RADON-RESISTANT CONSTRUCTION: ALTERNATIVE TECHNIQUES

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ABSTRACT

Several aspects of radon-resistant construction for new homes and buildings are commented on. The areas discussed include:

- The effectiveness of passive depressurization.
- A double-barrier, double-sump design to exclude radon in the exterior footing drainage system from flowing to the sub-slab aggregate.
- Interior footing tile depressurization for more effective sub-slab depressurization.
- Sub-aggregate barriers to decouple the aggregate under the slab from the underlying soil.
- The use of sub-slab sand for better slab construction.
- The use of sub-slab pressurization is discouraged.

INTRODUCTION

In the long term, substantial reduction in radon exposure can result from improved new home and building construction techniques that reduce radon entry. Designs for radon-resistant construction should minimize radon entry, enable application of cost effective active mitigation if needed and help achieve and maintain as many aspects of indoor air quality as possible. The U.S. Environmental Protection Agency (EPA) has published a report "Model Standards and Techniques for Control of Radon in New Residential Buildings" (1994), in which construction techniques to minimize radon entry in new structures and to facilitate its removal after construction are described. The EPA report includes a section on barriers to reduce radon entry including sub-slab membranes, caulking, sealing, and prevention of slab cracking. Other sections discuss designs for passive sub-slab depressurization and active depressurization if needed. Primary elements in these designs are a minimum of 4 inches of aggregate under the slab and a 3 inch or 4 inch diameter PVC pipe extending from the sub-slab aggregate through the home interior and out of the roof.

In this paper some of the model standards and techniques proposed by the EPA are commented on and some alternative approaches are suggested. Many of the comments and suggestions have appeared in previous publications and some are included in the EPA report on model standards as alternative methods.

PASSIVE DEPRESSURIZATION

Convective flow is a rather inefficient method for moving air. For a 3-in diameter stack, 30 ft. long with the air in the stack heated from 40 to 50° F the free convective flow is calculated at 14.1 cfm (Chen, 1992). The energy, in the form of heat, supplied to the air in the stack is 44.6 watts or 3.2 watts/cfm. A 90-watt fan with a free air flow of 270 cfm requires only 0.33 watts/cfm. When pulling against a static pressure the fan flow rate will decrease and the watts/cfm will increase.

If we estimate the cost for heating the air in a home at $0.65/therm, the cost for maintaining a convective flow of one cfm for a year in the passive stack is $0.61/cfm-yr. At an electric cost of $0.08/kw hr the cost for maintaining a flow of 1 cfm for a year using a 90-watt fan with a free flow of 270 cfm is $0.23/cfm-yr. Running a 90-watt fan continuously for a year would cost $63.07 and the exhausted house air would cost about another $50/yr in heat loss for a total cost of over $100/yr to run a typical sub-slab depressurization system. The total yearly cost for the passive stack with a flow rate of 14.1 cfm would be only $8.65 in heat loss. The passive system, although inefficient for moving air, is preferable if it works.

Passive stacks usually result in an indoor radon reduction of about 50% when compared with indoor concentrations with the stack sealed (Saum and Osborne 1990). In most cases the reduction obtained in the summer is similar to the winter reduction. As a result of ambient soil temperatures and heat transfer from the house during colder weather, the air or soil-gas in the sub-slab aggregate is probably in the temperature range of 40 to 60°F. When outdoor temperatures are less than the temperature of the sub-slab aggregate, the air or soil-gas from the aggregate will convectively vent from the passive stack. Any heating of the air while flowing through the stack will accelerate the venting. During warmer weather, with outdoor temperatures greater than 60°F, it is doubtful that air from the sub-slab aggregate will passively vent through the stack. It may be that during warmer weather air is flowing down the stack and passively ventilating the sub-slab aggregate.

To achieve passive ventilation rather than passive depressurization the pathways for outdoor air to flow to the sub-slab aggregate should have low resistance for gas flow, and the air flowing to the aggregate should not be heated. The depressurization of the sub-slab area caused by the depressurization in the house above the slab provides the force for pulling soil-gas and outdoor air, if pathways for are provided, into the sub-slab area. Designs for passive ventilation have been suggested and demonstrated (Kunz, 1991 and Fisk et al. 1995).

Sub-slab depressurization is preferable to sub-slab ventilation. Sub-slab ventilation does not reduce the flow of air from the aggregate and soil into a structure but dilutes the concentration of radon in the air infiltrating from the aggregate and soil. In addition to radon, the air infiltrating from the aggregate and soil may contain water vapor and other indoor air contaminants. Passive depressurization should be studied more thoroughly to be sure that it is working as intended.

DOUBLE BARRIER-DOUBLE SUMP

In earlier papers (Kunz 1991 and Kunz 1993) a double-barrier design for new construction was described for homes and buildings. A barrier placed on the soil under the sub-slab aggregate is an important element in this design. Numerical modeling and demonstrations indicate that a sub-aggregate barrier reduces the radon entry rate into structures and improves the performance of both passive and active sub-slab mitigation systems (Bonnefous et al. 1993 and Bonnefous et al. 1995). A concern regarding sub-aggregate barriers is that water might accumulate in the aggregate above the sub-aggregate barrier.

In the initial paper describing double-barrier construction (Kunz 1991), drainage of the aggregate into a sealed sump was suggested as a means to prevent water from accumulating in the aggregate. It was further suggested that drainage tiles around the exterior perimeter of the footings could be drained to daylight or a sewer (preferred) or drained to the sump using a trap that allows water to flow to the sump but seals against soil-gas flow to the sump. Another approach to achieve water drainage for the exterior footing drainage tile and to exclude radon in the exterior drainage system from flowing to the sub-slab aggregate is to provide a separate sealed sump for the exterior drainage system. In the double-sump design, one sump would be connected to the interior footing drainage tile and sub-slab aggregate and the other would be connected with the exterior footing drainage tile.

INTERIOR FOOTING TILE DEPRESSURIZATION OR VENTILATION

As a result of the stack effect, wind, combustion appliances, and exhaust fans the parts of homes and buildings interfacing with the soil can be depressurized relative to outdoor air pressures. Outdoor air is drawn through the soil near the structure, picking up radon emanating from the soil and rocks and transporting the radon into the home or building. Most of the resistance for the air flowing through the soil and into the structure is due to the soil and not the building envelope. Furthermore, most of the soil-gas entering a home or building generally enters at the wall-floor joint of the slab. Sub-slab depressurization should depressurize the sub-slab area near the wall-floor joint. This can be accomplished by a drainage system such as drainage tile running around the interior perimeter of the foundation footings. The interior drainage tile should be connected to the depressurization system. This could be accomplished by connecting the interior drainage tile to a sealed sump and connecting the depressurization system to the sump. This would maximize the depressurization in the sub-slab area where it would be most effective. The depressurization would then extend from the perimeter toward the interior of the sub-slab area. This approach should be more effective then using a suction pit or drainage tiles radiating out from a suction point.

SUB-AGGREGATE BARRIERS, FULL OR PARTIAL

To obtain more efficient depressurization or ventilation, a sub-aggregate barrier should be used, particularly when the soils under and around the structure are highly permeable to gas flow. To ensure drainage from the sub-slab aggregate, partial sub-aggregate barriers could be used. These barriers would extend from the footings in toward the center of the slab. The partial sub-aggregate barrier should extend inward about 5 to 10 ft. leaving an area in the center for water to drain from the aggregate. The partial sub-aggregate barrier would help decouple the interior drain tile from the underlying soil and make it necessary for air flowing through the soil to travel further, encountering more resistance before reaching the sub-slab aggregate. The sub-aggregate barrier would also reduce the diffusion of radon into the aggregate.

Connecting the depressurization system to the interior footing drainage tile with a full or partial sub-aggregate barrier creates a relatively small volume decoupled from direct contact with the soil that should be adequately depressurized with a low-wattage fan (10→35w). Three-inch diameter PVC tubing with convenient location (in wall, through garage or building exterior) can be used.

SUB-SLAB SAND

Current radon resistant new home construction guidelines call for a membrane barrier such as 6 mil polyethylene to be placed on top of the sub-slab aggregate. This can present a problem for the proper curing of the concrete slab when poured on top of the membrane since water will not drain away from the poured concrete. It may be preferable to place about three inches of sand on top of membrane so that water can drain from the concrete. If an interior footing drainage system of tile and aggregate is used, it may not be necessary to have aggregate under the rest of the slab.

The sand would allow for water drainage and, having moderate permeability for gas flow, the sand would provide some resistance for soil-gas flow to any possible cracks or openings in the slab. Interior footing drainage tile with aggregate around the tile combined with sand over a partial sub-sand barrier may be preferable to a membrane over aggregate.

SUB-SLAB PRESSURIZATION

Actively blowing outdoor air into the sub-slab aggregate is sometimes used in radon mitigation, particularly in areas with highly permeable soils. The outdoor air forces soil gas containing radon out of the sub-slab aggregate and the soil surrounding the foundation. The pressure in the aggregate and soil around the foundation is increased relative to indoor pressures, forcing more air to infiltrate the home from the soil and aggregate. It is possible that the air forced into the sub-slab aggregate may pick up water vapor, bioaerosols, and vapors from chemicals such as termicides placed in the aggregate and soil near the foundation. For this reason, sub-slab pressurization should probably not be used. The system used to reduce indoor radon concentrations should not increase the entry of other indoor air contaminants and preferably should decrease the entry of all potential contaminants from the soil and sub-slab aggregate. Sub-slab depressurization accomplishes this goal and is the preferred method for decreasing indoor radon concentrations and generally improving indoor air quality. Moisture entering basements and other parts of structures interfacing with the soil can result in increased bioaerosol concentrations and is a significant indoor air quality problem in many homes and buildings.

SUMMARY

Several aspects of radon resistant construction for new homes and buildings have been reviewed. The effectiveness of passive sub-slab depressurization was discussed and it was suggested that depressurization systems would be most effective if systems were designed to depressurize the interior footing perimeter of the sub-slab area. Full or partial sub-aggregate barriers would help decouple the interior footing drainage tile and the sub-slab aggregate from the soil and improve passive and active mitigation system performance. To help prevent radon that accumulates in the exterior footing drainage system from flowing to the sub-slab aggregate, the exterior drainage system should be drained to daylight, a sewer, or to a separate sealed sump. Sand placed on top of the barrier that is placed on top of the sub-slab aggregate would improve slab curing. Finally, it was suggested that sub-slab pressurization should not be used.

For generally better indoor air quality including reduced radon and dryer basements, an active depressurization system is recommended. For efficient, cost effective operation the system might include a low-wattage fan, three-inch diameter PVC piping connected to an interior footing drainage system with partial sub-aggregate barriers.

Most of the techniques mentioned in this paper have been presented in earlier publications and some are included in the EPA model standards and techniques as alternative methods.

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