Sealing the Top of Radon Soil Gas Collection Systems in New Construction

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Introduction[1]

The primary source of indoor radon is radon created in the underlying geology or soil from the breakdown of naturally occurring Uranium 238. Although radon can be conveyed into a home via its water supply or from contaminated building materials, the predominate mechanism is the entry of radon laden soil gases from beneath and through a building's foundation.

The entry of radon through a foundation is enhanced by negative pressures within the building created by thermal stack effects, unbalanced HVAC equipment or exhaust only ventilation systems that can draw soil air in through very small openings in the foundation. In areas of uneven terrain or highly permeable soils, as seen in parts of the Rocky Mountain West, wind can also create sub-grade pressures that will push radon in through a foundation.

Regardless if radon is pulled or pushed, the entry of radon from the underlying soil is a convective mechanism where radon is entrained with the movement of soil air through foundation openings and into the building rather than by concentration gradient driven diffusion through concrete slabs, as is the case with soil moisture.

The most common technique for reducing indoor radon in buildings is a system that intercepts radon laden soil gasses from directly beneath the building's foundation and provides an alternative pathway for the soil gasses to reach the atmosphere via a vent pipe. Under ideal conditions, such a "bypass" may be sufficient to reduce indoor radon to less than recognized guidance levels. However, this passive approach may not be sufficient to overcome interior vacuums or environmental effects and a radon fan is used to create a higher vacuum in the subgrade to more reliably collect the radon laden soil gasses prior to entry into the building.

In the case of existing homes, this involves one or two single point suction pits created in a slab foundation where radon containing air can be drawn laterally to those collection points and exhausted out. This causes the direction of convective air flow through foundation openings to be reversed with interior air going down rather than soil air coming up into the building.

Where reasonably accessible, openings in the slab, such as floor to wall joints, are caulked to reduce the loss of interior air and to improve the radon capture efficiency.

Experience with existing home remediation in Colorado and elsewhere has proven that where slab openings are not accessible for caulking or sealing, radon reductions are routinely achieved to levels less than the US EPA Action Level of 4 pCi/L.

New Construction Approaches

Incorporating radon systems during the construction of a building provides the opportunity to build in additional aspects of the system that cannot be easily done after construction. Many of these elements have been incorporated into a number of guidance documents and building codes as prescriptive measures.

Although there are subtle differences between the various guidances, they all have a common core of:

- Having a soil gas collector under the foundation able to easily draw radon from all portions of the occupied foundation and

- An air barrier above the soil gas collector that isolates it from the interior air.

The subject of this Technical Bulletin is to address point 2; the air barrier or sometimes referred to as a Ground Cover.

In the case of a slab foundation, the slab itself can serve as an air barrier, provided openings to the sub-grade are caulked and sealed at:

- Floor to wall joints
- Control joints
- Plumbing block outs
- Edges of piers
- Gasketed and bolted sump covers

Some guidance documents, either as an alternative to or as an additional provision, stipulate a soil gas retarder in the form of a polyethylene sheet be placed beneath the concrete slab as well. In some cases, a guidance merely states that its seams be overlapped and butted up to penetrations, where others stipulate the seams and edges be sealed with the sheeting rising up the foundation walls and also sealed to the walls.

In the case of an earthen crawlspace, where no slab exists, a well-sealed air barrier needs to be installed above the soil gas collector. Typically, this is a high-density polyethylene sheet laid above a 20-foot length of perforated pipe and sealed to walls, penetrations and at seams to avoid air loss and unintentional movement that would lead to gaps and air loss.

However, in the case of concrete slab, there are two options:

1. Thoroughly seal the vapor barrier/soil gas retarder,

OR

2. Cast the slab as would be normal with no special treatment of vapor barrier but seal slab openings after the concrete has set but before framing.

Casting a slab directly on a well-sealed vapor barrier can be problematic and add additional building costs. Also, the amount of sealant needed to thoroughly seal the vapor barrier is essentially the same as would be needed to seal the slab.

Some documents specify one or the other, while other documents specify sealing both vapor barrier AND the slab.

The purpose of the Ground Cover is to present an air barrier and not a diffusion barrier. A vapor barrier functions as a means to reduce the diffusion of soil moisture through a slab that would damage floor coverings. In the case of radon reduction, the purpose is to retard the movement of soil air through openings in the foundation.

In cases where active soil depressurization systems are used to collect volatile organic compounds (VOCs) and soil concentrations can be high, both diffusion and convective air flow through openings must be addressed. In this case, both vapor retarder and slab would be sealed to insure the highest degree of capture.

Another rationale for requiring a well-sealed vapor barrier in a radon system beneath a slab has been to ward against leakage that could occur in the future should the slab crack. That is, the vapor barrier could "bridge" under a slab crack and prevent degradation of the radon system.

Colorado Investigation

To determine the benefits of installing a well-sealed vapor retarder for both initial construction and as a safeguard against future slab cracking, a study was conducted on thirteen homes under construction in the same zip code area within Douglas County Colorado, where a high radon potential exists with homes in this area averaging 5.6 pCi/L with 41.8% of homes above 4 pCi/L[2].

All the homes were in the same subdivision and of similar basement foundation plans with a loop of 4-inch perforated pipe in the subgrade as the soil gas collector. In all thirteen homes the slabs were identically caulked and sealed. Eight "Case" homes did not have sealed poly barriers beneath the slabs and five "Control" homes did have sealed barriers.

Methodology

To determine the relative effectiveness, a variable speed fan was connected to the radon vent risers from each home. Holes were drilled through the slab at set distances from the collection point and the subgrade differential pressure was measured at varying air flow extraction rates. See Figure 1.

Figure 1: Variable speed fan and Cross-Slab Pressure Measurement Equipment

An increase in air extracted will cause an increase in negative pressure created beneath the slab. A plot of air flow versus differential pressure will yield a slope that expresses how much negative pressure can be developed (as a radon collection force) for each additional cubic foot a minute of air extracted. The results for the Case and Controls are provided in Figure 2 where the X and Y axes are the same for both cases for visual comparison.

Results of DP/Air Flow Measurements:

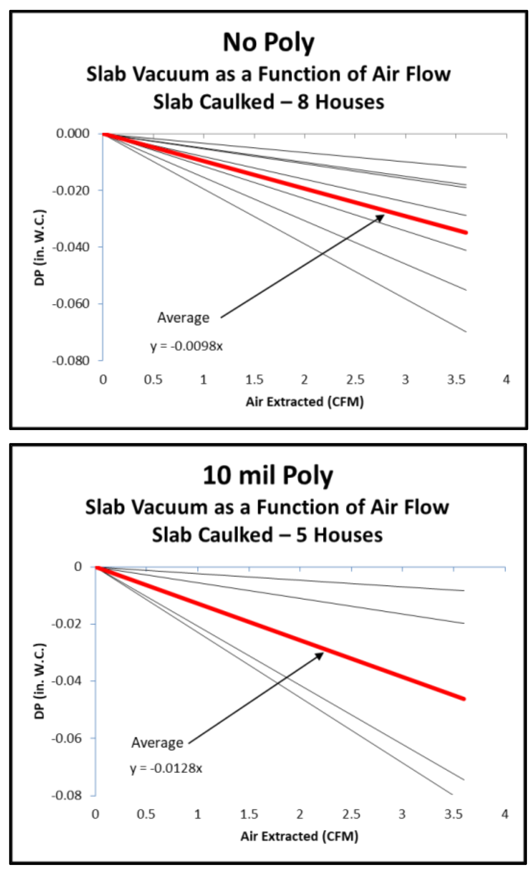

Figure 2: Comparative Results: Sub Slab Vacuums Created at Different Air Extraction Rates

A student T-test confirms what can be seen from a comparison of the graphs is that within a 95% confidence level there is no difference in the slope of the lines or rate at which negative pressure can be created in either case.

Radon Results

As an additional confirmation, radon measurements were conducted in all thirteen homes after construction. Tests were conducted by an independent, NRPP certified radon measurement professional, with tests conducted in the basement areas, under closed building conditions for a minimum of 2 days. The results of the post-construction measurements are shown in Figure 3.

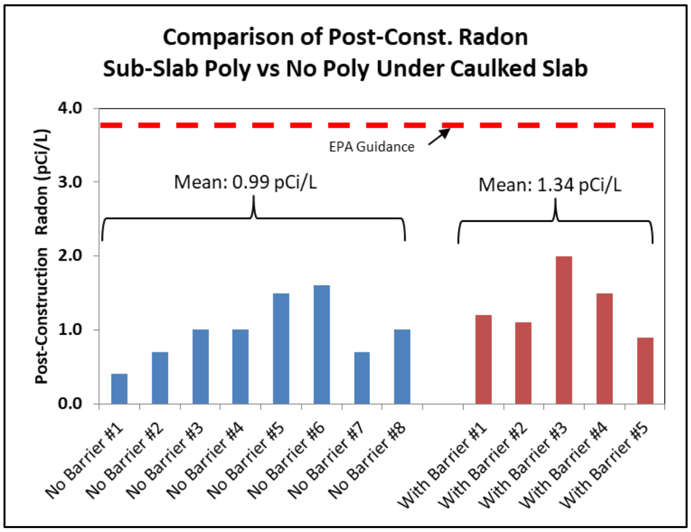

Figure 3: Post-Construction Radon Measurements

As can be seen from the post-construction radon results, all homes had results less than the EPA guidance of 4.0 pCi/L. Although the mean radon results for the homes without poly was lower than the those with poly a statistical review of the results showed, within a 95% confidence level, that there was no statistical difference in radon results between homes with sealed poly vs no sealed poly beneath caulked and sealed slabs.

The conclusion of this series of measurements, both mechanical and radon result related, indicates that a well-sealed polyethylene barrier under the slab is no more effective that only caulking the slab itself.

Another outcome of this study was that with a well-sealed slab, very little air needed to be extracted to develop the generally accepted differential pressure of -0.020 inches of water column. In fact, only a few CFM is needed. This is due to slab sealing and the ease at which the looped soil gas collector could collect soil gases. Consequently, lower power fans (15 watts) can be used to actively draw radon out in new home construction rather than higher wattage fans typically used in existing building mitigation projects. This reduces the energy conservation benefit one may get with a passive system having no fan versus a lower powered, active system with fan-which, with the higher assurance of reduction, may suggest that systems in high radon areas be installed initially with low power radon fans.

Future Benefit of Poly Under Slab

To address the benefit that a polyethylene sheeting can provide against future slab cracking, the same builder had constructed eight model homes along the front range of Colorado with active radon systems where 10 mil poly had been placed beneath the slab during construction. As they were model homes, there was enough time after their completion that stress cracks had developed in the slabs.

To test the hypothesis that poly would prevent the loss of air down through stress cracks, non-thermal smoke was applied at the stress cracks. If the poly beneath the slab did indeed provide a barrier to air loss, smoke would not be drawn down the cracks with the radon fan operational. The results are provided below

Table 1: Effectiveness of poly beneath future slab cracks

Hous e	Description of Tested Cracks	Smoke Direction
1	Control Joint Floor Cracks	Down Down
2	Control Joint Control Joint	Down Neutral
3	Floor Cracks Support Pad Block- outs	Down Down
4	Control Joint Support Pad Block- outs	Down Down
5	Floor Cracks Support Pad Block- outs	Down Down
6	Control Joint Support Pad Block- outs	Down Down
7	Control Joint	Down
8	Control Joint	Down

As can be seen, in all cases except one, air was still drawn down through the stress cracks even with the presence of 10 mil poly beneath the slab. In this case, the radon would still not enter the living space, but even with deliberate sealing of the poly, a pathway still existed between the interstitial space between the bottom of slab and the subgrade and the presence of the barrier did not provide protection against future stress cracking.

Discussion

The results obtained from the study are consistent with Darcy's Law regarding fluid flux through porous media which can be expressed by the following simple equation[3].

$$Q = \frac{-K\ A\ \Delta p}{\mu\ L}$$

Where:

Q = Flow rate
K = Permeability Coefficient
A = cross-sectional area
Δp= pressure gradient
μ= viscosity
L Length of pathway

The combination of slab or slab and poly will affect the Permeability coefficient (K). However, if the Pressure Gradient term (Δp) is negative, as would be the case when an active fan is creating a well distributed vacuum under the slab, the flow (Q) would also be negative. Hence, as long as there is an interface under which the radon fan is creating a negative pressure, the magnitude of the Permeability coefficient, as would be determined by slab or slab plus plastic has no effect.

Conclusion

Based upon this study and the experience that the radon industry has had with mitigating existing homes, a well-sealed polyethylene barrier under a basement slab offers no benefit beyond that which is provided with a well caulked slab. This is particularly applicable if an active radon system is employed at the outset.

The reason for this is that a radon system requires an air barrier rather than a diffusion barrier. This does not mean that vapor barriers should not be employed. Rather, vapor barriers can be installed as required for control of water vapor diffusion to protect floor finishes without additional treatment needed for radon.

Also, in circumstances of remediating sites with VOC's, more exhaustive sealing should be done since that mode of entry is based upon both diffusion and convective air movement.

The recommendation of not requiring a sealed barrier beneath a slab is consistent with ANSI/AARST Standard CC-1000 where an active radon fan is installed concurrently with a sealed barrier (i.e. sealed slab)[4].

Shifting the focus of sealing the top of the radon collection system to the slab rather than the soil gas retarder offers several advantages for the building inspector as well as the builder:

- Vapor barrier need not be inspected for leakage immediately prior to slab pour for sealing
- Slab caulking can be more easily inspected from above
- Vapor barriers can be installed as is normal without additional cost of sealing or a specialized trade
- Special moisture content is not required for concrete as would be the case when casting slab directly on sealed poly barrier.

Reference

[1] *Measuring and Mitigating Radon in Colorado*, Colorado Department of Public Health and Environment, 2018

[2] CDC, National Environmental Public Health Tracking Network, as of June 2020, https://ephtracking.cdc.gov

[3] *Experimental Measurements on the Permeability Coefficient of a Concrete Sample Under Low Pressure Differences*, Daoud and Renkin ,2001 AARST Radon Symposium.

[4] *Soil Gas Control Systems in New Construction of Buildings*, Sec 6.2.1, ANSI/AARST CC-1000, 2018

Radon Aware

In Colorado, about 50% of homes have unhealthy radon levels; that's equivalent to every person in the home having 200 chest x-rays every year. This compares with only 6% of homes having unhealthy radon levels across the rest of the country.

Radon is a naturally occurring, invisible gas that decays into radioactive particles and increases the risk of lung cancer for those living with radon trapped inside their homes. Radon exposure causes as many as 500 lung cancer deaths every year in Colorado.

The Public Health Radon Reduction Roadmap (PHR3) project aims to reduce radon exposure and its associated risk of lung cancer by encouraging and supporting Colorado communities in becoming *Radon Aware*. Education, training, and technical assistance is provided to Local Public Health Agencies, Elected Officials, Building Officials, Builders, Building Professionals, Affordable Housing Agencies/Authorities, Real Estate Professionals, and Homebuyers to promote the use of use of certified radon contractors and radon reduction best practices for existing and new single-family homes and existing and new multi-family homes.

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