was used as the passive stack, enhancing the natural suction developed on the SLD system; and d) the foundation walls were poured concrete, again minimizing wall-related entry.

5. One of the most important single variables influencing the performance of passive soil depressurization systems is the communication beneath the slab. All houses which had poor performance from the passive system (Houses 054 and 074) had poor/uneven sub-slab communication (and block foundations). However, the existence of good communication was not sufficient, by itself, to ensure high radon reductions from the passive system.

6. The performance of passive depressurization systems appeared to be somewhat better in houses having poured concrete foundation walls. In all of the houses having poured walls, the upper end of the performance range with a passive system was above 70% reduction. By comparison, of the seven block-foundation houses to receive passive systems, only three achieved upper-end reductions greater than 50%. This could be due in part to difficulty by the low-suction passive systems in treating the wall-related entry routes. In House 106, a basement-

plus-slab-on-grade house with a block foundation, performance improved perceptibly (from 0 - 50%, to 30-85%) when the original passive SSD system was expanded to include a BWD component, confirming the failure of the original SSD system to adequately treat the wall in this case.

7. For a given degree of sub-slab communication, and for a given material of construction for the foundation wall, it is not possible from these data to determine a significant effect of the substructure type on the performance of the passive systems. Except perhaps for textbook-case Houses 004 and 079 (which had pure basements), it is not possible, within the error bar of these results, to identify whether the passive systems give better performance in pure basement houses than they do in basements with adjoining wings.

8. In the passive SSD installations, a limited number of suction points were installed to minimize installation costs. The installation of additional sub-slab suction holes, or of a passive BWD component when block foundation walls were present, might have improved the performance of the passive systems.

9. The performance of a given passive system is presented as a range in this report because: a) the pre- and post-mitigation measurements are separated in time in many cases, and the radon source term might have changed between measurements; and b) the performance of the passive systems appears to be varying over time, depending upon wind conditions and temperature.

10. The suctions developed in the piping of these passive systems were typically in the range of 0.0 to 0.10 in. WG.* If sub- slab communication was very good, the resulting depressurization underneath the slab was observed to extend as far as 40 ft** from the suction pipe in one house, although the magnitude of this depressurization fluctuated, presumably due to varying winds.

11. Entry route sealing, as a passive mitigation measure by itself, was tested in one house which appeared amenable to this approach. The house was a pure basement house; the basement was unfinished, with all apparent entry routes accessible; and radon levels were only slightly elevated, so that high radon reductions were not necessary. The house had block foundation walls, capped with solid blocks. After sealing all apparent entry routes -- including painting the block walls with a waterproofing paint -- the radon reduction, if any, was limited (0 to 50%). This limited performance may be due in part to the fact that the paint did not appear to fully seal the block pores.

12. Active soil depressurization was tested in 18 of the 19 houses. All but one of the 13 houses with passive systems, discussed above, were converted to active systems by the end of the project. In addition, six houses received active systems immediately, because they did not appear to be amenable to passive testing (due to highly elevated pre-mitigation radon levels or to poor communication). The active techniques tested covered the range indicated for the passive systems in item 1 above. The house substructure types included basement and basement-plus-adjoining-wing houses, and one slab-on-grade house.

13. Radon levels were reduced to below 4 pCi/L, in both the basement and the living area, in 16 of the 18 houses where active depressurization systems were installed. Levels were reduced below 2 pCi/L on both stories in 12 of these houses. The radon reductions typically were above 90% in the 16 houses, and often ranged as high as 97 to 99+%, although the percentage reduction sometimes ranged as low as 50 to 80% where the pre-mitigation concentrations were only slightly elevated.

14. In the two houses which were not reduced below 4 pCi/L with the active systems (Houses 054 and 074), the reason was poor and uneven communication underneath the basement slab. (These two houses were subsequently reduced below 4 pCi/L by adding additional suction pipes in regions of the slabs where the suction field had not been extending with the initial single pipe.)

15. It is not apparent from these data that active systems performed any better in houses with block foundations than they did in houses with poured foundations. Thus, within the sensitivity of these data, it would appear that these active systems were adequately treating any block-wall-related entry routes, even though only two of the systems included specific BWD components. (However, both of the houses which failed to be reduced below 4 pCi/L did have block walls; block walls may be significant when sub-slab communication is poor.)

16. In four of the houses which had basements with adjoining slab-on-grade or crawl-space wings (Houses 008, 069, 076, and 106), radon levels on both stories were reduced below 4 pCi/L with active soil depressurization treating the basement only. Three of these houses were reduced below 2 pCi/L. All four of these houses were observed to have good aggregate under the basement slab, and/or suction field extension measurements showed good communication. Thus, it appears that -- with these combined-substructure houses -- it is possible to reduce radon in the entire house by treating the basement only, without specifically treating the adjoining wing, if the basement sub-slab communication is good (and, presumably, if the adjoining wing is not the primary radon source).

17. In general, the active systems achieved high suctions in the system piping (usually 0.4 to 1.6 in. WG, except where suctions were reduced by high flows from BWD legs or some other source). Suctions developed under the slabs at points remote from the suction pipes (20 to 40 ft away) ranged from zero to 0.9 in. WG from house to house, depending upon communication. In a few cases (Houses 096, 126, 143, and 163), good radon reductions were achieved despite the fact that no sub-slab depressurization could be measured at some test holes.

* 1 in. WG = 0.249 kPa.

** 1 ft = 0.305 m.

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The complete report, entitled "Testing of Indoor Radon Reduction Techniques in 19 Maryland Houses," (Order No. PB 90-244 393/AS; Cost: $31.00, subject to change) will be available only from:

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