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Project Summary

Demonstration of Radon Resistant Construction Techniques - Phase II

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The Florida Radon Research Program (FRRP), sponsored by the Environmental Protection Agency and the Florida Department of Community Affairs (DCA), is developing the technical basis for a radon-control construction standard. The full report summarizes a project that examined indoor radon in houses that were constructed according to the draft residential construction code.

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 data presented here are from work performed by the Florida Solar Energy Center designed to demonstrate radon resistant construction techniques in new Florida houses. Fifteen houses are included in the Phase II study. Some analysis, however, includes the 13 houses in the 1991 study, to expand the data pool from which conclusions can be drawn.

Three types of data were collected:

1) Soils were tested to determine type, permeability, radon and radium content, radium emanation coefficient, and moisture.

2) The house slab was examined to characterize the crack size and number, and the pressure field extension under the slab created by the sub-slab depressurization system was measured.

3) The house itself underwent extensive testing, including blower door, tracer gas, and duct leak measurements.

The full report discusses and provides a compliance checklist of the adherence of the subject houses to the radon codes and standards. It then explains the objectives, methods used, results expected, and problems encountered in each part of the project. Then the results of testing are presented, followed by an analysis of the data for correlations to radon intrusion.

Soil

Fill soil with high radium content continues to be used in the area of this study. A total of 70% (16 of 23) of the houses for which both radium measurements are available had higher radium values in the fill soil than in the native soil. Native soil radium seems to have a greater effect on final indoor radon levels, probably due to the thin fill soil layer under most houses. Neither native nor fill soil radium levels directly correlate with indoor radon, however. High levels of radium in fill soils can still import a radon problem onto a site that otherwise would not have one, based on native soil gas readings.

Sub-slab measurements of soil-gas radon taken at the same point on different days can vary by as much as 100%, and measurements taken at different points on a slab on the same day can also vary by 100% or more. This variability matches that of measurements taken in different seasons on the same slab, and leads to the conclusion that a number of measurements taken on the same day at different locations on a site are necessary to adequately characterize radon potential.

Slab

All sub-slab mitigation systems had adequate pressure field extension, although pressure fields for both monolithic and stem-wall slabs dropped to zero just inside or at the slab edge. The pressure field can be short-circuited if the ventilation mat or suction pit is located closer than 6 ft (1.8 m) from the slab edge. The 6 ft distance mentioned in the code should be taken as a minimum, as distances up to 40 ft (12.2 m), measured from the end of a ventilation mat to the slab edge, have been depressurized.

Post-tensioned slabs performed best at preventing cracks, containing an average crack length of 13 ft (4 m) in four slabs. Stem-wall systems had an average of 36 ft (11 m) of crack in 10 slabs, and monolithic slabs an average of 100 ft (30.5 m) in 14 slabs. Average crack length in slabs using plasticizer in the concrete was 63 ft (19.2 m), compared with 76 ft (23.2 m) in slabs without plasticizer. Plasticizer use seems to have the desired effect of reducing total crack length when all slabs are lumped together, but conflicting results appear when slabs are separated by type. Average crack length in two monolithic slabs with plasticizer was 35 ft (10.7 m), and was 114 ft (34.7 m) in 10 monolithic slabs without plasticizer. Stem-wall slabs, however, had an average of 75 ft (22.9 m) of cracks in three slabs with plasticizer and an average of only 16.5 ft (5 m) of cracks in eight slabs without plasticizer. Also, all three slabs in these groups with no cracks were among those without plasticizer. Clearly, more data are required before a definitive conclusion can be reached.

Placing reinforcement in the top portions of slab inside corners helps to prevent cracks from starting in these corners. Houses with corner reinforcement had 50% less total cracking than those without corner reinforcement. In at least one instance, however, the corner reinforcement merely forced the crack to start beyond the extent of the reinforcing bars.

Total crack length does not correlate with indoor radon levels. In some instances, high levels of radon were drawn through cracks during testing, but these tests used much higher levels of depressurization than those found in the house environment, and most cracks are protected by the intact vapor barriers under new homes. No data are available, however, on how long these vapor barriers will remain intact, and it is possible that radon levels in these houses will rise if vapor barriers deteriorate over time.

Pipe penetrations through slabs are another avenue for radon intrusion; testing would help determine the extent to which this occurs. Radon levels in houses without tar protecting pipes in slab penetrations had an average indoor radon level 33% higher than those with tar on the pipes. Monitoring in house 7 has also shown that slab penetrations for plumbing pipes not built to code standards can contribute to indoor radon levels.

High ambient radon levels found on the house 7 site were not duplicated on other reclaimed mine sites tested during the project. This site does present the opportunity, however, to study the effects of weather and atmospheric conditions on the exhalation rate of radon from the soil.

The best measure of slab leakiness is the amount of conditioned air being pulled through the slab during mitigation fan operation. Dividing by the house volume gives slab air changes per hour (ach), which takes into account all slab openings including cracks and pipe penetrations.

House

Houses needing mitigation system activation in the project were on average smaller and tighter, with a higher value for slab ach. Activated houses also had higher levels of depressurization than unactivated houses.

The radon stress test did not give meaningful results and was discarded during the project. No calculated values based on its data showed any correlation with indoor radon levels. The stress test should be relegated to research houses, where much longer time periods for testing are possible.

No direct correlations with indoor radon were found in this set of houses, due to the complex nature of the house as a system. It is usually impossible to isolate one building component from another during testing, and each component is likely to have an opposite effect on the results of a test. The factors seeming to have the closest relationship with indoor radon are the sub-slab radon level as the source term, the differential pressure across the slab as the driving force, and the slab ach as the medium of radon intrusion. House leakiness affects the dilution of the radon level once it has entered the house and may be the deciding factor as to whether or not a house's mitigation system should be activated.

There continue to be problems relating to energy efficiency, especially relating to house shell design and heating, ventilation, and air-conditioning (HVAC) system installation procedures. The lack of testing of these systems and the house envelope itself have led many builders to ignore certain building components and installation procedures that are causing energy inefficiency to be built into new homes.

Recommendations

Recommendations for the continuation of the new house evaluation project include shifting testing emphasis from slab cracks to slab pipe penetrations. The testing apparatus is available to use the same protocol on pipe penetrations as has been used on slab cracks. Number and types of slab penetrations should be catalogued as slab cracks have been. Sealing of sub-slab vapor barriers to the pipe penetrations and the use of tar on pipes where they contact the concrete should be considered as mandatory additions to the radon code.

Different types of pipe penetration protection should be tested in a laboratory setting to isolate the pipe penetration and determine the best way to protect against radon intrusion. Obtaining direct correlations between different types of protection for pipe penetrations and radon intrusion through the slab will be much easier when all other conditions can be controlled. Multiple penetrations can also be poured in the same test bed to allow more accurate results to be achieved through averaging.

Older homes should be investigated to determine if vapor barriers remain intact over long periods of time. Ignoring the repair of slab cracks while emphasis shifts to the testing of other slab penetrations could create a radon problem if vapor barriers do not last long. Older houses could be surveyed for cracks while new carpet is being installed. Vapor barrier integrity could easily be determined by using the same testing protocol now in place. Slab cores could also be cut to examine firsthand the condition of older vapor barriers.

Requirements for concrete slump should be relaxed from 4 to 5 in. (10 to 12.7 cm). Requiring a 4-in. slump would be unenforceable: it would require an inspector to be on hand for every concrete truck delivery on every slab built in the code area. It would also be an economic hardship to builders: 4-in. slump concrete cannot be pulled across a slab by hand and would require a pump truck to place the concrete on any slab with access problems.

Requirements for specific spacing of slab control joints should be dropped from the code. Average total crack length for the 28 houses over the 2-year project was 71 ft (21.6 m), with an average drop to 42 ft (12.8 m) after subtracting the three houses with the most cracks. Contrast this with an average control joint length requirement of 442 ft (134.7 m) based on the average project house footprint. The control joint spacing requirement clearly requires more work from the builder than can be justified, since slab cracks have not been shown to be directly correlated to indoor radon levels.

Testing of new houses should continue, to collect data on how sub-slab depressurization (SSD) works in real houses, and how the houses themselves perform as barriers to radon. Determining correlations between indoor radon levels and individual parts of the radon code will be difficult, however, due to the complex nature of real-world houses. Investigations of code sections that can be isolated in a laboratory setting will yield better results due to an enhanced ability to control the experiment.

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***David C. Sanchez** is the EPA Project Officer (see below).*
The complete report, entitled "Demonstration of Radon Resistant Construction Techniques - Phase II," (Order No. PB96-121512; Cost: $44.00, subject to change) will be available only from:
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