CONCRETE MASONRY &
HARDSCAPES ASSOCIATION

Provided By:

RADON-RESISTANT CONCRETE MASONRY FOUNDATION WALLS

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) estimates that nearly 1 of 15 homes in the United States has elevated indoor levels of radon, the radioactive soil gas which is the second-leading cause of lung cancer (ref. 1). Fortunately, straightforward techniques exist to effectively reduce indoor radon levels.

Four factors contribute to radon entry into buildings: uranium, present in soils throughout the United States; soil permeability, which allows the radon to travel through the soil to the building's foundation; pathways for radon entry, including cracks and plumbing penetrations; and lower air pressure inside the building, which draws radon inside. Radon-resistant construction techniques focus on controlling the pressure difference between the soil and indoor environment and on minimizing and sealing cracks and penetrations.

Concrete masonry's versatility and inherent strength and durability characteristics make it especially well-suited for foundation walls . To adequately resist soil gas entry, concrete masonry walls must be designed and constructed to minimize cracking. References 2 through 5 provide excellent information on proper mortar joints, footing construction, wall bracing, backfi lling, anchorage, waterproofi ng and structural design.

This TEK provides basic design guidance specifi c to radon-resistant concrete masonry basement and crawl space construction based on Appendix F of the International Residential Code (IRC) (ref. 6) and EPA guidelines. Although these recommendations have been developed primarily for new low-rise residential construction, the same basic principles also apply to schools and other large buildings.

POTENTIAL FOR ELEVATED RADON LEVELS

It is most cost-effective to install radon-resistant features in homes with the greatest potential for high indoor radon levels. As a tool to help predict where this might occur, the EPA and U.S. Geological Survey have identifi ed areas with high radon potential, based on indoor radon measurements, local geology and population densities (see http://www.epa. gov/radon/zonemap.html). State radon offi ces should also be consulted for more detailed local information. The EPA does not recommend soil testing as a method to predict the potential for elevated indoor radon levels.

The map assigns a zone number to each U. S. county based on potential indoor radon levels, as follows:

- Zone 1: high potential (indoor levels greater than 4 pCi/L)
- Zone 2: moderate potential (from 2 to 4 pCi/L)
- Zone 3: low potential (less than 2 pCi/L)

BUILDING CODE REQUIREMENTS

The 2003 IRC Appendix F contains radon control methods for new home construction. Note that because these requirements are contained in an appendix, rather than in the body of the code, they become part of the local building code only when Appendix F is specifi cally adopted by the jurisdiction. The requirements in Appendix F are intended to apply to construction in Zone 1, based on the EPA map described above.

In addition to incorporating radon reduction methods into buildings in Zone 1, or where recommended by state radon offi ces, the EPA encourages builders to include these techniques in other areas, because high indoor radon levels could potentially occur in any area of the United States, and the installation of a passive venting system is very economical during initial construction, but becomes much more diffi cult as a post-construction mitigation technique.

CONSTRUCTION REQUIREMENTS AND RECOMMENDATIONS

The basic approach to radon control in new buildings incorporates: soil depressurization to vent soil gases outside the building; designing the building's heating, cooling and ventilation system to provide a slight positive pressure to prevent radon from being drawn inside; and sealing major radon entry routes. Note that several of these requirements are required or considered good practice for issues such as water penetration resistance and/or energy effi ciency.

Sealing large openings and preventing large cracks is a key component of building radon-resistant foundations. However, fi eld research has shown that attempting to seal all foundation openings is neither practical nor effective as a stand-alone radon prevention technique (ref. 1).

IRC Appendix F requires installation of a passive depressurization system for the soil beneath a home in Zone 1. This passive depressurization has been found to effectively reduce indoor radon levels by about half and, in most cases, to levels below the EPA action level of 4 pCi/L (ref. 1). Should high indoor radon levels exist with the passive depressurization system in place, the system can easily be upgraded to include an in-line fan to actively draw radon away from the foundation. The IRC includes several requirements that facilitate this possible upgrade. Although not required by the IRC, the EPA recommends that all homes be tested for radon after occupancy, and that mitigation measures be taken with readings at or above 4 pCi/L.

Note that for schools and other large buildings, EPA recommends installing an active depressurization system (i.e., with operational in-line fan) during initial construction (ref. 7).

Basement Foundations

Figure 1 illustrates the requirements found in IRC Appendix F for installation of a passive sub-slab venting system for a residential basement. Note that these requirements apply to slab-on-grade foundations as well (see Figure 2).

The system is built on a layer of gas-permeable material, which allows the entire sub-slab area to be vented. The gas-permeable material should be placed under all fl oors that are in contact with the ground and are within the occupied spaces of the building. The soil-gas-retarder membrane serves two purposes: to bridge any cracks that may occur in the slab, thereby preventing radon migration up through the slab at these points; and to prevent concrete as it is being placed from fi lling the voids in the gas-permeable material. Separate sheets should be lapped at least 12 in. (305 mm), but need not be sealed. In addition, the sheeting should fi t closely around pipes, wires and other penetrations.

The vent pipe extends from the gas-permeable layer to an exhaust point above the roof, allowing any radon that collects below the slab to be removed before it is pulled into the building. IRC Appendix F specifi es a minimum vent pipe diameter of 3 in. (76 mm), although the EPA recommends a 4-in. (102-mm) vent pipe diameter to provide better passive venting (ref. 1). As an alternative to the vent pipe location shown in Figure 1, the IRC allows the vent pipe to be inserted directly into an interior perimeter drain tile loop or through a sealed sump cover, provided the sump is exposed to the gas-permeable layer or connected to it through a drainage system.

Where interior footings or other barriers interrupt the gas-permeable membrane, each area should have its own vent pipe. These individual vent pipes can be run and exhausted separately, or they can be connected to a single exhaust pipe.

Although the IRC does not stipulate where or how the vent pipe should be run, the EPA offers the following guidance with the goal of inducing a natural upward draft in the vent pipe. The vent pipe should ideally have a vertical run, or, if this is not possible, elbows should be minimized, as these will restrict air fl ow. In cold climates, the vent pipe should be run in an interior wall. This will help keep the vent pipe warm, enhancing the natural stack effect. Locating the vent pipe in a cold exterior wall could hence make it less effective. In hot climates, the effectiveness of the passive stack depends more on wind, a hot attic and sun heating the pipe (ref. 1). For shallow roofs in hot climates, a higher exhaust point may improve the passive draw through the vent pipe.

The exhaust location requirements listed in Figure 1 help ensure that exhausted radon is not drawn back into the building, or an adjacent building, through a window or other opening.

The solid masonry top course helps resist radon entry from the cells of the masonry units into the habitable space above. This can be accomplished by using 100% solid units or by fully grouting the top course (mesh or other grout-stop device is installed below the course to contain the grout to the top course). Although not required by the IRC, full mortar head joints in this course will also help provide a continuous barrier. When a brick ledge is used, the solid course should be immediately below the brick ledge. As with other parts of the foundation, below grade penetrations and openings must be fi lled with polyurethane caulk or equivalent.

Several accommodations must be made for possible future fan installation, to convert to an active depressurization system in the event that high radon levels are recorded after occupancy. The fi rst, that the vent pipe remain accessible through the attic or another area outside the habitable space (unless an approved roof-top electrical supply is provided for future use), ensures access for installing an in-line fan. The second requirement is for installation of an electrical circuit box at the anticipated vent pipe fan location, typically in the attic, as well as in anticipated locations of system failure alarms.

In addition, IRC Appendix F requires:

- all condensate drains must to be trapped or routed through nonperforated pipe to daylight,
- sump pits to be covered with a sealed lid,
- sumps used as a fl oor drain to have a lid with a trapped inlet,
- ducts passing through or below the slab to be seamless (unless the air-handling system is designed to maintain continuous positive pressure in the ducts),
- joints in ducts passing through or below the slab to be sealed,
- homes to be constructed to minimize building depressurization, as otherwise required in Section M1601, Chapter 11 and R602.8.

Crawl Space Foundations

Crawl space foundations require preventive measures similar to those for basements, or must be provided with an approved mechanical crawl space ventilation system.

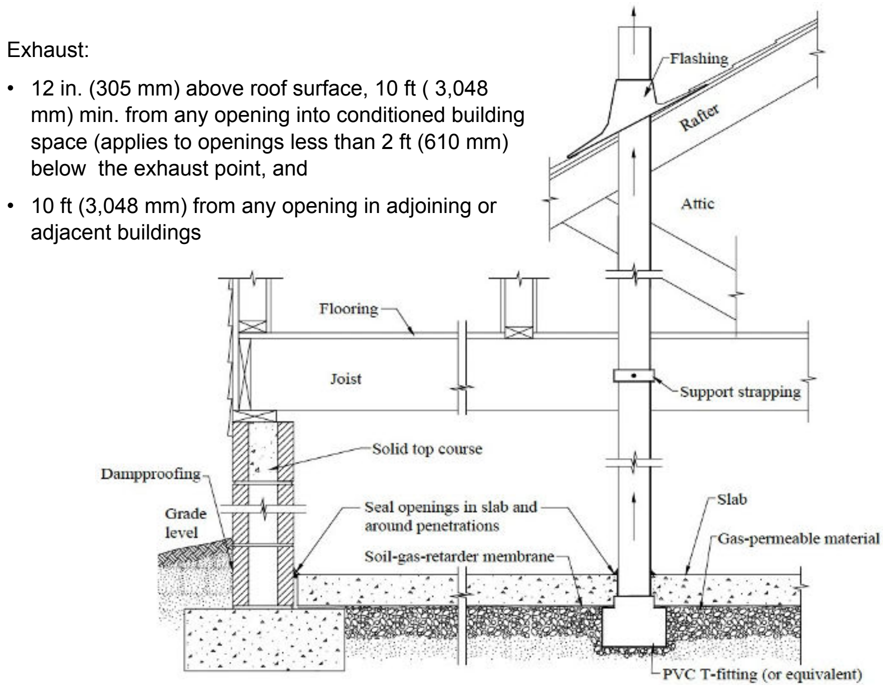
The IRC requirements for passive depressurization in a crawl space are illustrated in Figure 3. The major differences between the crawl space and basement requirements are:

- a requirement for natural ventilation per IRC Section R408,
- without a slab, it is difficult, if not impossible, to seal radon out at the crawl space floor, so sealing takes place at any penetrations through floors above crawl spaces as well as at access doors and other openings or penetrations between the crawl space and an adjoining basement,
- air-handling units located in crawl spaces must be sealed to prevent air from being drawn into the unit, and
- ducts in crawl spaces must have seams and joints sealed.

Combination Foundations

Buildings with combination basement/crawl space or slab-on-grade/crawl space foundations are required to have a separate radon vent pipe for each foundation area. The vent pipes can either be connected to a single vent that exhausts through the roof, or each can be exhausted separately (ref. 6).

In addition, the EPA recommends that special care be taken at points where the different foundation types meet, because additional soil-gas entry routes typically exist at these locations.



1. Gas-permeable material: 4-in. (102-mm) min. thickness of clean aggregate that will pass through a 2-in. (51-mm) sieve and be retained by a 1/4-in. (6.4-mm) sieve; or 4-in. (102-mm) min. thickness of sand overlain by a layer or strips of geotextile drainage matting designed to allow the lateral flow of soil gases; or other systems demonstrated to permit depressurization across the entire sub-floor area.
2. Soil-gas-retarder membrane: 6-mil (0.15-mm) or 3-mil (0.075-mm) cross-laminated polyethylene or equivalent flexible sheeting placed on top of the gas-permeable layer. The sheeting material is required to cover the entire floor area, with separate sections lapped at least 12 in. (305 mm). The sheeting must be installed to fit closely around pipes and other penetrations. All punctures or tears must be sealed or covered with additional sheeting.
3. Vent pipe: 3-in. (76-mm) minimum diameter ABS, PVC or equivalent gas-tight pipe, supported by a plumbing T or other approved connection and labeled "Radon Reduction System."
4. Masonry solid top course: continuous course of units grouted solid, 100% solid concrete masonry units, or masonry units with a solid top, such as a lintel unit.
5. Sealant: polyurethane caulk or equivalent elastomeric sealant applied per manufacturer's recommendations.
6. Dampproofing: per IRC Section R406.

Figure 1—Radon Control Measures for Basement Foundation (ref. 6)

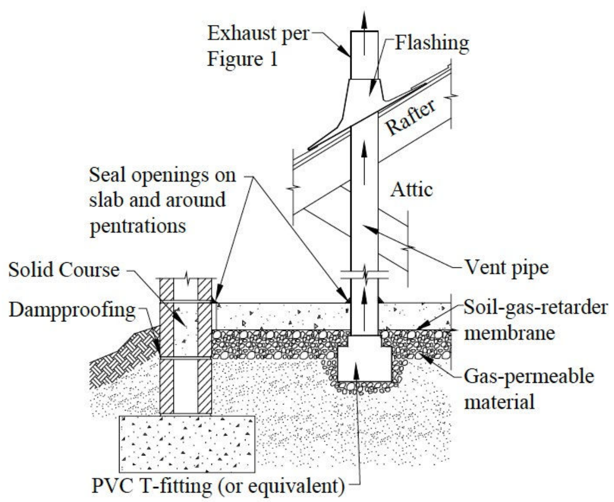


Figure 2—Radon Control Measures for Slab-on-Grade Foundation (ref. 6)

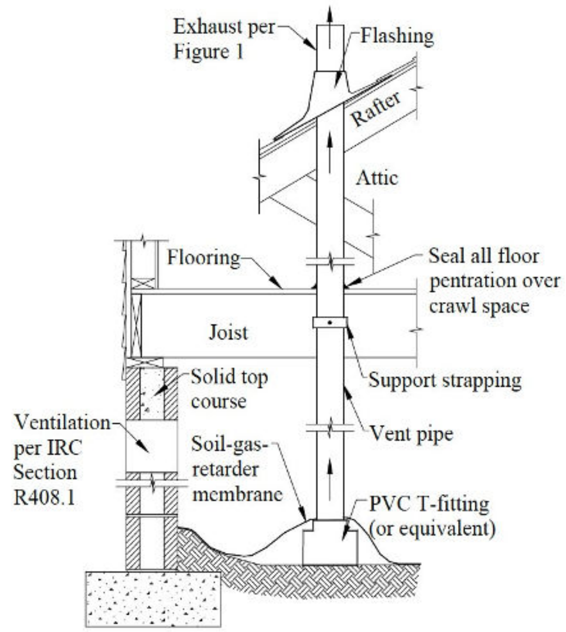


Figure 3—Radon Control Measures for Crawl Space Foundation (ref. 6)

REFERENCES

1. Building Radon Out, EPA/402-K-01-002. Environmental Protection Agency, 2001.
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3. *Allowable Stress Design of Concrete Masonry Foundation Walls*, TEK 05-01B, Concrete Masonry & Hardscapes Association, 2001.
4. *Strength Design of Reinforced Concrete Masonry Foundation Walls*, TEK 15-02B, Concrete Masonry & Hardscapes Association, 2004.
5. *Preventing Water Penetration in Below-Grade Concrete Masonry Walls,* TEK 19-03B, Concrete Masonry & Hardscapes Association, 2012.
6. International Residential Code for One- and Two-Family Dwellings. International Code Council, 2003.
7. Radon Prevention in the Design and Construction of Schools and Other Large Buildings, EPA 625/R-92/016. U. S. Environ-mental Protection Agency, 1994.

ABOUT CMHA

The Concrete Masonry & Hardscapes Association (CMHA) represents a unification of the Interlocking Concrete Pavement Institute (ICPI) and National Concrete Masonry Association (NCMA). CMHA is a trade association representing US and Canadian producers and suppliers in the concrete masonry and hardscape industry, as well as contractors of interlocking concrete pavement and segmental retaining walls. CMHA is the authority for segmental concrete products and systems, which are the best value and preferred choice for resilient pavement, structures, and living spaces. CMHA is dedicated to the advancement of these building systems through research, promotion, education, and the development of manufacturing guides, design codes and resources, testing standards, and construction practices.