#5506

RADON PREVENTION IN RESIDENTIAL NEW CONSTRUCTION: PASSIVE DESIGNS THAT WORK

by: C. Martin Grisham, B.S.
National Radon Consulting Group
New London, CT 06320

ABSTRACT

Various approaches and criteria have been developed and promulgated by EPA concerning radon prevention during new construction of private residences. Yet, very little information is available which describes cost effective passive radon reduction techniques for residential new construction. This paper will present two case studies of the evaluation, design, installation, and performance of successful passive radon prevention in new construction. Both case studies make extensive use of EPA recommended new construction techniques which, when utilized synergistically, provide long term average radon concentrations of less than two picocuries per liter of air in the lowest livable areas of each residence.

93

RADON PREVENTION IN RESIDENTIAL NEW CONSTRUCTION: PASSIVE DESIGNS THAT WORK

INTRODUCTION

Recent studies of the performance of new construction, passive radon reduction systems have been conducted (1). However, very little information is available about specific approaches taken to install cost effective passive systems that work. By using the EPA's approach to radon resistant new construction (2,3) as a general guide, two residences have been effectively protected from radon entry through the use of completely passive radon mitigation strategies.

The benefits associated with the implementation of passive radon reduction systems during the construction of a structure include:

a. A radon reduction system which is more aesthetically appealing than a similar retrofit system. Many times, during a retrofit operation, portions of the system will be visible to the homeowner, or the system will reduce effective storage space. This is particularly apparant when retrofit systems pass through storage closets in route to the roofline.

b. The ability to install a completely passive system which would require no on-going operating expense and would provide for minimal energy loss.

c. The ability to consistently provide annual average radon concentrations in the lowest liveable floor of the structure below 2.0 pCi/l of air.

d. And, through judicious use of on-site workers and a close relationship with the builder, the ability to provide the most cost effective means to attain the lowest reasonably achievable radon concentrations.

This paper is organized to provide a method of approach to new construction through the description of cost effective new construction techniques implemented in two residences in Connecticut. The approach begins with the site and building plan reviews. Then, a description of the development and implementation of mitigation strategies is provided. The discussion then concludes with an assessment of the performance of each system and the associated costs for each completed project.

SITE EVALUATION

The site evaluation is typically the first step when considering the use of radon resistant new construction techniques. It is during the site evaluation that the actual decision is made whether radon resistant techniques should be used. During the site evaluation various sources of data are reviewed to determine the likelihood of radon occurance. Should the likelihood exist, new construction techniques to reduce radon entry are implemented.

The site evaluations for both projects began with the acquisition of various pieces of data available through federal, state, and local government agencies. Such sources of data included topographical maps, bedrock and surface geology maps, aeroradioactivity maps, and state and local radon testing program results.

After a thorough review of the data available through the above sources the decision to implement radon resistant new construction techniques was made based on the following information:

a. Each residence is located in geologic areas documented to have a high percentage of homes (>15%) with radon levels in excess of the EPA's recommended action level of about 4 picocuries per liter of air (4,5).

b. Radon levels in other homes within the immediate geographic region of each structure have shown the presence of radon in excess of 20 pCi/l of air. This was evidenced by actual test results from homes in the immediate neighborhood.

c. The background gamma radiation at each site is in excess of 600 counts per minute (6).

4. Each home buyer was keenly aware of the potential for radon related health risks due to long-term exposure to radon and wished to decrease family exposure to levels as low as reasonably attainable. In both cases the home buyer wished guarantees of annual average radon levels below 2.0 pCi/l of air.

The use of direct soil gas measurements prior to construction were not considered to be a predictor of post construction indoor radon concentrations. Therefore, soil gas measurements were not conducted prior to construction of the structure.

BUILDING PLAN EVALUATION

Once the site assessments had been conducted and enough evidence was available to support the implementation of radon reduction techniques, a thorough examination of building plans was conducted. Examination of building plans reveals the nature and extent of thermal bypasses, the potential characteristics of the sub-slab area, the availability of verticle chases for locating the vent stack, and details about the foundation and slab which might have an affect radon entry.

HOUSE A BUILDING PLAN

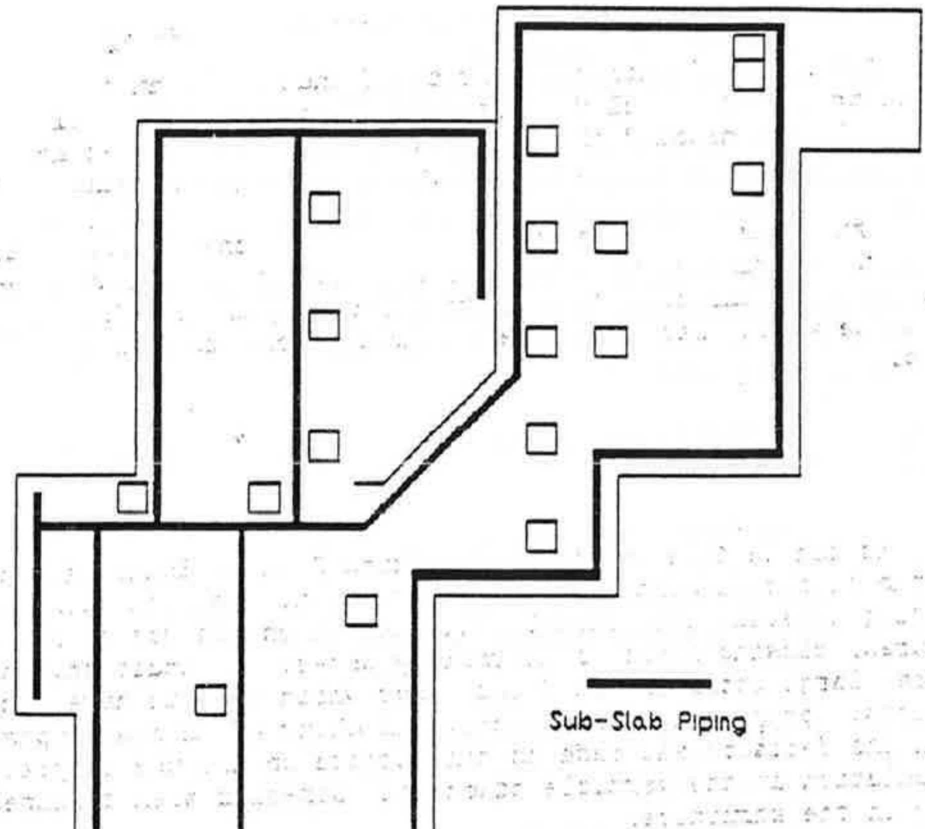

Figure 1. House A Foundation and Sub-Slab Piping Network

As can be seen in Figure 1., House A is an irregular shaped contemporary home with numerous inside corners in the foundation. This indicates a need for more sealing of cracks after the slab cures because typically cracks form from an inside corner and radiate toward the center of the slab. Each small square in the interior of the foundation indicates a concrete "pad" upon which lally columns and other structural supports are placed. The location of each of these pads dictates, to some extent, the placement of sub-slab piping networks.

A careful review of the lighting schedule showed that extensive use of recessed lights was planned. Each of these recessed fixtures is a potential thermal bypass which would allow the movement of air from the room below to the area above the fixture. Because of the extensive use of recessed fixtures, combined with the presence of vaulted ceilings, the decision was made not to address each individual thermal bypass. But instead, more emphasis would be placed on the sub-slab piping network and establishment of a negative pressure field.

The materials schedule for the foundation plan indicated that the use of processed gravel was planned for the sub-slab fill material (95% sand). This indicated that the installation of a sub-slab piping network would be necessary in order to provide adequate sub-slab permeability.

After discussing possible locations of the verticle stack with the builder, a decision was made to locate the stack in a double-wide wall to be used for plumbing. This allowed locating the stack near the center of the house where there would be adequate warmth to induce a stack effect in the pipe.

HOUSE B BUILDING PLAN

As can be seen in Figure 2., House B is basically a rectangle with a minimum of irregularities in the foundation. As with House A, the lighting schedule for House B indicated extensive use of recessed light fixtures, causing numerous thermal bypasses. In addition, there were several large rooms on the first floor which were to have vaulted ceilings, precluding the effective blocking of thermal bypasses. Here again the decision was made to concentrate on the use of pressure manipulation in the verticle stack and sub-slab area to impede radon entry in the structure.

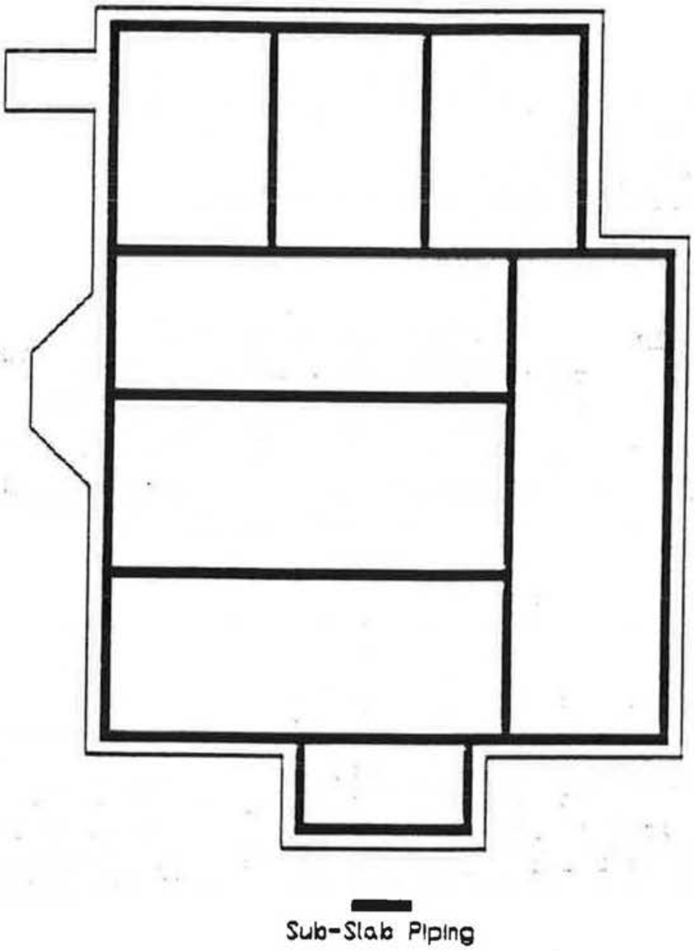

Figure 2. House B Foundation and Sub-Slab Piping Network

The materials list for the foundation plan indicated the use of crushed stone as sub-slab fill material. Due to the intended use of crushed stone fill, no piping network was planned. Only the use of a pipe stub inserted into the fill material would be necessary to ensure the negative pressure developed in the verticle stack would be transmitted to the sub-slab area.

After discussing the placement of the verticle stack with the builder, it was decided that the most appropriate location of the stack would be rising within the chimney chase. Although not a typical location, the local Building Official authorized this location since all flues rising within the chase were "zero clearance" type flues which would prevent excessive heat buildup in the chase.

MITIGATION STRATEGIES

The new construction strategies used included provision of sub-slab permeability during construction, prevention of radon entry through the use of barriers to radon movement from the soil into the structure, and the installation of a passive stack vent to develop differential pressures between the basement of the residence and the sub-slab fill material.

Reduction in the number and amount of thermal bypasses, as recommended by EPA, was not used. In both cases, the residences had too many thermal bypasses to facilitate cost effectively dealing with the treatment of each bypass source. Rather than attempt to treat each thermal bypass, more emphasis was placed on prevention of radon entry through establishment of sub-slab permeability and the miticulous use of sub-slab vapor barriers and entry route sealants.

PROVISION OF SUB-SLAB PERMEABILITY

Provision of sub-slab permeability is perhaps the most influential cost of the overall system. The type of sub-slab fill which is used will determine the necessary actions required to establish adequate permeability in the sub-slab fill material. In Connecticut, it is quite common to use "processed" or "bank-run" gravel as fill material. These are terms which indicate fill material which is approximately 95% sand and 5% stone.

In order to ensure adequate sub-slab permeability, three common techniques are available. The use of crushed stone as a fill material, although very desirable, is not a common practice in Connecticut because of the increase in construction cost. A more common method is the installation of a sub-slab piping network, much like a drainage system, into a bed of crushed stone beneath the slab. The least common method is the use of mat-type material because the expense of such material encourages residential builders to seek less expensive alternatives.

When using the sub-slab piping network to provide permeability, a significant amount of labor can be saved through proper timing. If the piping system can be installed during the installation of the fill material itself, all that may be required is the actual assembly and layout of the network. However, installation of the network at sometime after the fill material has been installed, will not only require that the piping system be assembled, but the fill material must be excavated, the piping network installed, covered with fill material, and then the excess fill material must be removed from the site.

House A

Since the building plans for House A indicated the use of processed gravel for fill material, the use of a piping network was required to ensure adequate sub-slab permeability. Figure 1. shows the arrangement of the piping system under the slab. In this house the piping network was actually installed by the foundation workers at the same time the fill material was installed. This provided a very cost effective provision of sub-slab permeability.

House B

The building plan specifications for House B indicated the use of crushed stone as the sub-slab fill material. However when the time came to install the fill, the builder used processed gravel (95% sand) due to the lack of available craushed stone. This became apparant after the fill material had been installed and compacted, creating a permeability problem. Modifications to the mitigation strategy had to be made; a piping network was designed and then subsequently installed. Since this house was being constructed during the winter, the fill material quickly froze and required the use of picks and adzes to excavate for the piping system.

CREATING BARRIERS TO RADON ENTRY

The creation of barriers to radon entry for both houses was accomplished in two steps. After the fill material and piping networks were installed, a continuous layer of cross laminated plastic sheeting (Radon Barrier) was installed. The sheeting was layed out on top of the fill material, then sealed around the foundation with a continuous bead of polyurethane caulk. Where layers of the plastic sheeting were overlapped, another continuous bead of caulk was used as glue for the two sections of sheeting.

Once the slabs had been poured and cured all slab-to-foundation, control joints, utility penetrations, and settling/stress cracks appearing in the slab were sealed. The sealing was accomplished by first enlarging the existing cracks, thoroughly cleaning the opened crack, applying a bead of sealant, then tooling the sealant into place. This technique digresses from the EPA recommendations in that no binding agent is applied to the crack prior to application of the sealant. From experience we have found that polyurethane sealant will bond well to clean, fresh concrete as long as all dust and debris is removed prior to application of the sealant.

CONTROL OF DIFFERENTIAL PRESSURE

The control of differential pressures was accomplished primarily by use of the stack effect to induce a negative pressure in the sub-slab fill material. The development and communication of the negative pressures developed by the stack effect was accomplished through the installation of a "vent stack". This stack uses the tendency of warm air rising in order to develop a negative pressure field in the sub-slab material. In order to be most efficient, the verticle vent stack should have the fewest possible restrictions to air flow.

In both structures, the vent stack was able to run vertically for approximately 30 feet with no bends. Two 90 degree bends and two 45 degree bends were required in the basement areas to connect the stack to the sub slab piping network. Through the use of four inch PVC pipe these bends provided minimal resistance to the air flows typical in a passive stack configuration.

SYSTEM INSTALLATION

Unlike retrofit applications where the entire system is typically installed in less than one day, the use of new construction techniques requires periodic involvement over a long period of time. In the case of House A, the construction period lasted over six months. In the case of House B, the construction of the residence took over 14 months. The economical use of time on site, as well as a close communicative relationship with the builder will save countless hours of on-site time and expenses during the construction of the structure. Construction schedules change on a daily, and sometimes hourly, basis.

The actual implementation of the mitigation strategy can be divided into four distinct phases; sub-slab preparation, slab pour, application of sealants, and finally the installation of the vent stack itself. Not every construction project will require these phases to be accomplished at different times. In the case of House A, the slab was poured as the laborers were completing the piping system. Whereas in House B, the slab was poured four months after the installation of the piping system and sub-slab fill material.

SYSTEM PERFORMANCE

The performance of the installed systems was verified through the use of various radon measurements, as well as, periodic differential pressure measurements. The radon measurements included short-term screening measurements and long term measurements. Differential pressure measurements were made once per month after the initial installation of the vent stack.

RADON MEASUREMENTS

Radon measurements began with short term measurements using activated charcoal canisters. Initial radon measurements were not made until the structure was under the interior finishing phases of construction. This ensured that all windows and doors had been installed and sealed, and the heating system was in operation. In the case of House A, where construction was completed in the summer, another short term measurement was conducted during the heating season.

In addition to the short term measurements, long term radon measurements were made using alpha-track devices to determine long term effectiveness of the installed systems. Intentions are to conduct further long term measurements over the next few years to determine the on-going effectiveness of the techniques used.

Table 1. shows the results of the radon measurements made in both structures.

	First Screening Measurement		Second Screening Measurement		Long Term Measurement
	Month	Result	Month	Result	
House A	JUN	< 0.5	FEB	1.9	0.7
House B	DEC	1.2	FEB	1.6	in progress

Table 1. New Construction Radon Measurements (pCi/l air)

DIFFERENTIAL PRESSURE MEASUREMENTS

Due to limitations in the ability to accumulate continuous long term data, the differential pressure measurements were made at periodic times in each structure. Measurement was made of the pressure differences between the basement of the structure and where the piping system penetrates the basement slab. No data was taken regarding the environmental conditions present at the time of the measurements. Although representative of relative operating pressures, the data does not represent average differential pressure maintained by the stack pipe. Table 2 shows the differential pressure measurements made in each structure.

House A		House B	
Month	Press.	Month	Press.
JUN	0.04	OCT	0.12
JUL	0.03	NOV	0.03
SEP	0.01	DEC	0.05
NOV	0.03	JAN	0.04
JAN	0.02	FEB	0.09
FEB	0.04		

Table 2. Differential Pressure Measurements (inches H20)

PROJECT COSTS

The costs associated with each phase of the new construction project for these structure is divided into three categories; sub-slab piping installation, sealing, and stack pipe installation. The total cost for each project is also reported. Although the total cost of each project is in excess of the average cost to provide radon mitigation services in a comparable existing structure, the long-term cost savings due to energy loss/consumption can be substantial. In addition, the new construction systems are virtually "invisible" and become an integrated part of the structure. This is unlike retrofit mitigation systems which are sometimes attached directly to the exterior of the structure.

Table 3 provides a breakdown of the costs associated with both projects.

	Sub-Slab Piping	Preventing Entry	Stack Vent Installation	Total Project Cost
House A	$ 450	$ 520	$ 645	$ 1,615
House B	$ 967	$ 465	$ 450	$ 1,882

Table 3. New Construction Project Cost

CONCLUSION

The ability to implement cost effective radon resistance into residential new construction is certainly attainable as evidenced in the two projects outlined in this paper. Through the use of EPA recommended new construction techniques and judicious use of on-site time, passive radon reduction strategies can be implemented during new construction that provide the home owner with significant long term cost savings.

More research needs to be conducted to quanitify the design parameters involved with the selection and location of the vent stack. In addition, more data needs to be collected concerning the relationship between environmental conditions and the development of sub-slab pressure differentials during the use of passive stack vent systems..

The work described in this paper was not funded by the U.S. Environmental Protection Agency and therefore the contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

REFERENCES

Saum, D. and Osborne, M. Radon mitigation performance of passive stacks in residential new construction. In: Proceedings of the 1990 International Symposium on Radon and Radon Reduction Technology. U.S. EPA, Washington, DC, 1990.

2. Osborne, M. Radon-Resistant Residential New Construction, U.S. EPA, Washington, DC.

3. Murane, D. Model standards and techniques for controlling radon levels within new buildings. In: Proceedings of the 1990 International Symposium on Radon and Radon Reduction Technology. U.S. EPA, Washington, DC, 1990.

4. EPA - Connecticut Radon Survey Report. Connecticut Department of Health Services, 1987.

5. Siniscalchi, A., Rothney, L., Toal, B., Thomas, M., Brown, D., van der Werff, M., and Dupuy, C. Radon exposure in Connecticut: Analysis of three statewide surveys of nearly one percent of single family homes. In: Proceedings of the 1990 International Symposium on Radon and Radon Reduction Technology. U.S. EPA, Washington, DC, 1990.

6. Popenoe, P. Aeroradioactivity and generalized geologic maps of parts of New York, Connecticut, Rhode Island and Massachusetts. Geophysical Investigations Map GP-359, U.S. Geological Survey, Washington, DC, 1966.