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AN EVALUATION OF INDOOR RADON REDUCTIONS POSSIBLE WITH THE USE OF DIFFUSION RESISTANT FLEXIBLE CONSTRUCTION MEMBRANES

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ABSTRACT

The importance of foundation construction design and materials used is recognized as critically important to the radon resistance of buildings. Numerous states have adopted "standards" or guidelines which prescribe methods and materials of construction. This paper provides a modeling assessment of the indoor radon reductions possible through the use of "improved" radon resistant membranes. The analysis focuses on quantifying the impacts on indoor radon concentrations of using "improved radon diffusion resistant membranes" for a typical experimentally determined range of membrane radon diffusion coefficients. The evaluation considers the application of radon resistant membranes to slab on grade construction typical of Florida and source strengths and site conditions typical of Florida. Guidance for the extrapolation of findings to non-Florida construction and site conditions is discussed.

ACKNOWLEDGEMENT

The inspiration for this paper is derived from a jointly sponsored research effort, CRADA No. 0122-95 of the U.S. EPA and Eastman Chemical Company of Kingsport, Tennessee, intended to develop methods and data on the radon diffusion barrier resistance of construction membranes. The model, RAETRAD 4.1, used for assessing the radon resistance of possible radon barrier, was provided by Rogers and Associates Engineering Corporation of Salt Lake City, Utah. Finally, Richard Snoddy with Acurex Environmental, Research Triangle Park, is acknowledged for his assistance in exercising the RAETRAD analysis.

INTRODUCTION

A maturation exists in government and private sector responses to dealing with the public health risk of indoor radon. Federal and state programs of problem assessment, control technology development, and demonstration, and the transfer of guidance reached their zenith of effort in the period 1988 to 1995 (EPA88, EPA91, EPA93, EPA94, DCA95). Government efforts are now focussed on outreach programs and privatization of certification programs. (RRTC95). Necessarily private sector efforts to deal with all aspects of the indoor radon problem have been challenged.

The current state of the art of radon control technology, as indicated by formalized guidance and extensive demonstrations (Henschel88, Fowler91, Leovic94, Tyson95, Hintenlang95, Najafi95, and Fowler96) indicate that an adequate technical basis exists for dealing with most indoor radon problem situations found in new construction and existing buildings. Yet there are problem situations, e.g., buildings built over high radon potential lands where more effective or robust control technologies are needed. An early expression of this concern, focused on one control strategy, is found in the proceedings of a workshop on innovative radon barriers sponsored by EPA and held at the National Association of Home Builders headquarters in Washington , DC on July 21, 1992 (Geomet92). Some of the above referenced control technology evaluations of new construction techniques (Tyson 95, Hintenlang 95, Najafi 95, and Fowler 96) also support consideration of the use of passive controls such as the use of vapor barriers employed and required in Florida new construction. This paper addresses this technical issue, in the context of Florida construction (DCA95), by using (1) a computer model (Nielson94) developed and enhanced in support of the Florida Radon Research Program(Sanchez91) and (2) existing data on the expected radon diffusion resistance performance of classes of flexible membranes.

ASSESSMENT APPROACH

Approach

This paper is an applications paper, i.e., it uses tools and information developed within the Florida Radon Research Program and research findings specific to the radon diffusion characteristics of selected flexible membranes as input for a computer model simulation and estimation of resultant indoor radon impacts. The following discussion presents a description of the main technical aspects and data input needed for background and understanding the context in which the computer simulations are undertaken.

Radon Diffusion Through Flexible Films

The study of gas diffusion as a mass transport process has been well defined since 1855 (Fick1855) and its application to contemporary problems is evidenced by the development of ASTM standards (ASTM82, ASTM84, ASTM95a, ASTM95b) and research specific to the radon transmission through plastic films (Jha82, Hafez86,Nielson96) including ongoing research (Perry96, Mosley96). Table 1 presents the diffusion coefficients determined by this research and some of the characteristics of these research tests. Of special note is the variability of test results, for nominally the same materials, between researchers. This variable result is largely explained by the uncertainty introduced by the quality of test materials and use of different test methods.

Florida Standard for Passive Radon Resistant New Residential Building Construction

The Florida Standard for Radon Resistant New Residential Construction was the result of a concentrated research effort, undertaken by the Florida Radon Research Program (FRRP) (1989-1995). The FRRP's initial effort was directed at indoor radon problem assessment and the development of diagnostic measurement and assessment tools. This effort was followed by an extensive effort directed at developing a quantitative basis for rank ordering the efficacy of selected radon-resistant construction techniques and control approaches. The results are individually reported in "new house evaluation studies"(Najafi95, Hintenlang95, Tyson95, and Fowler96) and presented in summary in Nielson96 and Nielson 95. Tables 2, 3, and 4 present house parameters and site conditions encountered at the study houses.

Table 1. Comparison of Test Results and Conditions for Radon Diffusion Coefficient Measurements

Publication ⇒	Jha 82	Hafez 86	Nielson 96
Units ⇒	$m^2\ s^{-1}$	$m^2\ s^{-1}$	$m^2\ s^{-1}$
Material ⇓			
Natural Rubber	$6.36x10^{-10}$		
Cellulose Nitrate	$1.24x10^{-11}$		
Cellulose Acetate		$7.5x10^{-13}$	
Polyvinylchloride	$5.00x10^{-11}$	$5.8x10^{-13}$	
Polyethylene		$7.8x10^{-12}$	$3.36x10^{-11}$
Polyethylene terephthalate		$3.0x10^{-13}$	
Polyester	$1.95x10^{-13}$		
Polycarbonate	$3.82x10^{-13}$	$2.4x10^{-12}$ $5.5x10^{-13}$	
Mylar	$8.36x10^{-14}$		
Test Conditions ⇓			
Exposure Time	NR	30 d	NR
Radon Source	Ore, Ra @ 1730 pCi/g	NR	Mill Tailings
Monitor	alpha	alpha-track	alpha
Steady State	yes	yes	NR
Thickness	NR	0.5, 1, 3 mil	6 mil

NR = Not Reported

No CRADA prototype data is reported.

Table 2. House Parameters by Study Cohort

Ref.		Base Area (m^2)	Occup. Vol.[a] (m^3)	Inside Height (m)	Equiv. Wid.[b] (m)	No. Stories	House Const.[c]	Floor Slab				SSV Syst.[h]
								Edge[d] Detail	Slump (cm)[e]	Super-plast.[f]	Rein-force.[g]	
Nielson 95	Mean	233	683	2.9	10.0	1.4			20			
	±S.D.	±59	±198	±0.3	±2.9	±0.5			± 1			
"	Mean	212	645	3.0	13.3	1.1			19			
	±S.D.	±35	±141	±0.2	±1.5	±0.2			± 2			
"	Mean	268	908	3.6	17.6	1.7			11			
	±S.D.	±108	±364	±1.2	±5.0	±0.4			± 1			
"	Mean	207	618	3.0	16.4	1			13			
	±S.D.	±33	±103	±0.2	±1.5	±0			± 2			
Nielson 94b	Mean	217	623	2.8	10.7				15			
	±S.D.	±43	±181	±0.3	±1.0				±3			
"	Mean	201	579	2.9	10.3				10			
	±S.D.	±21	±93	±0.2	±0.6				±0.0			
"	Mean	199	602	3.1	10.0				16			
	±S.D.	±81	±286	±1.0	±2.1				±4			
"	Mean	258	750	2.9	11.6				17			
	±S.D.	±52	±170	±0.3	±1.1				±4			

[a] Volume of the occupied space in the house.

[b] Width of the equivalent rectangular area of the house footprint.

[c] Construction: block (BL), frame (FR), or brick (BR).

[d] Slab edge detail: slab poured into stem wall (SSW) or monolithic slab (Mono).

[e] Concrete slump.

[f] Super plasticizer used in slab concrete (Yes or No).

[g] Slab reinforcement: wire mesh (W), glass fiber (F), or post-tensioned (PT).

[h] Sub-slab ventilation system: well point (WP), suction pit (SP), or ventilation mat (VM).

Table 3. House, Soil, and Ventilation Measurements by Study Cohort

Ref.	House ID	Soil Air Permeability (cm^2)	Soil[a] Moist. (% dry)	Fill[a] Moist. (% dry)	Fill Depth (cm)	House Perm.[b] (ach50)	Reported[c] Nat. Vent. (ach)	Slab[d] Crk. Area (cm^2)	Soil Density (g/cm^3)
Nielson 95	Mean ±S.D.	$2.3x10^{-7}$ $\pm1.1x10^{-7}$	7.2 ±5.4	5.7 ±3.1	35 ±15	5.2 ±1.2	0.29 ±0.07	50. ±67.	1.60[e]
"	Mean ±S.D.	$1.1x10^{-7}$ $\pm1.2x10^{-7}$	8.6 ±3.6	5.6 ±2.1	33 ±16	5.8 ±1.2	0.31 ±0.08	92. ±200.	1.60[e]
"	Mean ±S.D.	$7.4x10^{-8}$ $\pm7.8x10^{-8}$	7.3 ±2.5	7.2 ±2.9	28 ±5		0.20 ±0.07	94 ±104	1.60[e]
"	Mean ±S.D.	$1.1x10^{-7}$ $\pm1.2x10^{-7}$	8.3 ±3.3	7.4 ±1.9	28 ±5		0.18 ±0.02	330 ±240	1.60[e]
Nielson 94b	Mean ±S.D.		9.3 ±5.4				0.33 ±0.10	57 ±130	1.59 ±0.11
"	Mean ±S.D.		20.0				0.27 ±0.12	32 ±22	1.79 -
Nielson 95	Mean ±S.D.	$9.1x10^{-7}$ $\pm1.9x10^{-6}$	5.2 ±3.5	0 ±0		5.6 ±1.3	0.31 ±0.13	0.015 ±0.005	1.60 ±0.13
"	Mean ±S.D.	$9.0x10^{-7}$ $\pm1.7x10^{-6}$	3.6 ±1.1	---		5.8 ±1.2	0.17 ±0.04	0.014 ±0.004	1.63 ±0.09

[a] Moisture percentage, dry-weight basis.

[b] Infiltration air changes per hour at 50 Pa pressure, from blower-door test.

[c] Passive-condition air infiltration rate.

[d] Total area of observed slab cracks.

[e] Assummed typical soil densities, since none were reported.

Table 4. Sub-slab and Indoor Radon Measurements in Study Houses (Nielson 94b)

					Statistical Summary				
House ID	Soil Radon (pCi L^{-1})	Indoor Radon (pCi L^{-1})	Outdoor Radon (pCi L^{-1})	Subslab Radon (pCi L^{-1})	Statistic	Soil Radon (pCi L^{-1})	Indoor Radon (pCi L^{-1})	Outdoor Radon (pCi L^{-1})	Subslab Radon (pCi L^{-1})
F-01	5,510	1.6	0.4	4,310					
F-04	5,180	4.1	1.3	12,100					
F-05	19,900	1.5	0.1	4,490					
F-06	3,050	1.6	0.5	4,520					
F-07	2,690	1.4	0.3	4,240					
F-09	14,300								
F-12	5,700	2.7	0.6	6,480	G.M.,	6,230	2.0	0.4	5,640
F-13	5,990	2.5	0.7	6,210	GSD	1.99	1.49	2.23	1.46
F-02	1,480	1.6	0.6	886					
F-03	2,630	3.8	0.3	5,990					
F-08	1,310	3.3	0.3	4,000					
F-10	11,500	8.0	1.3	5,580					
F-11	2,760	1.9	0.4	4,180	G.M.,	2,720	3.1	0.6	4,000
F-14	2,510	3.1	1.3	8,270	GSD	2.17	1.77	1.97	2.19
1	1,680	2.3	0.5	730					
2	2,940	3.0	0.5	970					
3	1,190	2.2	0.5	488					
4	911	2.7	0.5	809					
5	2,900	2.5	0.5	1,220					
7	921	1.2	0.5	722					
9	1,300		0.5						
10	1,060	10.9	0.5	3,870					
11	10,700	2.8	0.5	8,480	G.M.,	2,070	2.8	0.5	5,840
12	6,980		0.5		GSD	2.38	1.86	1.00	1.46

The Florida Standard for Radon Resistant Construction (DCA95) is a performance based standard requiring the installation of passive construction features. It contains quantitative requirements to ensure a standard quality of construction, e.g., requirements specifying slump of concrete, and the use of ASTM rated sealants, and vapor barriers. Figures 1 and 2 show examples of how the Florida Standard addresses certain important radon-resistant construction features (Shanker93).

The RAETRAD Model

The RAETRAD (Radon Emanation and Transport into Dwellings model) (Nielson94, Rogers96) is a public-domain computer simulation model developed and refined within the FRRP. It has been used extensively in support of the Florida Standard development, especially in evaluations of (1) radon contributions of foundation soils and fill materials,(2) advective and diffusive radon transport, (3) geographic distributions of radon potential in Florida, and (4) the development of simplified models for the assessment of the radon resistance of building features. This paper uses the RAETRAD model to evaluate the indoor radon reduction potential of two distinct vapor membranes on the diffusive entry of radon into a typical Florida Standard house built over three distinct radon potential sites. Table 5 presents the scenarios evaluated using the RAETRAD model.

Table 5. Model Simulation Matrix

Scenario	House Parameters (see Table 6)	Soil Parameters Soil Ra Content ($pCiL^{-1}$)	Site Parameters Vapor Barrier Diffusion Coefficient (m^2s^{-1})
1	Set to Default	5.0	none
2	"	10.0	none
3	"	20.0	none
4	"	5.0	$1.00x10^{-11}$
5	"	10.0	$1.00x10^{-11}$
6	"	20.0	$1.00x10^{-11}$
7	"	5.0	$1.00x10^{-13}$
8	"	10.0	$1.00x10^{-13}$
9	"	20.0	$1.00x10^{-13}$

MODELING SCENARIOS RESULTS

Introduction

The purpose of the RAETRAD evaluation presented below is to identify the significance of improvements in moisture barrier radon diffusion resistances to the resultant indoor radon. The belief before this evaluation was that technically feasible enhancements to the diffusive resistance of vapor barriers should produce cost effective reductions in indoor radon, especially (1) in those instances where small reductions, though hard to come by reductions, in indoor radon are needed or (2) where radon source variability is such that more robust passive controls are a prudent addition to the Florida Standard. For example, the results of the "new house evaluation projects" identified exceptions to the adequacy of the Florida Standard's passive controls, on high radon potential sites, to always produce indoor radon concentrations below EPA's $4pCiL^{-1}$ action level (Tyson 95, Hintenlang 95, Najafi 95, and Fowler 96).

Baseline Conditions

Table 6 presents the baseline or reference house input parameters used in the RAETRAD model. These conditions are common to all scenarios listed in Table 5. Tables 7 and 8 present the foundation and soils (1) physical characteristics and (2) radiological characteristics input into the baseline (no barrier) and vapor barrier analysis runs. Vapor barrier thicknesses of 6 mils (150 μm) are used for all vapor barrier runs with the only parameter changing among runs being the radial and vertical diffusion coefficients. The diffusion coefficient values used, though hypothetical, are representative of the values shown in Table 1.

Table 6. House Parameter Values Used in Model Runs

Dimensions:	28.4 x 54.3 ft.
Area:	1542 ft^2
Fill Thickness:	1 unit (0.9 ft.)
Footing Depth:	3 units (2.9 ft.)
Indoor Pressure:	-2.4 Pa
Outdoor Pressure:	0 Pa
Outdoor Radon Conc.:	0 $pCiL^{-1}$
Floor Openings:	Eliptical Crack at Slab Edges, 1 cm width Utility Penetrations, 2 at 13 ft. from edge

Table 7. Foundation and Soil Characteristics

Materials:	Sand, Concrete, Membranes
Layers:	Soil, Floor, Footing
Parameters:	Density, Porosity, Saturation Fraction, Particle Diameter

Table 8. Foundation and Soils Radiological Characteristics

Materials:	Sand, Concrete, Membranes
Layers:	Soil, Floor, Footing
Parameters:	Radium Content, Emanation Fraction, Diffusion Coefficient, Permeability Coefficient, Adsorption Coefficient

Results

Table 9 presents the indoor radon concentrations predicted by RAETRAD for the selected soil radon potential and radon barrier diffusion coefficient test conditions. Those are compared with the baseline no barrier case.

Table 9. Comparison of Baseline (No Barrier) and Flexible Membrane Barrier Effects on Indoor Radon Concentration

Soil Radon Potential: Soil ^{226}Ra Content (pCig^{-1})	Indoor Radon Concentration (pCiL^{-1}) for Selected Barrier Conditions		
		Diffusion Coefficient (m^{2}s^{-1})	
	No Barrier	1 x 10^{-11}	1 x 10^{-13}
5.0	17.4	0.121	0.073
10.0	34.8	0.219	0.077
20.0	69.5	0.414	0.085

Figure 3 presents the above results on a semilog plot to show the overall relationship of indoor radon concentrations to building site radon potentials (soil radium content). This figure shows clearly the non linear nature of the radon entry process with respect to diffusion limiting processes and the proportionality of indoor radon concentrations to source strength for advective and high diffusion coefficient conditions.

CONCLUSION

- Placement of an integral impermeable flexible membrane (vapor barrier) under slab on grade construction can produce significant (100 x) reductions in indoor radon concentration from the no barrier case.
- In most cases, even for floating slab on grade construction, on moderately high radon potential (10pCig^{-1}, ^{226}Ra) soil, currently available and diffusion resistant membranes can keep indoor radon concentrations below 4pCiL^{-1}.
- Enhanced radon diffusion limiting membranes (e.g., going from 1 x 10^{-11} to 1 x 10^{-13} m^{2}s^{-1} diffusion coefficients) may become cost effective on high radon potential sites, i.e., sites greater than 20 pCig^{-1} ^{226}Ra.
- The placement of a completely intact vapor barrier is critical to limiting radon entry into new and existing structures even at the well-balanced indoor/outdoor pressure differential condition (-2.4 Pa) used in this analysis.
- Comparison of the performance of new house evaluation study results with RAETRAD model predictions indicate the potential for enhanced radon entry limiting performance of vapor barriers, perhaps through enhanced placement practices.

REFERENCES

EPA88 "The National Radon Measurement Proficiency Program." EPA 520/1-88-024, U.S. Environmental rotection Agency, Washington, DC 20460. September 1988.

EPA91 "The National Radon Contractor Proficiency Program." EPA 520/1-91-016, U.S. Environmental Protection Agency, Washington, D.C. 20460. June 1991.

EPA93 "Radon Mitigation Standards." EPA 402-R-93-078, U.S. Environmental Protection Agency, Washington, D.C. 20460. October 1993.

EPA94 "Model Standards and Techniques for Control of Radon in New Residential Buildings." EPA402-R-94-009, U. S. Environmental Protection Agency, Washington, D.C. 20460. March 1994.

DCA95 "Florida Standard for Passive Radon-Resistant New Residential Building Construction." Florida Department of Community Affairs, State of Florida, Talahassee, FL 32399-2100. July 1, 1995.

RRTC95 "Emanations." Newsletter of the Regional Radon Training Centers, Vol.5, No.4, Kansas State University, Manhattan, KS 66506-2508. September 1995.

HEN88 Henschel, D.B. "Radon Reduction Techniques for Detached Houses." EPA/625/5-87/019, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. January 1988.

Fowler91 Fowler, C.S., Williamson, A.D., Pyle, B. E., Belzer, F.E., Coker, R.N. "Hankbook, Design and Installation of a Home Radon Radiation System- Sub slab Depressurization Systems in Low Permeability Soils." USEPA/625/6-91/029, U. S. Environbmental Protection Agency, Research Triangle Park, NC 27711. July 1991.

Leovic94 Leovic, K.W. and Craig, A.B. "Radon Prevention in the Design and Construction of Schools and Other Large Buildings." EPA/625/R-92/016, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. June 1994.

Tyson95 Tyson, J.L. and Withers, C.R. "Demonstration of Radon Resistant Construction Techniques- Phase II Final Report." EPA-600/R-95-159, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. November 1995.

Hintenlang95 Hintenlang, D. E., Shanker, A., Najafi, F.T., and C.E. Roessler. "Evaluation of Building Design, Construction, and Performance for the Control of Radon in Florida Houses - Evaluation of Radon Resistant Construction Techniques in Eight New Houses. EPA-600/R-95-114, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. July 1995.

Najafi95 Najafi, F.T., Shanker, A.J., Roessler, C.E., Hintenlang, D.E., and Tyson, J. "New House Evaluation of Potential Building Design and Construction for the Control of Radon in Marion and Alachua Counties, Florida." EPA-600/R-95-170, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. December 1995.

Fowler96 Fowler, C.S., McDonough, S.E., Williamson, A.D. "Effectiveness of Radon Control Features in New House Construction South Central Florida." EPA-600/R-96-044, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. April 1996.

Geomet92 "Radon Barrier Systems." EPA Contract No. 68-D9-0166, Task No. 3-24 Geomet Report No. IE-2605. Geomet Technologies, Inc. Germantown, MD 20874. September 30, 1992

Sanchez91 Sanchez, D.C., Dixon, R., and Madani, M. "The Florida Radon Research Program: Technical Support for the Development of Radon Resistant Construction Standards" Presented at the Fifth Annual AARST National Radon Conference, October 9-12, 1991 Rockville, MD

Fick1855 Fick, A. "Ueber Diffusion." Annal. Physik 170:59-86: 1855 (In German)

ASTM82 "Standard Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting." ASTM D 1434-82, American Society for Testing and Materials. West Conshohocken, PA 19428. May 1995

ASTM84 "Standard Specification for Polyethylene Sheeting for Construction, Industrial, and Agricultural Applications." ASTM D4397-84, American Society for Testing and Materials. West Conshohocken, PA 19428. September 1984.

ASTM95a "Standard Test Methods for Water Vapor Transmission of Materials." ASTM E96-95, American Society for Testing and Materials. West Conshohocken, PA 19428. May 1995.

ASTM95b "Standard Test Method for Oxygen Gas Transmission Rate Through Plastic Film and Sheeting Using a Coulometric Sensor." ASTM E96-95, American Society for Testing and Materials. West Conshohocken, PA 19428. November 1995.

Jha82 Jha, G., Raghavayya, M., and Padmanabhan, H. "Radon Permeability of Some Membranes." Health Physics, V42, No 5, pp732-725. 1982

Hafez86 Hafez, A. And Somogyi, G. "Determination of Radon and Thoron Permeability through some Plastics by Track Technique." Nuclear Tracks, V12, Nos 1-6, pp 697-700. 1986

Nielson96 Nielson, K.K., Holt, R.B., and Rogers, V.C. "Residential Radon Resistant Construction Feature Selection System." EPA-600/R-96-005, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. February 1996.

Perry96 Perry, R. and Snoddy, R. , "A Method for Testing the Diffusion Coefficient of Polymer Films." Prepared for Presentation at the 1996 AARST International Radon Symposium, September 29-October 2, 1996. Haines City, FL

Mosley96 Mosley, R. "Description of a Method for Measuring the Diffusion Coefficient of Thin Films to ^{222}Rn Using a Total Alpha Detector." Prepared for Presentation at the 1996 AARST International Radon Symposium, September 29- October 2, 1996. Haines City, FL

Nielson95 Nielson, K.K., Holt, R.B., Rogers, V.C. "Lumped-Parameter Model Analysis of Data from the 1992 New House Evaluation Project Florida Radon Research Program." EPA-600/R-95-090, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.July 1995.

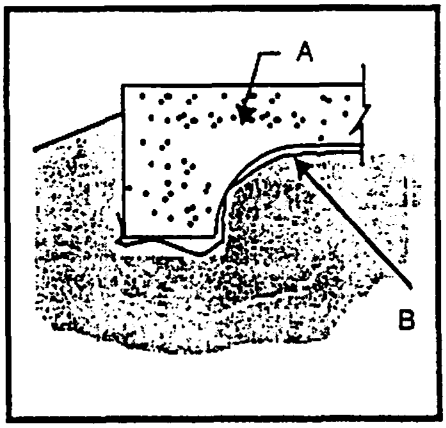
Shanker93 Shanker, A. "Guidelines for Radon-ResistantResidential Construction in the State of Florida." Final Report to the State of Florida, Department of Community Affairs. University of Florida. Gainesville, FL August 1993.

Nielson94 Nielson,K.K., Rogers,V.C., Rogers, V., and Holt, R.B. "The `RAETRAD Model of Radon Generation and Transport from Soils into Slab-on0Grade Houses." Health Physics, V67, No4. October 1994.

Rogers96 Rogers, V., Nielson, K.K., and Rogers, V.C. "RAETRAD Version 4.1 User Manual." RAE-G1R/33-2, Rogers and Associates Engineering Corporation. Salt Lake City, UT 84110-0330. June 1996.

Fig. 1 Monolithic Slab, Vapor Barrier Installation

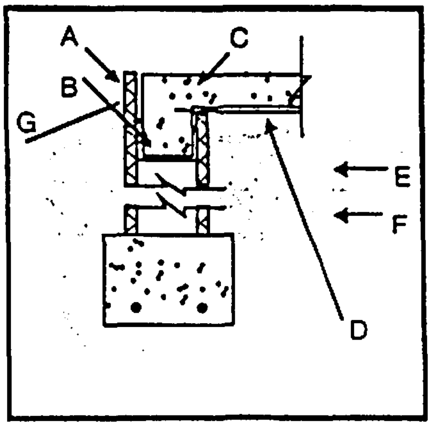
In monothic slab construction slab edges are thickened around the perimeter to form a monolithic concrete beam. The soil cover membrane should extend beyond the outer edge of the monolithic slab (see Figure 16). Monolithic slab is recommended for radon resistant construction.



A. 4" thick concrete slab with monolithic edge.
B. 6 mil soil cover membrane continues beyond outside edge of slab.

Fig. 2 Slab Poured Into Stem Wall Vapor Barrier Installation

When a slab is poured into a stem wall, concrete header blocks (see Figure 17 part A) serve as forms for the concrete slab. The soil cover membrane should extend at least 1" into the header block. The slab extends to the inside surface of header blocks. The cores of header blocks should be completely filled with concrete.



A. Concrete header blocks.
B. Fill header block cores along perimeter to form 8" thick cap.
C. 4" nominal concrete slab.
D. 6 mil vapor barrier at least 1" into the header block.
E. Compacted fill soil.
F. Undisturbed soil.
G. Grade.

Fig. 3 RAETRAD Model Results