BUILDING RESEARCH AND PRACTICE THE JOURNAL OF CIB NUMBER 6 1988

#3469

Radon

Practical problems reducing radon in houses

PRACTICAL PROBLEMS ENCOUNTERED DURING EFFORTS TO REDUCE RADON CONCENTRATION IN HOUSES

Michael C. Osborne

Michael C. Osborne and Terry Brennan

Michael Osborne of the United States Environmental Agency, EPA, and Terry Brennan of Camroden Associates discuss ten of the many daily problems including, inconsistent sub-slab aggregate, hidden pathways to chimneys, variation in concrete porosity, access to radon entry surfaces, diurnal/seasonal variation in radon concentrations, sealing large thermal by-passes and coping with direct rock exposure.

Michael Osborne de la United States Environmental Agency, EPA, et Terry Brennan, de Camroden Associates, exposent dix des nombreux problèmes les plus couramment rencontrés: granulats en sous-face incompatibles, chemins d'accès aux cheminées cachés, variation dans la porosité du béton, accessibilité du radon aux surfaces d'entrées, variations diurnes et saisonnières des concentrations en radon, étanchéification de grands points thermiques et roche directement mise à jour.

Introduction

In a surprisingly short time, the words 'radon' and 'radon mitigation' have been added to the daily vocabulary of many Americans. The job of resolving the radon problem, however, has not been limited to the highly educated few but has quickly become the job of plumbers, electricians, and solar energy salesmen who have had to take on the role of 'radon mitigators'. In an effort to improve the quality of radon mitigation, the US Environmental Protection Agency's (EPA) Office of Radiation Programs, in 1986 conducted 20 short courses across the country to educate both building tradesmen and government regulators. This training included information on the potentially harmful impacts of radon as well as the currently understood ways of alleviating the radon problem in the residential environment.

Along with the national emphasis on resolving the homeowner's radon problem has come an awareness of numerous difficulties that can be encountered which make the task more complicated than one might imagine. The US Environmental Protection Agency is currently funding several projects aimed at both identifying and resolving some of these problems. The ultimate goal of these projects is to simplify the job of the radon diagnostician and mitigator which, hopefully, will result in more homeowners reducing radon levels in their houses at a lower cost.

Background

Radon mitigation projects

Over the past two years, the Air and Energy Engineering Research Laboratory of EPA has conducted radon mitigation projects in Boyertown, Pennsylvania, and Clinton, New Jersey. In September 1986, a new radon reduction effort, co-funded by EPA and New York State Energy Research and Development Authority, was begun in Orange and

Putnam Counties of New York. Within the New York project, additional radon mitigation efforts were begun in Albany and Rensselaer Counties of New York early in 1987. Similar efforts will be conducted in other locations across the country as the need for the development and demonstration of radon mitigation alternatives continues to grow.

In each radon mitigation project, the first definable task has been the selection of houses in the target area where radon reduction efforts will result in recommendable mitigation techniques which may be applied to houses in other localities. The houses visited in the screening effort have already been identified by the State as having a measurable radon problem and having a homeowner who is interested in reducing the radon level.

Each screening visit includes an assessment of potential radon entry routes, an evaluation of the tightness of the building envelope, a determination of the similarity of the house substructure characteristics to those of other houses, and the applicability of potential radon mitigation alternatives to the structure. From these screening visits and from the experience of attempting to reduce radon levels in the selected houses, several problems which inhibit radon mitigation have become evident. Some of the problems are significant enough that houses being screened are rejected as too costly to mitigate at this stage in our research programme. Other houses are rejected because diagnostic techniques have not yet advanced to the point that attempts to identify the radon entry points. In some screening efforts houses are selected for mitigation based on data which are questionable due to diurnal and/or seasonal variations. All of these different types of problems are slowing progress in demonstrating viable radon-reducing alternatives. The purpose of this paper is to identify some of these problems, explain why they are of concern and, when possible, offer potential approaches to solutions.

Radon mitigation inhibitors

The types of problems that radon diagnosticians and mitigators encounter generally fall into three classes: *diagnostics*, *radon measurement*, and *physical mitigation*. These three problem categories also encompass the primary steps in the overall radon mitigation process. A problem in one area often impacts the other areas. For example, a problem which results in a faulty diagnosis will often result in inadequate physical mitigation, or a problem which prevents adequate or complete physical mitigation may make the interpretation of post-mitigation diagnoses extremely difficult. Improper interpretation of radon measurements often results in poor diagnosis of the radon problem and a less than satisfactory mitigation attempt. Any problem which makes radon reduction more difficult or more expensive is viewed as a *radon mitigation inhibitor*. As radon mitigation research continues, more and more inhibitors will be observed; however, the following 10 problems are viewed as some of the more significant radon mitigation inhibitors currently being encountered by radon diagnosticians and mitigators.

Diagnostics

Inconsistent sub-slab aggregate

From builder to builder and even from house to house no other factor is as important or as inconsistent as the presence, characteristics, and uniformity of the sub-slab aggregate beneath either slab-on-grade or basement homes. The importance of this construction feature stems from the very common and often quite successful application of the radon mitigation technique called sub-slab suction.

This technique has been most effective when several inches of crushed stone uniformly cover the area immediately beneath the slab. Unfortunately, in some homes slabs are poured directly on bedrock, while in other homes the slab is poured over undisturbed soil.

From the viewpoint of the radon diagnostician, the worst case is when portions of the slab randomly cover crushed stone, hard-packed soil, and bedrock. Many diagnosticians make test holes in the slab to verify the presence of sub-slab aggregate; yet, short of making 'Swiss cheese' out of the slab, this approach is not dependable. The diagnostician needs an instrument that measures the depth of the slab and discerns the presence and depth of any aggregate beneath the surface. The instrument must be compact enough to be used inside the houses and inexpensive enough to be owned by a radon diagnostician. Such an instrument would be a valuable tool in radon mitigation.

Hidden pathways in chimneys

In many cases, chimneys which penetrate the slab or are built on footings below grade are in theory avenues for radon entry into the houses. The problem really concerns both the diagnosis and the potential for mitigation. Some diagnosticians look for cracks in the mortar and test them with smoke sticks and grab samples, while others opt for flux measurements to determine the actual radon flow through the exposed stone and mortar. In either case, the size of the chimney often severely reduces the capability of reliable measurements. Such measurements are also subject to seasonal and diurnal limitations which will be discussed later under *Radon measurement*. In general, a method of accurate diagnosis of radon entry through chimney foundations is needed.

Variations in porosity of concrete/cinder block and block coatings

One of the potential sources of radon in concrete or cinder block basements or houses is the block itself – obviously, cracks in the block or in the mortar joints can significantly add to the contribution of radon through the block pores. Because of the large variety of aggregate materials used in the manufacture of blocks across the nation, generalization concerning block porosity is difficult. To diagnose properly the problem of a house with a block basement or block walls, the diagnostician must either measure the flow of radon through the block, assume a porosity, or plan to use an impenetrable surface coating regardless of porosity. Each of these alternatives has its drawbacks. Coating the blocks without verifying the need for sealing can be unnecessary and costly. Measurements of radon flow through blocks are subject to seasonal and diurnal variations which can result in order-of-magnitude errors. Moreover, assuming the porosity of blocks could result in equally erroneous results.

The diagnostician needs an instrument that measures the porosity of the block with its existing surface treatment. With this information and a list of recommended surface coatings related to block porosity, the diagnostician could recommend whether a block surface treatment is needed and, if needed, the type of surface treatment which would be most cost effective.

Access to radon entry surfaces

The majority of houses receiving radon mitigation to date have had unfinished basements. Being able to access and inspect floor slabs and block wall surfaces simplifies attempts to diagnose the potential for radon entry into the house. When applying radon mitigation to finished space (e.g. exterior walls covered by interior walls), higher priority goes to mitigation options that can be applied solely from the exterior of the house.

Such options, however, are primarily limited to slab-on-grade and crawl space houses. Finished basements are particularly difficult when they have wall-to-wall carpets on the floors and panelling or wallboard permanently fastened to the perimeter wall surfaces. Fortunately, most finished basements do have an unfinished workshop, laundry room, etc., where concrete floors and exposed block walls can be examined. Depending on what is observed in the unfinished space, mitigation also might be effectively applied from that space. However, for houses where access to the block walls or floors is needed, mitigation can require considerable expense. To diagnose the block wall surfaces behind stud walls or other partitions, the use of fibre optics is recommended. For wall cavities as large as stud walls, a technique for appplying surface coatings should be devised. Although finished basements do present more of a challenge for radon mitigation and more novel ways to access the covered surfaces need to be developed, successful inexpensive mitigation has been demonstrated on some finished houses by using currently available technology.

Radon measurement

Diurnal and seasonal variation in radon concentrations

Radon measurements are used by the diagnostician to verify (1) the magnitude of the radon problem, (2) the location of radon entry, and (3) the relative success that mitigation techniques offer. Besides the normal precision and accuracy consideration, the diagnostician needs to consider two other very significant variables which impact radon measurements. One of these, the seasonal variation, results from temperature differences which exist between the inside and outside of a house during the cold winter months. This phenomenon, known as the 'stack effect', occurs when the house is warmer than the outside air, resulting in depressurization of the house. The depressurized house tends to suck radon and other soil gases from the ground into the building cavity. Since radon diagnosticians and mitigators are generally unable to use annually averaged numbers each time they measure radon, seasonal variations must be considered. This is particularly important when mitigation is being conducted during the summer and houses are not being stressed by depressurization as they would be during the winter.

The other significant variable (which is not as well understood but nonetheless can be very important) is the diurnal or day/night variation in radon concentration. This variable is believed to be related to the changes in soil temperature and various meteorological factors. In some studies the diurnal variation has been extremely evident and predictable. In Clinton, New Jersey, radon measurements were observed to vary by as much as a factor of 20 in each 24-hour cycle over several days. Based on the wide range of daily radon readings the diagnostician must be extremely careful in drawing conclusions from grab sample data or even short-term continuous monitor data. Failure to consider either the seasonal or diurnal variations in radon data can be a significant hindrance to radon mitigation.

Impact of radon-in-water on radon-in-air

In some houses that have their own individual wells or that use water from a community well, a significant percentage of the radon measured in the house air could be coming from the radon found in the water. The rule-of-thumb often quoted is 1 picocurie per litre (pCi/l) in the air for every 10 000 pCi/l of radon in the water (ref. 1). This is an average concentration assuming normal water usage in a typical household. Unfortunately, this number does not reflect the wide swings in radon levels that occur in some rooms of the house where hot water is being used for showers, dishwashing, or clothes washing. Radon was measured in a house in Boyertown, Pennsylvania, where radon in water from an individual well was measured at 37 000 pCi/l. A shower in the bathroom was allowed to run for about 15 minutes at about 100°F (38°C) and, for a brief period of time, radon concentration in the bathroom increased by a factor of over 100.

Considering how quickly and dramatically radon levels can change with water usage, evaluating the effectiveness of non-water-related radon mitigation options without taking into consideration the proximity and frequency of water usage is likely to lead to false conclusions. Using a phased approach to mitigation, making certain that the radon-in-water problem is resolved first, may prevent potential problems in the interpretation of measurement data.

Physical mitigation

Sealing the top row of concrete blocks

One of the most commonly observed variables in block-wall basement construction is how the builder leaves the top row of concrete blocks. The possibilities range from using solid blocks which totally seal the top void to using hollow core blocks with a wood sill plate only partially covering the block openings. Since the block wall usually penetrates the slab and is exposed to soil gas from beneath the lowest block and from the side exposed to the soil, sealing the void in the top row of block is by itself a radon reducer. In addition, if block-wall suction is contemplated as a radon mitigation option, the void in the top row of blocks must be sealed to obtain adequate suction. Mortar and urethane foam have been recommended as materials to use in sealing these voids (ref. 2).

The experience of radon mitigators has shown that to fill large voids by this method requires first packing the void with newspaper or other material which acts as a support surface for the mortar or urethane. Due to the proximity of the top row of blocks to the basement ceiling, visual examination of the quality of the sealing effort is often prohibited. Unfortunately, attempts to seal the top row of blocks by this method are often time consuming, costly, and inadequate. A major contribution to future attempts to reduce radon levels in block wall basement houses would be the refinement of an effective method of quickly and cheaply filling the large voids in the top row of concrete blocks.

Isolating half-basements

Many older basement homes have large areas of the basement space which have direct soil exposure. Often these areas are separated by block wall partitions and tend to resemble crawl spaces more than basements. The simplest radon mitigation alternative for these areas is to treat them as crawl spaces and use natural or forced ventilation. Care must be taken to prevent freezing of water pipes when ventilating crawl spaces. If ventilation is used, the area with exposed soil must be isolated from the rest of the basement. Unfortunately, the concrete block walls which often separate these areas from the true basement portion are only laid to the vicinity of the overhead floor joists, creating a very difficult sealing problem. If the walls are not load bearing, it is necessary to seal between the top block and the floor joist and to seal the space between the block and the sub-floor between each two floor joists. A simple low-cost solution to this very common sealing problem is needed.

Sealing large thermal by-passes

The 'stack effect' caused by the severe depressurization of houses during the cold winter months is often exaggerated in houses with large thermal by-passes which short circuit the basement to the attic. These thermal by-passes are usually found around water and soil pipes and especially around chimneys. Plumbing chases can often be adequately sealed by normal insulating procedures but thermal by-passes around chimneys pose a significant problem. In some localities building codes prevent sealing these openings with wood or insulation due to the potential fire hazard; yet, ignoring them may result in the failure of an otherwise successful mitigation option during periods of significant house depressurization. A safe, inexpensive but effective method of sealing thermal by-passes around chimneys would help ensure long-term success of many radon mitigation options.

Coping with direct rock exposure

Although uncommon in many parts of the United States, rock outcroppings are more common in radon-prone regions. Until recently, EPA radon mitigation efforts avoided houses with direct soil or rock exposure within an established living space; however, currently several houses with rock outcroppings in basements are slated for radon mitigation in New York. Slightly elevated gamma readings on the surface of these rocks indicate that they will also be a potential radon source. Since these rocks are actually large boulders of granite, simply removing the rocks is not a viable alternative. Preventing emissions from the rocks by coating them with an impermeable material may be the preferred mitigation alternative. The problem is finding an aesthetically acceptable coating which is durable and offers adequate radon protection without giving off other undesirable indoor air emissions. The search for such a coating is currently underway.

Summary

The ten radon mitigation inhibiting problems identified in this paper represent only a few of the many daily problems encountered by diagnosticians and mitigators. Nonetheless, these are some of the current common problems that need to be considered and hopefully resolved in the near future. Researchers and practitioners of radon mitigation are encouraged to develop workable solutions to these and other radon-related problems. EPA's Air and Energy Engineering Research Laboratory is interested in receiving information concerning diagnostic, measurement, and mitigation alternatives that have been demonstrated to work or have shown potential of working.

References

1. Becker, A.P. *et al.* (1984) 'Evaluation of Waterborne Radon Impact on Indoor Air Quality and Assessment of Control Options.' US Environmental Protection Agency. EPA-600/7-84-093 (NTIS PB84-246404). September 1984.
2. Radon Reduction Methods – A Homeowner's Guide. US Environmental Protection Agency. OPA-86-005, August 1986.