RESEARCH HIGHLIGHT

Technical Series 00-130

Airtightness of Concrete Basement Slabs

INTRODUCTION

Radon is a radioactive gas known to be a major cause of lung cancer. It enters houses from the surrounding soil, primarily through cracks in basement floors and walls, as well as pipe penetrations.

To reduce the level of radon in a house, two approaches can be taken. One is to depressurize the sub-slab volume, with a sub-slab suction system. Alternatively, the floor can be made more airtight, which requires more than simply caulking and sealing the basement floor from the inside.

A project was undertaken to evaluate the effectiveness and economy of using polyethylene film to make concrete basement slabs more airtight.

RESEARCH PROJECT

The first step involved a review of information about radon exposure, entry control, energy conservation and building practices. This contributed to clarifying the issues to be addressed and refining details of the test procedures.

Next, the research looked at the technology of concrete slabs, polyethylene film and caulking materials. Three types of tests were conducted to assess the technical feasibility of using polyethylene as a substrate, before proceeding with tests of floor assemblies.

The main component of the research project involved laboratory tests to determine the effect of polyethylene substrates on the airtightness of cracked concrete slabs and floor-wall joints.

Tests were carried out using an airtight test cell approximately 1 m^2, assembled around a laboratory-built floor specimen consisting of gravel, polyethylene and a concrete slab. Airflow through the test cell and pressure in the gravel bed could be measured, and the width of the crack in the concrete was adjustable. Tests were conducted on the following slab configurations: 1) no polyethylene; 2) lapped and uncaulked polyethylene; 3) lapped and caulked polyethylene (with two different thicknesses of caulking); and 4) perforated polyethylene. The first three tests were repeated for floor-wall joints.

Two other laboratory tests were undertaken. One was to determine the effect of a metal waterstop on the airtightness of a crack in a concrete slab without a polyethylene substrate. The second determined if friction between concrete and sub-slab gravel could crack the concrete during shrinkage. This was done by testing the effect of one and two layers of polyethylene under a concrete slab.

The findings were presented and discussed in a forum attended by housing construction industry representatives and radon researchers. Several approaches to sealing the floor were discussed at the forum, such as perforated polyethylene and a waterstop system, but it was agreed that lapped and caulked polyethylene showed the most promise. The project proceeded with a field demonstration in Winnipeg.

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A polyethylene air barrier was placed on the sub-slab gravel of a new house under construction and a concrete slab was poured over it. The polyethylene was caulked to footings and to jack-post pads with acoustical sealant. All laps in the polyethylene were caulked, and the air barrier was caulked to plumbing pipe penetrations. The airtightness of the polyethylene was tested before the concrete floor was poured and after the concrete had cured for 14 days.

The research project also attempted to assess air leakage in existing basements for 10 houses in Saskatoon. However, due to variations in foundation construction and condition, and in house types and ages, the results proved inconclusive.

FINDINGS

The laboratory tests of concrete slabs showed polyethylene to be highly effective in achieving significant reduction in air flow (see Figure 1). Perforated polyethylene proved very air tight, with the cement paste leaking through and sealing the perforations. Caulking resulted in a further major reduction of air flow. The tests also revealed that concrete, properly mixed and free of cracks, is effectively impermeable to air. This countered previous suggestions that radon can enter houses through uncracked concrete slabs. The results for the different slab configurations, each with a crack width of 1.5 mm, are presented in Table 1.

Table 1 Flow Resistance (R) and Flow Coefficient (C) for Concrete Slabs with a Crack Width of 1.5 mm

Polyethylene Configuration	R (Pa s/L)	C (L/Pa s)
No polyethylene	25	4.0E-02
Lapped and uncaulked polyethylene	610	1.6E-03
Lapped and caulked polyethylene #1	9,200	1.1E-04
Perforated polyethylene	11,000	9.1E-05
Lapped and caulked polyethylene #2	42,000	2.4E-05

Three conclusions were drawn from the slab tests:

1) Perforations are not a serious problem.

2) Polyethylene has a very significant effect.

3) Caulking is necessary.

The results of the joint tests were less conclusive. Flow resistance for a floor-wall joint without polyethylene tested much higher than for a crack of the same width (see Figure 2). It was thought that the results were affected by the flow resistance of the floor-footing joint. In a house, floors are lifted off footings, but that was not possible with the test. It was suggested that little weight should be given to the floor-wall joint tests.

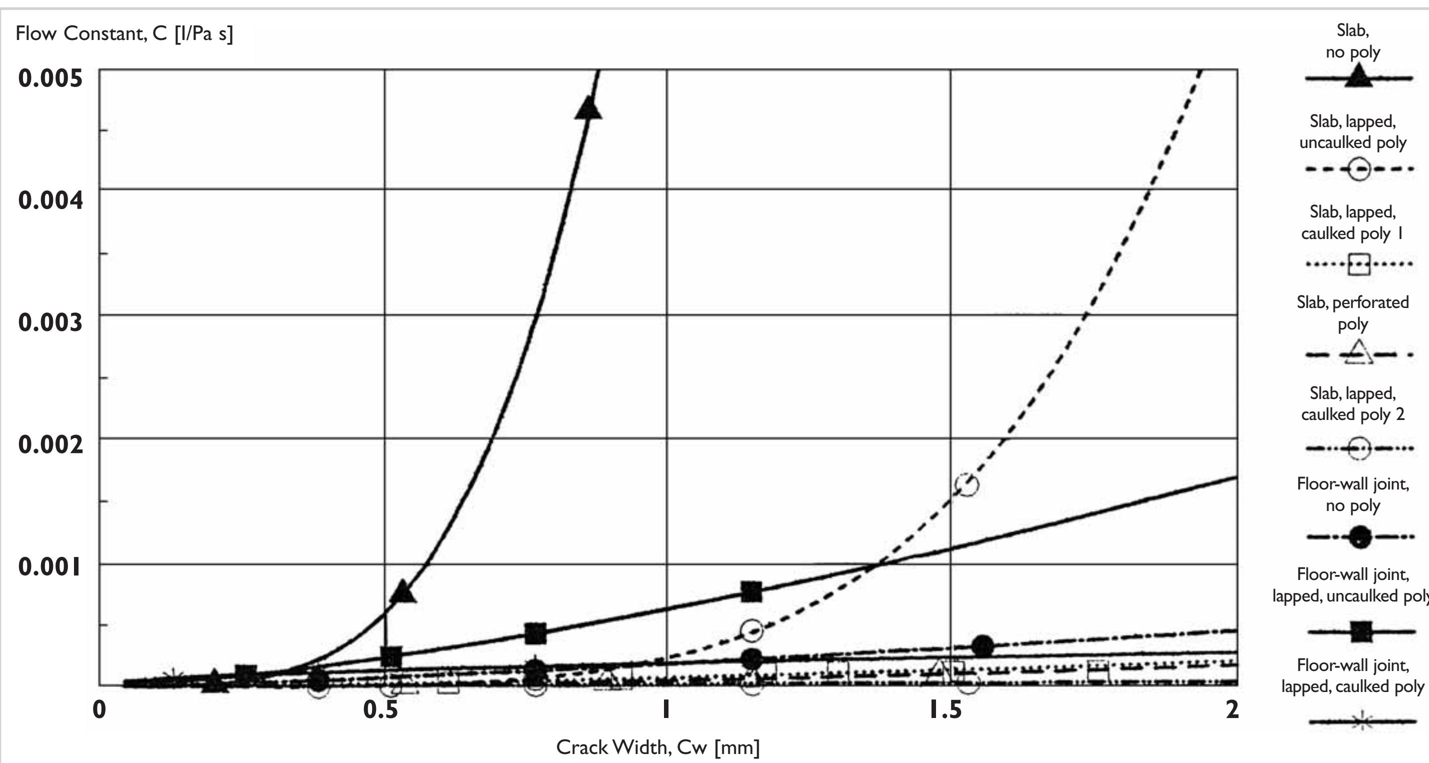

Figure 1 Flow Constant vs Crack Width for All Test Specimens

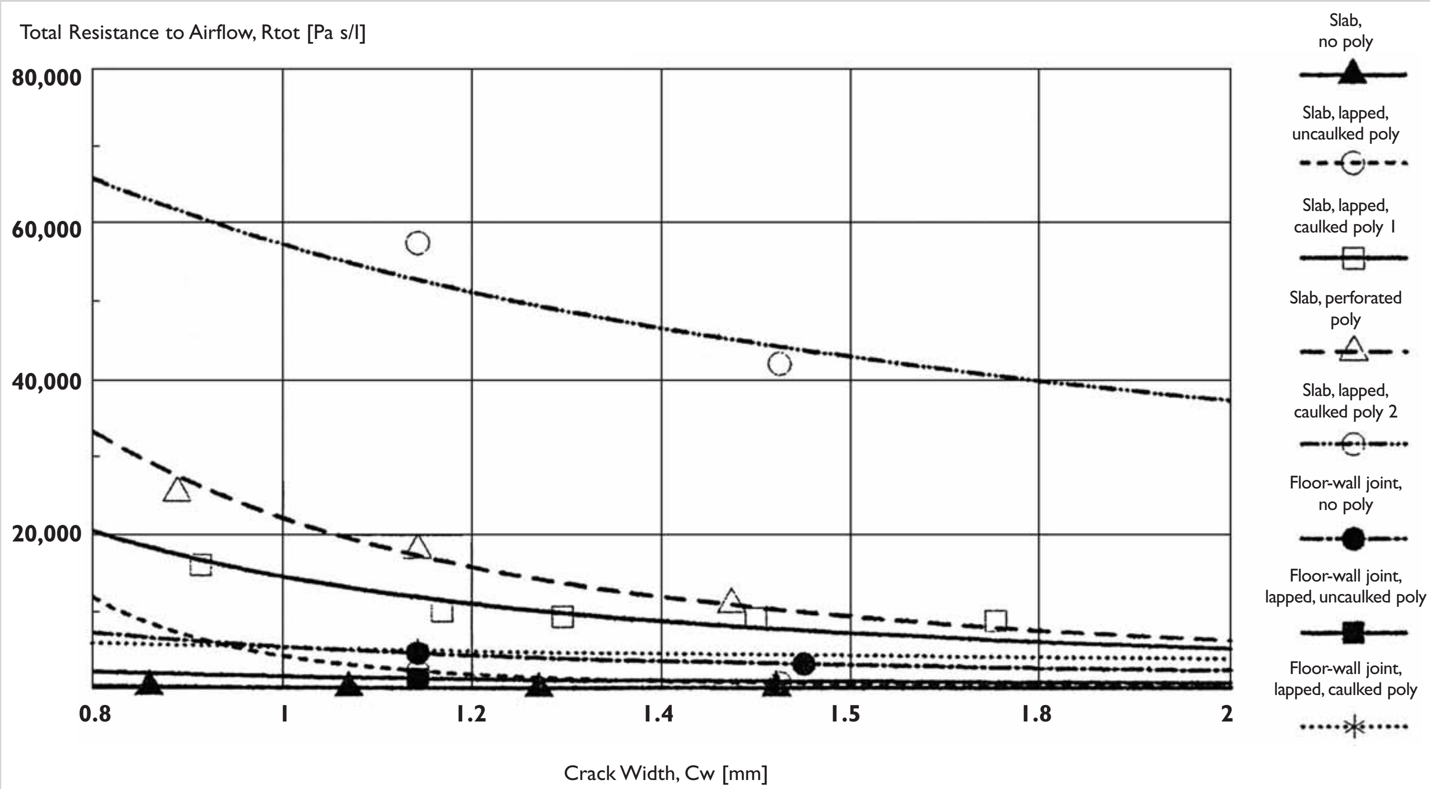

Figure 2 Total Resistance to Airflow vs Crack Width for All Test Specimens

As an alternative to polyethylene, which greatly affects the drying and curing of concrete, a waterstop was tested. This approach uses a strip of metal to produce a sealed control joint. It was found that the control joint produces a much tighter seal than lapped and caulked polyethylene, with a flow resistance of 400,000 Pa s/L for a 1.5 mm crack. It was concluded that this approach deserves further study, if waterstops for residential basement floors can be produced economically.

Friction tests showed that a second layer of polyethylene significantly reduces friction, but they also revealed that friction between concrete and sub-slab gravel is not sufficient to cause cracking. The results indicated instead that cracking due to shrinkage is caused by differential shrinking, or by shrinkage constrained by slab penetrations, such as pipes or columns.

In the field demonstration, the equivalent leakage area (ELA) of the soil measured 6.1 cm^2 before the polyethylene was laid. Once installed, the polyethylene reduced the ELA to a tenth of that, measuring 0.6 cm^2 before the concrete was poured. It alone provided the major barrier to air movement and was expected to reduce soil gas inflow by about 90 per cent. After the concrete had been poured and cured for two weeks, the airtightness was measured again. The soil's ELA dropped to 2.7 cm^2, probably due to compacting of the soil as it settled into the backfill zone and saturation from heavy rain during the test period. The ELA of the concrete and polyethylene was so low that no flow could be detected with a 50 Pa pressure difference. It was estimated that the ELA must be less than 0.05 cm^2. At that level, the soil gas inflow would be reduced by more than 98 per cent compared to a leaky floor.

Pouring concrete on an impermeable substrate poses a problem due to a lack of drainage. It entails extra costs in finishing the concrete or using a superplasticizer. Taking this into account, the costs for a lapped and caulked polyethylene substrate approach those for installing a sub-slab depressurization system in a new house. However, the sub-slab barrier has the advantage of being passive and probably longer lasting. It also does not use electricity nor does it increase infiltration.

CONCLUSIONS

The major conclusion to be drawn from this research is that a sub-slab polyethylene air barrier can be very effective in making concrete basement floors airtight, thereby preventing radon from leaking into houses. In fact, the 1990 and 1995 National Building Code (NBC) required that provision be made for soil gas control, except under garages and unenclosed portions of buildings, in areas where it can be demonstrated that soil gas does not constitute a hazard, or where single family dwellings are constructed to provide for subfloor depressurization.

An approved approach for soil gas control is the use of a below-slab barrier with joints lapped a minimum of 300 mm. The NBC does not specify that the material is to be polyethylene, but the Appendix to the 1997 NBC recognized that in most cases, 0.15 mm polyethylene will be used. As an alternate solution, the dwelling can be constructed to provide for sub-slab depressurization, where a vertical pipe is installed through the floor, with its bottom end opening into the granular fill below the slab. The sub-slab must be then depressurized by an exhaust fan if radon levels exceed the Canadian exposure guideline.

Despite these code clauses, there are few polyethylene or other soil gas barriers being laid under concrete floors in Canada in 2001. Requirements for soil gas control measures seem to be very localized and infrequent. Apparently, most jurisdictions decide that they meet the exemption of "...areas where it can be demonstrated that soil gas does not constitute a hazard..." and simply pour their slabs over gravel.

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Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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